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# Spatial Zoning of Tourism Carrying Capacity Using GIS in Darma Reservoir Ecotourism

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**ABSTRACT**

Tourism carrying capacity (TCC) assessment is essential for balancing tourism development and environmental sustainability, particularly in ecotourism destinations experiencing fluctuating visitor demand. This study aimed to determine the physical carrying capacity (PCC), real carrying capacity (RCC), and effective carrying capacity (ECC) of Darma Reservoir Ecotourism in Kuningan Regency, Indonesia, using a zone-based geographic information system (GIS) approach. The analysis integrated high-resolution spatial data, including data from the National Aeronautics and Space Administration Global Precipitation Measurement (GPM) on rainfall and the National Digital Elevation Model System (DEMNAS), to derive environmental correction factors for RCC calculations. PCC was calculated based on tourism area, recreational space requirements, and visitor rotation factors, whereas ECC incorporated management capacity through staff and facility adequacy assessments. The results showed that the overall land-based tourism area had a PCC of 3,123 visitors/day, which decreased to 1,955 visitors/day after environmental corrections and further declined to an ECC of 1,787 visitors/day after considering management capacity. Zone-specific ECC values were 37 visitors/day for Picnic 1, 215 visitors/day for Picnic 2, 30 visitors/day for the Camping Ground, and 883 boat trips/day for the Boat Tour zone. A comparison with actual visitation revealed that weekday and weekend visitor numbers remained below the ECC threshold, whereas peak-season visitation during Eid al-Fitr and New Year holidays substantially exceeded the carrying capacity. These findings indicate the need for adaptive tourism management, including visitor quotas and reservation systems during peak periods, alongside promotional and diversification strategies during the low season. The study demonstrates that integrating GIS-based spatial analysis with carrying-capacity assessment provides an effective framework for sustainable ecotourism management.

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## 1. INTRODUCTION

Tourism is an important sector for achieving sustainable development because it contributes to economic growth, employment creation, and community welfare. However, tourism activities can also generate environmental pressures through resource depletion, ecosystem disturbance, and increased pollution, potentially threatening the sustainability of tourism destinations. To address these challenges, ecotourism has emerged as an environmentally responsible tourism approach that balances economic benefits with conservation objectives. As ecotourism continues to grow globally and nationally, assessing tourism carrying capacity (TCC) has become increasingly important to determine the maximum number of visitors that can be accommodated without causing unacceptable environmental impacts or reducing visitor satisfaction (United Nations, 2015; Rodríguez et al., 2020; Baloch et al., 2023; Huo et al., 2024; Kemenparekraf RI, 2024; Yulianda & Mazaya, 2021).

Although TCC has been widely applied in tourism planning, many studies still treat tourism destinations as homogeneous areas and produce a single carrying-capacity value for the entire site. This approach may not accurately represent reservoir ecotourism destinations, where tourism activities, environmental conditions, and management capacities differ among functional zones. Furthermore, conventional assessments frequently rely on coarse environmental data, limiting the accuracy of carrying-capacity calculations. Therefore, a GIS-based approach that integrates spatial analysis with physical carrying capacity (PCC), real carrying capacity (RCC), and effective carrying capacity (ECC) is needed to provide more accurate and operationally useful results for sustainable tourism management (Guo, 2025; Mapalad, 2024).

The most widely adopted approach for TCC assessment is a hierarchical framework consisting of PCC, RCC, and ECC. PCC estimates the maximum physical capacity based on area and visitor rotation, RCC incorporates environmental correction factors, and ECC further adjusts capacity according to management capabilities. Previous studies have successfully applied this framework in protected areas, coastal tourism destinations, islands, and ecotourism sites, demonstrating its effectiveness in identifying visitor thresholds and supporting sustainable tourism planning. More recently, GIS has been integrated into TCC assessments to improve spatial analysis and tourism resource mapping, although its application remains largely limited to visualization and zoning functions (Cifuentes, 1992; de Sousa et al., 2014; Adrianto et al., 2021; Putri & Ansari, 2021; Marhanah et al., 2023; Darwis et al., 2024; Mapalad, 2024).

