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CASE STUDY

Sustainable healthy settlement on a small island as a cultural heritage area

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ABSTRACT

BACKGROUND AND OBJECTIVES: Penyengat Island is a small island in the Riau Archipelago Province, Indonesia, with a coastal settlement that embodies traditional Malay values. This island holds significance due to the historical connection to the Malay royal civilization along the Malacca Strait, which includes Indonesia, Malaysia, and Singapore. Therefore, this research analyzes the status and determinants of the sustainability of healthy settlement arrangements in the coastal area of Penyengat Island as a cultural heritage site.
METHODS: The study utilizes the multi-dimensional scaling-rapid appraisal for sustainability approach, employing the modified rapid appraisal for fisheries ordinance software technique for settlement analysis. Data collection was performed using a survey and literature review. The survey was conducted through field observations and interviews with respondents, while a literature review was carried out through secondary data collection related to settlements and cultural heritage. The data analysis was performed using multi-dimensional scaling, modified from the rapid assessment appraisal method for fisheries.
FINDINGS: The study reveals that the sustainability index status for the ecological and institutional legal dimensions in Penyengat island is sustainable. In contrast, the economic and socio-cultural dimensions recorded low sustainability, while the green infrastructure dimension was deemed unsustainable. Several attributes significantly influenced the sustainability of healthy settlement arrangements in the coastal area of Penyengat Island, including household waste management, lighting in houses, noise levels, residential density, clean water supply, corporate social responsibility (CSR) funding, occupation, income growth, technological innovation, tourist numbers, public perception of the distance between cultural heritage and settlements, social conflicts, implementation of mutual cooperation, community group management, handling cross-program problems, education and training, settlement regulations, community organization regarding settlements, socialization of regulations, cultural heritage organizations, hedgerows, additional vegetation, tree canopy expansion, and rain gardens. The multi-dimensional scaling analysis indicated that the ecological dimension of sustainability ranged from 51.71 to 60.67, corresponding to the moderate status in *Rukun Warga* 1 to 5. The economic dimension ranges from 40.46 to 48.23, indicating a less advanced status in *Rukun Warga* 1 to 5. The socio-cultural dimension ranges from 48.97 to 51.78, representing sufficient status in *Rukun Warga* 1 and less sustainable in *Rukun Warga* 2 to 5. The institutional, legal dimension ranges from 50.18 to 71.24, with a sufficiently continuous status in *Rukun Warga* 1 to 5. Lastly, the green infrastructure dimension ranges from-0.12 to 6.72, a non-continuous status in *Rukun Warga* 1 to 5.
CONCLUSION: The sustainability status of healthy settlement arrangements on Penyengat Island is relatively good. While Penyengat Island has made significant strides in achieving sustainable settlement arrangements, the green infrastructure dimension requires attention. Enhancing sustainability in this dimension involves addressing socio-cultural aspects and improving the institutional and legal framework. In summary, Penyengat Island can progress toward a more sustainable and resilient future by fostering community involvement, strengthening governance structures, and implementing sustainable practices.

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INTRODUCTION

Penyengat Island is a small island with an area of 4 km^2 in the Riau Archipelago Province, Indonesia (CBS, 2021). This location has been proposed as a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site due to the numerous cultural heritage buildings related to the Malay kingdom in the Straits of Malacca and is surrounded by coastal settlements. As the local population continues to grow, there is a need for more residential land, resulting in the construction of housing areas on the remains of cultural heritage buildings (Rijal *et al.,* 2019). An earlier study has identified several issues on Penyengat Island, including domestic waste management, tourism activities and clean water deficiency (Rosdatina *et al.,* 2019). Preserving existing reserve sites also requires better maintenance and support from the government, private sectors, and the community. Furthermore, health problems such as upper respiratory tract infection and tuberculosis require attention from the government to achieve Indonesia's national target of eliminating tuberculosis by 2035 and obtaining a tuberculosis-free status by 2050 (Martias and Dhermawan, 2018). Failure to organize the settlement on Penyengat Island could lead to environmental problems, which pose a risk to public health and deter foreign tourists from visiting the island. An integrated and comprehensive approach is essential in addressing the issues related to human settlements and the preservation of cultural heritage sites. The concept of healthy settlements and housing should incorporate sociological and technical considerations, including risk factor management, location, building design, qualifications, adaptation, management, use, maintenance, drinking water supply, adequate facilities for cooking, washing, food storage, and proper waste disposal (Ramelan *et al.,* 2017). The sustainable management of coastal settlements could be achieved through environmental rejuvenation, renovation and resettlement programs. Community empowerment and adequate funding would create a self-reliant society capable of handling settlement problems in coastal areas (Surya *et al.,* 2020). Thus, the current study aims to analyze the status and determinants of healthy settlement arrangements on Penyengat Island, particularly in the cultural heritage area, to enhance public health. This novel study discussed the physical (ecological dimensions and green infrastructure) and non-physical aspects (economic, socio-cultural, and institutional legal dimensions) based on the research findings and addressed the related issues accordingly. This study was conducted on Penyengat Island, Tanjungpinang City, Riau Archipelago Province, Indonesia, in 2022.

MATERIALS AND METHODS

Methods

This research utilized primary and secondary data. The primary data consisted of field observations and interviews with the residents. A checklist of standard parameters was developed by the researchers for the field observation. Meanwhile, interviews with the residents of Penyengat Island were conducted using a closed-ended questionnaire. Subsequently, the researchers sorted the interview findings and observation sheets according to previous studies with minor modifications. The secondary data was obtained from statistical sources (demographic, environmental, economic (RMPWPH, 2006), and socio-cultural data) and processed data from relevant agencies and previous research conducted on Penyengat Island (DMHRI, 1999). The sample size was determined using total sampling with inclusion and exclusion criteria. Respondents were recruited using proportional random sampling, as outlined in Table 1. In addition, the dimensions of healthy settlement arrangement on Penyengat Island comprise five dimensions and 50 attributes (see Table 2).

