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Research Article

Adaptation strategy to coastal erosion by rural communities: Lessons learned from Ujunggebang village, Indramayu, West Java, Indonesia

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Abstract

Coastal hazard due to wave activity, in the form of coastal erosion, has long been a problem in the coastal area of Ujunggebang. Loss of coastal land in the coastal area has removed a lot of rice fields, settlements, and public facilities. Efforts to maintain the coastline along 3,300 m of the coastal area, by building coastal defense structures (CDS), have been carried out by the central government since 2006 but, until 2015, the CDS that has been built is still only around 1782 m long, in some places the structure is damaged due to wave activity, and in general the structure is not high enough to prevent overtopping. Meanwhile, unprotected coastal segments with CDS have experienced significant erosion. The idea of land use change as an effort to adapt coastal hazards, which was conveyed through an idea socialization approach and through showing examples of coastal area management practices to villagers, gave birth to the idea of developing a coastal tourism area in the village as a complementary measure for the existing coastal defense structure. Although the main problem faced- coastal erosion- has not been resolved, the development of the tourism area has been recognized by the local government as successfully changing the life of the village community.

1. Introduction

Coastal erosion is one of the coastal hazards found in many parts of the world, and efforts to reduce its impact vary widely (The Heinz Center, 2000; Pilarczyk, 2003; Hedge, 2010; Rangel-Buitrago et al., 2015; Jonah, 2016; Williams et al., 2017; Jaafar et al., 2018; Baills et al., 2019), and change over time from the strategy of building coastal structures to reduce the effects of waves, turning into a strategy of empowering natural coastal defense systems, such as conserving, restoring, and/or expanding natural barriers, and finally developing into a site-specific approach that applies a mixed strategy or multiple strategies (National Academy of Sciences, 2014). Currently, ecosystem-based adaptation is receiving great attention world-wide, mainly due to the multiple benefits it provides in addition to coastal protection (Narayan et al., 2020).

Adaptation can be defined as adjustment to change, and adaptation decisions must respond to the process of change taking place on a temporary basis (Barnett et al., 2014), or the ability to tolerate the impact of disasters and respond quickly through the process of learning and preparation (Choi et al., 2018). Thus, adaptation to coastal hazards is an attempt to adjust to changes that occur in coastal areas that can cause losses so that, with these adjustments, the changes that occur do not

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cause losses or become acceptable. Land use change is part of adaptation (Rangel-Buitrago et al., 2015).

Adaptation efforts to coastal hazards are widely carried out at the national level, but their relevance is often questioned at the local level because it does not suit local needs (Narayan et al., 2020). An adaptation approach which is suitable for urban areas is not necessarily applicable to small villages due to the following possibilities: limitations of financial and engineering skills, hazards at the national level which are not the same as hazards at the local level, decision makers at the local level not having a clear mandate, and the implementation of adaptation decisions at the local level relying more on agreement within the community (Barnett et al., 2014). Synchronization of adaptation programs between central and local government is important for the successful implementation of an adaptation program (Richardson & Otero, 2012). Local community involvement is essential in the planning of adaptation programs to prevent opposition in the implementation of a program (Pearce, 2003). Adaptation efforts are ideally applied in a local context (Narayan et al., 2020).

Hazard mitigation can be defined as the effort to reduce loss of life and property by reducing the impact of disaster (Office for Costal Management, 2021). Hazard mitigation efforts may be implemented before, when, or after the hazard takes place. Thus, by definition, adaptation is part of mitigation efforts implemented before the hazard takes place, although some say that mitigation and adaptation are two different actions, due to differences in priorities for the measures (Duguma et al., 2014).

Efforts to mitigate coastal hazards can be carried out by using a local development approach, such as by regulating land use, and/or design approaches, such as planning building structures or planning activities that are suitable for environmental conditions (Pilarczyk, 2003; National Research Council, 2014; Herrington, n.d.). Building or developing tourist areas or recreational areas is included in efforts to mitigate coastal hazards (National Research Council, 2014).

The selection of coastal hazard mitigation strategies differs from one place to another, depending on the environmental conditions of the place, the nature and magnitude of the hazard that threatens the environment, and what will be protected; in addition, there are various other aspects that also need to be taken into account in choosing a strategy, such as financial, economic, social, technological, and political aspects (Moser, 2005; Jarungrattanapong & Manasboonphempool, 2009; Moser et al., 2012; Forbes et al., 2013; Narayan et al., 2020). For example, strategies to protect tourism areas are different from strategies to protect roads. Meanwhile, differences in perspectives or understanding of a problem or term also cause differences in the choice of coastal hazard mitigation actions (Anfuso et al., 2012). The management strategy developed should aim to minimize or eliminate impacts associated with coastal erosion, or increase benefit by reducing community vulnerability to coastal erosion hazards (Rangel-Buitrago et al., 2017). Hazard mitigation efforts can be carried out by all level of governments in varying capacities, but each level of the government is driven by objectives and authorities (National Academy of Sciences, 2014; National Research Council, 2014). The high cost of coastal defense structure (CDS) construction is often also an obstacle to mitigating coastal hazards and encourages decision makers to conduct a cost-benefit analysis in determining the choice of mitigation actions (Anfuso et al., 2012).

This paper aims to provide an overview on how coastal hazard adaptation can be carried out at the village level, in this case in Ujunggebang Village (UV), Indramayu, Indonesia (**Figure 1**). It is hoped that what has been done in UV can also be applied in other areas according to local environmental conditions. To achieve this goal, this paper provides an overview of: (1) the coastal environmental conditions of the study area that give rise to the thought of adaptation to the method of land use change, (2) how the idea of adaptation is conveyed to the village community, (3) how the idea of adaptation is applied so as to successfully change the lives of rural communities, (4) changes in land use as an adaptation effort, and (5) tourism development as an adaptation effort.

