Coastal erosion in Vietnam: Case studies and implication for integrated coastal zone management in the Vietnamese south-central coastline

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Abstract. Vietnam is a country that is heavily affected by global climate change, with the coastal zone and low-lying river deltas being especially vulnerable. The coastal zone has rapidly evolved over the past few decades, as coastal tourism and other social-economic developments and industries all seek fortune and exploit resources in this area. Along with this rapid economic growth, the coastal zone has suffered severe impacts of both human activities and global climate change, resulting in an increasing number of coastal hazards, such as typhoons, floods, saline intrusion, and coastal erosion. The purpose of this paper is to identify natural and human factors that affect coastal erosion through case studies in the south-central coastline. Measures for minimizing threats to both socio-economic activities and the surrounding natural environments are brought forward, in which integrated coastal zone management approach plays a key role. In addition to addressing the issues and potential management strategies, selected coastal areas in Vietnam characterized by severe coastal erosion are studied in terms of coastline dynamics, changing beach morphologies and coastal engineering structures through on-site measurements and aerial images. Seasonal variations and changing beach morphologies after the construction of coastal engineering works are clearly visible.

1. Introduction
Vietnam is one of the countries most affected by global climate change [1]. The coastal zone and river deltas are especially affected. The Vietnamese coastline stretches over 3,260 km and is home to about 20 million people, being one of the most densely populated areas in southeast Asia [2]. Many studies recognize the severe side-effects of the ongoing socio-economic developments in the narrowing coastal strip of Vietnam, which are exacerbated by poorly constructed engineering structures and natural hazards increased by global climate change, such as typhoons, floodings, sea-level rise, and rapid coastal erosion. The main purpose of this study is to review and identify the most serious threats to Vietnamese coastal areas through case studies of site investigation in the central coastline and summarize the
suggested and implemented solutions, assessing their effectiveness so far. First main threats to the (central) coastal zone of Vietnam are discussed, concerning natural hazards and issues related to socio-economic development. Then, current management strategies and future implications are reviewed, based on papers, reports and case studies, bringing forward the successes and failures if the integrated coastal zone management concept in Vietnam.

2. Study area and methods

2.1 Study site and sampling points

The study area is located along the coastline near Phan Thiet city. This region is characterized by a warm and humid climate, with rainfall increasing in the winter months starting from October. Most tourists visit during the drier summer months, starting from March. Two areas are investigated; Duc Long Ward, a seaward which is located in Binh Thuan province, south of Phan Thiet City and Doi Duong Beach which is located circa 4.5 km to the northeast along the coastline at the border of Phan Thiet City and is bordered by two river mouths (Phu Hai and Ca Ty rivers). Duc Long Ward currently is under construction, and a long sea ward is being built while new land is constructed. It is aiming at future tourism potentials. On the other hand, Doi Duong Beach is an already more developed tourist destination and has multiple hotels and restaurants assembled along the public Doi Duong beach. This research area is bordered by the Ca Ty River estuary on the southwestern side and the Phu Hai River estuary on the northeastern side (Figure 1). Methods used during this case study are literature review on site specific data and other similar cases in Vietnam. An analysis of historical satellite images on a temporal scale to explore landcover changes and field data and measurements are added via on-site investigations. During the field visits, the selected sites were studied in terms of coastal erosion, coastal engineering structures and sediment dynamics. In the field, evidence of coastal erosion is uncovered and explored in the beach morphologies, such as formation of beach scarps, sharps edges, fallen trees, collapsed, or damaged houses and structures, etc. During field observations, beach morphologies were identified and recorded, and an elaborate photo database was created. The main coastal engineering structures for the coastal erosion are described and studied in the field in terms of construction, erosion, ageing, and surrounding sediment dynamics.