Despite substantial progress in TCC research, several limitations remain. Many studies utilize generalized rainfall and slope data that may not adequately represent spatial variability within tourism destinations. In addition, GIS-based TCC studies often focus on site mapping without integrating high-resolution environmental datasets into correction factor calculations. Most importantly, existing studies generally provide static management recommendations and rarely distinguish between peak-season and low-season conditions. Consequently, there remains a need for a zone-based carrying-capacity assessment that integrates high-resolution spatial data and supports adaptive tourism management strategies based on seasonal visitation patterns (Mapalad, 2024; Wang et al., 2020).

This study aimed to determine the PCC, RCC, and ECC values of the Darma Reservoir Ecotourism Area using a zone-based GIS approach and to formulate adaptive management strategies based on carrying-capacity thresholds. The novelty of this study lies in the integration of high-resolution NASA GPM rainfall data and DEMNAS slope data into environmental correction factor calculations, as well as the development of seasonally adaptive management recommendations to address both overtourism during peak periods and underutilization during the low season. The study focused on selected tourism zones within the Darma Reservoir Ecotourism Area, including picnic, camping ground, and boat-tour zones, to support sustainable tourism management in the area.

## 2. METHOD

### 2.1. Materials

The materials used in this study consisted of primary and secondary data. Primary data included visitor questionnaire responses, manager interviews, visitor activity duration, visitor distribution across tourism zones, staff availability, facility availability, and actual visitor numbers. Secondary data included tourism zone area, NASA Global Precipitation Measurement (GPM) rainfall data, DEMNAS elevation data, satellite basemap imagery, and regulatory or literature-based standards for recreational space, slope classification, and tourism facilities. These data were used to calculate the physical carrying capacity (PCC), real carrying capacity (RCC), and effective carrying capacity (ECC).

### 2.2. Sample Preparation

The population in this study comprised the entire Darma Reservoir Ecotourism Area, including tourism activity zones, visitors, and tourism managers. Visitor respondents were selected using accidental sampling, whereas tourism managers were selected using purposive sampling. The sample size was determined using the Lemeshow formula because the total visitor population during the study period was uncertain. The calculation used a 95% confidence level, a proportion estimate of 0.5, and an 8% margin of error, resulting in 151 respondents.

$$n = \frac{Z^2 p(1-p)}{d^2} \tag{1}$$

where n is the minimum sample size, Z is the z-score at a 95% confidence level, p is the estimated population proportion, and d is the margin of error.

Visitors who used more than one tourism zone were recorded for each zone visited. Therefore, one respondent could contribute more than one zone-visit record. This approach was adopted to obtain the zone-specific average visit duration for the rotation factor calculation.

**Table 1.** Distribution of respondents by tourism zone

| Zone | Number of Respondents |
|---|---|
| Picnic 1 | 123 |
| Picnic 2 | 107 |
| Boat Tour | 20 |
| Camping Ground | 0 |
| Total Zone-Visit Reports | 250 |
| Total Unique Respondents | 151 |

### 2.3. Experimental Set-up

The study was conducted by calculating tourism carrying capacity at three levels: PCC, RCC, and ECC. PCC was calculated to determine the maximum number of visitors that could be physically accommodated in each tourism zone. RCC was calculated by reducing PCC using environmental correction factors, namely rainfall and slope. ECC was calculated by incorporating management capacity, including staff adequacy and facility availability. GIS was used to delineate tourism zones, calculate spatial area, extract slope data from the DEMNAS, and obtain rainfall data from NASA GPM.

$$PCC = \frac{A}{S} \times Rf \tag{2}$$

where $A$ is the available tourism area, $S$ is the recreational space requirement, and $Rf$ is the rotation factor.

$$Rf = \frac{Operating\ hours}{\text{Average visit duration}} \tag{3}$$

where Rf represents the number of visitor rotation cycles per day.

$$RCC = PCC \times CF_1 \times CF_2 \tag{4}$$

where $CF_1$ is the rainfall correction factor and $CF_2$ is the slope correction factor.

$$CF_x = 1 - \frac{Lmx}{Tmx} \tag{5}$$

where $CF_x$ is the correction factor for variable $x$, $Lmx$ is the limiting magnitude of variable $x$, and $Tmx$ is the total magnitude of variable $x$.

$$ECC = RCC \times MC \tag{6}$$

where MC is management capacity.

$$MC = \frac{Staff\ adequacy\ value + Facility\ adequacy\ value}{2} \quad (7)$$

where staff adequacy and facility adequacy are calculated by comparing the existing conditions with the ideal conditions.

