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Sustainability assessment of coastal ecosystems: DPSIR analysis for beaches at the Northeast Coast of Vietnam

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Abstract
The Northeastern coastal zone of Vietnam possesses high biodiversity and rich ecosystems like coral reefs, seagrasses, beaches and mangroves. It also includes the Ha Long Bay Natural Heritage site (UNESCO 1994) and the Cat Ba Biosphere Reserve (MAB/UNESCO 2004) as well as hosts the Economic Development Triangle (Hai Phong−Ha Noi–Quang Ninh) established by the Government of Vietnam. As one of the coastal ecosystems, sandy beach ecosystems attracted more attention during recent decades because of their essential role for human welfare and in environmental protection. A few studies concentrated on sustainable management of sandy beach based on environmental and ecological protection and enhance the beach quality for recreational use. The DPSIR (Driving force Pressure State Impact Response) framework describes the logical interaction among systems and finds out the cause and consequence of social-economic development activities to the environment and resources. In this study, the DPSIR was applied on the sandy beaches in the Northeastern coast of Vietnam to reveal the main environmental problems on sandy beaches including the decline of the natural landscape around the beaches and the degradation of the environment. It also pointed out that tourism development in association with urbanization and sea reclamation is the main driving forces for environmental degradation of the sandy beaches. Therefore, local authorities of Hai Phong and Quang Ninh should take into account several main responses to policies on inter-province coordination and managerial measures with a wider scope, which integrate socio-economic and physical factors, proximity, accessibility, and neighborhood to manage healthy coastal ecosystems and sandy beaches in particular. An integrated coastal management program for the Northeastern coast of Vietnam needs to be developed and carried out to follow the laws of Vietnam as well as to meet local urgent requirements.

Keywords Coastal ecosystem · DPSIR · Sandy beach · Sea reclamation · Sustainability assessment

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1 Introduction

Coastal ecosystems have multi-function for human life such as food and ecological service supply, coastline protection, natural disaster mitigation, carbon storage and human recreation (Ghermandi et al., 2012; Heckbert et al., 2012; Sarda, 2013). However, they are sensitive to environmental changes driven by natural processes and human activities (Kirwan & Megonigal, 2013; Lu et al., 2018). Development impacts coastal ecosystems by destroying them, declining biodiversity, land use, etc. Moreover, coastal ecosystems are impacted by pollution with nutrients, heavy metals, and POPs (persistent organic pollutants) resulting from intensive human activities (Lu et al., 2018,). Recently, sea reclamation and urbanization are the main activities that decline the coastal ecosystems in coastal countries (Andrés et al., 2018; Xu et al., 2018; Yu & Zhang, 2011). As one of the coastal ecosystems, sandy beach ecosystems attracted more attention during recent decades because of their essential role for human welfare and in environmental protection. Researches mainly focus on sandy beach ecology, pollution and management. A few studies concentrated on sustainable management of sandy beach based on environmental and ecological protection and enhance the beach quality for recreational use. Current strategies of beach management target user service improvement, and at the same time impairment of the natural environment (Lucrezi et al., 2016).

The DPSIR framework was derived from the stress–response model created by Statistics Canada, and then developed to Drivers Pressure State Impact Response (DPSIR) framework by the European Environment Agency in 1995 (EEA, 1999; Gari et al., 2015; Mateus & Campuzano, 2008). This conceptual framework describes the logical interaction among systems and finds out the cause and consequence of social-economic development activities to the environment and resources. Till now, it is applied in multi fields in environment assessment, especially in Europe (European Commission 1999; Patrício et al., 2016). It is used for studying changes in the coastal wetland of Xiamen, China; recognize the main cause—consequence lead to seagrass decrease in the Rio de Aveiro lagoon (Azevedo et al., 2013); assessment of ecosystem health (Wang et al., 2013). It is also useful to adapt management while identifying environmental solutions (Gari et al., 2015), assessing the state and change of the coastal environment, ecosystem and the impact on human well-being (Lin et al., 2007; Semeoshenkova et al., 2017) and assessment of the sustainable use of ecosystems (Borja et al., 2006, Lan TD, 2013). In general, it could say that the DPSIR framework used as a support tool for integrated coastal zone management due to its ability to identify the cause and effect chain of environmental problems in the coastal area, which also provides information for the authorities to adjust the socio-economic activities to achieve a balance between the development and environmental protection (Borja et al., 2006; Elliott, 2002; Maccarrone et al., 2014; Mateus & Campuzano, 2008; Pacheco et al., 2007). It was also applied to recognize pertinent issues and create potential actions for improving the implementation of coastal management activities (Goble et al., 2017). Most studies applied the DPSIR framework with various literature reviews for assessment so this framework would be appropriated for research subject or areas that have available data for each component of the DPSIR framework. For research subject or area which is limited of data, it will be a challenge if not combined with other methods.

Sandy beaches in combination with other main coastal ecosystems as corals, seagrass beds, mangroves, and tidal flats are the basis of the diversity of biology and the landscape in the Northeastern Vietnamese coastal areas. These ecosystems generate significant monetary income (tourism, aquaculture, etc.), but are also values for nature conservation. The

Northeastern Vietnamese economic triangle (Hanoi−Hai Phong−Quang Ninh) identified by the Government of Vietnam is dynamic and fast developing. It contributes significantly to the GDP of Hai Phong city and Quang Ninh province. This result also is increasing pressure on nature conservation and threatens ecosystems, including sandy beaches. More researches on pressures and responses of corals, mangroves and seagrass beds have been published (Hong, 2005; Thanh et al., 2011; Tien, 2009), but sandy beaches attracted fewer projects.

This study aims to apply the DPSIR framework and other experimental support to analyze the impact of natural processes and anthropogenic factors on coastal beach ecosystems of North Vietnam. The analysis result contributes to the conservation and sustainable use of coastal ecosystems by qualifying the driving forces that cause pressures and identifying policy options with an attractive cost–benefit balance. This is the basis for a sustainable option for the coastal ecosystems. In addition, the results of this study will add missing information on the sandy beaches of Vietnam to the world knowledge map.

