

Coastal Sustainability Analysis Using an Integrated Coastal Zone Management Approach for the Coastal Region of Bariavungtau Province, Vietnam

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Abstract

Most coastal regions are undergoing rapid development with concomitant environmental pollution and biodiversity loss, and sustainable development in coastal regions is thus an ongoing issue for managers and scientists. To implement feasible solutions for the sustainable development of coastal regions, researchers tend to use the integrated coastal zone management (ICZM) model to establish reasonable indicators for analysis and evaluation. This study proposed a combined multiple-criteria decision-making (MCDM) approach and geographic information system (GIS) to assess coastal sustainability. The sustainability index was established according to the ICZM approach based on the four subindices of economy, society, environment and management. A case study was conducted in the coastal region of Bariavungtau province, Vietnam, which includes 23 subregions. These were categorised into four sustainability levels; low, medium, high and extreme, which accounted for 30.43%, 30.43%, 13.04% and 26.09% of the region, respectively. Based on analysis and consultations with managers and experts, practical solutions were developed to increase sustainability in the subregions with low and medium sustainability levels. The solutions can support practitioners and policymakers in decision-making related to coastal sustainable development.

Keywords: Multiple-criteria decision-making; Geographic information system; Integrated coastal zone management; Sustainability; Coastal region

1. Introduction

With their rich biodiversity and capacity to provide many valuable services through their ecosystems (Domingues *et al.*, 2021), the world's coastal areas consistently offer significant development potential. The development dynamics of coastal areas are mainly focused on urbanisation, industrial growth, seaport activities, tourism and resource exploitation (Sekovski *et al.*, 2012). Over the past 50 years, coastal areas have accommodated 40% of the global population, and significant associated growth has been achieved via investment and development in coastal infrastructure, tourism and industry (Pasquali *et al.*, 2021). However, despite these

beneficial achievements, some coastal areas have been developed unsustainably, which has caused many multisectoral conflicts. The unsustainable development of coastal areas focuses solely on economic development, but attention needs to be paid to social aspects, environmental protection and institutional enforcement. Consequently, the challenges in coastal areas stem from the intersection of socioeconomic development and the safeguarding of coastal ecosystems against the adverse impacts of various hazards (P. de Alencar *et al.*, 2020). The integrated coastal zone management (ICZM) approach, which is a growth model, is therefore needed.

This multidisciplinary management model effectively integrates aspects related to socioeconomic development, environmental protection and institutional enforcement (Sonak *et al.*, 2008). The Bariavungtau coastal area is one of Vietnam's most dynamic developing regions (Ministry of Natural resources and Environment, 2021), with annual GDP growth of about 6.61% (Statistical Office, 2023). In 2010–2022, about 2,916 hectares of forest land in Bariavungtau province were developed for industry, and an additional 1,710 hectares will be converted by 2030 (Department of Natural Resources and Environment, 2023). However, the aquatic resources in some coastal areas have been overexploited as well as severely polluted due to a lack of control of discharge sources, and the population density is too high (Department of Natural Resources and Environment, 2020). Consequently, the Bariavungtau coastal area faces many challenges, and sustainable development processes are required (People's Committee, 2022).

Various definitions of 'sustainable development' have been proposed since the United Nations Conference on the Environment in Stockholm in 1972, during which sustainable development was first identified as a global issue (Patlins, 2017). According to Brooks (2010), sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Ntona *et al.* (2018) defined sustainable development as development that ensures balance and avoids multisectoral conflicts between economic, social and environmental aspects. Meanwhile, Honti *et al.* (2021) stated that sustainable development ensures the achievement of the goals of economic growth and industrialisation while maintaining the ability to conserve natural ecosystems. Based on these definitions, researchers have used many different approaches to quantify and evaluate the sustainability of coastal areas and determine reasonable solutions to ensure their sustainable development. Current research trends related to sustainable development assessments, especially for coastal areas, focus on comprehensive, systematic and multidimensional analyses based on set indicator systems (Chen *et al.*, 2023).