### 2.4. Parameters

The main parameters measured in this study were tourism zone area, recreational space requirement, operating hours, average visit duration, rotation factor, rainfall correction factor, slope correction factor, staff adequacy, facility adequacy, management capacity, and actual visitor numbers. Rainfall was classified into wet and dry months, whereas slope was classified based on the Minister of Agriculture Decree No. 837/KPTS/UM/11/1980. The final ECC values were compared with actual visitation during weekdays, weekends, peak seasons, and low seasons.

**Table 2.** Slope Class Scoring

| Slope Class | Inclination (%) | Description | Score |
|---|---|---|---|
| 1 | 0-8 | Flat | 20 |
| 2 | >8-15 | Gently sloping | 40 |
| 3 | >15-25 | Sloping | 60 |
| 4 | >25-45 | Steep | 80 |
| 5 | >45 | Very Steep | 100 |

Source: Minister of Agriculture Decree No. 837/KPTS/UM/11/1980

### 2.5. Statistical Analysis

Quantitative analysis was conducted using descriptive statistics and carrying-capacity equations. Visitor questionnaire data were summarized to determine the average visit duration and visitor perceptions of management adequacy. Likert-scale responses were converted into numerical values to support management capacity estimation. Carrying-capacity values were calculated sequentially from the PCC to the RCC and ECC, and the results were compared with actual visitor numbers to identify underutilization, normal use, or overcapacity conditions.

## 3. RESULTS AND DISCUSSION

### 3.1. General Information


**Figure 1.** Zone Map of Darma Reservoir Ecotourism

Darma Reservoir Ecotourism is one of the leading tourism destinations in Kuningan Regency, West Java, offering a combination of natural landscapes, water-based recreation, and community-based tourism activities. The tourism area comprises several functional zones, including food courts, UMKM areas, picnic zones, Sagara Asri Park, boat-tour zones, children's playgrounds, camping grounds, luxury camps, and mini zoos. Among these attractions, field observations revealed that visitor activities are concentrated primarily in the picnic zones, particularly Tabebuya Plaza and Kirei Plaza, which exhibit the highest visitor density within the tourism area. In contrast, the camping ground and boat-tour zones experience lower visitor concentrations but remain vulnerable to overcrowding during periods of exceptionally high visitation. Consequently, these zones were selected as the primary focus of the tourism carrying capacity (TCC) assessment.

**Table 3.** Total visitors of Darma Reservoir Ecotourism in 2025 (January-September)

| Month | January | February | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|---|---|
| Total Visitor | 33,821 | 16,270 | 2,236 | 44,502 | 15,575 | 16,697 | 15,237 | 10,789 | 10,539 |

The visitation data presented in Table 3 indicate considerable temporal variation throughout 2025. The highest monthly visitation was recorded in April (44,502 visitors), followed by January (33,821 visitors), while the lowest visitation occurred in March (2,236 visitors). Based on management records, average daily visitation reached approximately 200 visitors on weekdays and 1,200 visitors on weekends. During peak tourism periods, such as Eid al-Fitr and New Year holidays, daily visitor numbers increased dramatically, reaching 6,682 and 6,954 visitors, respectively. These fluctuations indicate substantial differences in tourism demand throughout the year and highlight the importance of assessing carrying capacity under varying visitation conditions.

The uneven spatial distribution of visitors observed at Darma Reservoir Ecotourism is consistent with patterns commonly reported in nature-based tourism destinations, where visitors tend to concentrate in areas offering the most attractive recreational experiences and convenient accessibility. Such concentration often creates localized tourism pressure, even when the overall destination remains below its carrying-capacity threshold (Guo, 2025). Similar findings have been reported in GIS-based tourism carrying-capacity studies, emphasizing the necessity of analyzing tourism destinations at the zonal level rather than treating them as homogeneous systems (Mapalad, 2024; Lee & Setiawan, 2026).