2 Materials and methodology

DPSIR framework was applied to determine the cause of environmental issues in the sandy beaches of Northeastern Vietnam. The qualitative assessment is carried out based on an aggregated collection of existing data, additional data survey and analysis of satellite images.

2.1 Data collection and processing

In this study, secondary data were gathered from previous scientific studies and projects on the coastal ecosystems carried out by the Institute of Marine Environment and resources. The socio-economic data collected from Hai Phong and Quang Ninh statistics and other internet information available. In addition, surveys on environment and beach profile were carried out by the authors to supplement missing information. The detailed description of the data is in Table 1.

Eight sandy beaches are selected to carry out the study. To evaluate the environmental state in the sandy beach, two surveys were taken in July 2018 (tourist season) and March 2019 to collect water, sediment samples and measure beach profiles. Beach profiles were measured at 12 transects at Tra Co (2 transects), Do Son 295 (1 transects), Do Son 2 (2 transects), Cat Co (1 transect), Ha Long (1 transect), Bai Dai (1 transect), Son Hao (1 transects), Hong Van (1 transect). At each transect, three samples of water and sediment were also collected. The analyzed water quality parameters include pH, DO, COD, $N{-}NO_3^+$, $N{-}NH_4^+$, $N{-}NO_2^-$, Chl-a. The water samples were then collected in plastic bottles and fixed with reagents according to TCVN 5993: 1995 (ISO 5667—3: 1985)—water quality—sampling—instructions for preservation and handling of samples (TCVN, 1995), then maintained in 4 °C. Water samples then were analyzed in the laboratory according to standard analysis documents of Viet Nam. COD was determined by oxidation using potassium permanganate ($KMnO_4$) in an alkaline medium; n-hexane was used to extract oil and grease in water, then dried with anhydrous $Na2SO_4$ and determined by colourimetric method; $P{-}PO4_3{-}$, $N{-}NO_2^-$, NH_4^+ were determined by colourimetric method; Chl-a was determined by spectrophotometric method.

Table 1 Data collection for the study

Data type	Parameter	Time	Source
Secondary data			
Socio-economic	Population, aquaculture, sand mining, beach use	2009–2019	Hai Phong, Quang Ninh Statistic Office,
Environmental data on beach	Dissolved oxygen (DO), chemical oxygen demand (COD), nitrite ($N{-}NO_2^-$), nitrate ($N{-}NO_3^+$) ammonium (NH_4^+), phosphate ($P{-}PO4_3^-$), chlorophyll-a (Chl-a), beach profiles	2012	Project: Study, evaluation and proposal on solutions for reasonable utilization and promote the value of the sandy beaches in Northeastern coastal area, code VAST 06.02/12–13; Institute of Environment and Resources Project: Coastal environmental monitoring and analysis in coastal areas of the North of Vietnam; Institute of Environment and Resources
Survey data			
Environmental monitoring data on the beach environment	DO, COD, N−NH4, N−NO3, $N{-}NH_4^+$, $P{-}PO4_3^-$; Chl-a; Beach profile transect	2018–2019	Project: Study on scientific basics to develop indices for sustainable use assessment of tourist sea beaches in North Vietnam, coded KHCBBI-01/18–2020, Institute of Environment and Resources
Satellite images			
SPOT 4	01 scene of SPOT image	5 December 2000	Database of Institute of Environment and Resources
SENTINEL 2	02 scenes of SENTINEL 2 image	2 December 2019	Copernicus Open Access Hub: https://scihub.copernicus.eu/dhus/#/home

Changes in the coastal ecosystem in the study area were assessed with maps of land-use and land cover change (LULC) from 2000 to 2019 using Arc GIS software. The LULC maps have resulted from satellite images of 2 scenes of Sentinel-2A images acquired on 12 December 2019 and 1 SPOT acquired on 5 December 2000 covering the Hai Phong—Ha Long coastal area. The change matrix of LULC generated from those maps indicated how one LULC type convert to another in the period from 2000 to 2019.

2.2 DPSIR framework

The DPSIR framework which was developed based on the stress–response model created by Statistics Canada was first introduced by the European Environment Agency in 1995 (Mateus & Campuzano, 2008). It has become increasingly accepted and used in various types of research to resolve problems involving coastal marine environments (Bell, 2012; Gari et al., 2015; Mateus & Campuzano, 2008). It provides a diagnostic tool to assess the environmental impact of human activities on marine ecosystems. It allows a holistic approach to the social-ecological system not only focusing on the environmental problem, but also on its drivers and pressures and thus on the direct link with the social-economical dimensions of the system (Lan et al., 2014). It surpasses the simple causal relations which do not capture the complexity of the real world (Maxim et al., 2009) and are the basis for a skilful approach to coastal and marine ecosystem management (Patrício et al., 2016). The components of the DPSIR framework are assessed by analyzing the impact of each component on the environmental quality of beaches. The DPSIR includes 5 components: (1) Driving forces (D)—identifying the natural processes and anthropogenic activities affecting the coastal ecosystems; (2) Pressure (P): the pressures on the coastal ecosystem caused by the driving forces, especially sandy beaches; (3) State (S)—the status of beaches was assessed by analyzing land-use and land cover changes between 2000 and 2019, the variation of the beach profile and the seasonal monitoring of the beach quality; (4) Impact—describes the consequences of the changes on the current environmental and social state of the sandy beaches; (5) Responses (R)—assessment of governmental and local policies and activities mitigating the pressures on the sandy beaches. The DPSIR framework helps to characterize relationships between the origins and consequences of environmental issues. To understand their dynamics, it is also useful to focus on the links between DPSIR components (EEA, 1999). A problem in the present has resulted from the pressure of driving forces in the past. So, the proper response could adjust the pressure and improve the state of the system. In this study, the framework was applied by using data from field survey, laboratory analysis and the collection of previous studies (Fig. 1).