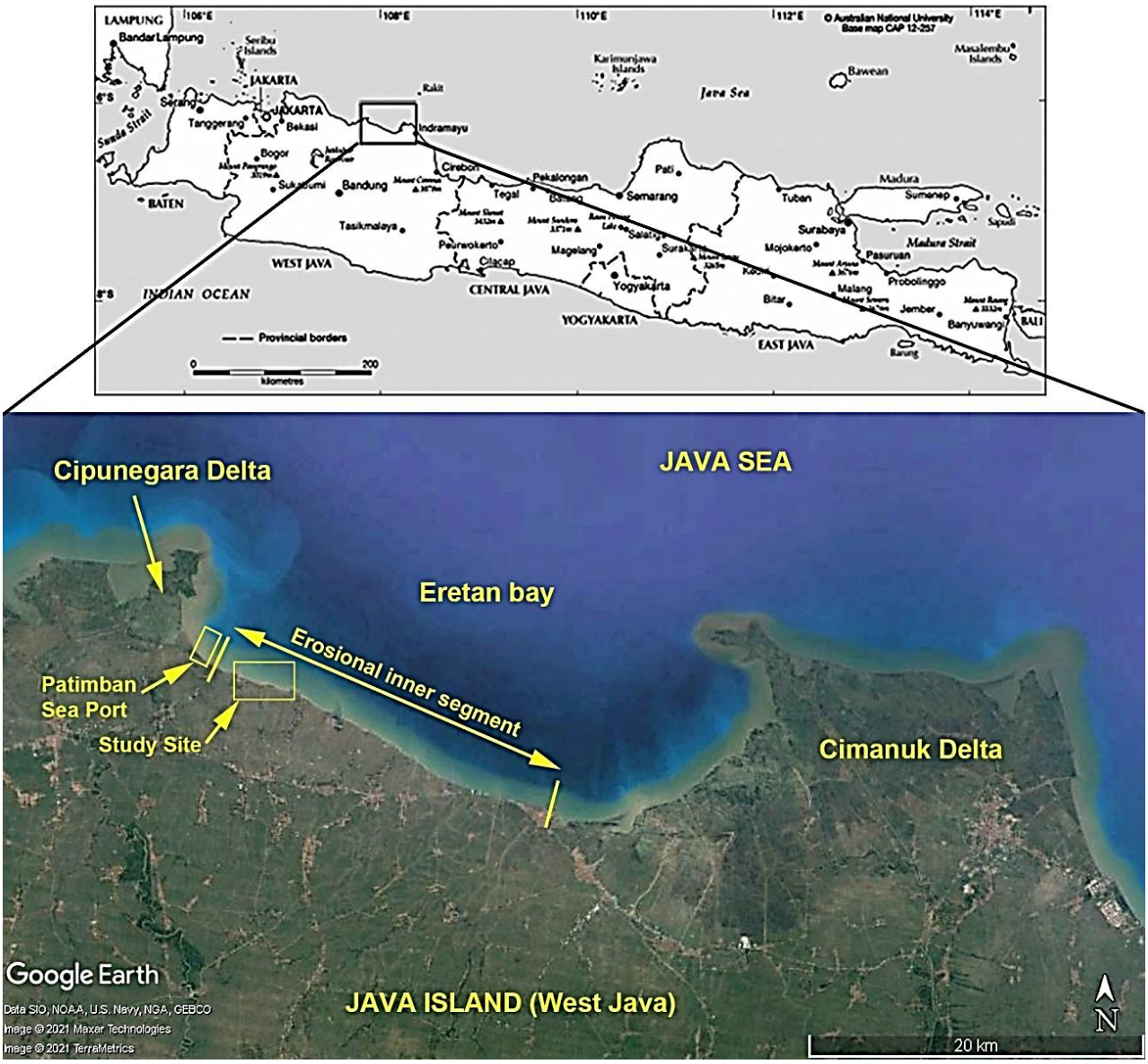

Figure 1 Site of study area (large quadrangle). Image from Google Earth, dated: 10 May 2021; Image axis: 6° 23' 23.21"S and 108° 02' 14.03"E.

2. Study site

The Ujunggebang coastal area is located on the northern coast of Java Island (**Figure 1**). The coastal segment of this area, which is about 2.4 km long, is part of the inner segment of Eretan Bay, which has a length of about 23 km and is an erosional segment (Setyawan et al., 2007). The coastal plains of Ujunggebang have an average elevation of less than one meter above mean sea level, and are composed of quaternary claystone. The coast in this area is an erosional cliff coast, with an intertidal wave cut platform composed of claystone with a cliff height of about 50 - 60 cm (micro-cliff) (**Figure 2**).

Figure 2 Ujunggebang coast in 2007 before CDS construction, with erosional micro-cliff of a height of about 50 - 60 cm and an intertidal wave-cut platform composed of claystone in low tide conditions. Adopted from Setyawan et al. (2007).

Physically, Ujunggebang coastal area is a coastal area around the coastline that extends from Truntum River Mouth in the west to Tegaltaman Headland in the east (**Figure 3**). Based on its coastline configuration, the coastal segment can be divided into two coastal cells. The first, a west coastal cell that starts from Muara Truntum to Pegagan Headland; the second, an east coastal cell ranging from Pegagan Headland to Tegaltaman Headland. The coastline on the west coastal cell has been reinforced with CDS, while the east coastal cell has not been strengthened with CDS and is now erosional.

Administratively, Ujunggebang coastal zone is within the administrative area of Indramayu Regency, and borders Subang Regency to the west. Meanwhile, at the village level administration, some of the coastal areas are in the administrative area of UV, and a small part in the east is within the Tegaltaman Village administration area. From here onwards, the coastal segment of this study area, which includes the west coast cell and the eastern part as a whole, is referred to as Ujunggebang Coast (UC), or Ujunggebang coastal area (**Figure 3**). The land use of Ujunggebang coastal area in 2020 can be seen in **Figure 4**.

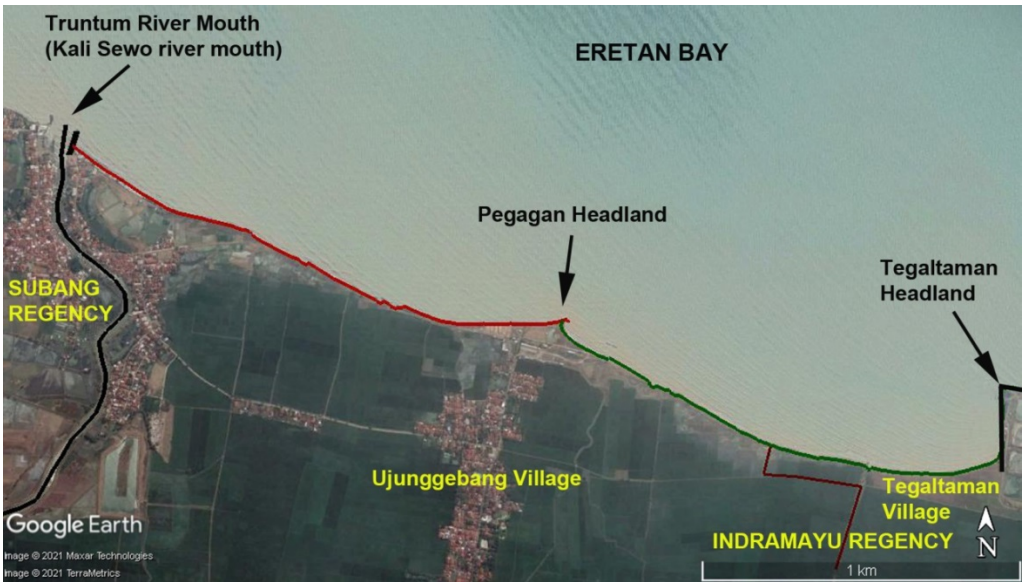

Figure 3 Administrative area in Ujunggebang coastal area. Red line: coastline with CDS; green line: coastline without CDS. Image from Google Earth, dated: 30 July 2020; Image axis: 6° 15' 13.57"S and 107° 55' 59.82"E.

Eretan Bay, where the UC is located, is a bay that opens to the north and is bounded by two birdfood deltas, namely, the Cimanuk delta to the east, and the Cipunegara delta to the west. To the west of the inner segment of Eretan Bay, or to the east of the Cipunegara delta, is now being built Patimban Port, by the Government of Indonesia, which is planned to support Tanjung Priok Port in Jakarta (Biro Komunikasi dan Informasi Publik, 2020) (**Figure 1**). The bathymetry conditions of the bay can be seen in **Figure 5**. The configuration of the Eretan Bay coastline that opens to the north causes the bay to be open to waves coming from the northwest, north, and northeast.