The substantial variation in monthly and seasonal visitation also reflects a common characteristic of ecotourism destinations, in which demand is strongly influenced by holiday periods, cultural events, and seasonal travel behavior. These fluctuations create challenges for tourism management because visitor pressure may remain relatively low during normal periods but increase rapidly during peak seasons, potentially leading to overtourism conditions if appropriate management measures are not implemented (Dodds & Butler, 2019; Boháč & Drápela, 2022).

The findings show that visitor pressure at the Darma Reservoir Ecotourism site is not spatially or temporally uniform. This supports carrying capacity assessments at the functional zone level to capture spatial heterogeneity. Identifying utilized zones and peak periods supports targeted interventions, including visitor redistribution, zoning policies, and seasonal tourism planning, and justifies calculating PCC, RCC, and ECC to assess sustainable visitor limits.

### 3.2. Physical Carrying Capacity (PCC)

**Table 4.** Calculation of Physical Carrying Capacity (PCC)

| Tourism Zone | A ($m^2$) | S ($m^2$/person or boat) | Operating hour | Average Visit Duration (hour) | Rotation Factor | PCC |
|---|---|---|---|---|---|---|
| Land zones | 42,000 | 50 | 10 | 2.69 | 3.72 | 3,123 |
| Picnic 1 | 612.15 | 65 | 10 | 1.16 | 8.62 | 81 |
| Picnic 2 | 2,829 | 65 | 10 | 0.92 | 10.87 | 473 |
| Camping Ground | 147 | 3.06 | 24 | 24 | 1 | 48 |
| Boat tour | 1,164,499 | 20,234.3 | 10 | 0.51 | 19.61 | 1,128 |

The PCC calculation presented in Table 4 indicates substantial variations among tourism zones owing to differences in available area, recreational space requirements, and visitor rotation factors. The overall land zone recorded a PCC of 3,123 visitors per day, representing the maximum number of visitors that can be physically accommodated under ideal conditions. Among individual tourism zones, Picnic 2 exhibited a PCC of 473 visitors per day, considerably higher than Picnic 1, which recorded a PCC of 81 visitors per day. This difference is primarily attributed to the larger area available in Picnic 2. The Camping Ground zone recorded a PCC of 48 visitors per day, reflecting the limited number of designated camping spaces. Meanwhile, the Boat Tour zone achieved the highest PCC value of 1,128 boat trips per day, equivalent to approximately 11,280 visitors assuming full boat occupancy.

The results indicate that both the area size and visitor rotation factor strongly influence the PCC values. Tourism zones with larger areas and shorter average visit durations generally exhibit higher carrying capacity values because they can accommodate a greater number of visitor cycles throughout the day.

The influence of area size and visitor turnover on PCC values is consistent with the conceptual framework of carrying-capacity assessment, in which available space and visitor rotation are considered the primary determinants of physical capacity (Cifuentes, 1992). Similar findings have been reported in ecotourism studies conducted in coastal and island destinations, where larger recreational areas were associated with higher carrying-capacity values (Adrianto et al., 2021; Putri & Ansari, 2021).

The relatively high PCC value observed in the boat tour zone also aligns with previous studies, which have shown that water-based tourism activities require substantially larger operational areas than land-based recreational activities. Consequently, carrying-capacity calculations for boating activities often produce significantly higher values owing to extensive spatial availability and rapid visitor turnover rates (Riungu et al., 2020; Adrianto et al., 2021; Juliansyah et al., 2026).