Table 1. Total Population and sample in the administrative region of Penyengat Island

No.	Location	Total Population/ Family Card	Number sample/ Family Card
1	RW1	204	79
2	RW2	129	63
3	RW3	160	43
4	RW4	136	68
5	RW5	151	64
Total		780	317

Table 2. Dimensions and attributes of sustainable settlement arrangement in the coastal area of Penyengat Island as a cultural heritage site

Attributes	Dimension
(1) Location; (2) Infrastructure; (3) Disease vectors; (4) Provision of clean water; (5) Household waste; (6) Garbage; (7) Occupancy density; (8) Indoor lighting; (9) Noise; (10) Building density; (11) Vegetation density.	*Ecology* (DMHRI, 1999)
(1) Community income; (2) Increase in income; (3) Decrease in income; (4) Number of tourists; (5) Type of work; (6) Job opportunities; (7) Corporate social responsibility funding support; (8) Market potential; (9) Dependence on tourism activities to support the economy; (10) Technological innovation that supports the people's economy.	*Economy* (RMPWPH, 2006)
(1) Community involvement in social activities; (2) Community group management; (3) Implementation of mutual cooperation; (4) Community knowledge level; (5) Local wisdom; (6) Public health degree; (7) Community perceptions about the distance between cultural heritage and settlement; (8) Community perception of housing conditions; (9) Community perceptions about the condition of cultural heritage; (10) Social conflict; (11) Government efforts to reallocate settlements.	*Social* (Butar-butar and Soemarno, 2012)
(1) Government apparatus dealing with settlement issues; (2) Government apparatus dealing with cultural heritage issues; (3) Community organizations dealing with settlement issues; (4) Community organizations dealing with cultural heritage issues; (5) Education and training for government officials; (6) The handling of health problems in settlements and cultural heritage is carried out through cross-programs; (7) Cultural conservation area regulations; (8) Healthy settlement arrangement regulations; (9) Dissemination of regulations regarding cultural heritage and settlement arrangements.	*Legal and Institutional* (Ariwibowo *et al.,* 2022)
(1) Addition of vegetation; (2) Rain gardens; (3) green roofs; (4) Rain barrels (5) Permeable pavements ; (6) Green walls ; (7) Xeriscaping; (8) Hedgerows; (9) Tree Canopy Expansion.	*Green Infrastructure* (Grum and Grum, 2020)

The sustainability analysis of healthy settlements was conducted using the multi-dimensional scaling (MDS) approach with the modified Rapfish software, Rapid Appraisal for Settlement Ecosystem (Rapsettle) (Kavanagh and Pitcher, 2004). The sustainability index was determined based on a scale of 0 (bad) to 100 (good) with the following outcomes: 00.00 - 20.00 (bad/unsustainable), 20.01 - 50.00 (less sustainable), 50.01-75.00 (quite sustainable), and 75.01-100.00 (good/sustainable). The leverage analysis was employed to identify the influential factors, while the Monte Carlo analysis assessed the impact of scoring errors for each attribute (Azizah *et al.,* 2023).

Analysis of existing conditions and ecological dimensions

The selection criteria (not available, optimal, and less optimal) were adopted from previous research. For instance, attributes such as community involvement in social activities are considered in the socio-cultural dimension, modified from Blind and Sumarno (2012).

(0) None: No CSR funding

(1) Less Optimal: The CSR funding is available but does not meet the target

(2) Optimal: The CSR funding support is available and utilized optimally and on target

These benchmarks were adopted and modified from Tesfamichael and Pitcher, 2006.

Study area

The geographic location of the study area is Penyengat Island, Tanjungpinang City, Riau Archipelago Province, Indonesia, in 2022 (see Fig. 1).

RESULTS AND DISCUSSION

Environmental condition on Penyengat Island

Penyengat Island is characterized by a dense coastal township with residential areas near cultural heritage buildings. The island topography consists primarily of coastal lowlands with several hilly areas. The average temperature on Penyengat Island is 27.4 degrees Celsius (°C), with a humidity level of approximately 83 per cent (%) and an average daily rainfall of 188.1 mm (TCRR, 2018). The island is home to 46 cultural heritage sites scattered across different locations (Pristiwasa and Augustinus, 2017). Penyengat Island is primarily accessed via water transportation, such as motorized boats (pompongs) and non-motorized boats, as there are limited land transportation options consisting of two-wheeled and three-wheeled vehicles (motorized rickshaws) (Destiana *et al.,* 2020). Education facilities on the island are limited to Junior High School (SMP) level,

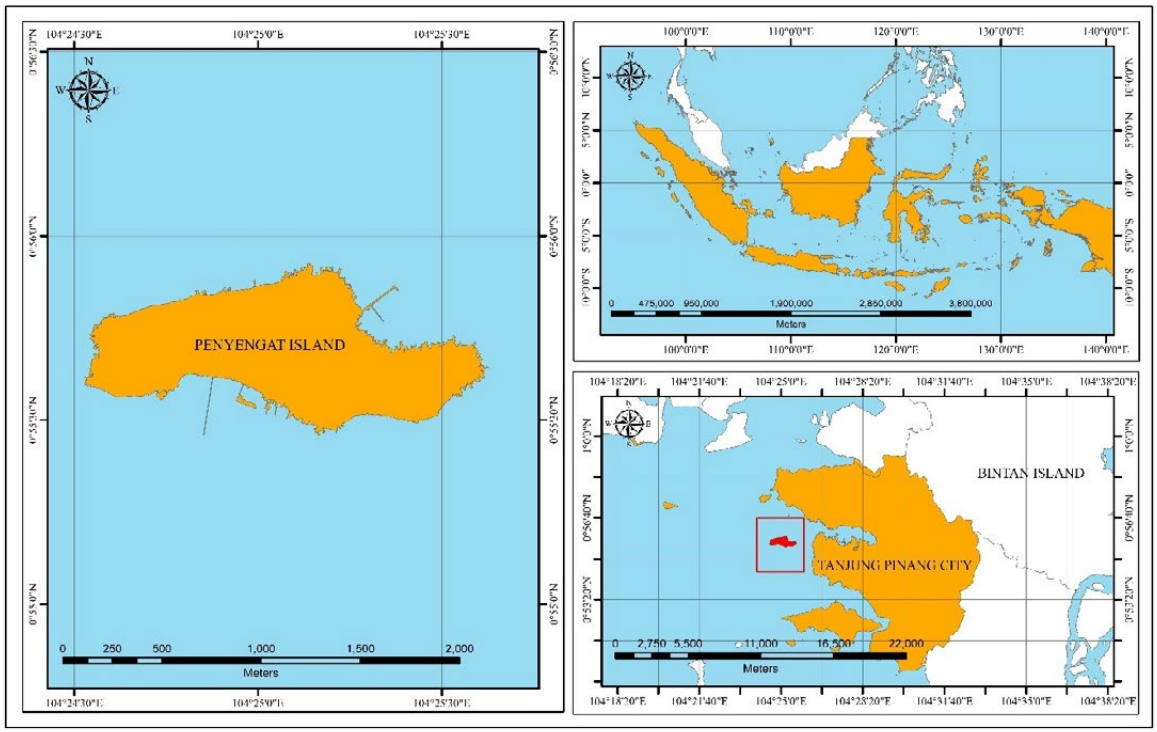

Fig. 1: Geographic location of the study area in Penyengat Island, Indonesia

and students who wish to pursue higher education are required to travel to Tanjungpinang City. Similarly, healthcare facilities on Penyengat Island are limited to auxiliary health centers, private midwives, and posyandu practices being the primary healthcare providers. Thus, residents are forced to seek medical assistance at hospitals in Tanjungpinang City during emergencies. The economy of Penyengat Island is supported by local shops and stalls, catering to the needs of residents and tourists (Mahadiansar and Romadhon, 2021).

