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Multidimensional Scaling Approach for Sustainable Tourism Development In Banyumas Regency

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The novelty in this study lies in the development of a sustainability analysis that specifically targets waterfall tourist destinations on the slopes of Mount Slamet by adding the dimension of institutional law and technological infrastructure to provide more precise and integrative policy recommendations

A B S T R A C T

This study uses the Multi-Dimensional Scaling (MDS) method to analyze the sustainability status of five waterfall tourist destinations in Banyumas Regency, which aims to guide future development strategies. This study is very important, given the limited research on the sustainability of Curug tourism, which faces challenges such as a declining number of visitors and a low economic contribution to Regional Original Revenue (PAD), at only 6.3%. Using five dimensions—Ecology, Economic, Socio-Cultural, Legal and Institutional, and Infrastructure and Technology—key findings show that overall sustainability status is in the "Moderately Sustainable" category. Curug Gede recorded the highest average score (54.59) and showed the best balance between the pillars, while Curug Ceheng was the only one categorized as "Less Sustainable" (44.746). Sustainability efforts are strongly supported by the Ecology and Legal and Institutional dimensions, but are consistently hampered by low scores on the economic and Socio-Cultural dimensions across locations. The leverage analysis highlights five attributes that are highly sensitive and require priority interventions: waste and emissions management (Ecology), tourism market potential (Economy), access for all (socio-cultural), implementation of natural resource surveillance (legal and institutional), and public transportation and technology-based promotion (infrastructure). These findings offer practical, long-term strategies to support holistic, sustainable development in the Curug tourism sector in Banyumas.

Contribution to Sustainable Development Goals (SDGs):

SDG 8: Decent Work and Economic Growth

SDG 11: Sustainable Cities and Communities

SDG 13: Climate Action

SDG 15: Life on Land

1. INTRODUCTION

1.1. Research Background

Tourism can support the progress of a region, supported by regulations regarding regional autonomy. This policy emphasizes that each region must manage its potential to improve people's welfare. The potential and ability to manage tourism are important factors in encouraging regional economic growth (1). This effort was also adopted by Banyumas Regency, an area that

has potential geographical conditions because it is under Mount Slamet, which holds a lot of natural beauty.

The problem of the tourism sector in Banyumas Regency is the lack of attention related to the natural potentials it has to become the basis for economic growth. BPS data for Banyumas Regency in 2022 shows that there are 92 tourist attractions managed by SOEs, local governments, BUMDes, and the private sector. However, if you compare in 2020, there are 102 tourist attractions. This decline is due to managers who are not ready to accept changes in demand and a lack of support from the community in encouraging tourism development.



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The decline in the number of tourists in Banyumas Regency is also accompanied by a decrease in the number of visitors. In 2019, tourist visits in Banyumas Regency reached 1.9 million and decreased significantly until 2021 to 476 thousand visitors. The decline was due to the Covid-19 Pandemic which limited community activities and a lack of tourism innovation. Therefore, to recover and prevent tourism from stopping due to stagnation and declining visitors, it is necessary to conduct an empirical study that analyzes tourism development in Banyumas Regency.

Tourism development must be carried out by looking at the priorities and circumstances of each tourist attraction (2). The very limited research on the sustainability of tourist attractions in Banyumas Regency is an important challenge in determining development priorities. This will have an impact on the lack of precision of the policies implemented so that tourism sector revenue is not maximized (3). In 2022, the contribution of the tourism sector to the PAD of Banyumas Regency will be 6.38 percent. This figure is still low when compared to areas that have similar geographical conditions such as Sleman (30%) and Magelang (10%) to PAD.

Sustainable tourism must pay attention to ecological aspects and sustainable economic development, as well as maintain cultural sustainability. This is important because culture is one of the important resources in the development of the tourism sector (4). Sustainable tourism development is a process and system that ensures the sustainability of natural resources and socio-cultural life, as well as providing economic benefits for future generations. Therefore, it is necessary to plan a sustainable development concept to maximize this potential (5).