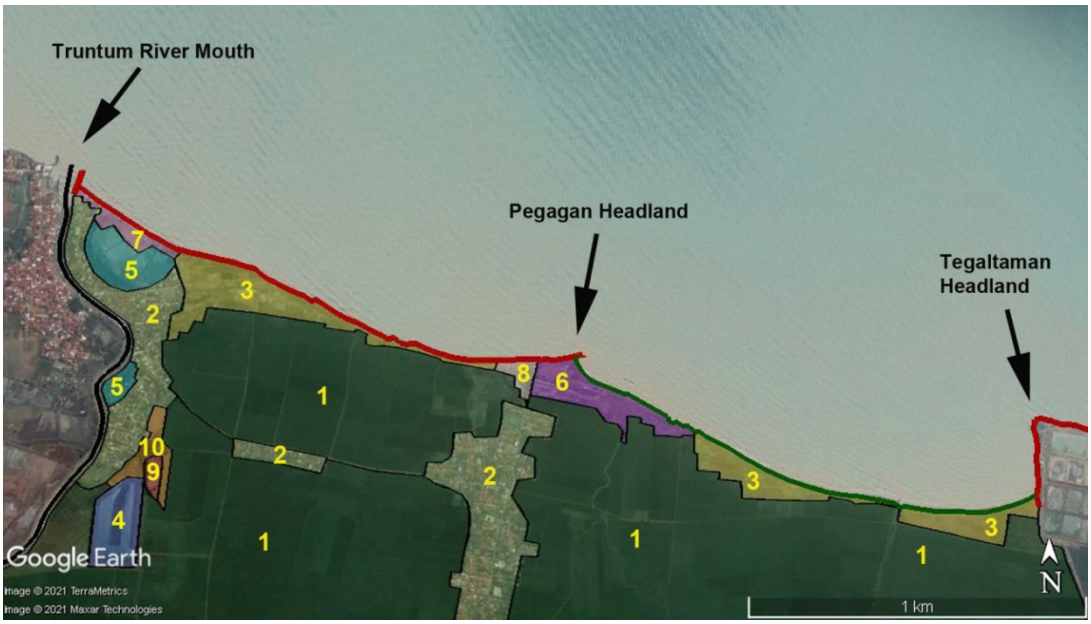

Figure 4 Land use in Ujunggebang coastal area. 1: Rice fields, 2: Residential area, 3: Deteriorated land, 4: Fresh water pond, 5: Ponds, 6: Pantai Plentong tourism site; 7: Tanjungpura tourism site, 8: Bamboo stacking fields, 9: Cemeteries, 10: Open land. Red line: coastline with CDS; green line: coastline without CDS. Image from Google Earth, dated: 30 July 2020; Image axis: 6° 15' 13.57"S and 107° 55' 59.82"E.

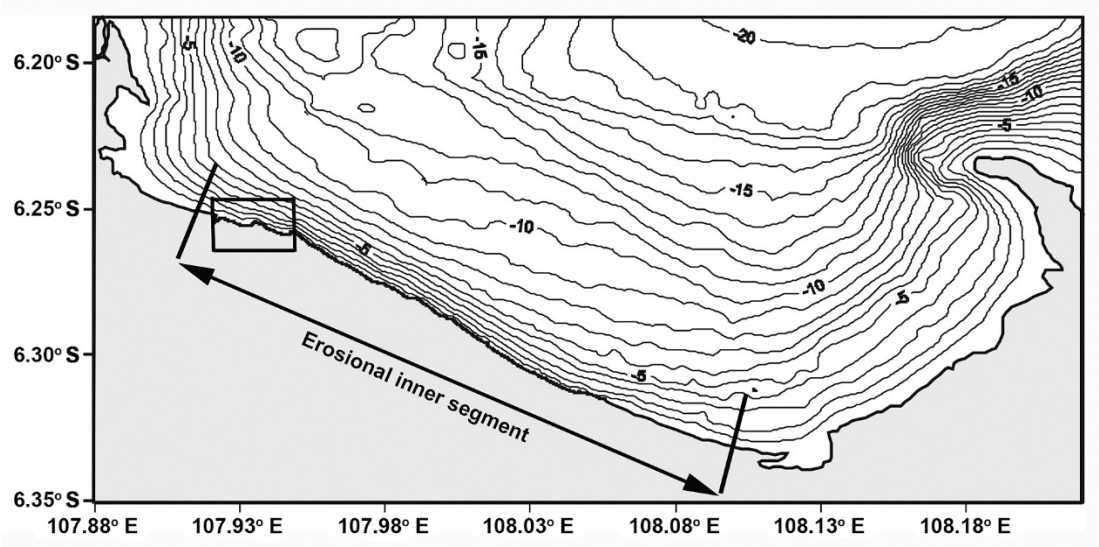

Figure 5 Bathymetry of Eretan Bay, Indramayu. Adopted from Setyawan et al. (2015).

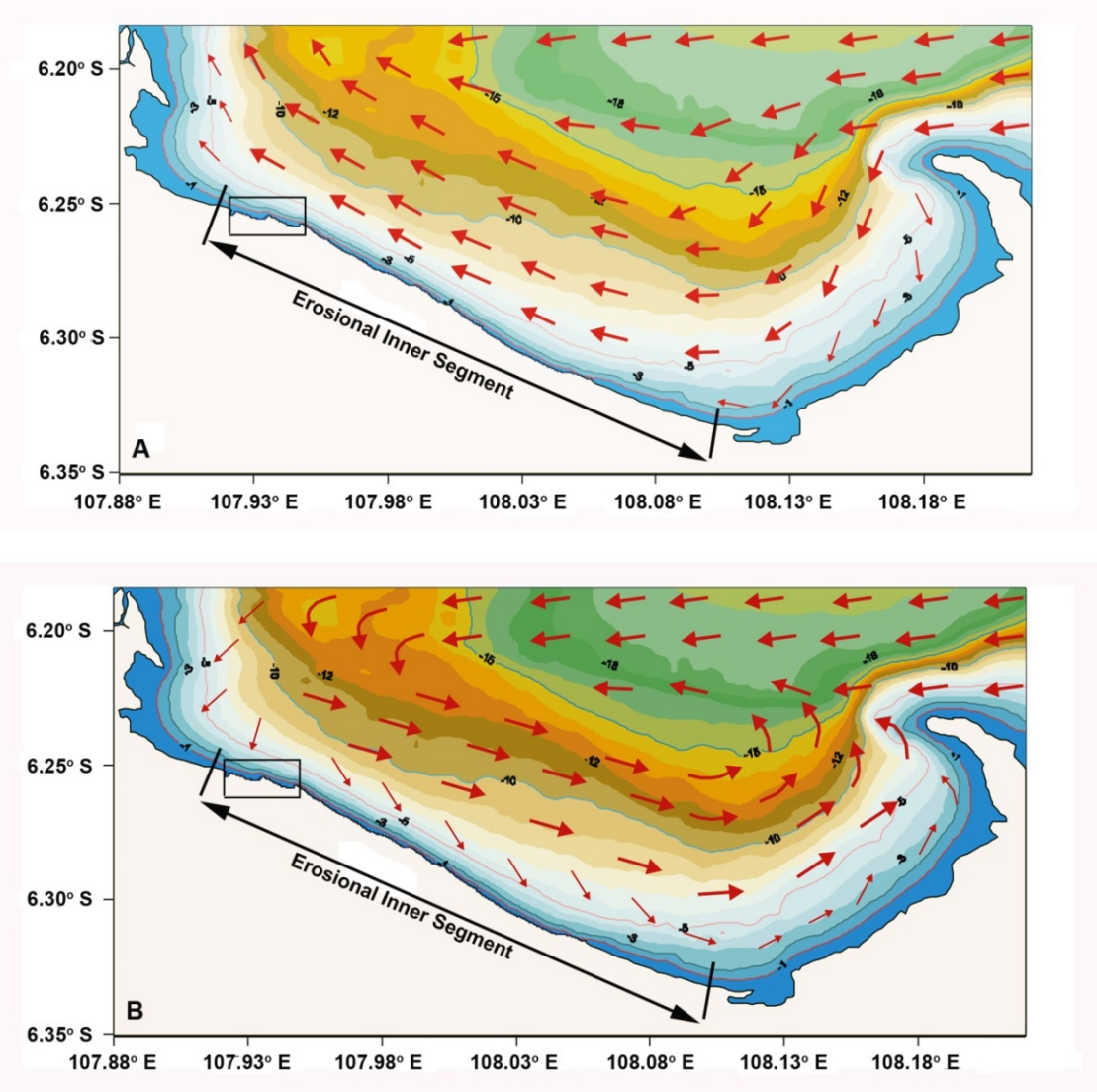

Figure 6 Current pattern in Eretan Bay during eastern monsoon (A, above) and western monsoon (B, below). Adopted from Setyawan et al. (2007).