Analysis of existing conditions and ecological dimensions on Penyengat Island

Analysis of the ecological conditions of settlements on Penyengat Island was performed according to the standards stipulated by the Ministry of Health, Decree Number. 829 of 1999 concerning Housing Health Requirements (DMHRI, 1999). The parameters evaluated in this study include location, infrastructure, disease vectors, clean water, household waste, garbage, residential density, lighting, noise, and building and vegetation density(Table 3). The health quality situation in housing is the most crucial factor for housing sustainability (Nasrabadi and Hataminejad, 2019).

The condition of the drainage waste network in RW1, RW2, RW4, and RW5 did not meet the standard requirements. Settlements on the coast often dispose of domestic wastes directly into the sea, leading to water pollution. Wastewater on Penyengat island includes domestic wastewater used for bathing and washing (gray water) and concentrated waste (black water) from households and other public and social facilities. Waste management that does not comply with local and international standards negatively impacts the environment, public health and society (Sunarti *et al.,* 2021; Asteria and Haryanto, 2021; Brotosusilo *et al.,* 2022; Elsaid and Aghezzaf, 2023). Poor housing quality has also been associated with numerous health conditions, including cognitive delays among children from neurotoxin exposure (Hernandez, 2019). Environmental protection should be prioritized when implementing the principles

Table 3: Analysis of existing settlements conditions in terms of ecological dimensions on Penyengat Island

No.	Ecology attribute		Criteria	RW1	RW2	RW3	RW4	RW5
1	Location	(0) (1) (2)	Not eligible Less qualified Qualify	(1)	(1)	(1)	(1)	(1)
2	Infrastructure	(0) (1) (2)	Not eligible Less qualified Qualify	(1)	(1)	(1)	(1)	(1)
3	Disease vectors	(0) (1) (2)	Not eligible Less qualified Qualify	(1)	(1)	(1)	(1)	(1)
4	Provision of clean water	(0) (1) (2)	Not eligible Less qualified Qualify	(1)	(2)	(2)	(1)	(2)
5	Household waste	(0) (1) (2)	Not eligible Less qualified Qualify	(0)	(0)	(1)	(0)	(0)
6	Garbage	(0) (1) (2)	Not eligible Less qualified Qualify	(1)	(1)	(1)	(1)	(1)
7	Occupancy density	(0) (1) (2)	Not eligible Less qualified Qualify	(2)	(1)	(1)	(1)	(2)
8	Indoor lighting	(0) (1) (2)	Not eligible Less qualified Qualify	(2)	(2)	(2)	(2)	(2)
9	Noise	(0) (1) (2)	Not eligible Less qualified Qualify	(2)	(2)	(2)	(2)	(2)
10	Building density	(0) (1) (2)	Tight Currently Not tight	(1)	(1)	(0)	(1)	(1)
11	Vegetation density	(0) (1) (2)	No vegetation Low vegetation Hight vegetation	(1)	(1)	(1)	(1)	(1)

of sustainable development and minimizing solid, liquid, and gas waste (Ghazali *et al.,* 2021; Zaman *et al.,* 2021; Weekes *et al.,* 2021; Alzghoul *et al.,* 2022; Le Dinh *et al.,* 2022). One of the recommendations to maintain and improve the quality of life that is in harmony with the environment is establishing "greening areas" (Gustiarini *et al.,* 2023).

Analysis of existing conditions and economic dimension on Penyengat Island

The economic dimension consists of 10 attributes that influence the sustainability of healthy settlement arrangements on Penyengat Island (see Table 4). Corporate social responsibility (CSR) funding is inadequate in supporting the island community. Local tourists predominantly drive tourism, necessitating robust marketing to promote Penyengat Island internationally. Given that Penyengat Island has been proposed as a world heritage site by UNESCO, CSR support is crucial for future development on the island. Furthermore, technological innovation that could enhance the local economy remains lacking. The local economy is mainly driven through a participatory approach by the community in all aspects and potential for development. This approach encourages creativity and self-reliance among the residents (Dewi, 2018). Another country that faces a similar vulnerability

Table 4: Analysis of existing settlement conditions in terms of economic dimension on Penyengat Island

No.	Economic attribute	Criteria	RW1	RW2	RW3	RW4	RW5
1	Community income	(0) Low (1) High (2) Very High	(1)	(1)	(1)	(1)	(1)
2	Income growth	(0) Low (1) High (2) Very High	(0)	(1)	(0)	(0)	(0)
3	Decreased income	(0) Low (1) High (2) Very High	(1)	(1)	(1)	(1)	(1)
4	Number of tourists	(0) Low (1) High (2) Very High	(1)	(1)	(1)	(1)	(1)
5	Type of work	(0) Low (1) High (2) Very High	(0)	(1)	(1)	(2)	(1)
6	Job opportunities	(0) Not available (1) Not fixed (2) Fixed	(1)	(1)	(1)	(1)	(1)
7	CSR funding	(0) Not available (1) Less than optimal (2) Optimal	(0)	(0)	(0)	(0)	(0)
8	Market potential	(0) Local (1) Local, national (2) Local, national, international	(1)	(1)	(1)	(1)	(1)
9	Dependence on tourism activities to support the economy	(0) Independent (1) Dependent (2) Highly dependent	(1)	(1)	(1)	(1)	(1)
10	Technological innovation to boost the people's economy	(0) Not available (0) Less than optimal (1) Optimal	(1)	(0)	(0)	(1)	(0)

in coastal areas is Jamaica, where the limited financial and technical resources and regulations by the central and regional governments led to poor economic growth and development (Ishemo, 2009).