Based on Permenparekrif Number 9 of 2021 concerning Sustainable Tourism Destination Guidelines, the existence of tourism must be socially acceptable and prioritize the local community. Tourism sustainability is a joint task between the government, the private sector, and the people of Banyumas Regency. The improper tourism development strategy will have an impact on the sustainability of tourist attractions (6). The benefits obtained by the community from tourism cannot be maximized if the tourist attraction fails. Tourism with the community is a tangible form of symbiosis mutualism where managers benefit from the existence of levies and the community benefits economically from the absorption of labor and high economic activity. There is a need to measure tourism sustainability to support national strategic policies related to the SDGs, sustainable tourism development, and optimize the economy of local communities.

The purpose of this research is to analyze the sustainability of tourism in developing tourism management. The sustainability referred to in this study is related to Economic, Social, and Environmental aspects. These three aspects are in accordance with the Sustainable Development model (7). This research uses three dimensions of sustainability based on the SDGs (Economic, Social, and Environmental) and also adds two other dimensions (legal and institutional dimensions and technological infrastructure).

The formulation of the problem in this study is that there is still limited research that specifically measures the status of tourism sustainability, especially in Banyumas Regency. Banyumas Regency has tourism characteristics based on its geographical location on the slopes of Mount Slamet, namely there are many waterfall tours (Waterfalls). Research on tourism sustainability in waterfall natural tourism is crucial given the

vulnerability of its ecosystems to increasing pressure on tourism activities, including the potential for damage to water resources, biodiversity uniqueness, and erosion risk. This urgency is reinforced by the potential economic and social impacts for local communities that depend on tourism, as well as its relevance to sustainable development goals and global climate change challenges.

This research is motivated by the phenomenon of many closed tours, especially in waterfall natural tourism that has unique characteristics, as well as the absence of systematic tourism sustainability measurement. To overcome this gap, the study will measure the sustainability status of various waterfall natural tourism using the Multidimensional Scaling (MDS) method. MDS was chosen because of its ability to analyze multidimensional sustainability data and visualize the relative position of each destination, so that sustainability patterns between tourism can be identified, factors causing tourism vulnerability revealed, and more sustainable management recommendations can be formulated to prevent future tourism closures. The locations in this study include five destinations that are geographically spread in the areas of Baturraden (Pancuran Pitu, Pancuran Telu, and Curug Gede), Karangsalam (Curug Ceheng), and Cilongok (Curug Cipendok) in Banyumas Regency. The determination of the distribution of this location aims to provide a representative spatial picture of the ecological characteristics and dynamics of waterfall tourism at various strategic points on the slopes of Mount Slamet.

This research is a development of an empirical study (8,9) which examines the role of promotion in tourism development and research (10,11) regarding PAD in provinces with the main advantages of tourism. The novelty in this study lies in the research locus and also the use of research methods. This study has significant differences compared to previous research, especially in the focus of the object and the addition of the analysis dimension. Researchers previously researched sustainability in non-tourism subjects (12–14). This study specifically examined the sustainability of waterfall natural tourism, which has distinctive ecological characteristics and tourism dynamics. Another crucial difference is the addition of institutional legal dimensions and technological infrastructure, which complement the general dimensions such as ecology, economics, and social used in previous studies (15–17). Although Wijaya's research also includes the dimensions of "law and institutions, infrastructure, and technology." (18). However, this study differs in that it places greater emphasis on an in-depth analysis of how regulations and specific technological developments affect the sustainability of waterfall tourism.

1.2. Literature Review

Previous research in literature review documents has tended to focus on non-tourism or tourism subjects with different ecological characteristics. The MDS literature, for example, examines sustainability in the management of mangrove protected forests (12), rice farming (13), peat swamp forest ecotourism (14), fisheries resource management (16), oil palm agribusiness (19), and the sustainability of Trans Jogja (20). Although some studies have targeted tourism, the focus has been on marine/coastal ecotourism ((21–23), coastal and marine tourism (24), or beach tourism management in general (22). The study, however, specifically examined the sustainability of waterfall natural tourism, which has the distinctive ecological

characteristics and dynamics of land-based tourism and waterfalls. This crucially distinguishes it from studies that focus on coastal, marine or agricultural ecosystems, thus filling in the knowledge gap on specific types of land tourism destinations.