A review of the literature revealed the use of various models to estimate and evaluate coastal area sustainability. Two-dimensional models focusing on economic and environmental aspects have been used in some studies (Le Gouvello *et al.*, 2017; Nakaoka *et al.*, 2018). For example, Halpern *et al.* (2012) established an index consisting of 10 criteria, with eight linked to economic aspects and two to the environment, to assess sustainable coastal quality worldwide. Using this approach, the authors suggested solutions for sustainable development through public awareness and coastal resource protection. In a study by Wei, 26 criteria were chosen to evaluate the sustainability of the coastal region of Nantong in China (Wei *et al.*, 2014). Satumanatpan *et al.* (2017) adopted 30 criteria to assess the sustainability of the Koh Tao coastal region in Thailand while simultaneously harmonising economic development and biodiversity protection. Other researchers have applied three-dimensional models that encompass economic, societal and environmental aspects (Halpern *et al.*, 2012; Piet *et al.*, 2019). Yu *et al.* (2010) selected 36 criteria comprising 16 for economic, 12 for social and eight for environmental aspects to evaluate the sustainability of the Yantai coastal region in China. In a study by Karnauskaitė *et al.* (2019), 36 criteria were chosen to evaluate sustainability in the development process of three of the coastal regions in Lithuania. In some studies, the management aspect has been incorporated into the evaluations of coastal sustainability. In Schernewski *et al.* (2014) study, 22 criteria, with five criteria related to management aspects, were selected to assess the sustainability of Neringa in Lithuania and Warnemünde in Germany, whereas Aryee *et al.* (2018) applied 41 criteria, with five criteria related to management aspects, to assess the sustainability of the coastal zone of the Accra Metropolitan Area in Ghana.

The reviewed studies embraced a variety of methodologies, including qualitative and quantitative approaches, to analyse and evaluate the sustainability of coastal areas. Notably, widely employed techniques include the driving force-pressure-state-impact-response method (Coelho *et al.*, 2010;

Goodwin et al., 2017), the system dynamic method (Li et al., 2020; Yang et al., 2020), the ocean health index method (Evans et al., 2019; Harris, 2012) and the assessment of marine ecosystem service value (Morf et al., 2017; Sangha et al., 2019). These methodologies primarily rely on indicators derived from diverse perspectives to ensure their scientific basis and practical applicability in analysing, evaluating and supporting decisions related to the sustainable development of coastal regions (Potts, 2006). However, by applying the ICZM model, an index is proposed based on the multi-criteria analysis method, in which the importance of the criteria and the component factors are the focus. Combined with the geographic information system (GIS) method, this approach, which has not previously been explored, can be used to evaluate and zone the sustainability of different subregions in coastal areas.

The two main contributions of this study are as follows: (a) It presents a complex index to assess the sustainability of coastal regions based on the ICZM approach and addresses four aspects: the economy, society, the environment and management. The index comprises four sets of appropriate criteria, with each criterion and subindex's weights determined based on MCDM methods. (b) It combines a complex index with the GIS method to calculate, evaluate and zone the

sustainability of each subregion in the coastal region of Bariavungtau province, Vietnam.

2. Methodology

2.1 Study area

The Bariavungtau coastal region is adjacent to the East Sea and spans approximately 72 km along the coastline of Vietnam. The region used in the calculation was 892.51 km², with geographic coordinates of 10°18'44" to 10°35'47" North latitude and 106°59'58" to 107°35'08" East longitude (Figure 1). Within this region, 21 industrial zones have successfully attracted 476 investment projects, with a total capital investment of US\$19.98 billion (Cuong et al., 2023). The area has numerous aquaculture sites, a seaport and renowned tourist destinations. Its population comprises 884,495 citizens, which indicates a population density of 636 people per km². The rapid pace of development in the study area has had several negative consequences, such as resource overexploitation and environmental pollution in multiple locations. These challenges pose a potential threat to the area's ecosystems and the livelihoods of its inhabitants. The study area was divided into 23 subregions to assess the sustainability of the region based on the distinctive natural, socioeconomic and environmental conditions.