![Figure 1. Location of research areas in central-south Vietnam: Duc Long Ward and Doi Duong Beach, retrieved from: https://www.openstreetmap.org](https://www.openstreetmap.org)

2.2 Aerial photograph analysis

Aerial images provided by Google Earth Pro from years 2006 until 2019 were obtained and analysed in terms of land use changes and beach dynamics over time. Pictures were obtained for different months each year to study the land use changes surrounding the beaches, and the changes beach volume and dynamics are examined.
3. Main coastal zone threats

3.1 Socio-economic development
Around the world, people are highly dependent on coastal resources. Due to the geographic position of Vietnam, its people rely even more heavily on these coastal resources. It is an elongated country with a 3,260 km long coastline, housing most of the rapidly growing population. In particular, the low-lying delta areas that are sensitive to climate change and prone to flooding are densely populated. Socio-economic developments in the coastal areas have posed numerous challenges and put pressure on the coastal system. Pollution, high smog levels in cities, floodings, salt intrusions and coastal erosion are a few of these challenges that are related to human induced global climate change.

Rapid urbanization and industrialization cause land-use change with consequences such as freshwater shortage and altered sedimentation flows [2]. New land claims have numerous harmful impacts on coastal habitats, including the loss of wetlands and overall loss of biodiversity. The degraded coastal ecosystems in Vietnam are also a major driver of disaster risk and a key component of disaster vulnerability. Industries in the coastal zone are focused on (amongst others) petroleum, sand-mining and tourism [3]. The long stretches of beaches attract many tourists, though these beaches are also characterized by the erosion phenomena that is leading to a serious retreat of the coastline. The width of some beaches is being reduced hundreds of meters to even kilometers over the past decades [4]. Resorts and other businesses are being built on unstable grounds, while local authorities spent large amounts of money to stabilize beach erosion. This mainly results in beaches being turned into concrete structures and massive sandbag walls, which are short-term solutions using non-durable materials to prevent erosion. Another side effect of these hastily engineered structures is the way they cause water to flow into unprotected areas in the long run, creating erosion at other areas along the coast or spreading further inland. This can be seen as a form of maladaptation and a big issue along the Vietnamese coast, which is inhabited by many vulnerable people who don’t receive protection or support from the government [5]. Additionally, sand-mining and coastal dike systems cause an increasing shortage of sediment transport to the coastal areas. This lack in sediment budget also induces coastal erosion and land loss problems [4]. Other activities that contribute to coastal erosion include land reclamation, the dredging of channels, and the destruction of mangrove forests. In Vietnam, coastal erosion is happening on a large scale, but not all sites along the shoreline are equally susceptible; areas around river deltas are much more vulnerable to erosion, hazards, or other anthropogenic activities due to deposits of soft sediments such as mud and clay. Coastal erosion has not only negative implications for the population, but also serious impacts on the environment. Ecosystems are affected by erosion; they are reduced in size, lose species, or are even entirely destroyed. For instance, mangrove forests that are typically found along the coastal zones are badly impacted due to the erosion and alterations in their habitat, which are in turn caused by pollution of organic matters connected to released sediments from the erosion process. In another example, the marine system is affected by disturbances of sea grass beds and coral reefs.

Erosion, combined with other human activities such as land-use change for aquaculture, has considerably deteriorated marine biodiversity and natural resources [6].