Another crucial difference lies in the addition of legal institutional dimensions and technological infrastructure to complement general dimensions such as ecology, economics, and social. Previous studies using MDS-Rapfish generally used 3 to 5 basic dimensions. Previous sustainability studies such as peat swamp forest ecotourism management (14) and tourism village sustainability (Nurhayati et al., 2021; Marhesa et al., 2022) often focus on ecological, economic, and social/sociocultural dimensions, plus institutions or accessibility. Although the study by (18) also included the dimensions of "law and institutions, infrastructure, and technology," this study has significant differences. The study by Wijaya (18) presents the results of the combined sustainability status (74.03%) of these dimensions, but this study places greater emphasis on an in-depth analysis of how regulations and specific technological developments separately affect the sustainability of waterfall tourism. This emphasis is in line with findings from other qualitative studies that highlight the need for strong institutional commitment and strategic innovation, such as the importance of strong cooperation and collaboration in marine tourism (23). By analyzing these additional dimensions in depth, this study seeks to fill the gap that focuses on static status assessment by providing a more prescriptive analysis of mechanisms.

Overall, this study contributes to the research gap by focusing MDS on untouched loci (waterfall tourism) and methodologically placing more emphasis on dynamic dimensions. Many studies in literature reviews conclude that sustainability status is in the category of less or moderately sustainable (12,13,20,21), often due to weaknesses in economic, social, and institutional aspects. By dissecting in depth the role of institutional law and technological infrastructure, this study explicitly examines the factors indicated as problem areas in the literature. This approach is expected to result in more detailed and applicable policy recommendations, moving beyond simply summarizing the status of sustainability, towards the identification of specific mechanisms needed to achieve holistic sustainability in waterfall natural tourism destinations.

1.3. Research Objective

This study aims to analyze the sustainability status of waterfall tourism destinations in Banyumas Regency using the Multidimensional Scaling (MDS) approach. Specifically, the research evaluates sustainability across five key dimensions ecological, economic, socio-cultural, legal and institutional, and infrastructure and technology to identify the relative sustainability position of each destination. In addition, the study seeks to determine the most sensitive attributes influencing sustainability performance and to formulate strategic recommendations that can support integrated and long-term sustainable tourism development in the region.

2. MATERIALS AND METHODS

This type of research is a quantitative descriptive research with a multidimensional scaling approach. The research was conducted from March 2025 to February 2026 with the final output of the published article. The tourist attractions chosen as research

samples are waterfall tourist attractions in Banyumas Regency which are registered with BPS and are waterfalls with many visitors. The tourist attractions to be researched include Cipendok Waterfall, Pancuran Telu, Pancuran Pitu, Ceheng Waterfall, and Gede Waterfall.

The determination of respondents in this study used 2 techniques of purposive sampling and accidental sampling. The purposive sampling technique is to select respondents who are considered to know better and can be trusted to be a source of data. The respondents who will give the questionnaire are the Manager, Traders, and the surrounding community. The score for each indicator was determined through scientific judgment that integrated the results of field surveys of 325 respondents—including managers, traders, local communities, and tourists—with relevant literature studies. This multi-source approach is applied to ensure the validity of the assessment from various stakeholder perspectives, thereby minimizing the potential for researcher bias in setting sustainability indices in each destination. The sampling for visitors in this study is the accidental sampling technique. The following are the number of research respondents:

Table 1. Number of Responden

No.	Respondent Characteristics	Sample
1.	Managers	5
2.	Tourist attraction traders	15
3.	The community around the tourist attraction area	15
4.	Visitor	30
	Number of Respoden	65
	Number of Attractions	5
	Overall Respondents	325
Multi Dimensional Scaling		