3 Study area

The Northeastern coast of Vietnam (Hai Phong City and Quang Ninh province at the border with China) entails over 3000 islands (Fig. 2), high biodiversity and rich ecosystems as coral reefs, seagrasses, and mangroves. It also includes the Ha Long Bay Natural Heritage site and the Cat Ba Biosphere Reserve. Both natural sites have been listed by UNESCO in 1994 and 2004, respectively. The area hosts the Economic Development Triangle: Hai Phong−Ha Noi–Quang Ninh established by the Government of Vietnam and witnesses an intensive development of coastal and marine-related sectors as tourism, ports and shipping/trade, aquaculture, mining, etc. Economic activities, infrastructure construction, and

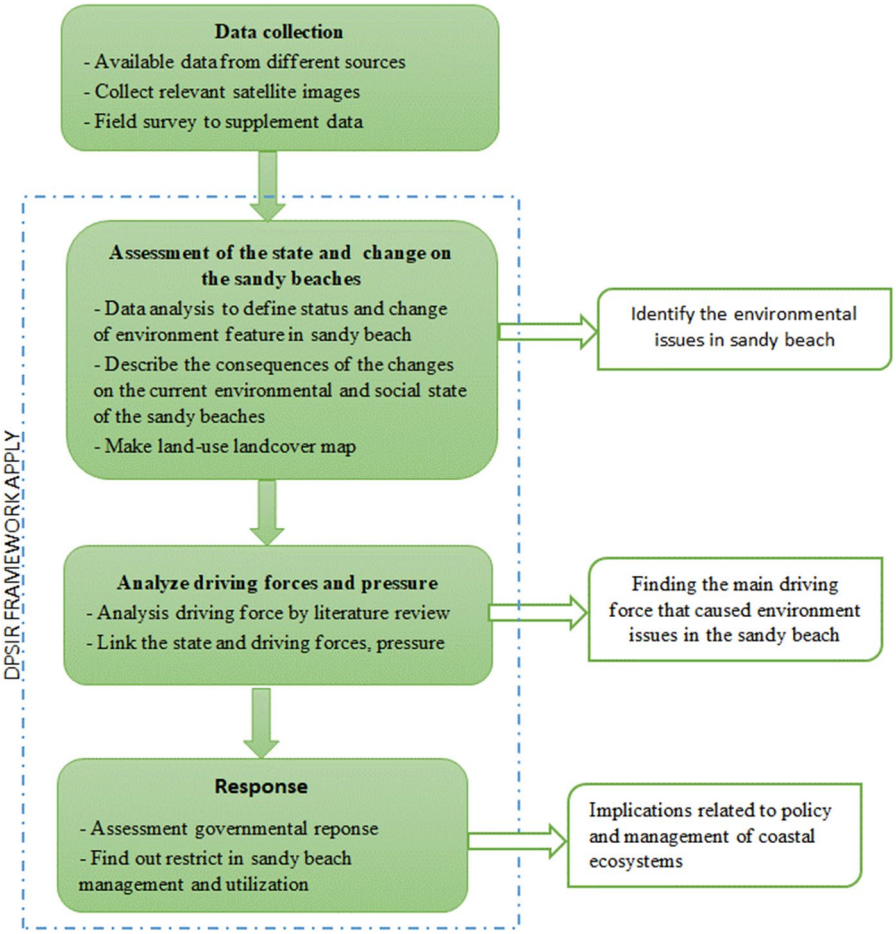

Fig. 1 Procedure in DPSIR analyzing for sandy beaches at Northeastern coast of Vietnam

natural resources utilization increase rapidly and threaten biodiversity and nature. The decline of mangroves and coral reefs in the area are documented (Lan et al., 2014; Yet, 2011). It is reported that 22,820 ha of mangroves (CIREN, 2009) grow in the estuaries and the tidal flats. Overall during the study period mangroves declined while the economy was increasing fast, especially happen in Ha Long, Cam Pha (Quang Ninh province), Bach Dang estuary (Hai Phong city) (Huong & Lan, 2009, 2019).

Coral reefs live in low tidal areas up to 6 m deep around the islands of Cat Ba, Long Chau (Hai Phong) and Ha Long Bay. Before, they were merely in a good condition with living coral ranging between 20 and 70% (Yet, 2011). During recent years, this ecosystem became significantly impaired and even destroyed in some sites. For example, the cover of living coral in Long Chau in 2007 was reduced by 30% as compared to 1999 (Quan & Ngai, 2008). About 2,000 ha of seagrass grows in large, scattered along the coast of Hai Phong and Quang Ninh province. During the period 2002 to 2017, more seagrass beds were located as such this ecosystem area increased (Luong & Thung, 2019).

Between Mong Cai (Quang Ninh) and Do Son (Hai Phong), about 200 sandy beaches stretch along the coast and around the limestone islands of Ha Long Bay and Cat Ba, and along the Northeast coast of Quang Ninh where terrigenous islands are formed. These beaches show limited biodiversity but are valuable for tourism. They are currently mainly used for tourism, fishing boat harbor and marine cage culture. Recent studies on these beaches show signals of erosion and deterioration of their environment (Huong & Lan, 2019; Huong et al., 2017; Nguyen, 2013).

4 Results and discussion

The DPSIR framework was used to assess the changes in sandy beaches of the Northeastern coast of Viet Nam. The main driving forces were recognized and their impacts on the system were evaluated:

4.1 State and impacts of the coastal ecosystem and beach ecosystems in Northeast Vietnam

Based on the analyzed collect data, land-use–land-cover change, some environmental issues in sandy beaches in Northeastern coast of Vietnam were defined. They include loss of landscapes surrounding the beaches; degradation of beach quality and beach erosion (Fig. 3).