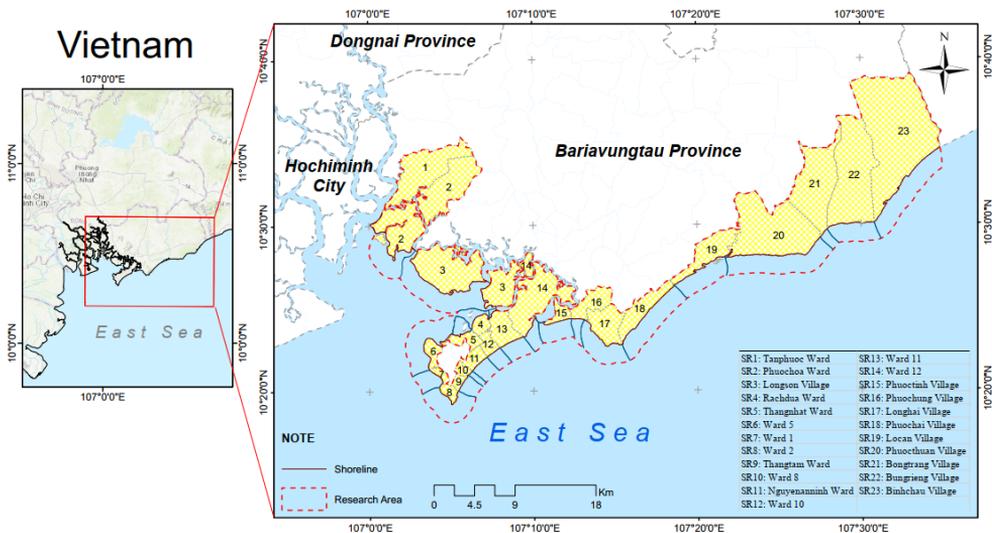


Figure 1. Research area

2.2 Methods

In this study, a new approach was developed based on a combination of the MCDM and GIS methods to analyse and assess the sustainability of the coastal area using the ICZM approach. The overall methodology followed in this study is represented in Figure 2.

2.2.1 Establish sets of criteria

2.2.1.1 Select suitable criteria

1) Establish sets of preliminary criteria: Based on the results of a review of the literature and the characteristics of the research area, the sets of preliminary criteria were established to assess the sustainability of the coast relating to the economy, society, environmental protection, and management. Each criterion in these preliminary sets is commonly and effectively used by scientists, represents outstanding study area features, and meets the four mentioned aspects. In addition, each criterion had a different level of importance and was selected based on five sub-criteria: ease of understanding, alignment with the goal, accuracy and transparency, sensitivity and data availability (Afshari et al., 2010).

2) Conduct a questionnaire survey: 10 experts from various domains were invited to take the survey. Among them, 50% had a scientific background related to the environment, and 50% had good knowledge of the study area. The collected data were used to determine the weighting of the sub-criteria using the analytic hierarchy process (AHP) method (Saaty, 1990) and the evaluation scores of each criterion.

3) Select suitable criteria: The simple additive weighting method was used to calculate the evaluation score for each criterion as a basis for screening and selecting suitable criteria for each set of criteria. The evaluation scores for each criterion were calculated using Eq. 1 (Afshari et al., 2010):

$$V(a_j) = \sum_{i=1}^m w_i v_{ij} \quad (\text{Eq. 1})$$

where $V(a_j)$ is the result of the evaluation value of the j^{th} criteria, w_i is the weight of the i^{th} sub-criteria, and v_{ij} is the value rated by the sub-criteria i for the j^{th} criteria.

After completing the aforementioned implementation steps, the weighting of the sub-criteria and the evaluation scores of each criterion were calculated, and the appropriate criteria for each set were selected. These are described in detail in Table 1 and 2.