3.2 Natural hazards and sea level rise (SLR)
Alongside anthropogenic activities, natural events also contribute to the high rate of coastal erosion in Vietnam. Some events or hazards have direct impacts while others are more indirect. For instance, coastal hazards, such as typhoons, storm surges, tropical storms, strong waves, and the rise of sea levels, not only directly impact the coastline, but also have adverse effects, such as floods or saline intrusion affecting infrastructure, deteriorating coastal (tourist) facilities and livelihoods, and causing problems further inland in agricultural zones. Due to climate change, these events will become more frequent and more intense. It is already evident that the sea level has risen faster over the last decades, with an average increase of 3.34 mm/year in the period of 1993 – 2014. The relative sea level in Vietnam has increased 5 cm over the last 30 years [7]. Such a rise in sea level would inundate wetlands and lowlands, accelerate coastal erosion, increase the salinity of estuaries and aquifers, deteriorate water quality and have a huge impact on the coastal ecosystems. Moreover, it also affects the population in coastal areas, triggering
displacement and increasing vulnerability to flooding and storm events. The two major river delta areas in Vietnam, the Red River Delta in the North and the Mekong River Delta in the South, are affected most by floodings and other climate change related issues. Saltwater intrusion is a major problem, with salt water currently infiltrating 30-50 km up the Red River and 60-70 km up the Mekong River and the salinity contour moving further inland over the decades [8]. In the dry season, there is a lack of freshwater due to saltwater intrusion, which causes issues in water extraction and irrigation for agricultural cultivation. Furthermore, major droughts induced by climate change occur. The overall impact is therefore not limited to the narrow coastal zone and includes serious effects further inland on rice production and other businesses [9]. With declining rice production, many farmers, if they are able to, have switched from rice farming to shrimp farming. This is a form of adaptation in response to climate change, as droughts, floods, and the increased salinity in the river deltas threaten the farmers’ crops. When these farmers settle in the coastal areas, mangrove forests are destroyed to make way for shrimp farms, which result in less protection and more erosion along the shoreline [10].

3.3. Integrated coastal zone management in Vietnam

Integrated coastal zone management (ICZM) is a multidisciplinary and dynamic process that is being developed to promote sustainability in coastal zones worldwide. It covers all aspects involved in coastal development, from data collection and planning to decision making and implementation, as well as, the management processes and monitoring afterwards. It is important for the successful implementation of ICZM that all involved stakeholders cooperate, as ICZM seeks to find balance between environmental, economic, social, cultural and recreational objectives over the long-term (see Figure 2). Stakeholders include policymakers, industrial sectors, administrative sectors, NGO’s, local residents etc.

![INTEGRATED COASTAL ZONE MANAGEMENT (ICZM)](image)

**Figure 2.** Schematic and simplified representation of the main components in the ICZM process.

In the last decade, with the support of international organizations, Vietnam has been trying to enhance the application of integrated coastal management for the entire coastal zone. So far, most strategies have focused on coastal development due to the many economic advantages of the marine resources [11]. Priority is given to developing business sectors and industries along the coast without paying proper attention to the conservation of natural resources and protection of ecosystems, which result in short-sighted visions. Unfortunately, this has led to serious environmental problems as described above. Many studies point out shortcomings of the ICZM plans in Vietnam that due to the lack of integrated planning, lack of coordination between different levels (e.g. central and provincial), lack of monitoring or the fact...
there is no appropriate legal framework. A legal framework is needed to manage and minimize the environmental impacts or impacts on societies [3]. Moreover, restricted exchange of information between different levels and areas, the reluctance to bear the costs of polluting the environment, a result of careless business establishments and corrupt governments, and the lack of sufficient data on activities and threats in coastal zone, result in poor awareness or knowledge by stakeholders. Additionally, different interests are represented by different sectoral authorities at the national level. As the local government is often the only body responsible for assessing and integrating different interests while also lacking resources to fully implement ICZM, it becomes difficult to prioritize on both national and local agendas [12].

To maintain good governance and sustainable development, treaties have been drafted at the international level, and Vietnam has signed a number of treaties binding the state to protect coastal resources. However, most of these agreements remain unimplemented due to various socio-political reasons, such as the fact that these documents are written by external experts with minimal understanding of local factors and conflicts [13]. Of all factors concerning the success rate of the ICZM process, the political will of the local government might be the most significant. The process can be more successful when the decision makers understand the long-term benefits on both social and economic levels. Nevertheless, cooperation with other countries can potentially improve the management process in the coastal zone of Vietnam. Such projects can be seen in the Delta Alliance, where countries that deal with similar issues of low-lying deltas share their experience and expertise to contribute to an increased resilience of their delta regions. For example, the Vietnam-Netherlands integrated coastal zone management project (VNICZM) is aimed at strengthening long-term ICZM capability in Vietnam and is now mainly focused on consulting the Vietnamese Government in the planning and development of a Vietnamese sustainable coastal zone while increasing knowledge among different stakeholders about the processes regarding ICZM. The project aims to stimulate both vertical and horizontal integration, including integration at national and local levels and actively seek citizen participation. It is not clear yet what role it will play in the Vietnamese policy processes or how effective it will be for the protection environmental resources, but it has become clear that for the ICZM plan to work fully, it will be a long-term effort to provide improved economic development and sustainable functioning of the entire coastal system [14].