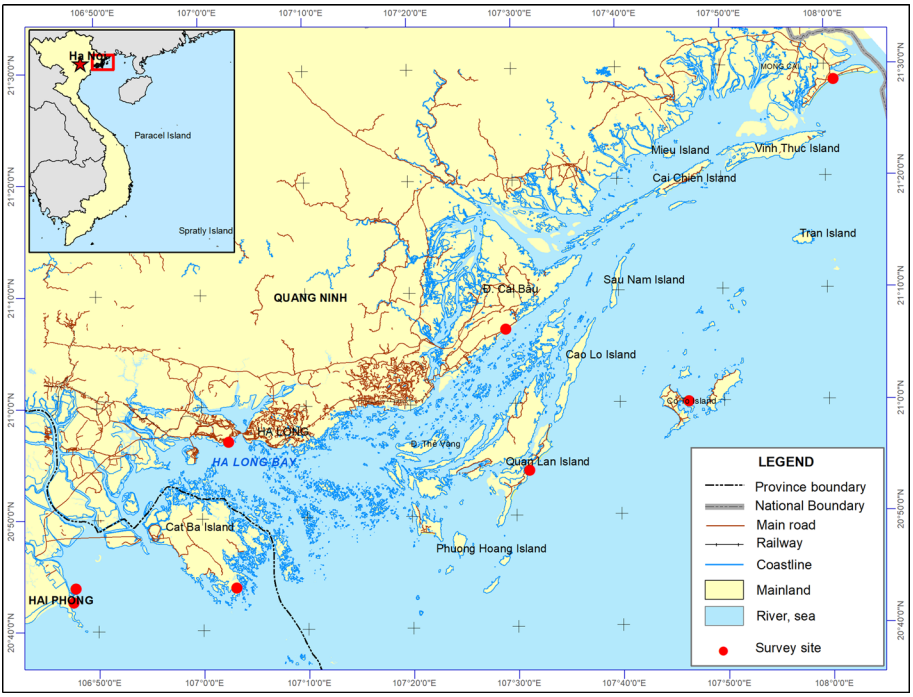

Fig. 2 Location of the study area

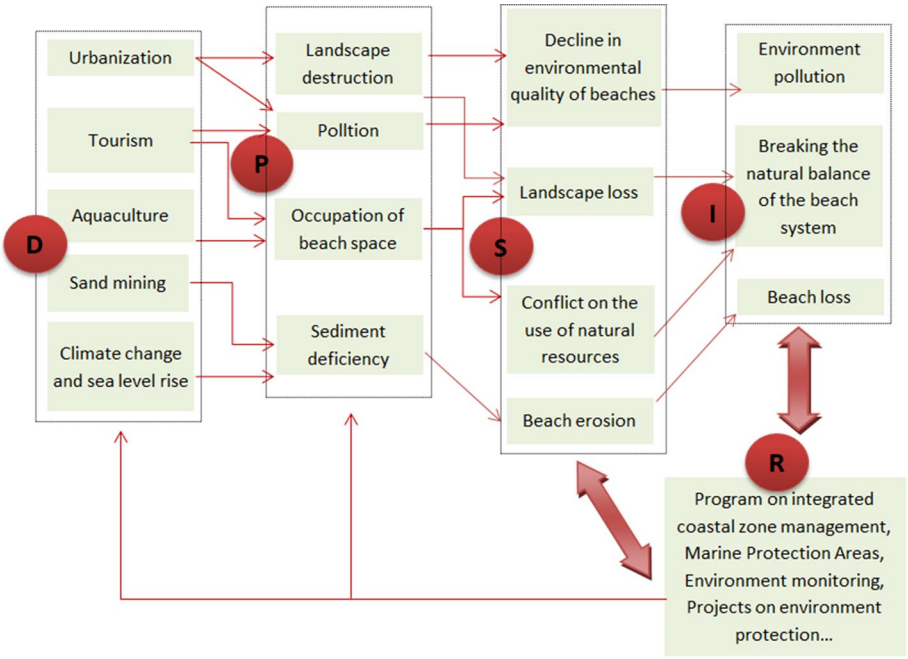

Fig. 3 DPSIR framework applied to sandy beaches in Vietnam

4.1.1 Loss of landscapes surrounding the beaches

Satellite images were processed to assess changes in land cover and land use in the study area from 2000–2019. The results of this step will provide information about the current status and changes in habitat around the sandy beaches. Quantifying these fluctuations will allow determining the pressures and existing environmental problems in the sandy beach ecosystem. Analysis of land-use and land-cover change in the coastal area of Hai Phong–Ha Long from 2000–2019 shows a significant change in the landscape surrounding the beaches (Fig. 4). The major changes are the increases of the residential area, build-up area and industrial zone, and the decreases at the same time the area of agricultural land, forest, aquaculture pond, water bodies. Detail analysis shows that the conversion of 766.8 ha of shallow water, 681.3 ha of aquaculture pond and 151.8 ha of mangroves in 2000 to the residential area in 2019. Also, 7.5 ha of shallow waters were converted into tourist beaches and 52 ha of mangroves were replaced by the recreational area during 2000–2019 (Fig. 4; Table 2).

Landscape changes around beaches in the study area were also driven by sand mining. This mining happened in the dunes behind the beaches and reduced the height of dunes. Most of the dunes in Quan Lan beach are exploited for the glass industry and that activities reduced the height of the dunes from 10−13 m to 3 m.

4.1.2 Degradation of beach quality

The sandy beaches of Do Son and Ha Long show signals of degradation, especially along tourist beaches. The water quality along the sandy beaches changes with intertidal zones.

