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Community Perceptions of Cultural Ecosystem Services in Urban Parks Identified Through Cluster Analysis in Banda Aceh, Indonesia

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ABSTRACT

Rapid urbanization can reduce the availability and quality of urban green spaces, increasing the need to understand how communities perceive the non-material benefits provided by urban parks. This study examines visitor perceptions of cultural ecosystem services (CES) across nine urban parks in Banda Aceh, Indonesia, using survey data from 177 visitors, descriptive statistics, and K-Means clustering. The inter-item correlation structure was adequate for multivariate analysis (KMO = 0.82; Bartlett's test: χ^2 = 2,173.858, df = 351, $p < 0.001$). Recreation-related benefits were perceived most strongly, whereas disaster-mitigation benefits received comparatively lower ratings. K-Means analysis identified two broad visitor-perception profiles; however, the low silhouette value (0.1748) indicates substantial overlap between the groups, and the segmentation is therefore interpreted as exploratory rather than as evidence of sharply separated visitor types. The findings are limited to the surveyed parks and respondents in Banda Aceh and indicate that perception-based CES assessment can provide complementary information for urban green-space planning.

1. INTRODUCTION

The rising urbanization phenomenon has become one of the most significant phenomena in the transformation of urban areas worldwide. Rapid urban growth is often followed by intensive land-use changes, an increase in population density, and a decline in green open spaces within urban areas. These conditions give rise to various environmental challenges, such as rising urban heat island effects, declining air quality, and a shrinking of public spaces that support the well-being of urban communities [1, 2]. In this context, urban green spaces play a crucial role as part of urban green infrastructure that can support urban sustainability by providing various ecosystem services [3-5].

The concept of ecosystem services serves as a key framework for understanding the contribution of ecosystems to human well-being. The Millennium Ecosystem Assessment classifies ecosystem services into four main categories, which are provisioning services, regulating services, cultural services, and supporting services [6]. In the urban context, attention to cultural ecosystem services (CES) is growing because these services reflect the non-material benefits that communities derive from their interactions with the natural environment, such as recreational experiences, the aesthetic value of landscape, sense of place, and social interactions [7, 8]. Various studies indicate that CES play a crucial role in enhancing the psychological well-being of communities and strengthening the relationship between humans and the natural environment in urban areas [5, 9, 10].

Urban green open spaces, particularly urban parks, are a key element in the provision of CES [11]. Urban parks provide spaces for various social and recreational activities that can improve the physical and mental health of the community and strengthen social cohesion within urban communities [12-14]. Additionally, urban parks play a role in improving urban environmental quality through various ecological functions such as microclimate regulation, air pollution reduction, and the enhancement of urban biodiversity [15-17]. Therefore, urban parks are increasingly viewed as a key component in sustainable urban development strategies and the implementation of nature-based solutions in urban areas [18].

In recent years, research on CES in urban green open spaces has evolved rapidly. Several studies indicate that park landscape characteristics, environmental quality, access to urban green spaces, and facilities around the urban parks have a significant influence on the public's perception of the benefits provided by green open spaces [19]. In addition, other studies indicate that the public's emotional connection to green open spaces also plays a role in shaping their experiences and perceptions of the benefits of CES [13].

Nevertheless, several studies indicate that public perceptions of CES do not always align with the ecological capacity of green open spaces themselves. In many cases, the public tends to be more aware of direct benefits such as

recreation and landscape aesthetics [20], while other ecological benefits, such as environmental regulation or disaster mitigation, are often overlooked by park visitors [21, 22]. They suggest that the evaluation of CES depends not only on the ecological characteristics of green open spaces but also on the perceptions and experiences of the public as users of these spaces.

Furthermore, most research on CES in urban green open spaces remains concentrated in cities across Europe, North America, and East Asia. Research on public perceptions of CES in developing cities, particularly in Southeast Asia, remains relatively limited. However, cities in this region face the dynamics of urbanization and land-use changes that can affect the availability and quality of urban green open spaces [23, 24]. Furthermore, most previous studies have evaluated CES at the city or regional level in general, while studies specifically evaluating variations in CES at the level of individual city parks within a single urban area remain relatively limited [25, 26].

Given these circumstances, there remains a need for a more comprehensive understanding of how the public perceives the various dimensions of CES provided by urban parks, as well as how these perceptions vary across different parks within a single urban area. The contribution of this study is empirical and planning-oriented rather than methodological. It compares perceived benefits across nine individual urban parks in a developing Southeast Asian city and identifies broad visitor-perception profiles within the same urban context. Therefore, this study aims to assess visitor perceptions of selected cultural and complementary ecological benefits in urban parks in Banda Aceh, identify broad perception profiles using K-Means clustering, and compare patterns across the nine surveyed parks. The findings are intended to provide locally relevant information for green open-space planning in Banda Aceh. The study does not measure the actual biophysical performance of the parks.

2. MATERIAL AND METHODS

2.1 Study location

Banda Aceh, the capital city of Aceh Province, is located at the northern tip of Sumatra Island and serves as an important center of governance, socio-economic activity, and cultural life. The city lies in a coastal lowland area facing the Indian Ocean, which strongly shapes its environmental characteristics and spatial development. Astronomically, Banda Aceh is positioned approximately between 5°30'–5°36' North Latitude and 95°16'–95°22' East Longitude, placing it within a tropical climate with relatively warm temperatures and seasonal rainfall patterns. As a designated National Activity Centre, Banda Aceh plays a key role in supporting regional development, particularly in public services, education, and administrative functions.