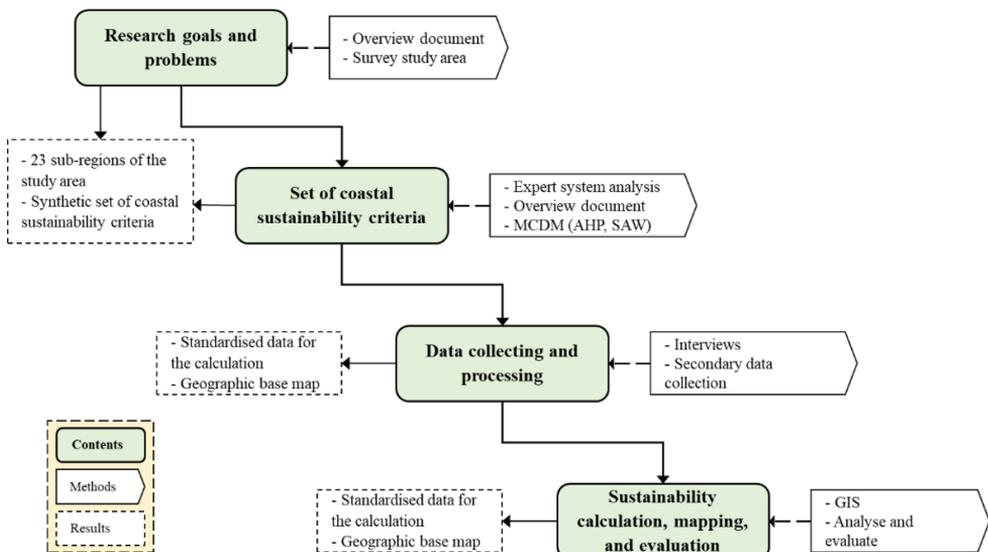


Figure 2. Methodology framework

Table 1. Evaluation scores of each criterion

Set of criteria	Notation	Values for each sub-criterion					Total value
		Ease of understanding	Alignment with the goal	Accuracy and transparency	Sensitivity	Data availability	
Economy		0.28*	0.17*	0.12*	0.13*	0.30*	
Income	E1	3.50	4.00	4.10	4.10	3.80	3.83
Unemployment rate	E2	4.10	4.00	3.60	4.10	4.00	3.99
Budget	E3	3.70	3.70	3.80	4.10	3.00	3.55
Trained worker	E4	3.80	4.50	3.80	3.90	4.20	4.05
Society		0.34*	0.17*	0.09*	0.14*	0.26*	
Population density	S1	3.40	3.90	4.10	4.20	3.50	3.69
Poverty rate	S2	4.00	4.30	3.30	4.00	4.00	3.99
Education	S3	4.10	3.60	4.10	4.20	3.00	3.74
Medical care	S4	3.00	4.10	3.00	3.60	4.40	3.64
Hygienic water	S5	3.10	2.30	2.60	2.80	2.60	2.75
Hygienic toilet facilities	S6	2.70	2.10	2.70	3.00	2.90	2.69
Environment		0.32*	0.19*	0.13*	0.10*	0.26*	
Mangroves	R1	3.60	4.00	4.10	4.40	4.00	3.93
Fish resources	R2	4.20	4.40	3.50	4.10	4.20	4.14
Degraded land	R3	4.20	4.00	4.00	4.40	3.40	3.95
Concentration of dissolved oxygen (DO)	R4	4.00	4.60	3.90	4.00	4.50	4.23
Concentration of PM ₁₀	R5	3.00	3.00	3.10	3.20	2.90	3.01
Solid waste	R6	2.70	2.60	2.90	2.90	2.70	2.73
Management		0.27*	0.13*	0.18*	0.08*	0.34*	
Fish resource management	M1	0.81	0.42	0.54	0.26	1.02	3.04
Law enforcement	M2	4.20	3.80	4.10	4.30	3.10	3.76
Community knowledge	M3	3.80	4.50	3.80	4.10	4.60	4.19
Environmental protection investment	M4	3.80	4.60	3.80	4.20	3.30	3.77
Environmental protection projects	M5	3.10	2.90	3.10	2.80	2.80	2.95

Note: * are the weights of the five sub-criteria used to screen the preliminary criteria of each factor (i.e. the economy, society, the environment and management). The sub-criteria were determined via expert consultation and the AHP method (i.e. ease of understanding, alignment with the goal, accuracy and transparency, sensitivity and data availability).

2.2.1.2 Determine the criteria and factor weights

The 10 selected experts were invited for a second consultation on the importance of the criteria in each set of criteria and the importance of the component factors (i.e., the economy, society, the environment and management). Based on the collected data and the application of the AHP method (Saaty, 1990), the weighting of the criteria and component factors were determined, as shown in Table 3.

2.2.2 Data collection and standardization

2.2.2.1 Data collection

Data collection is essential before conducting an assessment. The collected data must have a scientific basis and statistical value so that quantitative information can be extracted (Yu *et al.*, 2010). The data for this study were collected via interviews with 129 subjects (managers and residents) and combined with secondary information from various sources, as shown in Table 4.