4. Case studies at Duc Long Ward and Doi Duong beach at Phan Thiet city
Currently, there is a lack of data surrounding the environmental issues, morphological changes, and the consequences of the rapid social-economic development. With better knowledge of these issues, more informed and balanced decisions can be made for the affected regions in the future [2,7]. For this study, literature review has focused on central Vietnam, from Thanh Hoa to Binh Thuan province. In this region, over 160 beaches have experienced significant erosion since 1950 and many coastal engineering structures have been established to counteract the erosion and prevent buildings built close to the shoreline from collapsing. For more extended research, the sites of Duc Long Ward and Doi Duong beach near Phan Thiet city have been studied (Figure 1). The dominant economic sectors at these sites include the tourism industry and the fishing/seafood aquaculture businesses, all of which are rapidly developing. These developments have resulted in numerous human interventions in the natural systems. Case studies are conducted on these two selected sites along the south-central coastline of Vietnam (Duc Long Ward and Doi Duong Beach of Phan Thiet city, Binh Thuan province). Field investigations and aerial images reveal coastline dynamics and changing beach morphologies influenced by human activities, such as engineering structures and due to coastal erosion driven both by human and natural influences.

5. Results

5.1 Coastal engineering structures at sites of investigation
In 1995, a groin was constructed in the river mouth of the Ca Ty River estuary at the Duc Long site. Over time, this engineering structure developed a “groin-effect,” causing severe downdrift erosion on
the southern beach of Duc Long Ward over time. This erosion event resulted in hundreds of houses threatening to collapse, and residents had to be relocated (Figure 3b & 4b) at Tien Duc Area, Tien Thanh Commune. Later on, geo-textile dikes were constructed in this area to minimize wave energy, but this is only a short-term measure to protect the communities [2]. Field observations in 2017 revealed that local authorities had decided to construct a sea dike (sea forward dike) to create more land for the construction of houses and further developments. This land reclamation project is called the VietPearl City Project. The constructed seawall is relatively low, and the tetrapods in this area are no longer effective (Figure 3a). Where the seawall is low, there is a high risk of flooding, and waves are constantly washing over the seawall. There are plans to construct this seawall further along the coastline, continuing as a coastal seawall as a substitute of a sea forward dike. The erosion of tetrapods was studied during the field trip and observations showed that the design is ineffective, they were constructed with incorrect materials in terms of the cement/non-cement ratio and many already show signs of erosion. This poorly constructed seawall could have negative impacts on the future developments on this new strip of land.

Table 1. Coastal development activities at the study locations

| Site                  | Coastal development activities                                      |
|-----------------------|---------------------------------------------------------------------|
| 4: Duc Long Ward      | Residential area, fishing harbour, seawall, aquaculture practices  |
| 5: Doi Duong Beach    | Residential area, hotels and restaurants, public beach, fishing harbour (Phan Thiet Harbour), Ca Ty river estuary (south side), Phu Hai river estuary (north side) |

![Field observations](a)(b)(c)(d)

**Figure 3.** Field observations. (a) north of Duc Long the seawall is very low, (b) collapsing houses in the Duc Long area, (c) low seawall at the southern side of Doi Duong Beach, (d) no seawall, but visible seascars at the northern side of Doi Duong Beach.