The PCC results demonstrate that the physical capacity of Darma Reservoir ecotourism varies considerably across tourism zones. This finding complements the observations presented in Section 3.1, wherein visitor concentration was found to occur primarily within the picnic zones. Although the overall destination possesses substantial physical capacity, certain zones may approach their physical limits more rapidly than others due to localized visitor concentration. From a management perspective, these results highlight the importance of distributing visitors across multiple tourism zones to optimize space utilization and reduce pressure on highly visited areas. However, PCC represents only the theoretical maximum capacity because environmental and managerial constraints have not yet been incorporated into the analysis. Therefore, further refinement through RCC and ECC calculations is necessary to determine the realistic carrying capacity of each tourism zone.

### 3.3. Real Carrying Capacity (RCC)

The real carrying capacity (RCC) was calculated by incorporating environmental correction factors into the PCC values. In this study, two correction factors were used: rainfall ($CF_1$) and slope inclination ($CF_2$). These factors were selected because both directly influence visitor comfort, accessibility, mobility, and the suitability of outdoor tourism activities at the Darma Reservoir Ecotourism.

Rainfall data from 2015 to 2024 were used to determine the rainfall correction factor. The data were classified into dry and wet months based on the Schmidt–Ferguson classification, where dry months had rainfall below 60 mm and wet months had rainfall above 100 mm. The classification produced 20 dry and 92 wet months, resulting in a rainfall correction factor of 0.7826 (Table 5).

**Table 5.** Calculation of Rainfall ($CF_1$)

| Dry Month ($Lm_x$) | Wet Month ($Tm_x$) | Correction Factor |
|---|---|---|
| 20 | 92 | 0.7826 |

The rainfall correction factor indicates that rainfall reduces the physical carrying capacity by approximately 21.74%. This reduction is relevant because most tourism activities at Darma Reservoir are conducted in open spaces, particularly for picnicking. Under rainy conditions, visitor comfort decreases, outdoor activities are limited, and the usability of several tourism zones is reduced. Therefore, rainfall represents an important environmental constraint in determining the realistic capacity of the tourism area.

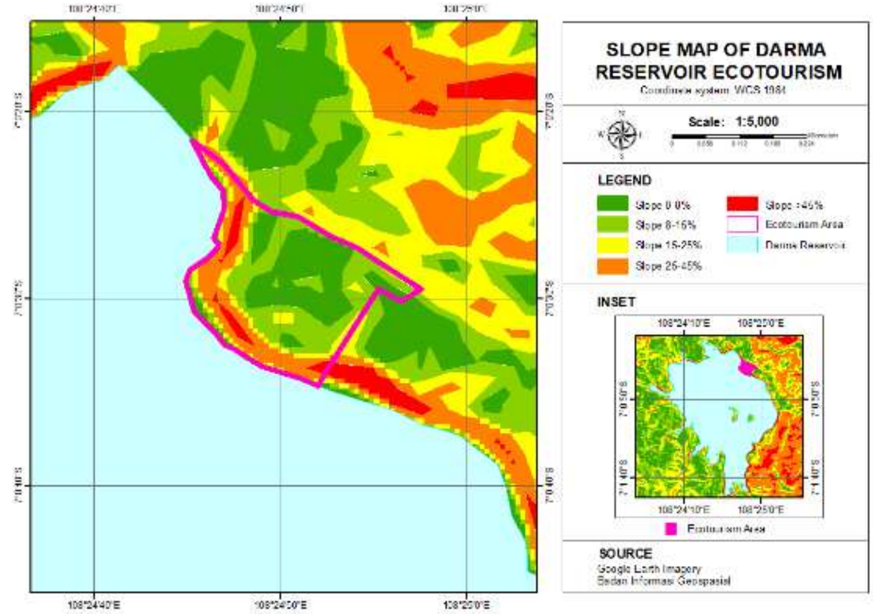


**Figure 2.** Slope Map of Darma Reservoir Ecotourism

Slope inclination was analyzed using DEMNAS data and classified based on the Minister of Agriculture Decree No. 837/KPTS/UM/11/1980. As shown in Figure 2, the tourism area is generally dominated by flat terrain with a slope range of 0%–8%. Based on this classification, the slope score was assigned a value of 20, producing a slope correction factor of 0.8 (Table 6). Although the area is categorized as flat, slight elevation differences still affect visitor movement between tourism zones, particularly in land-based areas.