Table 2. Selected criteria

Set of criteria	Criteria	Description
Economy	E1	The average monthly income of a household in the subregion: the higher the average monthly income of a household, the better the living standard of the people (Yu <i>et al.</i> , 2010)
	E2	The unemployment rate in the subregion: the higher the unemployment rate, the less sustainable the economy (Aryee <i>et al.</i> , 2018)
	E3	The rate of local budget revenue/expenditure in the subregion: the higher the budget revenue/expenditure ratio, the more developed the economy (Aryee <i>et al.</i> , 2018)
	E4	The rate of trained workers in the subregion: the higher the rate of trained workers, the more developed the economy (Karnauskaitė <i>et al.</i> , 2019)
Society	S1	The population density of the subregion: the higher the population density, the lower the social stability (Yu <i>et al.</i> , 2010)
	S2	The poverty rate in the subregion: the higher the poverty rate, the less sustainable the society (Aryee <i>et al.</i> , 2018)
	S3	The level of interest in education in the subregion: the higher the rate of school-age students, the more developed the society (Schernewski <i>et al.</i> , 2014)
	S4	The level of medical care in the subregion: the higher the number of doctors per 10,000 inhabitants, the better the healthcare (SUSTAIN partnership, 2012)
Environment	R1	The change in mangrove forest area in the subregion: the larger the mangrove forest area, the more sustainable the subregion (Karnauskaitė <i>et al.</i> , 2019)
	R2	The level of exploitation of the fish resources in the subregion: the higher the level of exploitation, the less sustainable the environment (Wei <i>et al.</i> , 2014)
	R3	The level of degraded land in the subregion: the higher the level of degraded land, the less sustainable and the more exploited the natural resources (Marti <i>et al.</i> , 2007)
	R4	The concentration of DO in the seawater in the subregion: the lower the concentration of DO, the more polluted the seawater environment (Pourebrahim <i>et al.</i> , 2010)
	R5	The concentration of PM ₁₀ in the air in the subregion: the lower concentration of PM ₁₀ , the more polluted the air (Aryee <i>et al.</i> , 2018)
Management	M1	The local government's management capacity to protect aquatic resources: the more communities in the subregion comply with the laws on protecting fish resources, the better the subregion's management (Virto, 2018)
	M2	The level of violation of the laws on environmental protection: the lower the number violators of the environmental protection laws, the better the community's compliance with the environmental protection laws (P. de Alencar <i>et al.</i> , 2020)
	M3	The level of concern about protecting biodiversity in coastal areas: the more a subregion focuses on implementing solutions to preserve biodiversity in coastal areas, the more sustainable the development of the subregion (Virto, 2018)
	M4	Responsibility for protecting resources and the environment: the more a subregion focuses on planning and investment in environmental infrastructure, the more developed the subregion in terms of sustainable development (Wei <i>et al.</i> , 2014)

Table 3. Weighting of the criteria and factors

Set of criteria/factors	Criteria	Weighting
Economy	E1	0.38
	E2	0.18
	E3	0.18
	E4	0.26
Society	S1	0.17
	S2	0.33
	S3	0.21
	S4	0.29
Environment	R1	0.19
	R2	0.18
	R3	0.16
	R4	0.24
	R5	0.23
Management	M1	0.29
	M2	0.14
	M3	0.24
	M4	0.33
Factors	Economy	0.28
	Society	0.26
	Environment	0.31
	Management	0.15

Table 4. Data sources

Criteria	Data source
E1	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
E2	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
E3	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
E4	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
S1	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
S2	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
S3	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
S4	<i>Statistical Yearbook 2022</i> (Statistical Office, 2023)
R1	Investigation and interviews
R2	Investigation and interviews
R3	Department of Natural Resources and Environment (Department of Natural Resources and Environment, 2016)
R4	Department of Natural Resources and Environment (Department of Natural Resources and Environment, 2023)
R5	Department of Natural Resources and Environment (Department of Natural Resources and Environment, 2023)
M1	Investigation and interviews
M2	Investigation and interviews
M3	Investigation and interviews
M4	Investigation and interviews

2.2.2.2 Data standardization

The collected data were measured on different scales, so it was necessary to standardise them using Eq. 2 and 3 (Adu *et al.*, 2018). Eq. 2 was employed where a criterion had a positive relationship with sustainability, while Eq. 3 was used where a criterion had a negative relationship with sustainability.

$$X_S = \frac{X_h - X_{min}}{X_{max} - X_{min}} \tag{Eq. 2}$$

$$X_S = \frac{X_{max} - X_h}{X_{max} - X_{min}} \tag{Eq. 3}$$

where X_S is the standardised value of the criteria, X_h is the collected value of the criteria, and X_{max} and X_{min} are the minimum and maximum collected values of the criteria, respectively.

2.3 Sustainability calculation and mapping

2.3.1 Determine the component factors

From the set of criteria and their weights, the economic, social, environmental and management values of the coastal area were determined using Eqs. 4, 5, 6 and 7 (Afshari et al., 2010):

$$EI_j = \sum_{i=1}^n W_i V_{ij} \quad (\text{Eq. 4})$$

$$SI_j = \sum_{k=1}^m W_k V_{kj} \quad (\text{Eq. 5})$$

$$RI_j = \sum_{l=1}^o W_l V_{lj} \quad (\text{Eq. 6})$$

$$MI_j = \sum_{h=1}^p W_h V_{hj} \quad (\text{Eq. 7})$$

where EI_j , SI_j , RI_j and MI_j are the economic, social, environmental and management values of the j^{th} subregion; W_i , W_k , W_l and W_h are the weights of the i^{th} , k^{th} , l^{th} and h^{th} criteria, respectively; and V_{ij} , V_{kj} , V_{lj} and V_{hj} are the values of the j^{th} subregion according to the i^{th} , k^{th} , l^{th} and h^{th} criteria, respectively.