At Doi Duong Beach, a low seawall has been constructed (see Figure 3c). There used to be a soft seawall made by pumping the sand into a tube and using geotextile, but this was effective. Now, a
low seawall is built to prevent the sea from moving further inland, and at the time of field investigation in 2017, there was no sight of erosion at this site. In the area south of Doi Duong Beach, the beach was very small or completely absent due to the seasonal wave direction at the time of investigation, threatening residential areas near the coastline (Figure 4a). Sand accumulated on the sidewalks, away from the beach, which can be explained by wave action or wind action. Waves go over the low seawall and transport sand land inward. Or, winds lift up the tiny sand particles that are then deposited at the sidewalk. An issue concerning sand accumulation inland is that the sand is not transported back to the beach, which can be explained by the Law on Coastal and Ocean Resources, and the interruption of natural process causes loose sand beaches. A section along this sidewalk has low shrubs planted, which should be maintained to prevent loose sand getting picked up by strong winds.

![Figure 4](https://www.google.com/maps)

**Figure 4.** Houses that are exposed to intense erosion. (a) Left: Doi Duong Beach, (b) Right: Duc Long ward. Retrieved from [https://www.google.com/maps](https://www.google.com/maps)

5.2 Aerial image analysis
At Doi Duong Beach, the aerial images from 2006-2019 demonstrate the construction and extension of the sea wall and the sediment input behind the seawall. For the development project the government has planned in this area (VietPearl), sediments dredged from the Phan Thiet Harbour and from surrounding areas are used for land reclamation. The aerial images of Figure 5 demonstrate this development, clearly showing the extension of the sea wall and the sediment infills through the last decade (2009-2019). The shore is extended all along the coastline from the harbour to circa 3 km further along the shoreline. The constructions are still in progress, and the VietPearl project intends to create a promenade with luxury hotels, resort, and shopping malls. The aerial images of Doi Duong beach from 2006 to 2019 show fluctuations in beach dynamics exist between the two river estuaries. The constructed river mouth structures in the estuaries of Ca Ty River (south side) and Phu Hai River (north side) in Doi Duong beach have blocked the inland sedimentation input. Due to the constructions in the Phan Thiet harbour (Figure 6), heavy sedimentation occurs in the harbour. The construction of a sea ward and the elongation of the headland add up to block the sediment flow out towards the sea, resulting in the harbour having to be frequently dredged and the longshore current, a current lateral to the shoreline from northeast to southwest, transporting less sediment along the coastline. This affects the beach dynamics of Doi Duong beach and Duc Long beach. At the research location of Duc Long Ward, the lack of sediment transport has led to serious erosion. Figure 3b shows an example of the collapsed houses due to the increasing downdrift side erosion, affecting mostly vulnerable people residing close to the shoreline. Now, with the construction for the VietPearl project, these houses are being closed in by sediment infills. Also visible in the aerial images are changing beach volumes over time, which may be explained by underlying factors that can include both seasonal changes and the coastal engineering structures. While it is significant to describe seasonal changes, it is not the aim of this study to do so, since the photos are obtained for different stages at different time periods, to describe the coastal development. However, it is essential to keep in mind that seasonal changes in wave direction and sediment input can also have many consequences for the beach volume and dynamics.
Figure 5. Aerial images of Duc Long Ward (March 2006- April 2019), retrieved from Google Earth Pro
6. Discussion on management strategies and future implications