With the help of Rapfish, a multi-dimensional scaling (MDS) approach was used to achieve the objectives of this study. One method for evaluating the indicators across every aspect of sustainable tourism management is the Rapbeachtour method. The rap-beachtour discusses sustainability from the perspective of economics, socio-culture, law and institutions, ecology, and technological infrastructure. Rapfish's approach to evaluating sustainability status is Rap-beachtour (19). Ecological, economic, socio-cultural, institutional, legal, and technological aspects all have a role in determining the attributes of tourism development. The relevant dimension is represented by each of the selected attributes. The following are the attributes used in this study

A multidimensional analysis of the score values of each attribute is used to identify one or more points that represent a sustainability position to construct an index and category of sustainability status. The following table displays the score values of each dimension, which are the values of the sustainability index:

Table 2. Dimension and Attribute

No.	Sustainability Dimension	Sustainability Indicators
1.	Ecology (PERMENPAR No. 9 Year 2021 Guidelines Tourism Destinations Sustainable)	A1 Conservation of natural heritage
		A2 Resource management
		A3 Waste and emissions management
		A4 Clean water conditions and availability
		A5 Cleanliness of tourist attractions
		A6 Supporting Facilities
2.	Economy (19)	B1 Sightseeing
		B2 Revenue: The average community around the tourist area
		B3 Absorption of labor in tourist areas
		B4 The level of community welfare
		B5 Contribution of the tourism sector to regional income
		B6 Tourism market potential
3.	Social and Cultural (19)	C1 Community empowerment program
		C2 Level of formal education
		C3 The Role of Local Government
		C4 Access for all
		C5 Community participation
		C6
		C7 Security
4.	Institution & Law (19)	D1 Policy and planning Tourist Attraction
		D2 Management Compliance with management rules
		D3 Coordination Delivery lembaga/stakeholder
		D4 Community compliance level
		D5 Implementation, supervision, and promotion of natural resources
		D6 Support Local Government Policy
5.	Technology Infrastructure (19)	E1 Supporting Facilities and Infrastructure
		E2 Infrastructure, Telecommunications, and Information
		E3 How to promote
		E4 Public transport to tourist sites
		E5 Public Facilities and Infrastructure
		E6 Support for road facilities and infrastructure

Table 3. Sustainability Scoring

Index Value	Category
0-25.00	Not sustainable
25.01-50.00	Less sustainable
50.01-75.00	Moderately sustainable
75.01-100.00	Highly sustainable

Kavanagh recommends five stages to be passed in the Rap-Tour procedure: 1) determination of indicators as assessment criteria and identification of current conditions; 2) assessment (score) of each indicator; 3) the ordering of each indicator; 4) Monte Carlo analysis and sensitivity; 5) needs analysis (20). Each indicator in each criterion is given a score based on scientific judgment at the time the score. Scores were analyzed with Rap-Tour to determine the sustainability status of each criterion according to the index category. The most sensitive indicators that contribute to the tourism sustainability index are shown through sensitivity analysis by looking at the form of changes in the root mean square (rms) of the ordinance on the X-axis.

2.1. Monte Carlo Simulation

Monte Carlo Simulation Analysis is a simulation statistical method to evaluate the effect of random errors on the process of guessing a certain statistical value. Monte Carlo simulation to estimate the influence of errors in the analysis process was performed at a 95% confidence interval. The results of the analysis are expressed in the form of Monte Carlo index values, which are further distinguished from the index values of the MDS analysis results. The level of confidence in the dimensions was tested using Monte Carlo simulation analysis.

3. RESULT AND DISCUSSION

3.1. Factors affecting rice production

The results of the analysis of the sustainability of waterfall tourist destinations in five dimensions (ecology, economy, socio-cultural, legal and institutional, as well as infrastructure and technology) show variations in the level of sustainability between research sites. In general, the average sustainability value places most destinations in the category of being quite sustainable, although there is one location that is still in the category of less sustainable. These findings provide an overview of the potential as well as challenges that must be faced in realizing sustainability-based tourism in the research area.