2.3.2 Sustainability calculation

The overall sustainability index for each coastal subregion was estimated by summing the sustainability levels of each subregion for

the economic, societal, environmental and management dimensions, as shown in Eq. 8:

$$SSI = W_{EI} EI + W_{SI} SI + W_{RI} RI + W_{MI} MI \quad (\text{Eq. 8})$$

where SSI is the value representing the sustainability level; EI , SI , RI and MI are the economic, social, environmental and management values, respectively; and W_{EI} , W_{SI} , W_{RI} and W_{MI} are the respective weights.

2.3.3 Mapping

Based on the standardised data value of each criterion, the algorithms Eqs. 4 – 8, and GIS methodological approach (Dhiman et al., 2018), GIS software was used to calculate the values representing the sustainability levels. With the overlay method in GIS, each assessment value data file and the weight of each corresponding criterion or subindex were assigned on an attribute layer, which was then combined with the layer map data to create a sustainability map of the 23 subregions categorised into four levels: low, moderate, high and extreme. The model used to estimate the sustainability level of each subregion is presented in Figure 3.

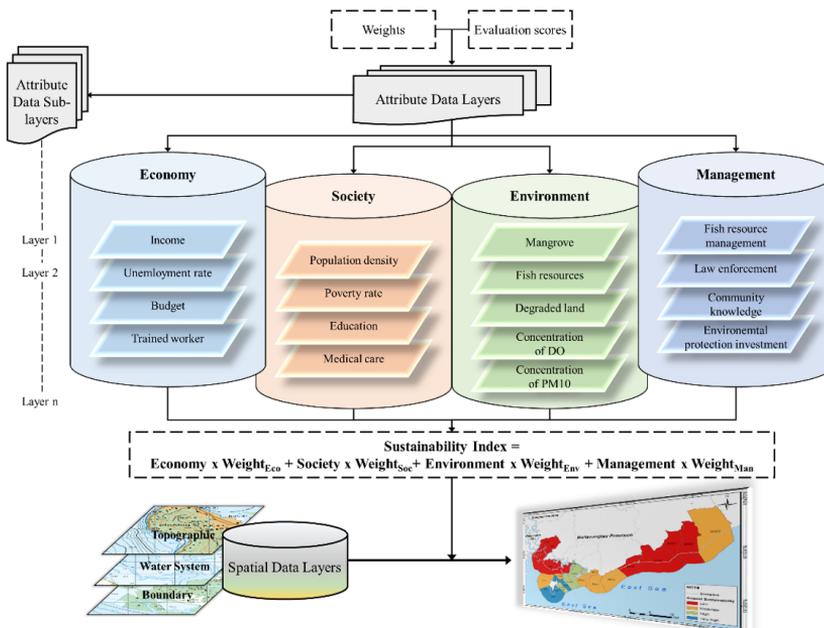


Figure 3. Coastal sustainability calculation model based on the GIS approach

3. Results and Discussion

3.1 Assessment and classification of coastal sustainability

Based on the standardised collected data and Eqs. 4 – 8, the sustainability value of each subregion was calculated, as shown in Table 5. The sustainability values ranged from 0.32 to 0.78 and were ranked on four levels from 1 to 4, which corresponded with the sustainability levels low, moderate, high and extreme. The classification results of each subregion were used for zoning (Figure 4). The results of the calculation and zoning showed the following:

a) Most (14/23; 60.87%) of the subregions had low and moderate sustainability levels and were underdeveloped. The remaining 39.13% had high and extreme levels of sustainability. Specifically:

- The subregions with low sustainability (SR1, SR2, SR3, SR19, SR20, SR21 and SR22), where SR2 and SR19 had the lowest sustainability, were less developed coastal subregions. SR20 and SR21 had the lowest average income and highest unemployment rates compared to the other subregions. In addition, the social security issues in SR19, SR20, SR21 and SR22 had not been addressed. Furthermore, the fields of education and health in SR20 and SR21 had not received attention, and the population concentrations were relatively high in SR1 and SR22. The management capacity of some subregions (SR3 and SR19) was limited, and attention needed to be paid to environmental protection and biodiversity.

- The subregions of moderate sustainability (SR4, SR6, SR15, SR16, SR17, SR18 and SR23) were similar to those with low levels of sustainability, but the economic and management conditions were better. These subregions also did not pay much attention to social security issues; notably, the education sector was low in SR4 and SR6. The environmental field also had many limitations. SR4, SR6, SR15, SR16 and SR18 did not have effectively controlled waste sources during the development process, so the seawater and air quality were lower than in other subregions. Additionally, violations due to the overexploitation of aquatic resources were common in SR4, SR15 and SR16.