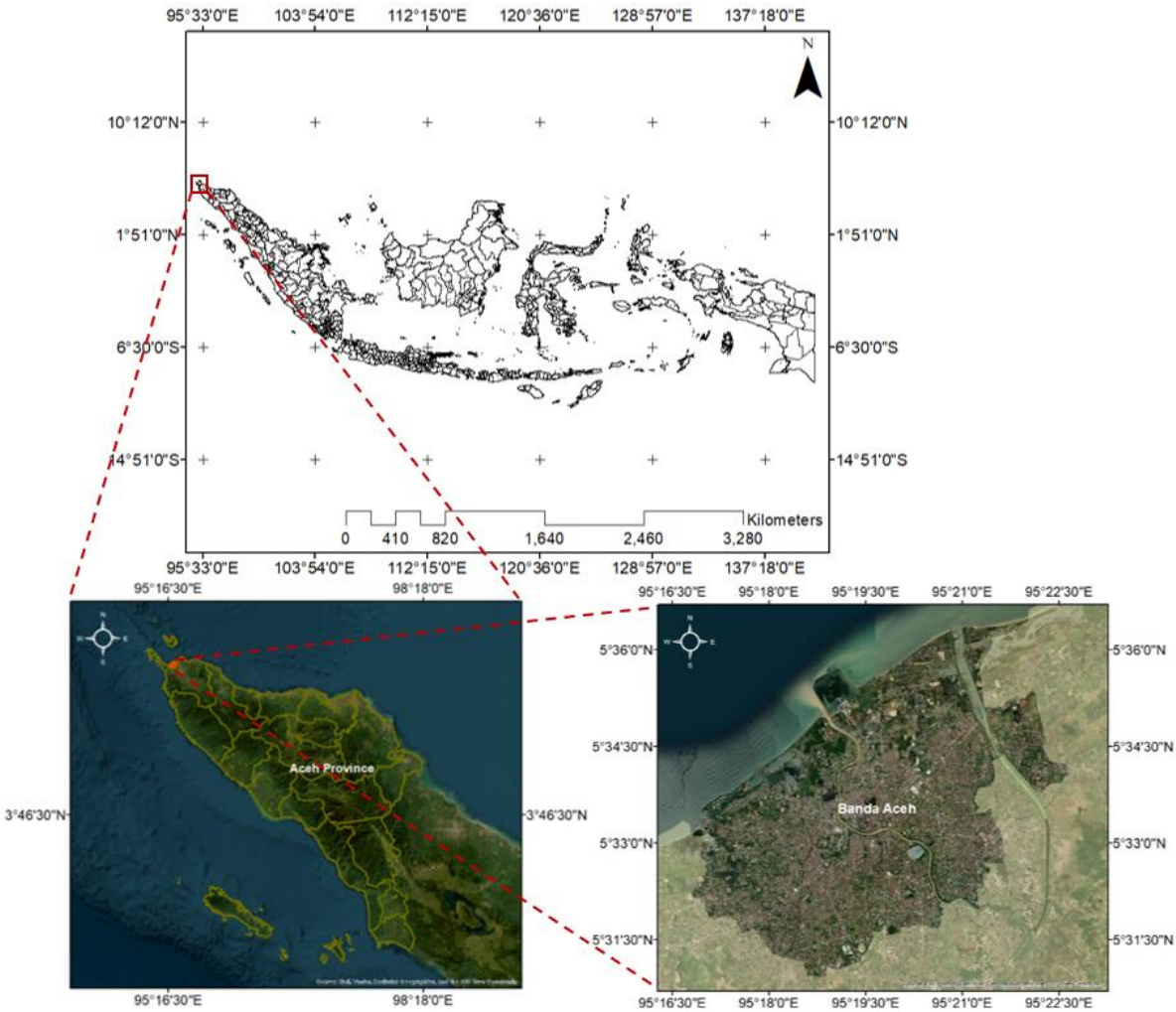

Figure 1. Study location

From a demographic perspective, the city has a relatively dense and growing population, which continues to influence urban expansion and land use changes. Its economy is largely driven by the service sector, including trade, public services, and administration, reflecting its character as a service-based urban centre rather than an industrial one. These conditions underscore the growing significance of urban green spaces, such as city parks, not merely as ecological assets, but also as vital components that enhance the overall quality of urban life (see Figure 1).

2.2 Data source

Primary data were obtained through a questionnaire survey of 177 visitors to nine urban parks in Banda Aceh: Taman Sari Park, Sri Ratu Saifudin Park, BNI Tibang Park, Blang Padang Public Green Space, Trembesi Forest Park, Krueng Neng Park, Kencana Park, Meuraxa Recreation Park, and Putro Phang Park. The survey recorded respondent characteristics, including gender, age, education, and employment status, together with ratings of perceived park benefits. The locations of the nine parks are shown in Figure 2.

Respondents were selected using accidental (convenience) sampling, involving park visitors who were present during the survey and willing to participate. The survey was conducted from 1 to 30 August 2023. A total of 177 respondents were obtained from nine urban parks, with the following distribution: Taman Sari Park (30), Sri Ratu Saifudin Park (20), BNI Tibang Park (20), Blang Padang Public Green Space (20), Trembesi Forest Park (20), Krueng Neng Park (20), Kencana Park (12), Meuraxa Recreation Park (15), and Putro Phang Park (20). The survey did not apply specific weekday/weekend or time-of-day stratification. Therefore, possible temporal differences in park use were not specifically examined in this study.

2.3 Research variables

This study assessed nine perceived benefit dimensions, namely recreation, cultural heritage, aesthetics, education, social value, health, spiritual value, disaster mitigation, and environmental/ecological value. The first seven dimensions represent commonly recognized CES [6-8], while disaster mitigation and environmental/ecological value were included as complementary regulating and ecological benefits. Each dimension was represented by three questionnaire items (X_1P_1–X_9P_3), while overall satisfaction was measured separately using Y1. Responses were recorded using a 4-point Likert-type scale, ranging from 1 (very dissatisfied) to 4 (very satisfied). The questionnaire showed good internal consistency, with a Cronbach's alpha value of 0.89.