**Table 6.** Calculation of Slope Inclination ($CF_2$)

| Slope Inclination Score ($Lm_x$) | Total Score ($Tm_x$) | Correction Factor |
|---|---|---|
| 20 | 100 | 0.8 |

The slope correction factor was applied to land-based tourism zones because terrain conditions influence walking speed, accessibility, and visitor mobility. However, the slope correction factor was not applied to the boat tour zone because boating activities are conducted on the water surface and are not affected by land elevation. Therefore, the boat tour zone used a slope correction value of 1.

**Table 7.** Calculation of Real Carrying Capacity (RCC)

| Tourism zone | PCC | Rainfall ($CF_1$) | Slope ($CF_2$) | RCC |
|---|---|---|---|---|
| Land zones | 3,123 | 0.7826 | 0.8 | 1,955 |
| Picnic 1 | 81 | 0.7826 | 0.8 | 51 |
| Picnic 2 | 473 | 0.7826 | 0.8 | 296 |
| Camping Ground | 48 | 0.7826 | 0.8 | 30 |
| Boat tour | 1,128 | 0.7826 | 1 | 883 |

The RCC results presented in Table 7 show that the incorporation of rainfall and slope correction factors substantially reduced the carrying capacity of all tourism zones. The RCC of the overall land zone decreased from 3,123 to 1,955 visitors/day. The number of visitors at Picnic 1 and Picnic 2 decreased from 81 to 51 and from 473 to 296, respectively. The Camping Ground zone saw a decrease from 48 to 30 visitors per day. Meanwhile, the Boat Tour zone experienced a decrease from 1,128 to 883 boat trips/day because it was affected only by rainfall and not by the slope inclination.

These results indicate that environmental constraints significantly influence the realistic capacity of Darma Reservoir ecotourism. Land-based zones experienced greater reductions because they were affected by both rainfall and slope inclination, whereas the boat tour zone experienced a smaller reduction because slope was not considered a limiting factor. This finding confirms that RCC provides a more realistic estimate than PCC because it considers site-specific environmental limitations.

The reduction from PCC to RCC is consistent with the concept of tourism carrying capacity, in which environmental correction factors are applied to adjust the theoretical physical capacity into a more realistic visitor threshold (Cifuentes, 1992; de Sousa et al., 2014). Similar studies have also shown that rainfall, slope, accessibility, and other environmental constraints can significantly reduce the carrying capacity of nature-based tourism destinations (Ayumadany et al., 2022; Soria-Díaz et al., 2022).

The use of GIS-derived rainfall and slope data strengthens the accuracy of the RCC calculation because the integration of NASA GPM and DEMNAS allows environmental correction factors to better represent spatial conditions within the tourism area than conventional approaches that rely on single-station rainfall data or generalized topographic maps. This approach supports a more precise and zone-based tourism carrying capacity assessment, demonstrating that carrying capacity cannot be determined only by the physical area and visitor rotation but must also include environmental limitations to avoid overestimating the number of visitors that can be sustainably accommodated. Practically, the RCC values provide a more reliable basis for visitor management, particularly for land-based zones that are more sensitive to rainfall and terrain conditions, and also provide the basis for the next stage of analysis, namely effective carrying capacity, which incorporates management capacity into the final operational visitor threshold (Gottfried Konecny, 2014; Mandowen G Rosalina & Mambrasar H Rinto, 2021; Mapalad, 2024).

### 3.4. Effective Carrying Capacity (ECC)

The ECC calculation incorporates management capacity into the carrying capacity assessment to determine the maximum number of visitors that can be accommodated under actual operational conditions. Management capacity was evaluated based on staff adequacy and facility availability in the tourism area.

**Table 8.** Total Existing Staff and Ideal Staff for Darma Reservoir Ecotourism

| Management | Total Existing Staff | Total Ideal Staff |
|---|---|---|
| Janitors | 11 | 15 |
| Security | 6 | 8 |
| Managerial | 5 | 5 |
| Ticketing | 3 | 3 |
| Marketing | 2 | 2 |
| Boat tour | 25 | 25 |
| Camping ground | 13 | 13 |
| Total | 65 | 71 |

The staff assessment indicates that Darma Reservoir Ecotourism employs 65 personnel, whereas the ideal requirement is 71. The largest staff shortages occur in janitorial and security services, which are critical for maintaining the comfort and safety of visitors. These deficiencies reduce the overall management capacity and, consequently, influence the ECC value.