- In the subregions with high levels of sustainability (SR11, SR13 and SR14), although considerable attention was paid to socioeconomic development, a development model based on the ICZM model was needed. Some subregions had problems related to the environment, such as the overexploitation of aquatic resources (SR14) and poor air quality (SR14). At the same time, some subregions (SR13 and SR14) had violated the laws governing the exploitation of aquatic resources and environmental protection and had not focused on implementing measures to protect biodiversity.

- The subregions with extreme sustainability levels (SR5, SR7, SR8, SR9, SR10 and SR22) had the highest levels of sustainability. These subregions adhered to the ICZM model during development, which ensured harmony between economic development and the implementation of social security and environmental protection. These subregions were also very interested in the field of management, especially on promotional activities to raise public awareness about the rational exploitation of resources and environmental protection (SR9 and SR10), investment in environmental protection (SR8 and SR9) and the implementation of biodiversity protection solutions (SR5, SR7 and SR8).

b) Among the four subindices used to calculate and evaluate the sustainability levels of the coastal areas, the environmental subindex played the most important role, followed by the economic and social subindices and, finally, the management subindex. Our calculation also showed that the environmental subindex value accounted for the most significant proportion (31.00%) of the total value when evaluating and ranking the sustainability of the coastal area subregions. The criteria of the environmental subindex demonstrated the characteristics of the study area and described the rapid development of the local socioeconomy. Evidence from managers and field surveys showed that it hurt environmental resources, especially negative changes in seawater and air environment quality, reduced mangroves, and destroyed aquatic resources. According to the ICZM approach, the sustainable development

strategies for coastal areas must first focus on criteria related to the environment, then on criteria related to the economy and, finally, on criteria pertaining to society and management.

3.2 Strategies to increase sustainability in coastal areas

From the calculation results and consultation with managers and experts in the study area, two primary strategies were proposed to increase sustainability in coastal areas with low and medium levels of sustainability:

a) Stable livelihoods. Appropriate policies should be developed to attract environmentally friendly projects and local labour resources, with the latter supported via vocational training. These policies will create many jobs

and stable livelihoods. Moreover, this strategy will contribute to reducing the unemployment rate and increasing local budget revenue.

b) Development based on an ICZM approach. The master plan for the socioeconomic development of coastal areas should be reviewed and adjusted. Besides economic development, environmental protection needs to be constantly enhanced to ensure the reasonable exploitation of aquatic resources and the protection of mangroves, seawater and air quality. In addition, social aspects related to health policies, education and poverty reduction need more attention. Management aspects related to raising public awareness about sustainable development and investing in environmental protection and biodiversity also require consideration.

Table 5. Sustainability calculation results for each subregion

Subregion	Notation	Economy	Society	Environment	Management	Sustainability
Tanphuoc Ward	SR1	0.08	0.15	0.07	0.07	0.37
Phuchoa Ward	SR2	0.07	0.15	0.05	0.05	0.32
Longson Village	SR3	0.07	0.13	0.15	0.04	0.39
Rachdua Ward	SR4	0.17	0.16	0.11	0.05	0.48
Thangnhat Ward	SR5	0.20	0.22	0.17	0.11	0.70
Ward 5	SR6	0.17	0.14	0.12	0.08	0.52
Ward 1	SR7	0.22	0.22	0.23	0.12	0.78
Ward 2	SR8	0.19	0.22	0.22	0.13	0.75
Ward Thangtam	SR9	0.21	0.21	0.20	0.14	0.76
Ward 8	SR10	0.19	0.18	0.24	0.10	0.71
Nguyenanninh Ward	SR11	0.23	0.19	0.18	0.05	0.65
Ward 10	SR12	0.22	0.21	0.26	0.03	0.72
Ward 11	SR13	0.23	0.18	0.16	0.04	0.61
Ward 12	SR14	0.21	0.19	0.14	0.05	0.59
Phuoc tinh Village	SR15	0.15	0.15	0.12	0.06	0.48
Phuochung Village	SR16	0.14	0.17	0.11	0.06	0.48
Longhai Village	SR17	0.16	0.15	0.14	0.09	0.54
Phuochai Village	SR18	0.15	0.16	0.15	0.05	0.50
Locan Village	SR19	0.06	0.10	0.16	0.01	0.32
Phuochuan Village	SR20	0.03	0.10	0.18	0.05	0.37
Bongtrang Village	SR21	0.01	0.09	0.19	0.05	0.35
Bungrieng Village	SR22	0.03	0.12	0.15	0.07	0.37
Binhchau Village	SR23	0.13	0.13	0.15	0.05	0.46