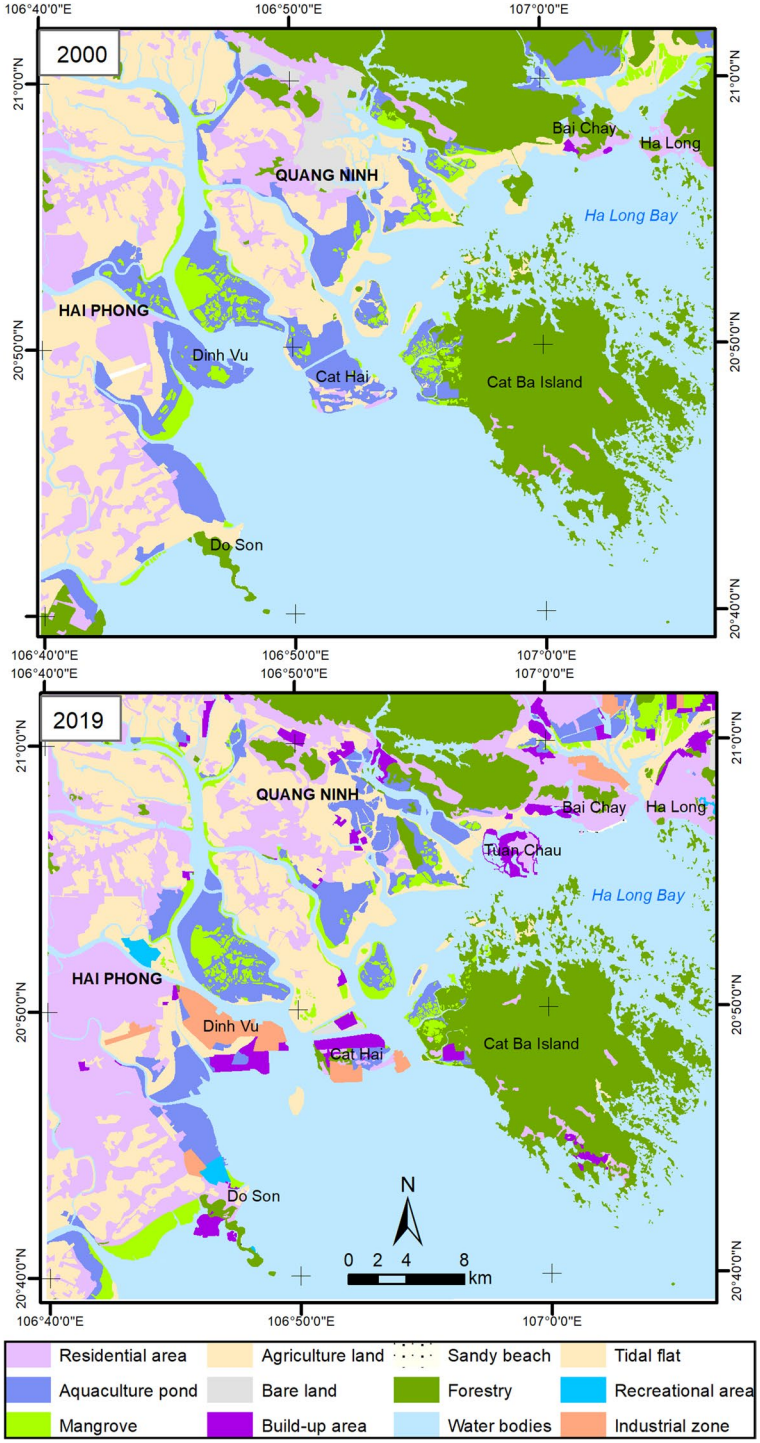

Fig. 4 Changes in the landscapes around the beaches of Hai Phong−Ha Long in the period of 2000–2019

Table 2 Matrix of land-use and land-cover change between 2000 and 2019 in Hai Phong–Quang Ninh coastal area

2019	2000											
	RA	AP	MAN	AL	BL	BA	BEA	FOR	WB	TF	IZ	REC
RA	*15,247.3*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AP	681.3	*6236.0*	389.3	3236.5	156.0	1100.0	0.0	517.5	362.5	19.3	1171.3	487.3
MAN	151.8	1513.0	*2889.5*	173.8	28.0	130.8	0.0	0.0	54.0	62.8	138.5	52.5
AL	9349.5	950.8	122.0	*17,369.8*	144.3	556.5	0.5	368.5	330.0	154.5	133.0	0.3
BL	109.8	161.0	0.0	2080.0	*0.0*	343.8	0.0	0.8	2.0	1.8	0.0	0.0
BA	41.3	0.0	0.0	0.0	0.0	*16.3*	0.0	0.0	0.0	0.0	0.0	0.0
BEA	2.5	0.0	0.0	0.0	0.0	0.0	*7.8*	0.0	0.0	0.0	0.0	0.0
FOR	4461.8	296.8	715.5	794.3	362.3	312.0	4.5	*27,537.0*	79.3	78.0	383.8	71.3
WB	766.8	1247.8	1280.3	353.3	17.3	1669.8	53.8	130.5	*83,235.8*	1580.0	989.8	9.0
TL	69.5	1047.5	556.3	10.0	0.0	450.3	0.0	38.8	250.0	*2772.5*	21.0	0.0
IZ	3.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	*72.8*	0.0

The value in the italics cell indicates no change in LULC categories for the period of 2000–2019

RA Residential area, *AP* Aquaculture pond, *MAN* mangrove, *AL* Agricultural land, *BL* Barren land, *BA* Build-up area, *FOR* forest, *WB* Water bodies, *TF* Tidal flat, *IZ* Industrial zone, *REC* Recreational area

In the high tide areas, the interstitial water quality was worse than that in the low tide areas (Fig. 5). Also, the quality of interstitial water in tourist beaches is lower than that in the others. The densities of total coliform and E.coli were much higher during Summer. At some beaches, the concentration of total coliforms was in the tourism season 3 to 5 times higher than that during other seasons (Huong & Lan, 2019). This indicates that microbiological pollution along sandy beaches is caused by untreated waste from tourism activities.

More tourists during the summertime also result in problems with waste discharge and environmental sanitation along the beaches. According to the Do Son Statistics Department (2012), tourism caused a 6.4% increase in solid waste. Waste increases by a factor of 2.5 during the tourism season. Also, the amount of waste during tourism months (May to September) increases (Nghiep, 2012). More pollution and impact on the esthetic quality of the beaches resulting waste are prominent issues along the famous beaches of Northeast Vietnam (Do Son, Cat Ba, Bai Chay, etc.). The Management Board of the Bai Chay Beach claims that six tons of rubbish were collected a day during Summer 2019 along the beach (Thao, 2019). Untreated wastewater from restaurants and new residential areas is directly discharged in the water near the tourist beaches. This is the case in Do Son Beach, Bai Chay and some beaches of the Cat Ba islands. Moreover, tourist beaches are flooded with plastic bags and other wastes discharged by beach users.

4.1.3 Beach erosion and reduction

Coastal erosion takes place when the balance of accretion and erosion is disturbed. This may be caused by a variety of reasons. One of the most immediate and important erosion factors is wave dynamics. The Northern coast from Mong Cai to Lach Truong shows 192 km of erosion. However, beaches are relatively stable and merely subject to seasonal changes (Thanh et al., 1994; Ve et al., 2014).