**Table 9.** Total Existing Facilities and Total Ideal Facilities for Darma Reservoir Ecotourism

| Management | Total Existing Facilities | Total Ideal Facilities |
|---|---|---|
| Toilet | 36 | 36 |
| Sink | 14 | 16 |
| Trash Can | 35 | 35 |
| First Aid Kit | 3 | 9 |
| Disabilities Facilities | 3 | 3 |
| Medical Room | 1 | 1 |
| Total | 90 | 98 |

A facility assessment revealed that most tourism-supporting facilities were available in sufficient quantities. However, shortages remained for several important facilities, particularly sinks and first-aid equipment. Although the facility adequacy ratio remained relatively high, these deficiencies indicate opportunities to improve service quality and visitor safety within the tourism area.

**Table 10.** Calculation of Effective Carrying Capacity (ECC)

| Tourism Zone | RCC | Staff Value | Facilities Value | Management Capacity (Average of Staff and Facilities Value) | ECC |
|---|---|---|---|---|---|
| Land zones | 1,955 | 0.910 | 0.92 | 0.91 | 1,787 |
| Picnic 1 | 51 | 0.725 | 1 | 0.725 | 37 |
| Picnic 2 | 296 | 0.725 | 1 | 0.725 | 215 |
| Camping Ground | 30 | 1 | 1 | 1 | 30 |
| Boat Tour | 883 | 1 | 1 | 1 | 883 |

The incorporation of management capacity further reduced carrying-capacity values from the RCC to the ECC. The overall land zone recorded an ECC value of 1,787 visitors/day, compared with an RCC value of 1,955 visitors/day. Picnic 1 and Picnic 2 exhibited the greatest reductions, reaching ECC values of 37 and 215 visitors/day, respectively. This decrease was primarily caused by lower management-capacity values resulting from the absence of dedicated staff in these zones. In contrast, the Camping Ground and Boat Tour zones maintained ECC values equal to their RCC values because their management capacity reached an ideal level. The Boat Tour zone achieved an ECC value of 883 boat trips/day, equivalent to approximately 8,830 visitors/day assuming full boat occupancy.

The reduction from the RCC to the ECC demonstrates the importance of incorporating management capacity into tourism carrying-capacity assessments. Previous studies have emphasized that environmental conditions alone cannot fully determine tourism capacity because management effectiveness directly influences the ability of destinations to provide services, maintain infrastructure, and ensure visitor safety (Salerno et al., 2013; Aldalbahi, 2025). Consequently, ECC is generally considered a more realistic measure of operational capacity than PCC or RCC alone.

The findings also support the conceptual framework proposed by Cifuentes, where management capacity acts as a limiting factor that modifies environmentally derived carrying-capacity values (Cifuentes, 1992). Similar results have been reported in ecotourism and protected-area studies, where insufficient staffing levels and facility shortages significantly reduced the final carrying-capacity threshold despite favorable environmental conditions (Putri & Ansari, 2021; Sari & Rahayu, 2018). Therefore, improving management resources can directly increase the effective capacity of tourism destinations.

The ECC results indicate that management capacity plays a crucial role in determining the operational carrying capacity of the Darma Reservoir Ecotourism. This finding extends the results presented in Sections 3.2 and 3.3, where the physical and environmental capacities were shown to be substantially higher than the final ECC values. While PCC and RCC describe the physical and environmental limits of tourism activities, ECC reflects the actual capacity that can be sustainably managed under the existing operational conditions.

From a practical perspective, the results suggest that improvements in staffing levels and supporting facilities could increase the effective carrying capacity of several tourism zones, particularly in Picnic 1 and Picnic 2. The findings also provide a quantitative basis for management planning, allowing destination managers to prioritize investments in personnel, sanitation infrastructure, and visitor services. Consequently, ECC serves as a more appropriate benchmark for evaluating actual visitor numbers and determining whether tourism activities remain within sustainable management limits.