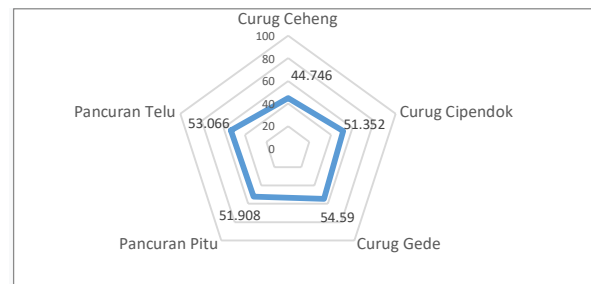


Fig 1. Sustainability Indexes

Comparatively, Curug Gede occupies the best position with the highest average value, driven by relatively better socio-

cultural, legal, and infrastructural aspects. On the other hand, Curug Ceheng is the destination with the lowest sustainability, especially due to the weak socio-cultural and economic dimensions. Meanwhile, Cipendok Waterfall, Pancuran Pitu, and Pancuran Telu are in the category of being quite sustainable with an almost balanced average score, although each still faces challenges in the economic and socio-cultural dimensions.

Table 4. Multidimensional Score

No.	Location	Ekologi	Economy	Socio-Cultural	Ins. Law	Tech. Inf	Average	Status
1	Curug Ceheng	56.97	38.16	34.85	53.51	40.24	44.746	Less
2	Curug Cipendok	69.49	38.62	44.38	59.65	44.62	51.352	Moderate
3	Curug Gede	61.44	44.28	56.02	60.02	51.19	54.59	Moderate
4	Pancuran Pitu	66.97	43.41	42.91	59.08	47.17	51.908	Moderate
5	Pancura Telu	69.99	41.83	44.65	58.29	50.57	53.066	Moderate

Curug Ceheng obtained an average score of 44,746, which is included in the less sustainable category. The low score was mainly influenced by the socio-cultural (34.85) and economic (38.16) dimensions, which indicated that there was still a lack of community participation, low economic empowerment, and limited tourism contribution to local welfare. However, the ecological (56.97) and legal and institutional dimensions (53.51) show moderately sustainable achievements. This indicates that the environmental aspect is relatively more maintained, but it is still necessary to strengthen community empowerment strategies and tourism-based creative economy development to improve overall sustainability.

Cipendok Waterfall received an average score of 51,352, which is categorized as quite sustainable. The ecological dimension (69.49) shows a high value, reflecting the existence of good environmental management, including conservation and cleanliness of tourist areas. However, the economic score (38.62) is still low, showing that the economic potential of tourism activities is not optimal. The socio-cultural dimension (44.38) is also relatively low, so community involvement and strengthening local cultural identity need to be further improved. Thus, even

though the ecological aspect is superior, the sustainability of this destination will be stronger if the economic and socio-cultural dimensions receive balanced attention.

Curug Gede obtained the highest average score, which was 54.59, which placed it in the category of quite sustainable. The highest scores were found in the socio-cultural dimensions (56.02) and law and institutions (60.02), which showed that the role of the community, local government support, and inter-institutional coordination had been quite good. In addition, the infrastructure and technology dimensions (51.19) are also relatively better than other locations, indicating progress in the provision of tourism facilities and accessibility. However, the economic dimension (44.28) still shows limitations, so the increase in tourism's contribution to community and regional income needs to be further strengthened.

Pancuran Pitu obtained an average score of 51,908 with a moderately sustainable status. The ecological dimension (66.97) and law and institutions (59.08) dominated with quite good achievements, reflecting attention to environmental sustainability and institutional governance aspects. However, the economic (43.41) and socio-cultural (42.91) scores are still low, indicating challenges in community empowerment and equitable distribution of tourism economic benefits. Meanwhile, the infrastructure dimension (47.17) is in the less sustainable category, which means that the availability of facilities, transportation, and promotion still needs to be improved.