Currents and waves in the waters of Eretan Bay are affected by the monsoon. In the eastern monsoon, currents in the Java Sea also move from east to west, but enter Eretan Bay through the eastern side, then move down the coast to the west and out through the west side (**Figure 6**). The maximum current speed was recorded in July, at 70 cm/s. In the western monsoon, currents in the Java Sea move from east to west and enter the bay through the western side, then move down the coast to the east and out through the eastern side (**Figure 6**). The maximum current speed was recorded in March, at 60 cm/s. Waves in the waters of Eretan Bay show a clear difference in altitude between waves in the western monsoon and in the eastern monsoon. Waves in the eastern monsoon are generally higher than waves in the western monsoon (**Figure 7**). Forecasts of wave direction, conducted based on wind direction, show that, in the western monsoon, the waves come and enter the bay from the north to the northwest, while during the eastern monsoon and transition periods, the waves comes from the east (Setyawan et al., 2007). Satellite images from Google Earth footage from 2008 - 2020 show that the direction of wave propagation into Eretan Bay and up to Ujunggebang coast in April to October is from the northeast.

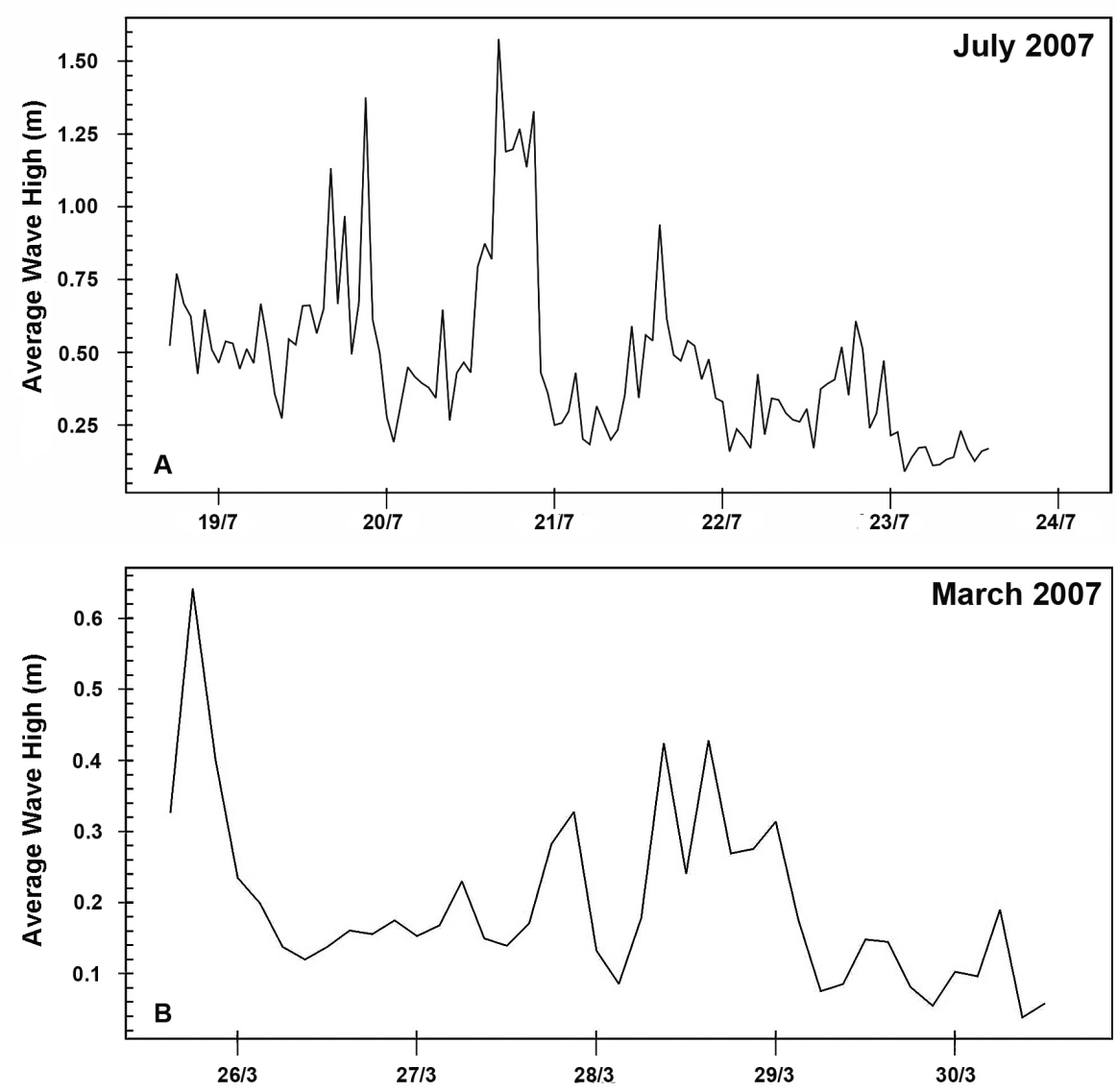

Figure 7 Wave conditions in Eretan Bay during eastern monsoon (A, above) and western monsoon (B, below). Adopted from Setyawan et al. (2007).

3. Adaptation solution for coastal erosion for rural community

Coastal erosion can be defined as the loss of coastal building material due to wave and current activity along a coast that works together to release the building material of the coast and transport it elsewhere. In the process of coastal erosion, wave activity that hits a coast can cause the material to be released; then, the material is transported elsewhere by longshore currents or rip currents.

Adaptation is the process of adjusting to change (Barnett et al., 2014), and adaptability is the ability to tolerate processes or impacts and to respond quickly through learning and preparation (Choi et al., 2018). Thus, this can also be done by taking actions that can minimize the impact of a process so that it can be accepted or so intervention can be made (Williams et al., 2017). For the process of coastal erosion, adaptation efforts can be done by minimizing or lowering the strength of waves and currents working on the coast or by strengthening the coast with CDS (Pilarczyk, 2018). The choice of adaptation actions required is determined by environmental factors (waves, currents, sediment transport, and geological conditions), which objects to protect, problems faced (such as overtopping, slope erosion, or foot scouring), and the purpose of the protection carried out (Pilarczyk, 2018; Jarungrattanapong & Manasboonphempool, 2009; Kriesel & Friedman, 2003). The adaptation process is a process that continues in response to changes that occur continuously, and the process cannot be completed with a single action (Barnett et al., 2014). Adaptation measures can have various different consequences and impacts, depending on the site to which they are applied. Therefore, any operational decision will have to take the local context into account (Baills et al., 2019). According to Williams et al. (2017) adaptation actions for coastal erosion that can be done on land include:

1) Defense. This action is done to maintain the position of the coastline. Included in the defense action is building coastal defense with hard or soft engineering. Defense measures are costly.