Analysis of existing settlement conditions in terms of socio-cultural dimensions on Penyengat Island

The findings for each attribute in the socio-cultural dimension highlight the urgency for stronger support from the community and government in managing settlements and preserving cultural heritage (see Table 5). The residents opined that the government has not fully committed to effectively relocating settlements for residents who occupy former cultural heritage areas, leading to social conflicts due to land ownership disputes (Swastiwi, 2022). Therefore, providing, developing, and maintaining tourism facilities is essential to enhance the appeal of Penyengat Island's natural and historical assets while preserving the cultural identity (Jacom *et al.,* 2021). Empowering various community groups, engaging youth organizations with specific interests, and involving community leaders in tourism management is vital in promoting international tourism and ensuring effective island management (Arifin *et al.,* 2021). Moreover, improving public awareness in coastal areas will help the community to reduce associated risks and capitalizing on the opportunities related to climate change (Shaffril *et al.*, 2015). Most importantly, it is important to preserve and optimize the utilization of cultural resources, which are determining factors affecting ecotourism performance (Mulyadi, 2018).

Table 5: Analysis of the existing settlement's conditions in terms of socio-cultural dimensions on Penyengat Island

No.	Socio-cultural attributes	Criteria	RW1	RW2	RW3	RW4	RW5
1	Community involvement in social activities	(0) Not available (1) Less than optimal (2) Optimal	(1)	(1)	(1)	(1)	(1)
2	Management of community groups	(0) not available (1) Less than optimal (2) Optimal	(1)	(1)	(1)	(1)	(1)
3	Collaborative implementation	(0) Not available (1) Less than optimal (2) Optimal	(1)	(1)	(1)	(1)	(1)
4	Community knowledge level	(0) Lacking (1) Enough (2) Excellent	(1)	(1)	(1)	(1)	(1)
5	Local wisdom	(0) Not available (1) Less conserved (2) Preserved	(1)	(1)	(1)	(1)	(1)
6	Public health degree	(0) Lacking (1) Enough (2) Excellent	(1)	(1)	(1)	(1)	(1)
7	Community perceptions about the distance between cultural heritage and settlements	(0) Very Close (1) Near (2) Far	(2)	(1)	(1)	(1)	(1)
8	Community perceptions of housing conditions	(0) Not good (1) Good (2) Very good	(1)	(1)	(1)	(1)	(1)
9	Community perceptions about the condition of cultural heritage	(0) Not good (1) Good (2) Very good	(1)	(1)	(1)	(1)	(1)
10	Social conflict	(0) Very often (1) Often (2) Sometimes	(0)	(0)	(0)	(0)	(0)
11	Government efforts to relocate settlements	(0) Not available (1) Less than optimal (2) Optimal	(1)	(1)	(1)	(1)	(1)

Analysis of existing settlements conditions in terms of institutional and legal dimensions on Penyengat Island

Regulations pertaining to cultural heritage areas and settlement arrangements are in place but incomplete and not effectively implemented. Government agencies responsible for the settlement and cultural heritage issues on Penyengat Island are perceived to be less than optimal in their approach (Sutianto *et al.,* 2023). The handling of housing health problems and cultural heritage preservation lacks an integrated and cross-program approach essential for supporting the sustainability of settlement arrangements on Penyengat Island (see Table 6). Establishing regional regulations to ensure legal certainty and active community involvement is essential in managing coastal areas, which aligns with the local community's wisdom and values. Formulating regional regulations encouraging community participation in coastal area management empowers coastal communities and promotes independent management (Ikhwan *et al.,* 2020). In addition, coastal zone planning and law enforcement are vital in managing coastal areas (Liu and Xing, 2019).

Analysis of existing settlements conditions in terms of green infrastructure dimensions on Penyengat Island

The state of attributes related to the green infrastructure dimension varied in this study (see

Table 6: Analysis of existing legal and institutional conditions on Penyengat Island

No.	Legal and institutional attributes	Criteria		RW1	RW2	RW3	RW4	RW5
1	Government approach in dealing with settlement issues	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(2)	(1)	(1)	(1)
2	Government approach in dealing with cultural heritage issues	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(2)	(1)	(1)	(1)
3	Community organizations approach to dealing with settlement issues	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(2)	(1)	(1)	(1)
4	Community organizations approach to dealing with cultural heritage issues	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(2)	(1)	(1)	(1)
5	Education and training for government officials	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(1)	(1)	(1)	(1)
6	Handling of health problems in settlements and cultural heritage is carried out through cross-programs	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(1)	(1)	(1)	(1)
7	Cultural conservation area regulation	(0) (1) (2)	Not available Incomplete Complete	(1)	(2)	(1)	(1)	(1)
8	Healthy settlement arrangement regulations	(0) (1) (2)	Not available Incomplete Complete	(1)	(1)	(1)	(1)	(1)
9	Dissemination of regulations regarding cultural heritage and settlement arrangements	(0) (1) (2)	Not available Less than optimal Optimal	(1)	(1)	(1)	(1)	(1)

Table 7). Adding vegetation and natural features to improve air quality in RW4 meets the qualified condition (2). In contrast, the hedgerow, which serves as a wind buffer and wildlife habitat in RW2 and RW3, was in less than qualified condition (1). Therefore, there is an urgent need to address the criteria that do not meet the requirements to improve the green infrastructure dimensions on the island. Renovation of residential buildings that are not in accordance with standards should also be avoided, as this step could increase energy consumption (Gabel *et al.*, 2023).

Sustainability index

The Rapsettle analysis was conducted in five locations (five RW) on Penyengat Island, which was determined based on the division of administrative areas. Table 8 details the sustainability index values for each dimension, stress values and R^2.

Table 8 demonstrates the differences between findings in the MDS and the small Monte Carlo analysis. The small Monte Carlo analysis indicated that the scoring errors are relatively small, with minimal variation in scoring due to differences in opinion, stable analysis process, and the occurrence of data entry errors or lost data was avoided. These results indicated that the MDS analysis used is valid and reliable for assessing the sustainability of healthy settlement arrangements on Penyengat Island. The validity of the MDS analysis results can also be assessed by examining the Goodness of Fit values, specifically the stress value and the coefficient of determination (R^2) at the 95% confidence level. Table 6 demonstrates that the stress value < 0.25 and the R^2 value is close to 1, suggesting that the analysis results are statistically valid and that there is no need for additional attributes as the analyzed aspects accurately reflect the actual conditions. These attributes effectively explained the sustainability of healthy settlements, and the results provided strong evidence that the Rapsettle analysis for determining the sustainability

Table 7: Analysis of the settlements existing conditions in terms of green infrastructure on Penyengat Island