Telu Shower has an average score of 53,066, which belongs to the moderately sustainable category. The ecology dimension obtained the highest score (69.99), indicating the existence of relatively good environmental management. Scores on the legal and institutional dimensions (58.29) and infrastructure and technology (50.57) also support sustainability achievements. However, the economic (41.83) and socio-cultural (44.65) scores are still low, indicating the need for a stronger strategy to improve the welfare of local communities as well as their involvement in tourism management.

Table 5. Stress value and RSQ

Test	Ecological Dimension	Economic Dimension	Socio-Cultural Dimension	Legal Dimensions	Institutional Dimensions	Infrastructure	Technology
Stress Value	0.186298	0.207831	0.198061	0.215888		0.207591	
Squared Correlation (RSQ) =	0.938967	0.917642	0.921216	0.910945		0.915731	

Source: MDS Analysis

The results of the Rapid Appraisal Test (RAP) using the Multi-Dimensional Scaling (MDS) method showed that the resulting model had a very high level of reliability, even with slight mapping inaccuracies. This reliability is confirmed by a highly consistent Squared Correlation (RSQ) value, ranging from 0.91 to 0.94, which means that more than 91% of the variation in the original distance data between locations/dimensions can be effectively explained by the MDS model. Meanwhile, a Stress value ranging from 0.18 to 0.22 (the highest on the Legal/Institutional Dimension) indicates that the resulting visualization map has a moderately acceptable fit level but there is still a moderate deviation between the actual distance and the mapped distance, suggesting that although the map is structurally accurate, the interpretation of the distance between points should be done with a little caution. The highest *stress* value in the legal and institutional dimensions is likely triggered by data

discrepancies or sharp differences of views between managers who focus on formal compliance and local communities who feel the implementation of policies directly in the field. The inconsistency of responses between respondent groups indicates that there are challenges in coordination between stakeholders and natural resource supervision that have not been fully integrated in all destinations. Overall, this model is valid and representative for analyzing sustainability.

3.2. Leverage

The analysis of leverage attributes on the five dimensions of tourism sustainability is an important stage to identify the factors that have the most influence on changes in the sustainability index. Attributes that have a high leverage value are referred to as sensitive attributes, because any changes to these attributes will have a significant impact on the sustainability conditions of tourist destinations. Thus, the focus on management and

improvement should be directed to these attributes so that the sustainable tourism development strategy can run effectively. In this study, the results of the analysis show that there are a number of sensitive attributes in each dimension—ecology, economic, socio-cultural, legal and institutional, as well as infrastructure and technology—that need to be prioritized to improve the quality and competitiveness of nature-based tourist destinations.