2) Accommodation. This action is a form of adaptation effort by regulating the use of affected land to reduce the impact that arises so that it can be tolerated. The implications of this choice of action include continuing to use the land at a certain level of danger. The choice of this action must be low cost or no cost, such as changing elevation of a building or land use.

3) Managed Retreat or Realignment. Choosing this adaptation action means allowing the processes that cause erosion to take place and minimizing the impact of those processes by moving important objects that may be affected landward, such as government buildings, electrical installations, settlements, and highways onshore away from the coastline. This choice of action also means making changes to land use by relocating infrastructure landward. This option is usually less costly than structural stabilization.

4) Sacrifice. Choosing this alternative adaptation measures means allowing the erosion process to take place, with no active intervention taken whatsoever. This choice is taken when leaving land threatened by erosion is more profitable- financially, geomorphologically, or ecologically- rather than trying to survive by building a defensive structure.

According to Baills et al. (2019), the act of adaptation to coastal erosion can be divided into four groups:

1) Measures for flexible management of the natural area. Actions that fall into this category are the act of studying natural processes to know the character of those processes, with the results then used to plan future actions or control the process of change. This action is suitable for unpopulated areas. Coastal management approaches that are included in this category: (1) Monitoring of natural evolution, and (2) Accompaniment of natural processes.

2) Measures addressing hazards. This act of adaptation is directly related to hazards. Included in this adaptation action group is to use hard engineering or soft engineering for coastal defense. Hard engineering is building coastal defenses that modify the environment by changing

natural processes. Soft engineering is an action that does not radically change environmental conditions and does not counteract natural processes.

3) Measures addressing assets. This adaptation action is taken to reduce asset vulnerability in coastal areas. Actions taken include strengthening individual buildings to increase community resilience, including changing land use and planned retreat.

4) Complementary measures. This group of adaptation actions is complementary or additional to the main adaptation actions that existed previously. By implementing these actions, it is expected that the goal of adaptation is achieved. Actions that include complementary groups of actions are improving the knowledge of the population, the education of the population, and the information conveyed to the population. Also included in this group of actions is the planning or change of land use.

Coastal erosion is a process that can occur in certain places in coastal areas, either in urban or built-up areas or in rural areas. Coastal erosion is a process that causes the loss of waterfront land, which is expressed by shifting the coastline landward. The choice of "hard engineering" action with CDS as an adaptation effort is carried out to stop the rate of erosion or keep the coastline from shifting or to fix coastline (Baills et al., 2019; Williams et al., 2017). The choice of coastal defense action by building a CDS requires high costs and technical capabilities to realize it, so this option is generally only done by central government, because local community and government rarely have the technical skills and financial resources necessary to build CDS (Barnett et al., 2014).

If erosion occurs in urban or built-up areas and endangers critical infrastructure such as highways, government-owned facilities, or energy installations, then the choice of hard engineering is easy to apply by central government. However, on the contrary, if coastal erosion occurs in rural areas, then the problem is often one that must be faced by the local community itself for various reasons, such as the hazard at the local level not being significant to the national level, so the central government does not view addressing the problem as a top priority. Thus, in rural areas, if no hard structure is built, or if it is built but proves inadequate, then efforts to meet the needs independently or self-sufficiently become an option (Baills et al., 2019).

In conditions where the coastal erosion process continues to take place while effective coastal defense efforts are not built, and there is no ability to build CDS independently, then the remaining adaptation option is sacrifice or retreat done by force. Meanwhile, if the main adaptation efforts that have been done are inadequate, then complementary measures are carried out. Complementary measures are acts of complementing a previous but inadequate act of adaptation, and the action itself is not sufficient enough to stand alone as an adaptation effort (Baills et al., 2019). Actually, there are many choices of adaptation actions, but the most preferred act of adaptation is one that can immediately provide an advantage (Baills et al., 2019). For villagers, the choice of adaptation measure is certainly that which costs the least and has the most benefits they can immediately receive. The choice of adaptation measures that can provide advantages in addition to harm reduction is important for the improvement of coastal communities' resilience (Narayan et al., 2020).

4. Methodology

This study was conducted at Ujunggebang coastal zone (**Figure 4**). The data in this study were collected by analysis of satellite imagery, field observations, and unstructured interviews with the Village Head, or Kuwu, from archives of news stories from various mass media and scientific publications, and unpublished internal reports. To achieve the goal, the study was carried out with the following stages:

- Stage 1 - Field study and Image Analysis.
- Stage 2 - Determination of appropriate adaptation measures.
- Stage 3 - Socialization of the results of the study and recommended adaptation strategies.
- Stage 4 - Study of Pantai Plentong tourism destination.

In this study, Stage 1, 2, and 3 were conducted in 2007 and 2015, before Pantai Plentong developed, while Stage 4 was conducted in 2018 - 2020 on Pantai Plentong.

4.1 Stage 1: Field study and image analysis

Field studies were conducted to obtain: (1) coastal geomorphology and coastal process data; (2) data of coastal hazards and their cause; (3) villagers' perceptions of coastal hazards and adaptation efforts; (4) data of activities of villagers on coastal land near the coast, and (5) data of Pantai Plentong development and management.

Field data of coastal geomorphological conditions and coastal processes in the study area were obtained from internal reports of research that were conducted in 2007 and 2015, and which were not published (Setyawan et al., 2007 and 2015). Data of villagers' perceptions of coastal hazards and adaptation efforts, and villagers' activities on near coast coastal land, were obtained from unpublished internal reports from Setyawan et al. (2015).

Data of the development and management of the Pantai Plentong tourism area were obtained from field observations conducted in 2018, 2019, and 2020.

Satellite images recorded from 1985 to 2020 were obtained from Google Earth and analyzed visually to obtain: (1) an overview of the geomorphological conditions of the coastal area of UV; (2) coastline change patterns that occurred in the coastal area; and (3) wave propagation and sediment transport directions along the coast. Instead of visual expression, sediment transport direction can be deduced from wave incidence direction toward a coastline (Komar, 1976; Dyer, 1986; Adams et al., 2011; Klein et al., 2020; Oh et al., 2020). Visual analysis of satellite images for object recognition was done by observing satellite images on a monitor screen. Object recognition was done by using interpretation elements: tone/hue, texture, pattern, shape, size, height/elevation, and location/association (Tempfli et al., 2009). The zooming facility provided by Google Earth was used to observe the details of the analyzed objects, such as observing the CDS and wave propagation patterns in coastal waters. Image overlay and drawing facilities in Google Earth were used to analyze coastline changes.

Table 1 Stages to determine CDS and AM.

Stages to determine CDS		Stages to determine AM	
Stage 1	Identification of the problems.	Stage 1	Identification of the problems.
Stage 2	Determination of what to achieve by implementing a CDS.	Stage 2	Determination of what to achieve by implementing an AM.
Stage 3	Environmental condition analysis: coastal geomorphology and coastal processes.	Stage 3	Environmental condition analysis: coastal geomorphology, coastal land use, and villagers' activities on the coastal land.
Stage 4	Determination of some alternatives of CDS.	Stage 4	Determination of some alternatives of AM.
Stage 5	Advantage and disadvantage analysis of the alternatives.	Stage 5	Advantage and disadvantage analysis of the alternatives.
Stage 6	Choice of CDS option that is considered most suitable for local conditions.	Stage 6	Choice of AM option that is considered most suitable for local conditions.