No.	Atribut		Criteria	RW1	RW2	RW3	RW4	RW5
1	Addition of vegetation	(0)	Not eligible	(0)	(0)	(0)	(2)	(0)
		(1)	Less qualified					
		(2)	Qualified					
2	Rain gardens	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
3	Green roof	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
4	Rain barrels	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
5	Permeable pavements	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
6	Green walls	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
7	Xeriscaping	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
8	Hedgerow	(0)	Not eligible	(0)	(1)	(1)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					
9	Tree canopy expansion	(0)	Not eligible	(0)	(0)	(0)	(0)	(0)
		(1)	Less qualified					
		(2)	Qualified					

of settlement arrangements around the Penyengat Island cultural heritage area is highly reliable. The ecological dimension sustainability status was analyzed using MDS analysis, which categorized the sustainability status. The MDS analysis of the ecological dimension attributes revealed the index value and sustainability status in the sufficiently sustainable category for all locations (RW1, RW2, RW3, RW4, and RW5). The sustainability index values in RW1 - RW5 ranged from 51.71 (lowest in RW4) to 60.37 (highest in RW5), indicating a fairly sustainable category (see Fig. 2).

The leverage analysis revealed five attributes that act as levers for the sustainability of the ecological dimension: 1) household waste, 2) lighting in the house, 3) noise, 4) occupancy density, and 5) clean water supply (see Fig. 3). A research conducted in India concerning industrial and household waste disposal reported a decline in water quality in coastal areas and watersheds (Krishnakumar *et al.*, 2017).

The MDS analysis for the attributes in the economic dimension indicated that the index value and sustainability status are in the less sustainable category for all locations (RW1, RW2, RW3, RW4 and RW5). The highest index value is in RW4 (48.23), with a less advanced status (see Fig. 4).

The leverage analysis conducted on the economic dimension identified five attributes as sustainability levers: (1) CSR support, (2) Type of work, (3) Income growth, (4) Technological innovation, and (5) Number of tourists (see Fig. 5). Support from various stakeholders, including the government and private sectors, is crucial in enhancing the economic potential of Penyengat Island. Contribution from the private sector through CSR funding could significantly improve the local economy on Penyengat Island (Prayuda *et al.*, 2022). Furthermore, boosting tourism in the archipelago would create job opportunities for local residents (Francis and Nair., 2020).

The MDS analysis of the attributes for the socio-cultural dimension demonstrates the index value and sustainability status for RW1 was sufficiently

Table 8. The MDS, Monte Carlo, sustainability status and statistics analysis

No.	Dimensions	MDS	Monte Carlo	Difference	Sustainability Status	Stress	R^2
1	*Ecology*					0.16	0.95
	RW1	55.77	55.36	0.41	quite sustainable quite sustainable		
	RW2	55.32	55.04	0.28			
	RW3	57.03	56.30	0.73	quite sustainable quite sustainable quite sustainable		
	RW4	51.71	51.60	0.11			
	RW5	60.37	59.52	0.85			
2	*Economy*					0.17	0.94
	RW1	40.46	40.70	0.24	less sustainable		
	RW2	45.85	45.95	0.1	less sustainable		
	RW3	43.33	43.68	0.35	less sustainable		
	RW4	48.23	48.57	0.34	less sustainable		
	RW5	43.33	43.70	0.37	less sustainable		
3	*Socio-cultural*					0.19	0.92
	RW1	51.78	51.59	0.19	quite sustainable		
	RW2	48.97	49.19	0.22	less sustainable		
	RW3	48.97	48.70	0.27	less sustainable		
	RW4	48.97	49.13	0.16	less sustainable		
	RW5	48.97	49.04	0.07	less sustainable		
4	*Law and Institutions*					0.21	0.92
	RW1	50.18	50.32	0.14	quite sustainable quite sustainable		
	RW2	71.24	69.65	1.59			
	RW3	50.18	50.16	0.02	quite sustainable quite sustainable		
	RW4	50.22	50.26	0.04			
	RW5	50.22	50.07	0.15	quite sustainable		
5	*Green Infrastructure*					0.13	0.95
	RW1	-0.12	2.91	3.03	unsustainable		
	RW2	6.71	9.63	2.92	unsustainable		
	RW3	6.72	8.83	2.11	unsustainable		
	RW4	3.92	7.15	3.23	unsustainable		
	RW5	-0.12	3.36	3.48	unsustainable		

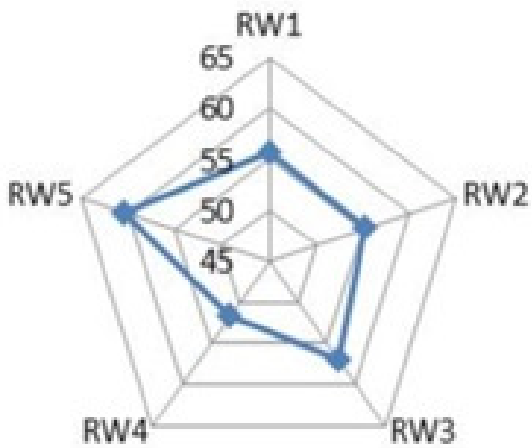

Fig. 2: Kite diagram of the ecological dimension showing the score for the sustainability status of settlement planning on Penyengat Island

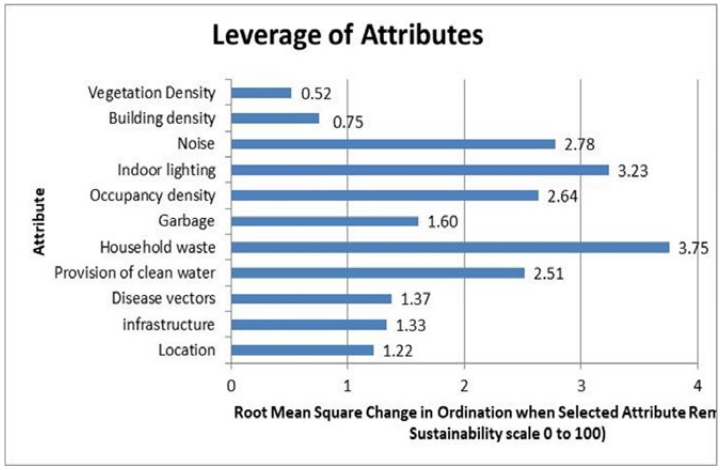

Fig. 3: Leverage attributes of the ecological dimension

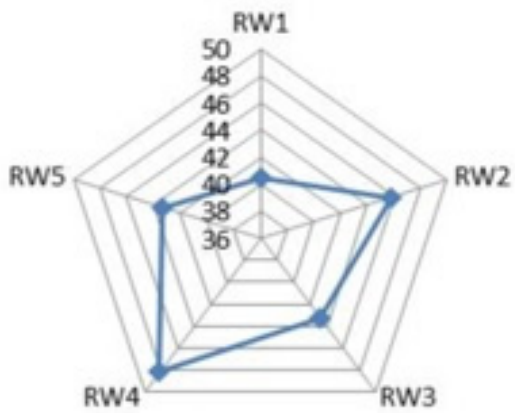

Fig. 4: Kite diagram of the economic dimension demonstrating the score for the status of the sustainability of settlement planning on Penyengat Island