Beach erosion profiles show that beaches in the study area tend to erosion during the rainy season and accretion during the dry season (Figs. 6, 7). Beach width declines during the rainy season by 0.2 to 1.1 m as compared to the dry season. However, the overall beach profile does not change significantly on a yearly basis. This finding is in line with the observation of the previous studies (Thanh, 1999).

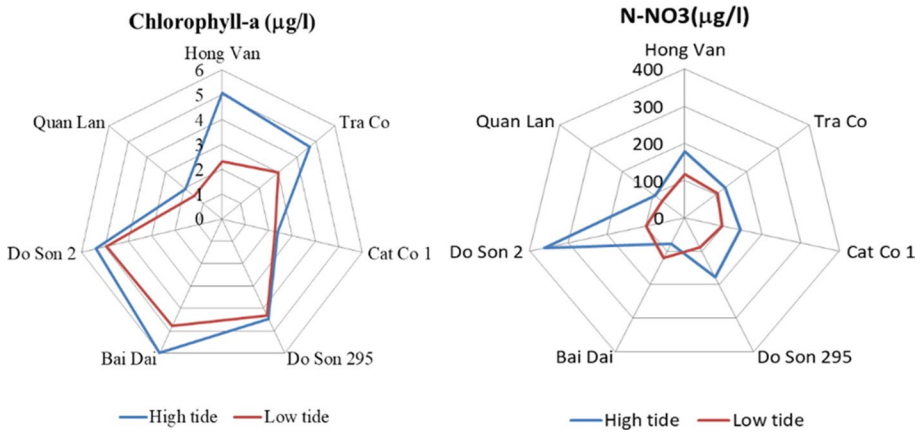

Fig. 5 Changes in quality of interstitial water of sandy beaches by tidal zone

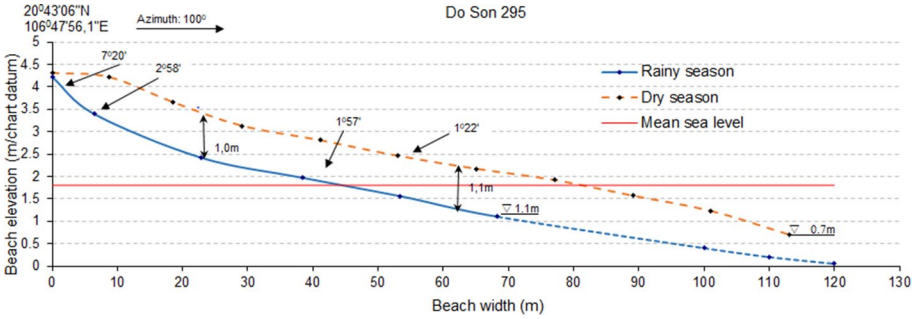

Fig. 6 Seasonal variation of beach profile in Do Son 295 beach (July 2018 and March 2019)

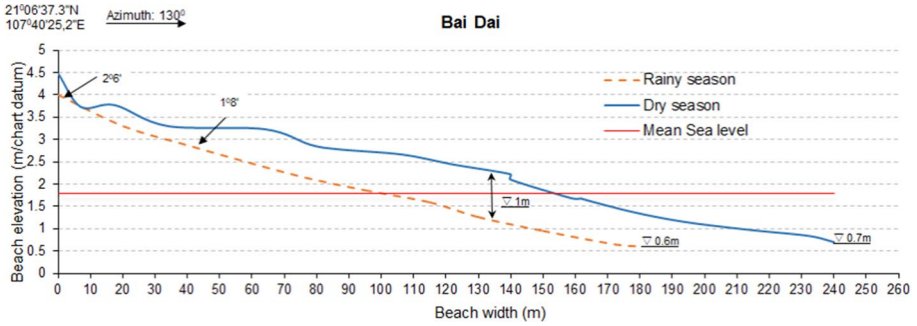

Fig. 7 Seasonal variation of beach profile in Bai Dai (July 2018 and March 2019)

4.2 Drivers and pressures

Driving forces (drivers) of the changes in the coastal ecosystems include natural and anthropogenic elements (climate change and sea-level rise, and human development activities). Main human development activities in the area include urbanization, tourism, mining and aquaculture (Dieu and Hoa 2014; Trang, 2019). As a result of the increasing and high population density along the coasts of Hai Phong and Quang Ninh, estimating about 3.3 million people, rapid urbanization took place. Hai Phong witnesses 45.48% of urban dwellers and in Quang Ninh, the corresponding figure is 64.06% (Fig. 8). Hai Phong and Quang Ninh are at the top 12 provinces/cities with the highest urbanization rate in Vietnam (Central Census Steering Committee, 2019). The urbanization rate in the study area increased fast during 2 last decades. The urbanization rate of Hai Phong and Quang Ninh from 2000–2019 increased by 11.43% and 25.48%, respectively (Fig. 8). From 2000 to 2009, Hai Phong and Quang Ninh had a similar rate of urbanization growth, around 10%. In this decade (2009–2019), there was a significant difference between the two provinces: the rate of urbanization in Hai Phong decreased slightly while that in Quang Ninh increased about 20% (Fig. 8). Since 2015, three districts of the Quang Ninh province (Uong Bi, Cam Pha and Mong Cai) were promoted to the more urbanized type II cities (municipal classification by the Government of Vietnam). Urbanization promotes the need for resources use, material exploitation, and

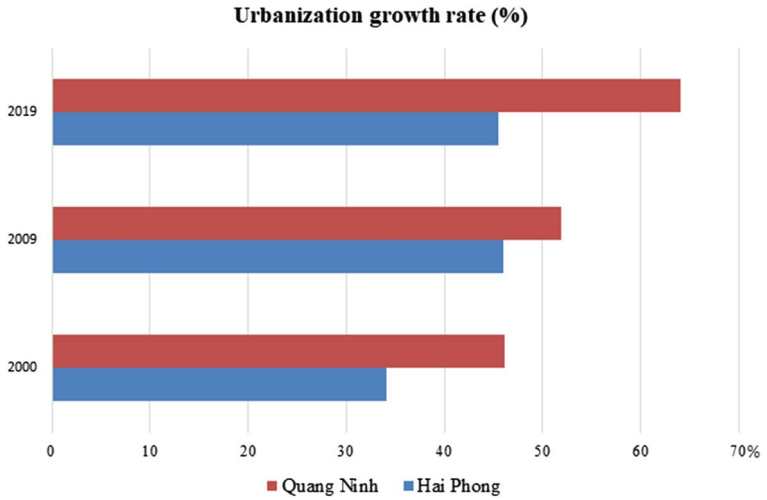

Fig. 8 The rate of urbanization growth of Hai Phong and Quang Ninh in 2000- 2019 (Source of data: Viet Nam General statistic Office,2000–2020)

infrastructure development in coastal areas. And these activities exert pressure on the coastal ecosystem in general and sandy beach in particular.