2.4 Data analysis method

The analysis was conducted in four stages. First, descriptive statistics were used to summarize the questionnaire responses. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were then used as diagnostics of sampling adequacy and inter-item correlation structure [27, 28]; these tests were not treated as direct validation of K-Means clustering. Second, variables used for clustering were standardized to reduce the influence of scale differences. Third, candidate cluster solutions were evaluated using the within-cluster sum of squares (WCSS) elbow pattern and the silhouette index. Finally, K-Means clustering was applied to identify broad respondent-perception profiles [29], followed by comparison of perceived benefit patterns across the surveyed parks. Park location was retained as a survey identifier and was not interpreted as a CES score.

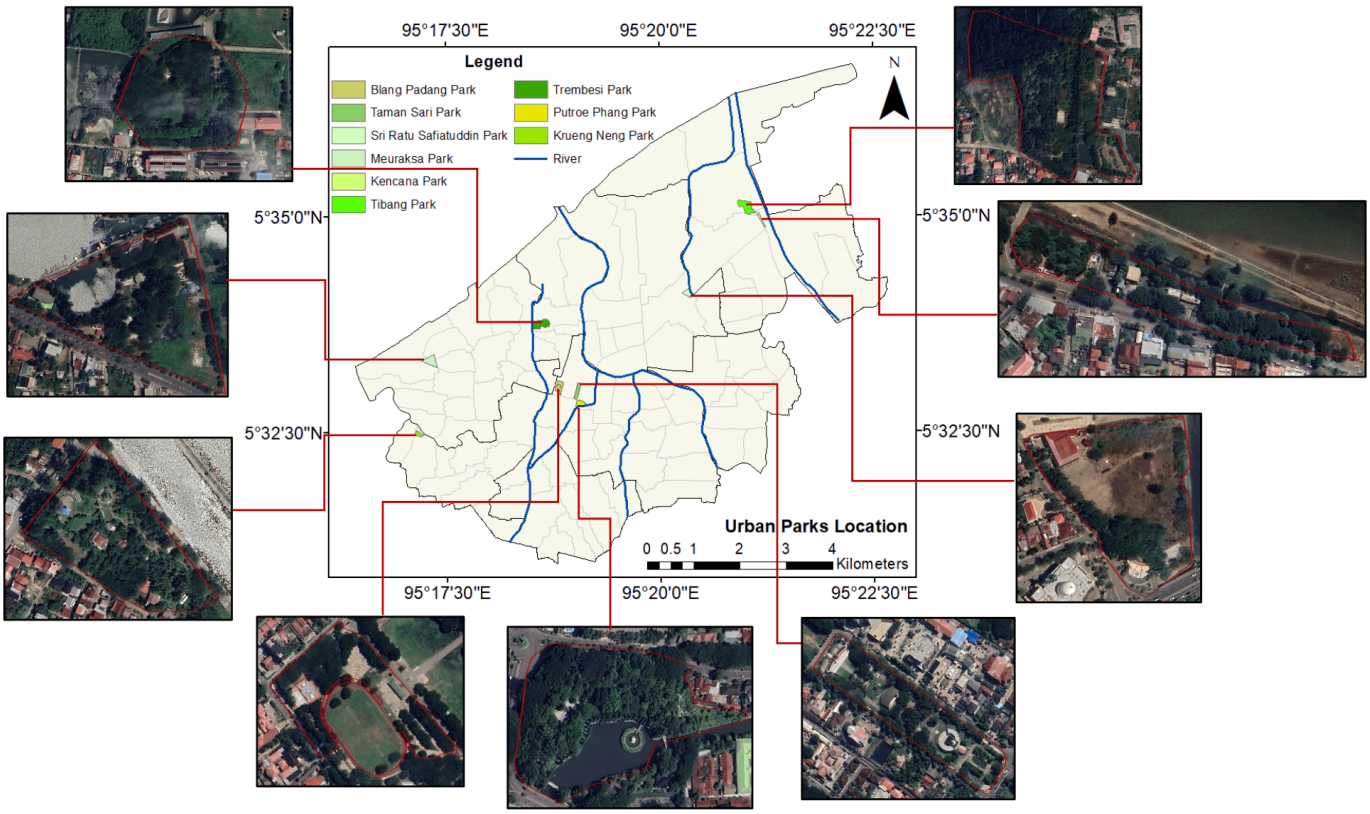

Figure 2. Nine parks in Banda Aceh

2.4.1 Kaiser-Meyer-Olkin test

The KMO measure was used to assess whether the questionnaire items shared sufficient common variance for multivariate interpretation. Values above 0.50 were considered acceptable, with higher values indicating better sampling adequacy, as summarized in Table 1 [27, 28]. The KMO result was interpreted together with Bartlett's test and was not used as a stand-alone measure of cluster validity.

Table 1. Sampling adequacy classification according to Kaiser-Meyer-Olkin (KMO) value

KMO Value	Description
≤0.9	Satisfying
0.8 – 0.9	Very Good
0.7 – 0.8	Good
0.6 – 0.7	Quite Good
0.5 – 0.6	Not Good Enough
≤0.5	Not Fit

The Kaiser-Meyer-Olkin value can be obtained using Eq. (1) as follows.

$$KMO = \frac{\sum_{i=1}^{p}\sum_{k=1}^{p} r_{ik}^2}{\sum_{i=1}^{p}\sum_{k=1}^{p} r_{ik}^2 + \sum_{i=1}^{p}\sum_{k=1}^{p} a_{ik}^2} \quad (1)$$

where,

r_{ik}: coefficient of correlation between variables i and k

a_{ik}: partial coefficient of correlation between variable i and k, where, $i = 1,2,3, \dots, p$ and $k = 1,2,3, \dots, p$.

If the KMO value is greater than 0.5, then the indicator is still acceptable and worthy of being factored, and conversely, if the KMO value < 0.5, then the indicator is not fit for being factored.