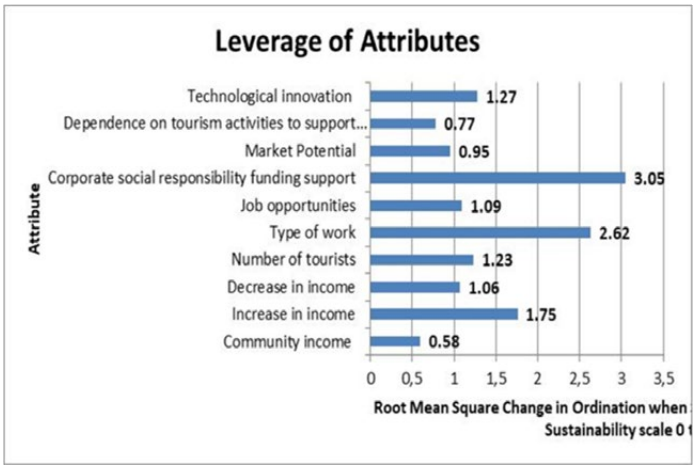

Fig. 5: Sustainability attribute leverage in the economic dimensions

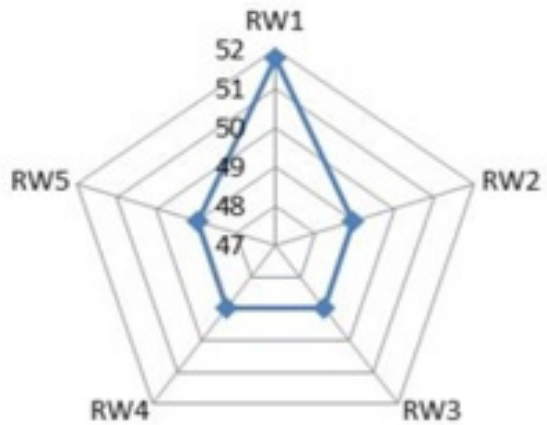

Fig. 6: Kite diagram of the socio-cultural dimension showing the score for the status of the sustainability of settlement planning on Penyengat Island

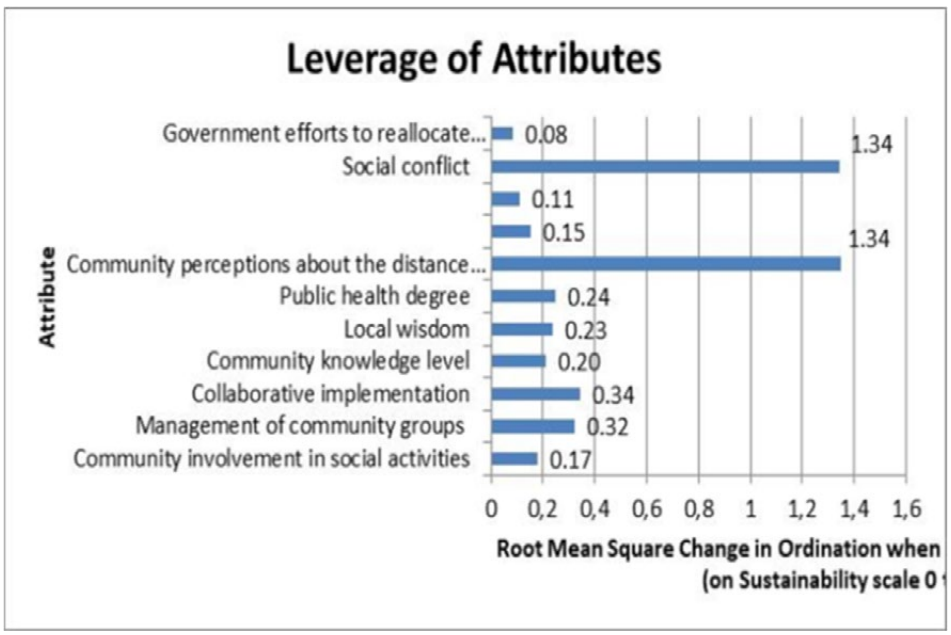

Fig. 7: Sustainability attribute leverage for socio-cultural dimensions

continuous, while RW2, RW3, RW4 and RW5 were categorized as less continuous. The highest index value was recorded in RW1 (51.78) with a sufficiently continuing status (see Fig. 6).

The leverage analysis conducted on the socio-cultural dimension identified four attributes as sustainability levers: (1) Community perceptions about the distance between cultural heritage and settlements, (2) Social conflict, (3) Implementation of mutual cooperation, and (4) Management of community groups (see Fig. 7). It is essential to focus on improving the quality of human resources to enhance social development on Penyengat Island. The community expects the authority to focus on five main sectors, namely infrastructure, health, culture, social, and environment, in implementing

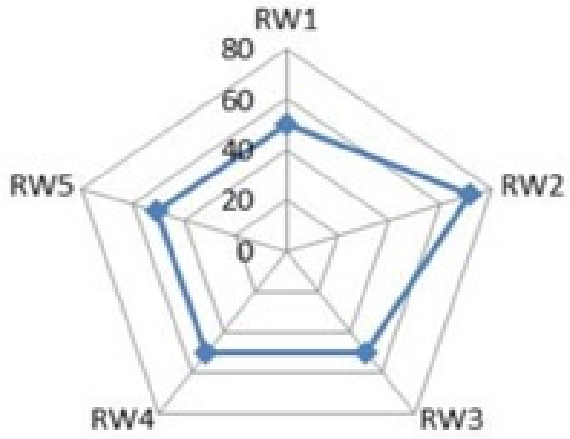

Fig. 8: Kite diagram of institutional legal dimensions showing the score for the sustainability status of settlement arrangements on Penyengat Island