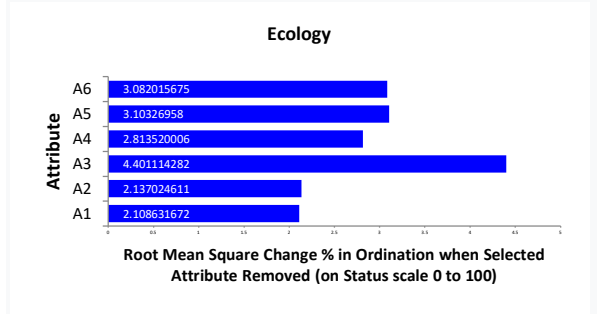


Fig 2. Leverage Attribute Ecological Dimension

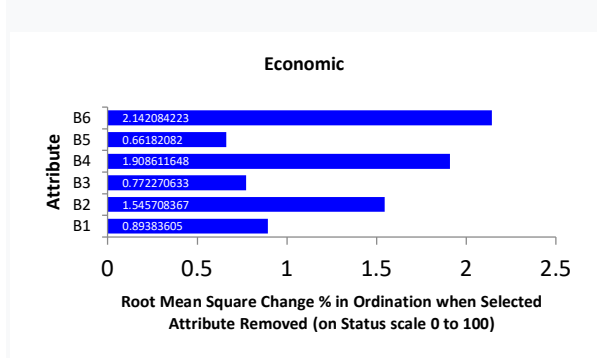


Fig 3. Leverage Attribute Economic Dimension

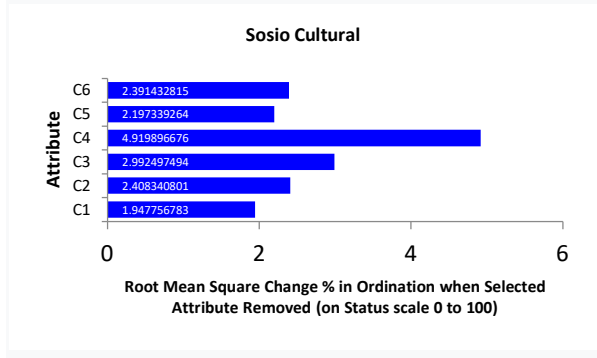


Fig 4. Leverage Attribute Socio-Cultural Dimension

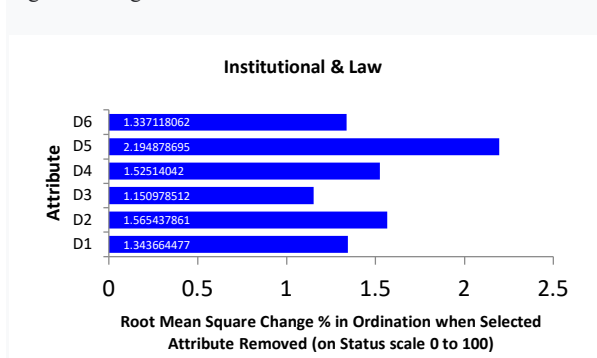


Fig 5. Leverage Attribute Dimension law & Institutional

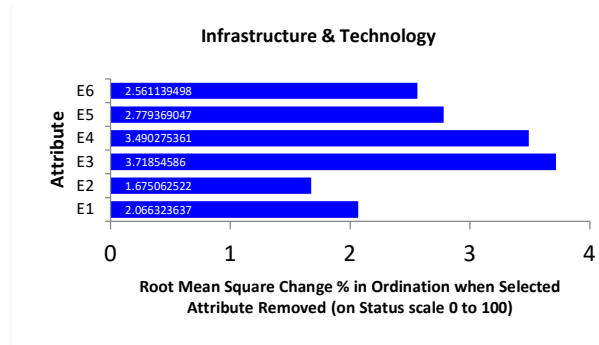


Fig 6. Leverage Attribute Dimension Infrastructure and Technology

The results of the leverage analysis showed that in the ecological dimension, the most sensitive attribute was waste and emissions management (A3) with the highest score of 4.40. This emphasizes the importance of good environmental governance as the main determinant of the sustainability of natural tourist destinations. In addition, the cleanliness attributes of tourist attractions (A5) and supporting facilities (A6) also have a great influence, showing that clean environmental conditions and the support of environmentally friendly facilities are key factors in maintaining nature-based tourist attractions.

In the economic dimension, the attribute with the highest sensitivity is the potential of the tourism market (B6) with a score of 2.14, followed by the level of community welfare (B4). These findings indicate that economic sustainability is heavily influenced by the ability of destinations to expand their markets and attract new tourists. The same can be seen in the socio-cultural dimension, where access for all (C4) has the highest score of 4.91. This shows that the success of tourism management is not only determined by the physical aspects of the environment, but also by the affordability, inclusivity, and participation of the people involved in it.