2.4.2 Bartlett test

Bartlett's test of sphericity was used to test whether the correlation matrix differed significantly from an identity matrix. A significant result indicates that the questionnaire items contain sufficient intercorrelation for multivariate interpretation [27, 28]. The test statistic was calculated using Eq. (2).

$$H_0: R = I$$

$$H_1: R \neq I$$

While the Eq. (2) for the statistical test is shown as follows:

$$\chi^2_{hitung} = -\left[(n-1) - \frac{(2p+5)}{6}\right] ln|R| \quad (2)$$

where,

n: observations number

p: variable number

$|R|$: correlation matrix determinant

The hypothesis is rejected (H_0) if $\chi^2_{hitung} > \chi^2_{\alpha,\frac{p(p-1)}{2}}$. A correlation matrix is said to resemble an identity matrix if the determinant value is close to 1. The variables used in this study and their measurement scales are shown in Table 2.

Table 2. Research variables

Variable	Description	Scale
Y_1	Satisfactory Level	Likert-type ordinal rating
X_1	Recreation Value	Likert-type ordinal rating
X_2	Cultural Heritage Value	Likert-type ordinal rating
X_3	Aesthetic Value	Likert-type ordinal rating
X_4	Education Value	Likert-type ordinal rating
X_5	Social Value	Likert-type ordinal rating
X_6	Health Value	Likert-type ordinal rating
X_7	Spiritual Value	Likert-type ordinal rating
X_8	Disaster Mitigation Value	Likert-type ordinal rating
X_9	Environmental/Ecological Value	Likert-type ordinal rating

2.4.3 Cluster analysis

Cluster analysis was used to explore whether respondents exhibited broadly similar perception profiles. This study applied K-Means, a non-hierarchical partitioning method that assigns observations to the nearest cluster centroid [27-29]. Because K-Means requires the number of clusters (K) to be specified in advance, candidate solutions from K = 2 to K = 6 were evaluated using the average Silhouette score and WCSS. WCSS describes the reduction in within-cluster dispersion as K increases, whereas the silhouette index summarizes within-cluster cohesion and between-cluster separation. Given the relatively low silhouette value obtained in this study, cluster membership is interpreted as exploratory segmentation rather than as a definitive classification of visitors. In the assignment step, Euclidean distances from each observation to the cluster centroids were calculated using Eq. (3):

$$d_{ij} = \sqrt{\sum_{k=1}^{p}\left(x_{ik} - x_{jk}\right)^2} \quad (3)$$

where,

d_{ij}: distance between object i and object j

i,j: 1,2, …, n

k: 1,2, …, p

x_{ik}: observed value of object i against object k

x_{jk}: observed value of object j against object k

K-Means is a non-hierarchical data clustering method that aims to partition data into one or more clusters. This method partitions data into clusters so that data with similar characteristics are grouped into the same cluster, while data with different characteristics are grouped into other clusters. The objective of data clustering is to minimize the objective function set during the clustering process, which generally aims to minimize the variation between clusters [20].

The K-means method is a method whose algorithm describes that each item in a cluster has a nearest centroid or average. The steps in K-means analysis are as follows [19].

(1) Categorizing an item into a k-cluster.

(2) Calculate the centroid value using Eq. (4).

$$v_{ij} = \frac{\sum_{k=1}^{N_i} x_{kj}}{N_i} \quad (4)$$

where,

v_{ij}: centroid or average number of *cluster-i* for variable-*j*

N_i: data number classified to *cluster-i*

i, k: index from cluster

j: index from variable

x_{kj}: the k data value inside *cluster* in *j*-variable

(3) Then, group the items based on the nearest centroid (using Euclidean distance), using the following Eq. (5).

$$D_e = \sqrt{\left(\sum_{i=1}^{p}(x_i - s_i)^2\right)} \quad (5)$$

where,

D_e: Euclidean distance

i: number of objects

p: number of variables

x: object coordinate

s: centroid coordinate

(4) Recalculate the group whenever a new item is added, or an item is removed.

(5) Repeat steps 2 and 3 until there are no more items that can be added or removed, at which point the convergence criteria are met.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Respondent characteristics

This research involved 177 respondents who were visitors to nine city parks in Banda Aceh, namely Taman Sari Park, Sri Ratu Saifudin Park, BNI Tibang Park, Blang Padang Public Green Space, Trembesi Forest Park, Krueng Neng Park, Kencana Park, Meuraxa Recreation Park, and Putro Phang Park. The sociodemographic characteristics of the respondents are presented in Table 3.

Based on Table 3, the distribution of respondents by gender shows that women (52.54%) slightly outnumber men (47.46%). In terms of age, the majority of respondents were in the 11–29 age group (50.85%), followed by the 30–44 age group (42.37%), while the group aged 45 and older had a relatively small proportion. Younger age groups were more strongly represented in the surveyed sample.

Respondents with a senior high school education constituted the largest educational group (38.42%), followed by those with a bachelor's degree (30.51%). These findings suggest that most surveyed visitors had completed secondary or higher education. Meanwhile, based on employment status, students and college students constitute the largest group of visitors (33.90%), followed by private-sector employees (28.25%) and homemakers (14.69%).

Table 3. Sociodemographic characteristics of survey respondents (n = 177)

Variable	Category	Respondents (%)
Gender	Male	47.46%
	Female	52.54%
Age	11-29	50.85%
	30-44	42.37%
	45-59	6.22%
	≥60	0.56%
Education	Elementary	1.13%
	Junior High School	6.22%
	Senior High School	38.42%
	Vocational High School	6.22%
	Associate degree (2nd Year)	1.13%
	Associate degree (3rd Year)	5.65%
	Associate Degree (4th Year)	1.13%
	Bachelor Degree	30.51%
	Master Degree	7.35%
	Doctoral Degree	1.13%
	Unidentified	1.13%
Employment Status	ASN (Civil Servant)	10.17%
	Unemployed	3.95%
	BUMD	0.56%
	BUMN	0.56%
	Housewife	14.69%
	NGO	0.56%
	Student and College Student	33.90%
	Farmer	0.56%
	Private Employee	28.25%
	TNI	0.56%
	Entrepreneur	5.08%
	Unidentified	1.13%

3.1.2 Data adequacy and statistical validation

Before clustering, the internal consistency and correlation structure of the questionnaire items were examined. Cronbach's alpha was 0.89, indicating good internal consistency. The overall KMO value was 0.82 (Table 4), indicating very good sampling adequacy according to the classification in Table 1. Bartlett's test was statistically significant (chi-square = 2,173.858, df = 351, $p < 0.001$) (Table 5), indicating that the correlation matrix differed significantly from an identity matrix. These results support multivariate interpretation of the questionnaire items, but they should not be interpreted as direct evidence of cluster quality.