4.2 Stage 2: Determination of appropriate adaptation measures

In this stage, analysis of field study data was carried out to determine: (1) appropriate CDS, and (2) appropriate accommodation measures (AM) (land uses) to reduce the effect of coastal hazards.

For the purpose of providing advice on overcoming the problem of coastal erosion in Ujunggebang coastal zone, especially in the tourism area of Pantai Plentong, the selection of a CDS and an AM were carried out, following the stages listed in **Table 1**.

4.3 Stage 3: Socialization

Socialization of the results of the study and recommended adaptation strategies were conducted in two stages. The first stage of socialization was addressed to the village head, and the second stage of socialization was addressed to the villagers. Socialization for villagers was given to representatives of village groups in two forms of activities, namely, first, lecture and discussion activities, and second, field study activities for several locations for examples of coastal area management.

4.4 Stage 4: Study of Pantai Plentong tourism destination

Unstructured interviews with the Village Head, or Kuwu, who is also the manager of the Pantai Plentong tourism area, were carried out on various occasions when visiting the tourist area in 2018, 2019, and 2020. The interview materials included daily tourism area operations, development and collaboration plans, and information on the problems faced related to coastal hazards.

Data on Pantai Plentong from news archives and scientific publications were collected through internet searches. These data were used to complete information about the tourism area that had not been obtained from interviews and field observations, and to confirm the results of the interviews.

5. Results

5.1 Coastal hazards in UV

As with other parts of the Eretan Bay inner segment, coastal erosion has long been a problem in UV. There is no data on when coastal erosion began in the village, but a topographic map with a scale of 1:250,000 dated 1954, from the U.S. Army Corps of Engineers showing the coastline in 1954, showed there was still more than 1000 m to the sea from the current shoreline position (U.S. Army Corps of Engineers, 1954). The erosion can be ascertained to have been occurring due to wave activity, and it is unlikely to have been caused by a tsunami or tropical cyclone for the following two reasons: (1) the study area is located on the northern coast of Java Island. The situation is different from the southern coast of the island, which historically was repeatedly hit by tsunamis that emerged from the Indian Ocean (Widiyantoro et al., 2020); and (2) theoretically, the Indonesian Archipelago cannot be crossed by tropical cyclones. The coastal areas of islands in the Indonesian Archipelago that can be affected by tropical cyclones that develop in the Indian Ocean and Western Australia waters are coastal areas of islands facing the Indian Ocean, such as Sumatra, Java, Bali, and the islands of the Nusa Tenggara Islands (Mulyana et al., 2018).

A study conducted by Setyawan et al. (2007) revealed that coastal erosion and coastal land deterioration (**Figure 8**) due to overtopping in UV that occurs due to wave activity is a coastal hazard that has long been a problem in the village. In the period from 1994 - 2007, there was a shift in the shoreline towards the land in UV, about 250 meters inland, with a rate 20 m/year, or 1.5 m/month. The shift in coastline has caused the loss of the village's coastal land, on which there are residential lands, rice fields, ponds, and various public facilities, such as village roads and cemeteries (**Figure 9**). There are two hamlets that have been lost due to erosion, namely, Ujunggebang and Plentong Hamlet (Handayani, 2021).

Analysis of satellite imagery obtained from Google Earth footage from 1985 to 2020 provides an overview of the coastline changes that occurred from 1985 to 2020 (**Figure 10**). The figure confirms two things. First, that the coastline reinforced with a CDS is more stable than the coastline left without a CDS. Second, in coastal areas with high rates of coastal erosion, efforts to inhibit the rate of erosion need to be done immediately to prevent greater losses.

Figure 8 Deteriorated coastal land in Pegagan Hamlet, UV in 2008 that originated from rice fields (left) and from ponds (right). Photo: W B Setyawan's personal collection.

Figure 9 Erosion of abandoned cemeteries in UV in 2008. Photo: W B Setyawan's personal collection.

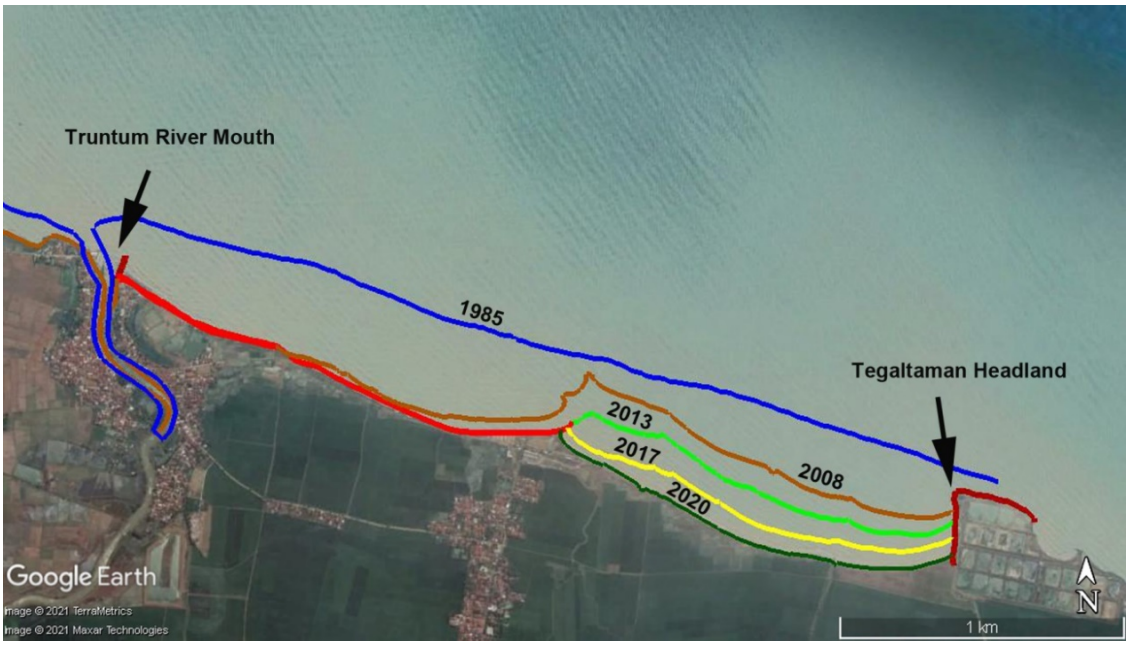

Figure 10 Coastline change in Ujunggebang coastal area from 1985 to 2020. This figure confirms that the coastline reinforced with a CDS is more stable than the coastline left without a CDS.

5.2 Coastal hazard adaptation at Ujunggebang

5.2.1 Defending the coastline

Central government efforts through the Citarum River Basin Center (BBWSC) to maintain the position of the coastline at around 3,300 m in the UC are carried out gradually by building a CDS. In 2006, a 645 m long CDS was built (Setyawan et al., 2007) (**Figure 11**), and then extended again to reach 1,782 m in 2013 (Setyawan et al., 2015) (**Figure 12**). Until 2020, there is still a coastline of about 1,518 m in length that has not been reinforced with CDS. The height of the CDS is about 1 m from the surface of the coastal front land. The CDS is made of stone arrangements.