In the legal and institutional dimensions, the attributes of implementation, supervision, and promotion of natural resources (D5) were the most sensitive factors with a score of 2.19, which confirms that regulations need to be followed by consistent implementation in the field. Meanwhile, in the infrastructure and technology dimension, public transportation to tourist locations (E4), with a score of 3.49, occupies the highest position, followed by promotion methods (E3). This shows that accessibility and effective promotion are vital elements to strengthen the sustainability of tourist destinations. The attributes of public transportation (E4) are the most sensitive factor in the infrastructure dimension because the geographical location of the waterfall located in the mountainous area on the slopes of Mount Slamet tends to be difficult to reach by regular modes of public transportation. This limited accessibility leads to tourists' dependence on private vehicles, so increasing the provision of special transportation or improving road access is vital to maintain the sustainability of visits to these destinations

Based on the results of the leverage analysis, it can be concluded that the sustainability of waterfall tourist destinations is greatly influenced by sensitive attributes spread across five main dimensions. The ecological dimension emphasizes the importance of waste management and environmental cleanliness, while the economic dimension highlights the strategic role of the tourism market's potential in improving people's welfare. In the

socio-cultural dimension, inclusive accessibility is the most dominant factor, while the legal and institutional dimensions emphasize the need for consistency in policy implementation and supervision. On the other hand, the availability of public transportation and effective promotion are key to the infrastructure and technology dimensions. Thus, increasing tourism sustainability depends not only on ecological aspects, but also on the synergy between strengthening the market, community participation, good governance, and adequate infrastructure support.

Table 6. Monte Carlo

No	Location	Ecology	Economy	Soc. Cultural	Inst. Law	Tech. Inf	Avg	Status
1	Curug Ceheng	57.52	38.63	34.39	54.01	41.51	45.21	Less
2	Curug Cipendok	69.10	38.41	44.40	59.96	44.70	51.32	Enough
3	Curug Gede	61.54	43.92	56.14	60.47	51.59	54.73	Enough
4	Pancuran Pitu	67.87	43.59	43.06	59.77	47.65	52.39	Enough
5	Pancuran Telu	70.46	42.38	45.28	58.53	51.03	53.54	Enough

Source: MDS Analysis

The results of Monte Carlo's analysis, which was carried out 25 times with normal error distribution, showed that most of the waterfall tourist destinations were in the category of quite sustainable, except for Curug Ceheng, which was still in the less sustainable category with an average score of 45.21. The ecological dimension in general occupies a relatively high value in all locations (ranging from 57.52–70.46), indicating that aspects of environmental sustainability and resource management are well maintained. However, the economic dimension showed the lowest achievement in all locations (38.41–43.92), indicating that the potential of tourism in improving people's welfare, labor absorption, and contribution to regional income is not optimal.

The socio-cultural dimension shows considerable variation, with the lowest score at Curug Ceheng (34.39) and the highest at Curug Gede (56.14). This shows that community involvement, empowerment, and accessibility are still unevenly distributed in all destinations. The legal and institutional dimensions showed a relatively stable score (54.01–60.47), indicating that there is good regulatory and policy support, although there is still a need for strengthening in implementation and supervision. In the infrastructure and technology dimension, the achievement ranges from 41.51–51.59, which means that access to transportation, infrastructure, and technology-based promotion is still a challenge. Overall, Monte Carlo strengthened the MDS results that economic, socio-cultural, and infrastructure aspects are factors that must be prioritized in efforts to improve the sustainability of waterfall tourism in the research area.

4. CONCLUSION

The results of Multi-Dimensional Scaling (MDS) analysis on five waterfall or waterfall tourist locations in Banyumas Regency show that the sustainability status of destinations in general is in the category of quite sustainable. Curug Gede occupies the best position, while Curug Ceheng is the only one that is still in the less sustainable category. Sustainability in all locations is strongly supported by the Ecology and Legal and Institutional dimensions which have relatively high scores, but are consistently hampered by low scores in the Economic and Socio-Cultural

dimensions. To achieve a higher and more balanced status of sustainability, development strategies should focus on the sensitive attributes that have been identified, namely waste and emissions management, tourism market potential, access for all, implementation and supervision of natural resources, as well as the improvement of public transportation and technology-based promotion, in order to strengthen community empowerment and local economic contributions.

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