3.1.3 Descriptive statistics for the cultural ecosystem indicator

Descriptive statistics for the variables are presented in Table 6, while Figure 3 shows their distributions. The perception scores are reported on the original questionnaire scale; no transformation was applied to the scores for the descriptive analysis. The perception scores in Table 6 are expressed on the original 4-point response scale. Park code is retained only as an identifier and should not be interpreted as a perception score.

Table 4. Kaiser-Meyer-Olkin (KMO) factor adequacy

X_1P_1	X_1P_2	X_1P_3	X_2P_1	X_2P_2	X_2P_3	X_3P_1	X_3P_2	X_3P_3	X_4P_1
0.79	0.80	0.83	0.84	0.84	0.82	0.81	0.88	0.91	0.77
X_4P_2	X_4P_3	X_5P_1	X_5P_2	X_5P_3	X_6P_1	X_6P_2	X_6P_3	X_7P_1	X_7P_2
0.81	0.81	0.87	0.83	0.80	0.83	0.81	0.81	0.85	0.77
X_7P_3	X_8P_1	X_8P_2	X_8P_3	X_9P_1	X_9P_2	X_9P_3	Y_1		
0.88	0.65	0.66	0.82	0.81	0.87	0.87	0.91		

Note: Overall KMO value = 0.82.

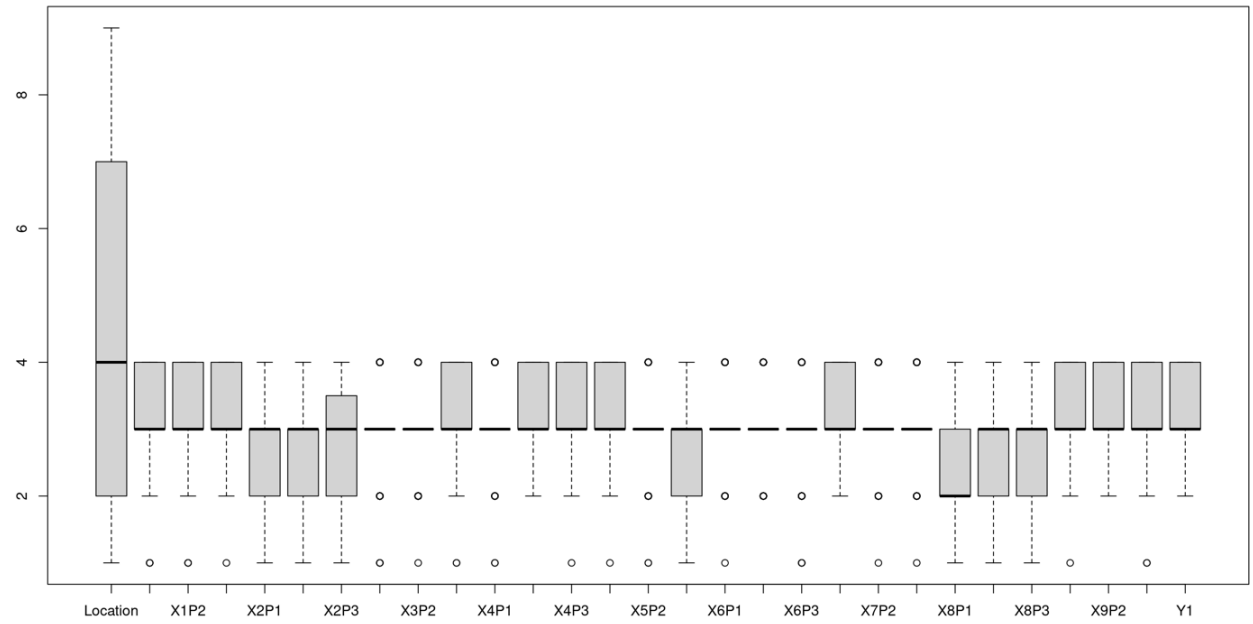

Figure 3. Boxplot of variables used in the analysis

3.1.4 Correlation between cultural ecosystem indicators

Table 7 summarizes the correlation structure among the variables used in the preliminary multivariate analysis. The observed correlations vary in magnitude, indicating that some perception items share common response patterns while others capture relatively different aspects of respondents' evaluations. Y1 represents the overall perception score and was included in the correlation analysis to examine its relationship with other variables. It was not included in the descriptive statistics, which focused on individual questionnaire items.

Table 5. Bartlett's test of sphericity for the questionnaire items

Chi-Square	df	p-Value	Decision
2,173.858	351	<0.001	Reject H_0

Table 6. Descriptive statistics of questionnaire responses

Questionnaire Items	Statistical Measures							
	Median	Mean	SE Mean	95% CI Half-Width	Variance	Std. Dev	Coef. Var	Valid n
X_1P_1	3.000	3.29378	0.04696	0.09269	0.39047	0.62487	0.18971	177
X_1P_2	3.000	3.29378	0.04558	0.08995	0.36774	0.60642	0.18411	177
X_1P_3	3.000	3.38983	0.04167	0.08224	0.30739	0.55443	0.16355	177
X_2P_1	3.000	2.84180	0.06195	0.12226	0.67937	0.82424	0.29004	177
X_2P_2	3.000	2.89830	0.06053	0.11947	0.64869	0.80541	0.27789	177
X_2P_3	3.000	2.90909	0.06409	0.12650	0.72311	0.85036	0.29231	176*
X_3P_1	3.000	3.06214	0.05140	0.10144	0.46770	0.68389	0.22333	177
X_3P_2	3.000	3.02259	0.04529	0.08938	0.36312	0.60259	0.19936	177
X_3P_3	3.000	3.10734	0.04839	0.09550	0.41454	0.64385	0.20720	177
X_4P_1	3.000	3.10169	0.04538	0.08957	0.36459	0.60382	0.19467	177
X_4P_2	3.000	3.22598	0.04200	0.08289	0.31227	0.55881	0.17322	177
X_4P_3	3.000	3.31073	0.04668	0.09214	0.38585	0.62116	0.18762	177