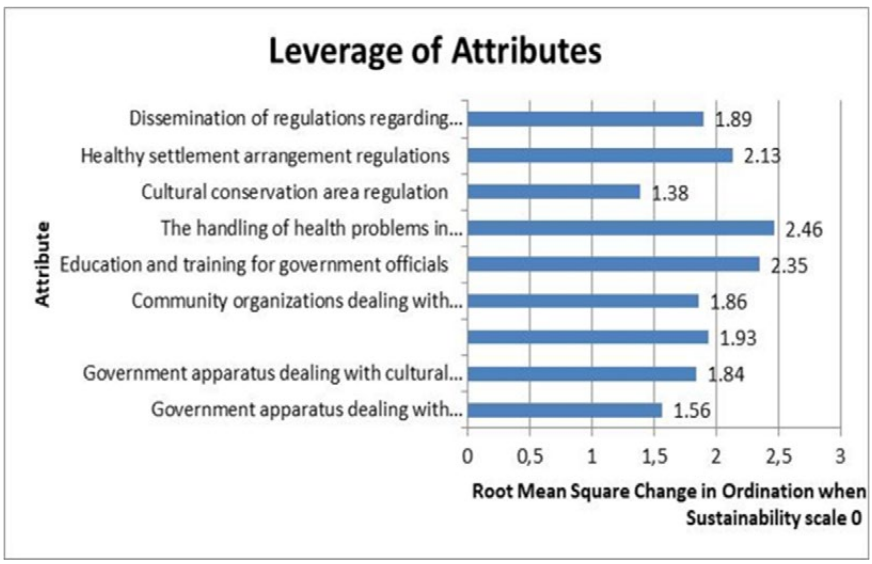

Fig. 9: Sustainability leverage attributes for institutional law dimension

social development innovations. These innovations could increase the independence and well-being of the people of Penyengat Island by adopting community-based approaches (Ikhwan *et al.,* 2021). In addition, cultural resources could improve ecotourism and the quality of life for local residents (Mulyadi, A., 2018). Ultimately, healthy tourism is beneficial in improving the health status of coastal area residents (Wall *et al.,* 2017).

The MDS analysis of the attributes for the Institutional Law dimension recorded the index value and sustainability status in the sufficiently continuous category at all locations (RW1, RW2, RW3, RW4 and RW5). The highest index value was recorded at RW2 (71.24) with sufficiently continuing status (Fig. 8).

The leverage analysis conducted on the institutional legal dimension identified six attributes

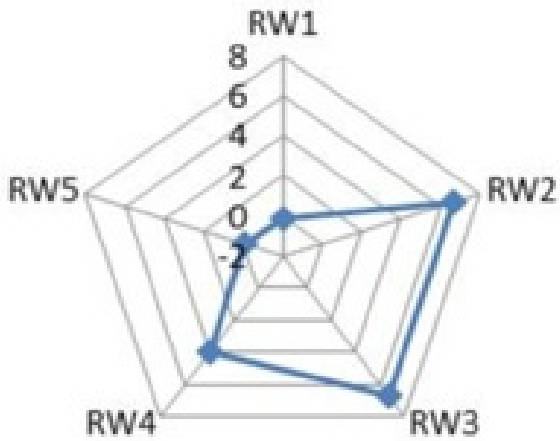

Fig. 10: Kite diagram of the green infrastructure dimension showing the score for the sustainability status of settlement planning on Penyengat Island

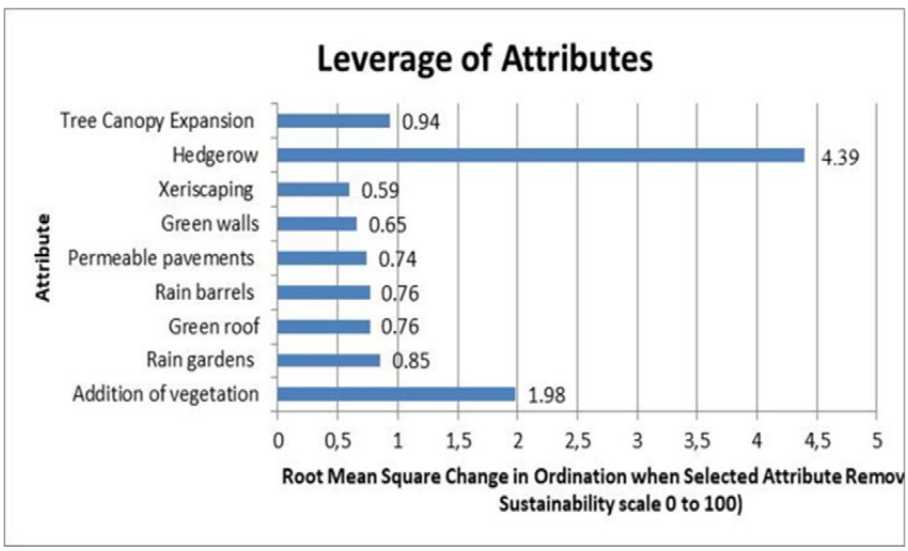

Fig. 11: Sustainability leverage attributes for green infrastructure dimension

as sustainability levers: (1) Handling cross-program problems, (2) Education and training, (3) Settlement regulations, (4) Community organizations regarding settlements, (5) Dissemination of regulations, and (6) Cultural heritage organizations (Fig. 9). It is crucial to establish government regulations policies and strategies that can boost tourism development on Penyengat Island, hence, making the island more accessible to the international community (Kachniewska *et al.,* 2015). Precisely, emphasis on legislative management is essential in dealing with coastal urban problems (Huynh *et al.,* 2015).

The MDS analysis of the attributes for the green infrastructure dimension shows the index value and sustainability status in the unsustainable category at all locations (RW1, RW2, RW3, RW4 and RW5). The lowest index values were recorded at RW1 (-0.12) and RW5 (-0.12) with a discontinued status (Fig. 10).