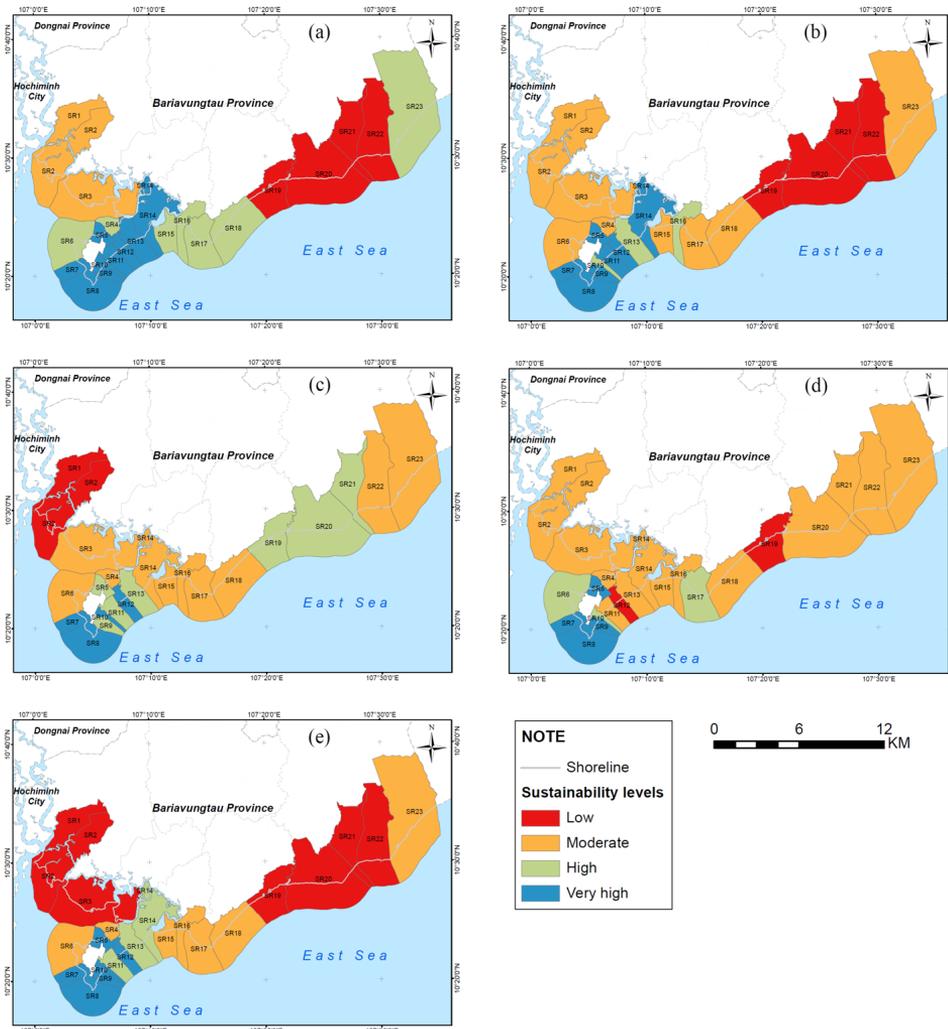


Figure 4. Map of the coastal subregion in terms of (a) the economy, (b) society, (c) environment, (d) management and (e) sustainability

4. Conclusion

Based on the ICZM approach, a composite index was developed that depends on four aspects, namely, the economy, society, the environment, and management to assess the sustainability of the coastal area of Bariavungtau province, Vietnam. The MCDM method was applied to screen and establish four sets of appropriate criteria and determine each criterion and subindex's weights for analysis and evaluation. The GIS method was also applied to zone the sustainability of each coastal region based on its estimated composite index value. The strategies were subsequently developed to

increase sustainability in the subregions zoned as having low and medium levels of sustainability. The research approach makes an important contribution to related research and the research results also contribute to the sustainable development of coastal regions in Vietnam. However, the scope of the study only concentrates on the local coastal level, so more extensive research is needed at the regional and higher levels. The study area is a dynamic development area with many potential risks, so it is essential to have an appropriate scientific basis based on the MCDM and ICZM model to evaluate and develop comprehensive strategies toward future sustainable development goals.

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