X_5P_1	3.000	3.23728	0.04164	0.08219	0.30701	0.55408	0.17115	177
X_5P_2	3.000	3.07344	0.04534	0.08948	0.36389	0.60323	0.19627	177
X_5P_3	3.000	2.70621	0.04897	0.09665	0.42456	0.65158	0.24077	177
X_6P_1	3.000	3.07909	0.04120	0.08132	0.30052	0.54820	0.17804	177
X_6P_2	3.000	3.07344	0.04008	0.07910	0.28434	0.53324	0.17349	177
X_6P_3	3.000	2.92655	0.05005	0.09878	0.44343	0.66591	0.22754	177
X_7P_1	3.000	3.28813	0.04097	0.08086	0.29718	0.54514	0.16579	177
X_7P_2	3.000	3.11864	0.04183	0.08255	0.30970	0.55651	0.17844	177
X_7P_3	3.000	3.08474	0.04304	0.08495	0.32800	0.57271	0.18566	177
X_8P_1	3.000	2.44632	0.05770	0.11388	0.58943	0.76774	0.31383	177
X_8P_2	3.000	2.46327	0.05778	0.11403	0.59097	0.76874	0.31208	177
X_8P_3	3.000	2.54237	0.05190	0.10243	0.47688	0.69057	0.27162	177
X_9P_1	3.000	3.22598	0.04423	0.08730	0.34636	0.58852	0.18243	177
X_9P_2	3.000	3.36723	0.03971	0.07837	0.27914	0.52834	0.15690	177
X_9P_3	3.000	3.23728	0.04673	0.09222	0.38655	0.62173	0.19205	177

Note: *Valid n = 176 (estimated from SE and SD).

Table 7. Correlation matrix of variables used in the preliminary analysis

Variables	X_1P_1	X_nP_n	X_9P1	X_9P_2	X_9P_3	Y_1
X_1P_1	1	…	0.26648813	0.2220742	0.18516306	0.21307740
X_1P_2	0.59561056	…	0.32235972	0.2820344	0.20586878	0.27016537
X_1P_3	0.43835168	…	0.33792782	0.2261819	0.12571653	0.20512857
X_2P_1	0.35550232	…	0.12096691	0.2254867	0.23997387	0.23662903
X_2P_2	0.34193687	…	0.18061367	0.2351340	0.20731419	0.16746818
X_2P_3	0.30775243	…	0.25748436	0.3408391	0.38578190	0.23655042
X_3P_1	0.24953510	…	0.31782483	0.3453226	0.41945285	0.26668607
X_3P_2	0.10298146	…	0.30594001	0.3485539	0.33441022	0.28597697
X_3P_3	0.14712698	…	0.41544099	0.3511313	0.30504282	0.29430941
X_4P_1	0.17636409	…	0.12682517	0.2919020	0.26831978	0.33564328
X_4P_2	0.26438627	…	0.36211908	0.3523769	0.23726514	0.37477406
X_4P_3	0.29044511	…	0.25754262	0.2043273	0.26406794	0.21658275
X_5P_1	0.35546277	…	0.40960685	0.3411304	0.26444983	0.21965025
X_5P_2	0.25896931	…	0.20904856	0.2001282	0.13506032	0.13996306
X_5P_3	0.25504794	…	0.11484951	0.1006115	0.13098130	0.14101847
X_6P_1	0.34643912	…	0.17322227	0.2326314	0.22801381	0.20461352
X_6P_2	0.24180634	…	0.25459293	0.2465640	0.25561526	0.23506330
X_6P_3	0.14773073	…	0.11508160	0.2547393	0.26190911	0.24186352
X_7P_1	0.10035819	…	0.34488315	0.3998840	0.36709280	0.24964648
X_7P_2	-0.01910792	…	0.26462715	0.2761025	0.23017535	0.18286636
X_7P_3	0.26344065	…	0.26314021	0.3659960	0.23042447	0.35145008
X_8P_1	0.09227118	…	0.10244589	0.1679290	0.11015510	0.01648456
X_8P_2	0.17634952	…	0.06868118	0.1522983	0.08966131	0.05818448
X_8P_3	0.20799266	…	0.21396727	0.1829127	0.12201687	0.15314163
X_9P_1	0.26648813	…	1	0.6086771	0.38056559	0.35585296
X_9P_2	0.22207421	…	0.60867713	1	0.54616647	0.46989154
X_9P_3	0.18516306	…	0.38056559	0.5461665	1	0.39317344
Y_1	0.21307740	…	0.35585296	0.4698915	0.39317344	1

3.1.5 Cluster analysis of visitors' perceptions

K-Means clustering was applied to the 177 respondents to identify differences in their perceptions of CES. Candidate solutions from K = 2 to K = 6 were compared using the average Silhouette score and WCSS. The results are presented in Table 8.

Table 8. Comparison of candidate K-Means solutions

K	Average Silhouette	WCSS
2	0.1748	3,880.25
3	0.1051	3,600.46
4	0.1029	3,414.32
5	0.0981	3,296.69
6	0.0845	3,189.73

Note: WCSS = Within-cluster sum of squares.

The highest Silhouette score was obtained for K = 2 (0.1748). The WCSS also showed the largest reduction from K = 1 to K = 2, followed by smaller reductions for higher K values. This pattern indicates an elbow around K = 2, as shown in Figure 4.