At the same time as the urbanization, sea reclamation took place along the coast of Hai Phong and Quang Ninh and destroyed natural landscapes which did not recover (Thanh & Dieu, 2006). The rate of sea reclamation in four coastal wards and city ranged from 0.5 to 38.0 m/year during 2010–2015 (Table 3) (Department of Natural resources and Environment of Quang Ninh, 2014). The result of land-use and land-cover change in the study area figures out the area of build-up area increases 4521.8 ha from 2000–2019 and most of them are converted from water bodies (1669.8 ha), aquaculture pond (1100 ha) and mangrove (554.5 ha) (Table 2). Sea reclamation makes change much to the coastal ecosystems.

Industrial zones, currently in operation or planned for the near future cover diverse industrial sectors such as mining (coal, construction sand), construction materials, power production, metallurgy and mechanics. This generates pollution and industrial waste. Many tourism types including marine ecotourism, cultural tourism, and spiritual tourism attract an increasing number of visitors. In 2017, Hai Phong welcomed 7.79 million visitors and

Table 3 Status of sea reclamation in the Quang Ninh Province

Location	The distance encroached to the sea (m)		Rate (m/year)	
	Max	Min	Max	Min
1. Hung Thang Ward	1,127	79	30.0	1.3
2. Hong Ha Ward	722	72	18.5	1.7
3. Ha Tu Ward	1,452	72	38.0	1.0
4. Cam Pha city	1,048	172	27.0	0.5

(Department of Natural resources and Environment of Quang Ninh, 2014)

Quang Ninh received 9.9 million, an increase in 18% as compared to the year before. Tourism attracted also migrants from other regions which increased the population density. Infrastructure and entertainment are developed along the beaches and the surrounding areas for tourist services. Major pressures from tourism activities include waste and the degradation of the landscape near the beaches. If the rate of solid waste per tourist is 0.67 kg/person/day (Dieu and Hoa 2014) then in 2017, the average amount of solid waste generated by tourists would be 32,472.05 kg per day. At the same time and until today, the system of waste treatment in tourist areas is incomplete and suffers from underinvestment. This contributes to more environmental stress on the sandy beaches.

Both inland and offshore sand mining give a great impact on the beaches in the study area. Sand exploitation in the dunes behind beaches in the Van Don District (Quang Ninh province) destroys the natural landscape. This pressure increases with the illegal exploitation without control by the authorities in the Van Don District. The marine sand of Hai Phong and Quang Ninh is used for infrastructure tourism projects. At present, the demand for sand exceeds its supply. The sand reserves in Hai Phong meet only 56.8% of the demand for the ongoing projects in the city (Vinh et al., 2019).

Aquaculture in the study area grows fast (Dieu and Hoa 2014). The environmental issues related to aquaculture include the lack of irrigation system, waste treatment, and pollution caused by the overuse of chemicals for disease prevention. Moreover, the cultures of clams need carbonate sand for the nursery. These materials were collected on the sandy beaches. In 2016, the authority of the Quang Ninh province allowed the Van Don District to exploit 142,000m^3 of carbonate sand in Hon Chin Island to grow bivalves (Quang Ninh Province 2017).

Long and short term processes that impact the coastal ecosystems include climate change and sea-level rise, and extreme weather phenomena. Climate change and population growth are inexpressively major driving forces that give pressures on the coastal ecosystems (USGS, 2010). Typical pressures on coastal ecosystems include declination of their areas, quality and services (Andrés et al., 2018). Although these impacts are hardly quantified, scientists acknowledge that sandy beaches are the most sensitive and impacted sites for sea-level rise and storms. Sea level rise causes coastal erosion and submerges of beaches (Thanh et al., 1994). Typhoons landing at the Northeastern coast of Vietnam also contributes to beach loss and deposit solid waste in many beaches in Do Son, Cat Ba (Hai Phong), and around the islands in Quang Ninh.

4.3 Responses

Controlling the negative impacts on coastal ecosystems in the study area entails environmental protection policies, defining marine protected areas, a coastal setback line. Hai Phong City established 14 areas to set up coastal setback lines along its 262 km of coastline. In the Quang Ninh province, defining coastal setback lines is currently in progress.

Policy responses include Vietnam's law on environmental protection, the law on natural resources, environment, sea and islands, local regulations on the management and use of Ha Long Bay, management of tourism activities in the bays of Cat Ba Island, the Cat Hai District, and in Hai Phong City, regulations on beach use, a conservation plan, and a biodiversity plan have been issued by the local authorities. Moreover, many projects on environmental protection and sustainable use of resources have been implemented in the study area. Mangrove planting and coral restoration significantly contributed to the maintenance of coastal ecosystems. In Ha Long on average 9.5m^3 of solid waste is collected each day.

Especially, the campaigns "Let's clean the sea" and "Anti plastic waste" were implemented in Quang Ninh in 2019. These campaigns were successful and raised awareness among local people about the protection of the marine environment (Hoang Anh, 2019).

Information and education in Hai Phong–Quang Ninh raised awareness on limiting waste discharges into the bay environment. Marine environmental monitoring stations in Tra Co, Co To, Van Don and Ha Long provide data on the quality of the marine environment. These are effective management activities that improve the environmental quality of coastal sandy areas.