Increased urbanization in the coastal zone and the growth of the population are the underlying factors that contribute to the many problems discussed in this article. While it is a difficult task to manage this growth, a first step is to recognize that the development of social and economic activities has resulted in many negative impacts in the coastal zone. When more natural approaches, such as mangrove planting, sand dunes, or forests, are integrated with the already existing structures, such as dikes and other protection structures, more resilience can be created in these densely populated areas [11]. Natural approaches can also create more co-benefits, which is highlighted in the IPCC land-based solution report (IPCC, 2019). For instance, by actively (re)planting mangroves along the shoreline, erosion and salinity intrusion can be prevented to some extent, while important ecological functions such as increasing biodiversity and providing shelter for many species are also fulfilled [15]. Moreover, lagoons could provide coastal protection and act as a buffer zone for saltwater intrusion, while attracting many diverse species, such as the shorebirds. An example is Vietnam’s first marine protected area (MPA) in Nha Trang Bay, where potentially charging tourist fees to visit the area can also contribute to limiting...
industrial development and stimulating the protected area [15]. The degraded coastal ecosystems in Vietnam are a major driver of disaster risk and a key component of disaster vulnerability. A method to reduce hazard vulnerability is the Ecosystem-based Disaster Risk Reduction (Eco-DRR), a natural management approach established through conservation and restoration of ecosystems. For example, rebuilding or maintaining sand dunes can result in better protection of the inner land, while also preventing coastal erosion from extreme weather events, as dunes may recover naturally after typhoons or extreme weather events [16]. This will increase the resilience capacity of both ecosystems and social systems. On the other hand, researchers may be more concerned in finding fast responses and suggest investing in upgrading dike systems and constructing adequate jetties to stop further erosion or prevent washout of beach resorts [4,17]. This could be counteracted by managing the building industry through recommendations to not build too close to the beach, to remove man-made structures along the shoreline to allow for more natural approaches that create buffer zones with more dynamic environments close to the shore. To reduce pollution in the coastal zone, a strategy is needed to reduce waste and fertilizers from the discharge source. It is necessary to find the main drivers of environmental pollution and expose the agents that threaten the environment [3]. It is also advised that impact assessments are made before construction in order to minimize risks and reduce the number of hazards caused by socio-economic developments in the coastal zone [2]. To minimize the impact of land-use, changes from cultivation industries and aquatic farming activities should become less intense or be downsized and implemented on smaller scales. Moreover, when planning constructions or other near-shore activities, seasonal changes have to be taken into account. For example, nearshore bars should be dredged in the calm seasons instead of the stormy season, which allows for reduced erosion and shoreline retreat [18].

7. Conclusion

Along the coastline in Vietnam, coastal engineering structures are rapidly constructed to reduce the impacts of coastal erosion. These coastal engineering structures often lack monitoring and are not built to last for a long time. In fact, these structures appear to increase the vulnerability of the shoreline over time. The impacts of global climate change will further amplify this pressing situation and create more inequities for vulnerable people living close to the shoreline. In order to exploit the potential of coastal areas in an efficient way, while also protecting and maintaining long-term values of the coastal ecosystems, integrated decisions and solutions are required. This is formulated in the ICZM strategy, where the balance between coastal development and environmental conservation is emphasized. However, for ICZM to work efficiently it is important to acknowledge that the coastal zone is dynamic and is constantly evolving. Therefore, monitoring and evaluation are also essential process steps to determine the progress after implementation of plans. Knowledge and awareness building at all levels is crucial for ICZM. When public understanding is enhanced in regard to the values of the coastal zone, more responsibility can be created for the sustainable use of natural resources. With an integrated approach through all levels, where citizen participation is encouraged, new ideas from local environments can be brought forth. By implementing more natural management approaches, with less human interference, co-benefits can be created and the resilience capacity of both ecosystems and socio-economic systems would increase. Main messages of the literature study suggest that Vietnam should promulgate a legal framework to establish a coastal law network for more balanced and sustainable coastal development. Moreover, the government should invest more in research and data collection regarding trends in shoreline dynamics and on the impact of environmental resources. Cooperation with international organizations that are involved in climate change can help with research and with the development of appropriate action programs.

Through analysis of aerial photographs and field visits, the case studies along the central coast of Vietnam demonstrate connections between the construction of coastal engineering structures and coastal erosion and landform changes. An increasing downdrift side erosion is observed over the last few decades due to construction of coastal engineering works in the harbours and along the shoreline, like seawards and groins. Further, due to strong seasonal fluctuations, many residential areas close to the beach and recently built beach resorts are in danger of collapsing, and ecosystems are further degraded. For effective prevention of coastal erosion, it is necessary to study and monitor the mechanisms causing erosion, which can be different at each coastal section. When local sites are studied in more detail,
suitable management strategies can be developed and adapted to the local needs. It is essential to gain a good understanding of the environmental, geographical and socio-economic context first, before implementation of new management approach.

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