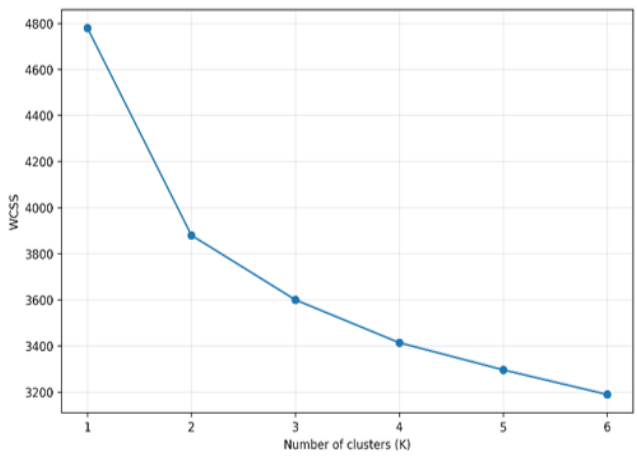

Figure 4. Within-cluster sum of squares (WCSS) elbow plot for respondent-level K-Means clustering

Therefore, K = 2 was retained for the respondent-level analysis. Although the Silhouette score remains relatively low, the two clusters are interpreted as broad differences in respondent perceptions rather than clearly separated groups.

As shown in Table 9, Cluster 1 generally has higher average scores than Cluster 2 across most indicators. This suggests that respondents in Cluster 1 tend to perceive greater benefits from urban parks, while respondents in Cluster 2 tend to give relatively lower assessments.

Table 9. Cluster centroids for variables used in the K-Means analysis

Variable Indicator	Cluster 1 (n = 81)	Cluster 2 (n = 96)
X_1P_1	3.5556	3.0729
X_1P_2	3.6049	3.0312
X_1P_3	3.6296	3.1875
X_2P_1	3.2099	2.5312
X_2P_2	3.2469	2.6042
X_2P_3	3.2593	2.6146
X_3P_1	3.3827	2.7917
X_3P_2	3.3704	2.7292
X_3P_3	3.4321	2.8333
X_4P_1	3.4198	2.8333
X_4P_2	3.5802	2.9271
X_4P_3	3.6914	2.9896
X_5P_1	3.5432	2.9792
X_5P_2	3.2963	2.8854
X_5P_3	2.8642	2.5729
X_6P_1	3.2593	2.9271
X_6P_2	3.2469	2.9271
X_6P_3	3.1235	2.7604
X_7P_1	3.6667	2.9688
X_7P_2	3.4074	2.8750
X_7P_3	3.3827	2.8333
X_8P_1	2.5062	2.3958
X_8P_2	2.5432	2.3958
X_8P_3	2.7407	2.3750
X_9P_1	3.5926	2.9167
X_9P_2	3.7037	3.0833
X_9P_3	3.5309	2.9896

3.1.6 Overall spatial distribution of ecosystem services

A separate K-Means clustering analysis was conducted at the park level to examine similarities among the nine urban parks based on their CES profiles. Unlike the respondent-level analysis in Section 3.1.5, the unit of analysis in this section is the urban park. The analysis resulted in four park clusters.

Table 10. Mean cluster-center scores for the four park clusters

Cultural Ecosystem Service Dimension	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Recreation	3.644	3.311	3.144	3.333
Cultural heritage	3.333	2.719	2.359	3.288
Aesthetics	3.556	3.015	2.824	3.052
Education	3.711	3.170	3.065	3.261
Social value	3.100	2.896	2.771	3.098
Health	3.456	3.207	2.784	3.098
Spiritual value	3.067	2.696	2.725	3.098
Disaster mitigation	2.967	2.533	2.601	2.941
Environmental / ecological value	3.733	3.341	2.967	3.333

To provide a clearer interpretation of the clusters, the cluster-center values of the three questionnaire items representing each dimension were averaged. The resulting profiles are presented in Table 10.

Table 10 shows that the four park clusters have different patterns of perceived CES. Cluster 1 generally has relatively higher scores across most dimensions, particularly environmental/ecological value, education, recreation, and aesthetics. Cluster 3 tends to show lower scores for several dimensions, while Clusters 2 and 4 show intermediate patterns. Disaster mitigation received relatively lower scores across all four clusters. These differences provide the basis for distinguishing the CES profiles of the surveyed parks.

The distribution in Table 11 shows the parks belonging to each cluster based on similarities in their CES profiles. Cluster 1 consists of BNI Tibang Park and Blang Padang Public Green Space; Cluster 2 includes Kencana Park, Meuraxa Recreation Park, and Putro Phang Park; Cluster 3 consists of Taman Sari Park and Sri Ratu Saifudin Park; and Cluster 4 includes Trembesi Forest Park and Krueng Neng Park. This park-level grouping is separate from the two respondent clusters described in Section 3.1.5.

The clustering results show that parks with similar perceived benefit patterns were grouped together. This park-level classification provides an additional perspective on differences among the nine parks and should be distinguished from the two respondent clusters described in the previous section.

Table 11. Distribution of the nine urban parks across the four park clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4
BNI Tibang Park Blang Padang Public Green Space	Kencana Park Meuraxa Recreation Park Putro Phang Park	Taman Sari Park Sri Ratu Saifudin Park	Trembesi Forest Park Krueng Neng Park

3.2 Discussion

3.2.1 Public perception of cultural ecosystem service

The findings indicate that respondents perceived the surveyed urban parks in Banda Aceh as providing several non-material benefits associated with CES, including recreation, aesthetic experience, education, spiritual value, and social interaction. CES provides a useful framework for examining relationships among people, landscapes, and well-being in urban settings [7, 8, 15]. The present results should therefore be understood as visitor-reported perceptions of benefits rather than direct measurements of ecosystem-service supply.