The leverage analysis conducted on the green infrastructure dimension identified four attributes

Table 9. Comparisons of research results on sustainable health using different methods

Tools	Variables	Implication	Sources
Structural Equation Model (SEM) analysis	Sustainable housing, physical sustainability of housing, environmental sustainability of housing	The results offer valuable insights to support the sustainability of housing in the study area and similar cases, which may vary in different contexts.	Nasrabadi and Hataminejad, 2019
Analytic hierarchy process (AHP)	Housing environment, mobility, community facilities, community social capital	Comparative studies can be applied to other cities in China or Asia.	Wu, 2010
Path analysis	Travellers, locals, resources	This research suggested ecotourism discussion and focus on developing countries, particularly in the Riau Islands, Indonesia.	Aras, 2018
Destination Management Organizations (DMO)	Rural tourism, sustainable development, agro-tourism	This study concluded practical implications for Destination Marketing Organizations (DMOs) and tourism leaders continuously evaluating rural tourism initiatives.	Kachniewska, 2015
Nud.Ist Vivo (Nvivo) 12 plus Critical discourse analysis	Tourism, sustainable development	The practical implication of this paper is to adopt a bottom-up approach for a comprehensive understanding of the alignment of tourism with the SDGs in Abaco Cays.	Francis, 2020
Geografical information system (GIS), Cluster analysis	Groundwater quality, hydrochemistry	The results of this study can be used to develop appropriate water management plans for sustainable development in the region.	Krishnakumar, 2015)
The database is developed in Postgre SQL	Climate change, adaptation, risking it, coastal greening	Community-based climate change strategies and management plans must be effectively implemented to build, monitor, and maintain community infrastructure that helps protect the local population from natural hazards and disasters.	Touhiduzzaman, 2008
Geographic Information System (GIS)	Climate change, vulnerability, coastal erosion, geographic information systems	The three qualitative models, based on a cognitive approach, utilizing a set of parameters determined in this research, serve as effective tools for the spatial distribution of erosion in various mangroves worldwide.	Fernando Morgado, 2017
Balanced scorecard Cronbach's alpha	Critical success factors, key performance indicators, coastal urban projects	Future studies could include other types of marine projects in different regions. Such studies can contribute to the findings of this research.	Nguyen, 2020
Analysis of variances (ANOVA), independent t-test	Climate change, rural development, adaptation of coastal communities	It is recommended that information management activities related to climate change be actively carried out by NGOs, universities, and relevant stakeholders.	Bolong, 2015
EZ-TEXT program	Clean and healthy coastal communities, public response	There is a need for intervention in health education. Government commitment is required to explore the potential of agricultural products as the pharmaceutical industry and to assess and review the relevant regulations concerning healthcare facilities.	Rizal, 2018
Path analysis	Public relations, activities in public spaces, sensitivity to location	The study findings suggest that land development policies should avoid damaging public spaces. Public areas should be developed to facilitate activities that promote citizens' active participation in sustainable community development.	Passanan, 2019
Construction theory grounded approach	Public health, tourism	This study concludes that strategies for engaging in healthy tourism offerings include interventions to curb alcohol consumption, regenerate areas, and promote eudaimonic well-being – which ultimately enhance place perceptions.	Susanna Curtin, 2017
Multi-dimensional scale (MDS), Rapfish analysis	Ecological dimensions, economic dimensions, socio-cultural dimensions, institutional, legal dimensions, green infrastructure dimensions	The research has implications for the sustainability of small islands with historical value while maintaining environmental preservation.	The current study

as sustainability levers: (1) Hedgerow, (2) Additional vegetation, (3) Tree Canopy Expansion, and (4) Rain gardens (see Fig. 11). One of the challenges faced in the settlement arrangement sector in urban areas is the financing for green infrastructure maintenance, posing a major constraint in ensuring the sustainability of green infrastructure in urban settlements (Bagheri *et al.,* 2021). Coastal area planning is key to a comprehensive coastal management system (Liu and Sing, 2019). In addition, seawater adversely impacts the building foundations and infrastructure systems in coastal areas (Elshinnawy and Almaliki, 2019).

CONCLUSION

The arrangement of healthy settlements on Penyengat Island as a cultural heritage has been assessed in different dimensions. The MDS analysis showed that the sustainability value of the ecological dimension ranged from 51.71 – 60.67 with a moderate status at locations RW1 to RW5, while the economic dimension ranged from 40.46 – 48.23 with a less advanced status in all locations. The socio-cultural dimension ranged from 48.97 – 51.78, with sufficient status at RW1 and less sustainable at RW2 to RW5. Meanwhile, the institutional legal dimension ranged from 50.18-71.24, with a sufficiently continuous status in all locations (RW1 to RW5). The green infrastructure dimension ranged from -0.12 – 6.72, with a non-continuous status at locations R1 to RW5. The ecological dimension was quite sustainable at RW1, RW2, RW3, RW4, and RW5 but was categorized as less sustainable in the same locations. In the socio-cultural dimension, RW1 is considered quite sustainable, while RW2, RW3, RW4, and RW5 are classified as less sustainable. In contrast, the institutional, legal dimension is quite sustainable in all locations. The green infrastructure dimension is deemed unsustainable in RW1, RW2, RW3, RW4, and RW5. This research provided a holistic understanding of various attributes from each dimension as determining factors. These attributes could serve as a reference in developing strategies to structure healthy settlements in the coastal areas in the cultural heritage sites of Penyengat Island. The identified leverage attributes that significantly influenced the sustainability of healthy settlement arrangements in the coastal area of Penyengat Island as a cultural heritage include household waste, lighting in the house, noise, residential density, clean water supply, CSR funding support, type of work, increased income, technological innovation, number of tourists, public perception of the distance between cultural heritage and settlements, social conflict, implementation of mutual cooperation, management of community groups, handling cross-program problems, education and training, settlement regulations, community organizations regarding settlements, socialization of regulations, cultural heritage organizations, hedgerow, additional vegetation, tree canopy expansion, and rain gardens. It is essential for the government and relevant stakeholders to prioritize these leverage attributes by developing and implementing appropriate policies. These strategies would ensure the maintenance of sustainable and healthy settlement arrangements in the coastal area of Penyengat Island as a cultural heritage site.

AUTHOR CONTRIBUTIONS

I. Martias conducted the literature review, developed the research design and model, and collected and analyzed the data. R. Rifardi arranged and designed the study. A. Agrina analyzed and interpreted the data. I. Suprayogi prepared the manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and, or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS

%	Percent
°C	degrees Celsius
AHP	Analytic hierarchy process
ANOVA	Analysis of variances
CSR	Corporate social responsibility
DMO	Destination Management Organizations
et al.,	And others
EZ-Text	Enterprise Zones Text
Fig.	Figure
GIS	Geographic Information System
Km^2	Square kilometer
MDS	Multi dimensional scale
Nvivo	Nud.Ist Vivo
Rapfish	Rapid Appraisal for Fisheries
Rapsettle	Rapid appraisal for settlement ecosystem
R^2	Coefficient of determination
RW.	Administrative region (Rukun Warga)
SEM	Structural Equation Model
SMP	Junior high school
SQL	Structured Query Language
UNESCO	United Nations Educational, Scientific and Cultural Organization

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