### 3.5. Tourism Management Strategy Based on Carrying Capacity

A comparison between the ECC values and actual visitation data reveals substantial differences in capacity utilization across tourism seasons. The average weekday visitation was approximately 200 visitors/day, while the average weekend visitation was 1,200 visitors/day. Both values remained below the overall ECC threshold of 1,787 visitors/day, indicating that tourism activities generally operate within sustainable limits during normal periods.

**Table 11.** Daily Visitor Numbers for Darma Reservoir Ecotourism

| Average Weekdays | Average Weekends | Eid Al-Fitr | New Year | Month Ramadan (Low Season) |
|---|---|---|---|---|
| 200 | 1,200 | 6,682 | 6,954 | 8 |

However, visitation patterns change significantly during peak tourism seasons. During Eid al-Fitr and New Year holidays, daily visitor numbers reached 6,682 and 6,954, respectively, greatly exceeding the ECC threshold. These values indicate that the tourism area experienced overcapacity conditions during these periods. In contrast, visitation during Ramadan averaged only eight visitors/day, representing a very small proportion of the available carrying capacity and indicating substantial underutilization of tourism resources.

The occurrence of both overcapacity and underutilization within the same tourism destination reflects the dynamic nature of tourism demand. Similar patterns have been reported in nature-based tourism destinations, where visitor concentrations occur during specific holidays and seasonal events, creating overtourism conditions despite relatively low visitation during other periods (Dodds & Butler, 2019; Boháč & Drápela, 2022). These findings highlight the limitations of static tourism management approaches and reinforce the importance of adaptive carrying-capacity management.

Previous studies have suggested that visitor quotas, reservation systems, and spatial redistribution strategies can effectively mitigate overtourism by controlling visitor flows and reducing pressure on sensitive tourism zones (Wang et al., 2020). Simultaneously, promotional programs, activity diversification, and pricing incentives have been proposed as mechanisms for increasing visitation during low-demand periods and improving destination utilization efficiency (Marhanah et al., 2023).

The findings demonstrate that carrying-capacity assessment should not be viewed solely as a tool for limiting visitor numbers but also as a framework for optimizing tourism management during different visitation periods. The ECC value of 1,787 visitors/day indicates that Darma Reservoir Ecotourism still possesses substantial unused capacity during weekdays and normal tourism periods. Therefore, strategies such as targeted promotions, discounted weekday tickets, tourism package development, and activity diversification could be implemented to increase visitation without exceeding sustainable limits.

Conversely, the substantial exceedance of ECC during Eid al-Fitr and New Year holidays indicates the need for stricter visitor management measures. These measures may include online reservation systems, daily visitor quotas, timed-entry mechanisms, and visitor redistribution toward less crowded tourism zones. When viewed together with the PCC, RCC, and ECC results presented in previous sections, the findings confirm that sustainable tourism management at Darma Reservoir requires both spatial and temporal adaptation. Such an approach would allow managers to maximize economic benefits during low-demand periods while protecting environmental quality and visitor experience during periods of exceptionally high visitation.

## 4. CONCLUSIONS

This study assessed the tourism carrying capacity (TCC) of Darma Reservoir Ecotourism using a zone-based approach through PCC, RCC, and ECC calculations. The results showed that the carrying capacity differed among zones owing to variations in area, environmental constraints, and management capacity. The overall ECC for the land-based tourism area was 1,787 visitors per day, indicating that weekday and weekend visits remain below the sustainable threshold.

The integration of NASA GPM rainfall data and DEMNAS slope data improved the accuracy of environmental correction factors, whereas the inclusion of staff and facility adequacy provided a more realistic operational capacity. However, peak-season visitation during Eid al-Fitr and New Year exceeded the ECC, indicating an overtourism risk. Therefore, visitor quotas, reservation systems, and flow redistribution are needed during peak periods, whereas promotion and activity diversification can be applied during the low season. Future studies should examine visitor preferences and responses to adaptive management strategies.

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