The findings of this study indicate that most of the respondents view urban parks as public spaces that provide significant social and recreational benefits. This aligns with various global studies showing that urban parks play a crucial role in enhancing the quality of life for urban residents through recreational activities, social interaction, and nature experiences amidst dense urban environments [4, 22]. In the context of a developing city like Banda Aceh, urban parks serve as vital public spaces by providing residents with access to green spaces. This resource is otherwise limited in urban areas.

In addition to their recreational functions, urban parks also serve as spaces that foster social connections among community members. Social interaction in green open spaces

often strengthens social cohesion and enhances a sense of ownership of urban spaces [12]. This study indicates that the values of social relationships and health also received relatively high ratings from respondents, suggesting that urban parks are not merely recreational spaces but also social spaces that support community activities.

These results reinforce the argument that urban green open spaces are an important part of urban green infrastructure that contributes to human well-being. Green infrastructure not only provides ecological functions such as improved air quality and urban heat mitigation but also generates social and cultural benefits for the community [2, 4].

3.2.2 Relation between cultural ecosystem service indicators

The correlation analysis indicates that several questionnaire items are interrelated, supporting the view that public perceptions of park benefits are multidimensional. Rather than representing completely independent benefits, recreational, aesthetic, social, health, and environmental experiences may be perceived simultaneously during park use. This interpretation is consistent with the broader CES literature, which emphasizes the interconnected nature of cultural benefits [7, 8].

Previous research indicates that landscape features such as vegetation, plant diversity, and the presence of water elements significantly influence visitors' recreational and aesthetic experiences in parks [13]. Therefore, parks with high landscape quality tend to yield higher CES values compared to those with low landscape quality.

Furthermore, the relationship between health and recreational values indicates that people utilize urban parks as spaces for physical activities such as walking, exercising, and relaxation. Global research shows that access to green open spaces is associated with improved physical and mental health among urban residents [30, 31].

The relationships among these indicators suggest that CES cannot be understood in isolation but must be analyzed holistically. Therefore, a multidimensional approach is essential for evaluating the benefits of urban parks for communities. This approach is also increasingly being used in research on urban ecosystem services because it captures the complexity of the relationships between people and the urban environment [18].

3.2.3 Visitor's perception segmentation

K-Means clustering identified two broad respondent-perception profiles. Among the candidate solutions, K = 2 produced the highest Silhouette score (0.1748) and was also supported by the WCSS elbow pattern. However, the relatively low Silhouette value indicates weak separation and considerable overlap between the groups. The clusters should therefore be interpreted as broad tendencies in perception rather than clearly distinct visitor types [31, 32].

The exploratory segmentation nevertheless suggests that visitors do not evaluate park benefits in exactly the same way. Previous studies indicate that socio-economic characteristics, education, age, and patterns of park use can influence perceptions of urban green spaces [15, 22]. These possible drivers were not tested as determinants of cluster membership in the present study and should therefore be considered hypotheses for further research rather than explanations established by the current analysis.

In Taytay Bay, Palawan, Philippines, local residents identified recreation as one of the most important cultural ecosystem services [33]. In this study, recreational value was the most dominant indicator influencing the evaluation of CES. It indicates that the public primarily views urban parks as spaces for recreation and leisure activities. This phenomenon is also observed in various cities worldwide, where recreational functions are among the primary reasons people visit urban parks [13].

In contrast, perceived disaster-mitigation benefits received relatively lower ratings than several other dimensions. This finding indicates lower recognition or salience of this function among respondents; it does not demonstrate that the parks have low actual disaster-mitigation capacity. Assessing that capacity would require biophysical, hydrological, or other ecological measurements beyond the scope of this perception-based study. Existing literature nevertheless shows that green open spaces can contribute to functions such as water regulation, buffering, and urban resilience [2, 21].

3.2.4 Urban planning implication and regulation

The findings can inform urban planning and green open-space management in Banda Aceh by identifying the benefits that surveyed visitors recognize most strongly. Perception-based evidence can complement ecological and spatial assessments when planners consider park functions, user experience, and public priorities. In this sense, integrating ecosystem-service perspectives into planning can support multifunctional green infrastructure and nature-based solutions [4, 18, 34].

Recreational and environmental/ecological benefits received relatively strong ratings in the survey, suggesting that comfort, landscape quality, access to recreational opportunities, and environmental experience are relevant considerations for park management [35, 36]. The comparatively lower rating of disaster-mitigation benefits may also indicate a need for clearer public communication about the broader regulating functions that green spaces can support [36-38]. These recommendations are perception-informed planning priorities and should not be interpreted as substitutes for direct ecological performance assessment.

In the long term, the development of urban parks should be integrated into a sustainable urban development strategy. Incorporating green open spaces into the city's infrastructure system can enhance the city's resilience to climate change while simultaneously improving the quality of life for residents [21].

3.2.5 Study limitations

Several limitations should be considered when interpreting the findings. First, the study was conducted in a single city and involved 177 visitors across nine urban parks; consequently, the results should not be generalized beyond the study context. Second, the analysis is based on self-reported perceptions and does not directly measure ecological or biophysical performance. Third, possible temporal variation associated with season, weekday versus weekend use, and time of visit was not explicitly analyzed. Finally, the relatively low silhouette value indicates weak separation between the identified perception profiles, so the clustering results should be treated as exploratory. Future research could combine larger and temporally stratified samples with direct ecological measurements and additional validation of visitor-perception segments.

4. CONCLUSIONS

This study examined visitor perceptions of CES and complementary ecological benefits across nine urban parks in Banda Aceh using descriptive analysis and K-Means clustering. Among the surveyed respondents, recreational benefits were perceived particularly strongly, whereas disaster-mitigation benefits received comparatively lower ratings. The two-cluster solution suggests broad differences in perception profiles, but the low silhouette value indicates substantial overlap and requires cautious, exploratory interpretation. Importantly, the results represent visitors' perceptions and should not be interpreted as direct measurements of the ecological quality or disaster-mitigation capacity of the parks. Within these limitations, the study shows that perception-based assessment can complement urban green-space planning by identifying how different park benefits are recognized by users in Banda Aceh.

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