However, the responses only solve temporary and fragmented problems in the sandy beach. It is still a lack of proper management policy that eliminates the negative impact of urbanization, sea reclamation and illegal sand mining on coastal ecosystems in general and sandy beaches in particular. It is a fact that beach ecosystems do not attract as much attention as other environmental issues. Efforts by the central and local governments on beach protection are still limited. Sandy beaches are intensively used but no specific regulations on proper management and use exist.

Hai Phong and Quang Ninh are famous tourist destinations with the Natural Heritage sites of Ha Long Bay and Cat Ba Biospheres Reserve as key reference points. The developing tourism sector needs infrastructure and services. Meanwhile, coastal land resources in the areas are limited. Therefore, sea reclamation is an economically attractive option. The cost of sea reclamation is less than the compensation cost for using residential areas. Major tourism infrastructure projects in Hai Phong and Quang Ninh are developed in the shallow coastal waters and on the sandy beaches (e.g. Hoa Phuong resort (Do Son, Hai Phong) and Bai Chay (Ha Long, Quang Ninh)). Sea reclamation not only destroys the surrounding landscape, but also increases pollution during construction and operation. Sea reclamation needs to be controlled to achieve sustainable use of coastal ecosystems in the study area.

Although offshore sand mining does not directly affect coastal sandy beaches, it will have long term and cumulative impacts because of the current changes near sand mining sites, the sedimentation equilibrium loss and the sediment deficiency of the coastal currents – the major dynamic regimes to form beaches. Studies indicate that offshore sand mining activities in Hai Phong increased the extent of the abrasion (abrasion rate) around the sand mining sites (Lan et al., 2020).

Beach environment problems such as changes in the nature of sandy beaches, discharge of untreated wastewater into the sea along the Northeastern coast of Vietnam, are similar to those in countries like Chile (González & Holtmann-Ahumada, 2017). This applies in particular during beach use, especially in the early stages when the infrastructure for entertainment is established. Most of the recreational beaches in the study area are now in a transition toward modern and luxurious destinations for domestic and international tourists. This applies in Do Son, Ha Long, Tuan Chau, Van Don and Tra Co (Quang Ninh People Committee, 2014) where many tourism projects are implemented.

Analysis of the DPSIR for the beach in the study area shows some implications related to policy and management of coastal ecosystems in general and sandy beach ecosystem in particular, including main issues: presently managerial measurements focusing only on tackling the current state of the environment and ecological problems, lack of strategic plans or ecosystem-based management programs, and particularly no environmental measures developed for sandy beach ecosystem in the study area. Although at the national level in Vietnam, the systems of environmental policies and their relevant laws and regulations covering coastal and marine areas have been well developed and periodically amended to meet the national requirements, local policies and regulations for coastal management, particularly for the coastal ecosystem as beaches are not much paid attention. Moreover, an

inter-province managerial coordination in coastal environment protection takes no effect in the study area. It is recommended that, at the national level, a policy on inter-province managerial coordination for the coastal and marine area should be issued and a relevant national coordination body is considered to set up then the local ones will be formed. Also, programs on ecosystem-based management should be carried out. At provincial levels, some specific issues related to coastal management need to be in consideration as follows.

Tools for beach management that target the sustainable use of sandy beaches are indicated. Beach quality awards need to be implemented on tourism beaches along the Northeastern coast of Vietnam. These awards will assist to enhance beaches and reference points, which maintain their natural characteristics. They use a variety of means toward the sustainable development of coastal and creational beaches, as models exist in Portugal, Spain and Italy (Semeoshenkova & Newton, 2015).

Lack of regulations and weak maintenance result currently in a deficient policy in beach protection. Moreover, weak coordination exists between Hai Phong and Quang Ninh on common coastal environmental programs. This situation also exists along the eastern beach of the Amazon (de Sousa-Felix et al., 2017). Policy on beach management needs to become more specific and effective. At the same time, environmental monitoring programs on sandy beaches need to be established, detailed and widespread.

Other responses to achieve sustainable use of coastal ecosystems are related to changes in human behavior to maintain the ecological balances and to make optimal use of their services. The adjustment of human activities includes controlling tourism activities, urbanization, and sea reclamation by adjusting policies and management methods. Policies on the management of marine ecosystems, especially those for sandy beaches integrate natural, cultural and social factors to protect the biodiversity and to maintain essential ecological processes. Therefore, it is necessary to minimize the encroachment to the beaches, including the dunes behind the beach.

To cope with the management weaknesses and shortages of coastal ecosystems in Northeastern Vietnam, an integrated coastal zone management (ICZM) program needs to be developed and implemented as soon as possible. The program is also required by the law of Vietnam on natural resources and the environment of seas and islands.

5 Conclusion remarks

The DPSIR framework allows evaluating the impacts of natural processes and human activities on the sandy beaches in the Northeastern coast of Vietnam. These reveal the main environmental problems on sandy beaches including the decline of the natural landscape around the beaches and the degradation of the environment. Among the drivers, coastal urbanization, sea reclamation, and tourism that impact the coastal ecosystems are identified.

The application of the DPSIR framework on the sandy beaches in the Northeastern coast of Vietnam pointed out that tourism development in association with urbanization and sea reclamation is the main driving forces for environmental degradation of the sandy beaches. Other drivers include sand mining, aquaculture and processes as sea-level rise and extreme weather phenomena. Also, the less documented impact of climate change and sea-level rise on sandy beaches is recorded and forecasted. The intensive

main drivers have created more pressures of increasing wastes to pollute beach environments, destroying the natural landscape and beach structure.

Overall, the driving forces have become more complex and diverse, creating stronger pressures on the sandy beach ecosystem and making the beach ecosystem degraded over time in the study area. Therefore, local authorities of Hai Phong and Quang Ninh should take into account several main responses to policies on inter-province coordination and managerial measures with a wider scope, which integrate socio-economic and physical factors, proximity, accessibility, and neighborhood to manage healthy coastal ecosystems and sandy beaches in particular. An integrated coastal management program for the Northeastern coast of Vietnam needs to be developed and carried out to follow the laws of Vietnam as well as to meet local urgent requirements.

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