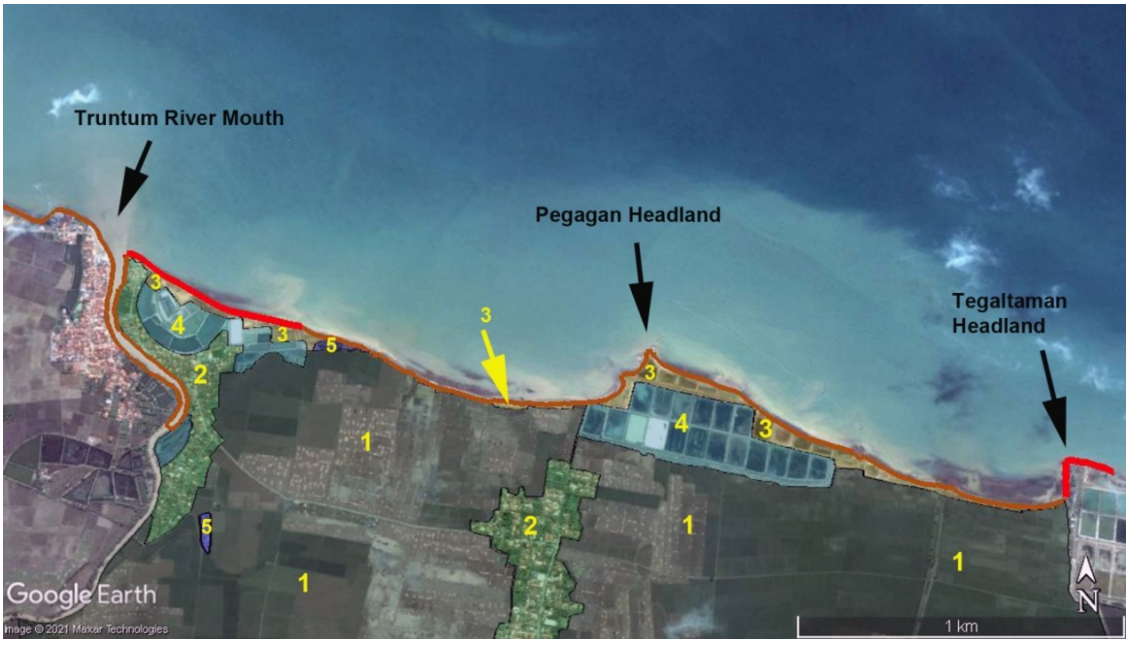

Figure 11 Land use in Ujunggebang coastal area in 2008. 1: Rice fields, 2: Residential area, 3: Deteriorated coastal land, 4: Ponds, and 5: Cemeteries; Thick red lines: CDS.

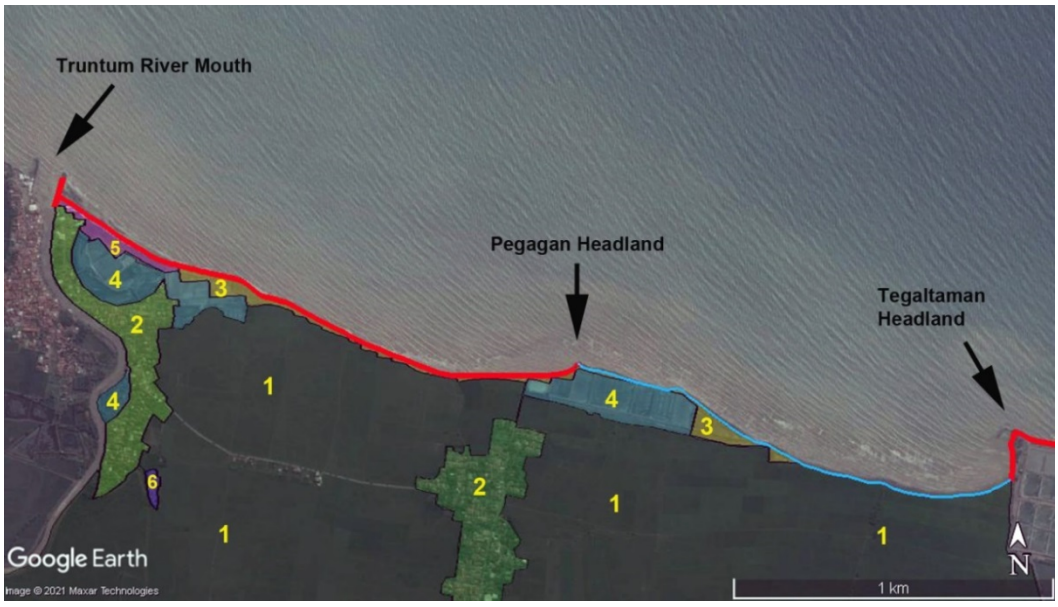

Figure 12 Land use in Ujunggebang coastal area in 2015. 1: Rice fields, 2: Residential area, 3: Deteriorated coastal land, 4: Ponds, 5: Tanjungpura tourism site, and 6: Cemeteries; Thick red lines: CDS.

In 2015, the body of the CDS was seen to be damaged in some parts due to wave activity (**Figure 13**). The damage continues to grow with the number of locations of damage points increasing, and until 2020 an effort to improve the CDS was not seen. The coastal land behind it was deteriorated due to seawater overtopping at an average of about 10 m so that the rice fields behind the CDS could not be planted with rice (**Figure 14**). Damage to coastal defense structures due to wave activity occurs due to the use of materials that are heavily inadequate to deal with wave energy in the study area; meanwhile, overtopping occurs because the structure is not high enough to deal with waves in the study area (W H Sulistyawan, September 29, 2021, personal communication). Meanwhile, in the coastal segment that has not been reinforced with CDS, coastal erosion continues significantly (**Figure 10**). This is the situation which is very worrying for the residents of UV, as revealed in interviews and dialogues.

Figure 13 Damaged CDS in Pegagan Hamlet, UV, in 2015. Photographed facing westward. Adopted from Setyawan et al. (2015).

Figure 14 Deteriorated land behind CDS in Pegagan Hamlet, UV, in 2015. Photo: W B Setyawan's personal collection.

In 2019, efforts to improve the conditions of coastal segments that experienced erosion in tourism areas were carried out by the Citarum River Basin Center (BBWSC) by building a seawall. However, the construction activity was stopped temporarily because there was no agreement on the site of the building between the government's development plan (BBWSC) and the UV government. The reason for the termination was because the structures to be built were not placed in a location deemed by the village government to have a high erosion rate, but on a temporary sandy beach. The argument for the decision was that, if the structure was built on a sand beach, it would block the view and reduce interaction between visitors to the tourism and marine areas, while the erosion problem would not be resolved (Cahyadi, 2019b). The suspension of the construction of coastal engineering buildings shows the importance of program compatibility between central and local governments in managing coastal areas (Pearce, 2003; Richardson & Otero, 2012). The construction of the seawall then resumed after a new site was agreed.

5.2.2 Villager's perceptions of coastal hazards and adaptation efforts

UV is inhabited by 1333 families, spread across 5 hamlets (Setyawan et al., 2015). Two of the five are hamlets that are directly adjacent to the sea, namely, Tanjungpura and Pegagan Hamlets. Tanjungpura Hamlet, situated around Truntum river mouth to the east of Kali Sewo, is directly adjacent to the sea, with a coastline that has been reinforced with CDS. On the coastal land of this hamlet, tourism activities have grown uncontrollably and without management organizations. The Pegagan Hamlet is located in the middle of the Ujunggebang coastal segment, and between the hamlet and the coastline there is a distance of about 150 m.

The results of interviews with 29 randomly selected families of Ujunggebang villagers gave a picture that there were concerns that coastal erosion would continue and reach Pegagan Hamlet, and they agreed to whatever action would be taken to inhibit the rate of erosion. This is because they did not know what to do to address the erosion problem. The results of the interview were confirmed in a dialogue with a representative group of Ujunggebang Villagers when socializing the results of research and adaptation plans for coastal erosion (Setyawan et al., 2015).

The socialization was attended by representatives of Ujunggebang villagers who live close to the coastline and representatives of residents who farm on coastal land near the coast, as well as community leaders. From these socialization activities, the views of the villagers about the coastal

hazards they face and their views on the adaptation plan could be known, as summarized from Setyawan et al. (2015) (**Table 2**).

Table 2 An overview of the views of the residents of UV in 2015 on coastal hazards and adaptation efforts, revealed from dialogue in the socialization activities of research results and adaptation effort plans for coastal hazards. The data are summarized from Setyawan et al. (2015).

No.	Records of socialization activities in UV in 2015	Comments
1	Villagers were well aware of the problem of coastal erosion that occurs in their villages and have felt the losses caused by the erosion.	Coastal erosion has been perceived as a common problem.
2	The CDS built by the government was very beneficial, but the villagers did not feel they owned it, so they did not try to repair it when the structure was damaged, because there was no communication with local residents when the construction of the structure was carried out.	This point shows the importance of communication between central government and the village government and local residents in managing coastal areas.
3	Villagers strongly support the research activities and are very hopeful that the proposed concept of coastal area management could be realized soon.	Villagers support the proposed adaptation plan.
4	Coastal tourism activities in the simplest form existed in UV, and the villagers were very enthusiastic about the plan to develop their village's coastal area into a coastal tourism area.	The villagers agreed with the plan for the development of a tourism area on their village's coast.
5	Villagers need to look at examples of erosional coastline management that has been successful.	Villagers need comparative studies.
6	Villagers need to look at examples of coastal area management that has been successful with a zoning system.	Villagers need comparative studies.
7	Examples of coastal area management activities can be done on land owned by the village.	The village government agreed to use village-owned land as pilot land.
8	Villagers need assistance in managing coastal areas, among others related to development activities or mobilizing the activities of villagers related to the management of coastal zones.	Villagers need assistance in coastal zone management activities.
9	In 2015, villagers were of the view that the development of coastal areas is part of the management of coastal areas carried out by investors, and they were not involved in such activities.	This point shows that, in 2015, villagers did not think that they could manage coastal areas.
10	In 2015, the villagers did not think that they were independently able to manage the coastal area as a tourism area.	It is necessary to change the minds of villagers so that they think that they are able to manage coastal areas as tourism areas.

5.2.3 Activities of villagers on coastal land near the coast

In 2015, land use in the coastal area of Ujunggebang on coastal land within about 500 m of the coastline was rice fields, ponds, and settlements, as well as deteriorated land along the coast and tourist areas in Tanjungpura Hamlet (**Figure 12**). Rice fields were the dominant land use. Settlements close to the coast were Tanjungpura Hamlet around the Truntum River Mouth, and Pegagan Hamlet located around the south of the Pegagan Headland at a distance of about 100 m from the coastline. Near coast ponds in Tanjungpura Hamlet were local ponds in unproductive conditions, while in Pegagan Hamlet, the ponds were managed by farm entrepreneurs and were the remaining land of pond fishery businesses damaged by coastal erosion (Setyawan et al., 2015).

Meanwhile, the daily human activities seen in the area near the coast in UV in 2015 were (1) agricultural activities, in the form of planting rice in rice fields, and (2) disorganized tourism activities in Tanjungpura Hamlet that developed in some deteriorated land along the coast associated with sandy beaches formed at the corner between CDS along the coast and jetty at the river mouth (Setyawan et al., 2015).

5.2.4 Changing coastal land use as adaptation effort

Most of the coastal land in UV is rice fields and a few ponds, which are privately owned, so that the problem of coastal erosion becomes a personal problem as well. Such a situation is very unfavorable for efforts to defend the coastline. Therefore, the pattern of coastal land management needs to be improved, so that the problem of coastal erosion does not become a personal problem for the land owner but becomes a village problem.

The idea of land use changes (in the form of buffer zone development) as an adaptation effort to coastal hazards in UV emerged after the study of coastal geomorphology and erosion in the coastal area of Eretan Bay in 2007 conducted by Setyawan et al. (2007). As mentioned earlier, the study found that coastal hazards faced by this area are coastline erosion and coastal land deterioration by seawater overtopping when waves hit the coast at high tide. The deteriorated land was distributed along the coastland (**Figure 11**). Based on the idea that overcoming the problem of coastal erosion or shoreline shifting means not only to inhibit the rate of erosion or the rate of shoreline shift, but also to improve the condition of the physical environment of the coastal zone, so that the coast becomes more beautiful and can be used for other purposes, by paying attention to geomorphological conditions and coastal processes in the study area, Setyawan et al. (2007) proposed three techniques to overcome the problem of erosion or coastline shift at the inner segment of Eretan Bay which includes the UV segment, namely: (1) coastal cell stabilization, (2) groin field construction, and (3) buffer zone development.

As an effort to protect coastal land from damage due to wave activity, it is necessary to have a buffer zone that separates the sea from the existing land use zones. A Coastal Buffer Zone (CBZ) is a land area adjacent to a coastline which acts as a natural transition zone between the coast and adjacent upland development (Coastal Resources Management Council, n.d.). The coastal zone is a sensitive area in term of ecology, geology, and nature, and also is an area of multiple uses which compete with each other for specific purposes or benefits. Therefore, in these conditions, CBZ is needed in order to achieve the goal of sustainable development and to minimize the potential conflicts among various uses in the coastal area (Li et al., 2010). When the function is considered, CBZ can be referred to as a protective zone (Ma, 2016; Boateng, 2012). The establishment of a buffer zone around an object or managed environment can form an effort to manage the object or environment with land use control (Norris, 1993).

Based on the results of field observations of coastal conditions in the study area, a CBZ is needed for three reasons: first, to protect the coastline from human activities, which are directly related to the coastal cliffs and can weaken them; second, to protect human activities on the coastal plains from the direct influence of the sea; and third, to make room for the retreat of the coastline until it reaches a stable position. Furthermore, the development of the CBZ differs from one coastal

segment to another. This is in accordance with the character of the coastal segment and the planned development of the coastal plain behind the coastal segment.

Determination of the form of CBZ to be developed needs to be carried out by considering the latest physical environmental conditions when field research was carried out, community activities in coastal areas, technical considerations for implementation, and the wishes or aspirations of villagers. Based on these considerations, the choice was made to develop coastal areas for tourism activities.

Meanwhile, disorganized adaptation efforts by residents of Tanjungpura Hamlet emerged, along with the presence of the CDS in the form of unregulated tourism activities in Tanjungpura Hamlet (Truntum), which was triggered by the presence of sand deposits at the meeting point between the CDS and the jetty (**Figure 15**) (Setyawan et al., 2015). To improve the conditions, it is necessary to regulate them by implementing a zoning system. Zoning has actually been developed in the tourism area, but has not been developed consciously by taking into account the function of each zone. To implement a zoning system, cooperation and citizen involvement are very important.

Figure 15 Sand deposits in front of CDS on east side of Truntum river mouth east jetty. Unregulated bamboo hut for tourism activity built on CDS. Photographed facing westward. Adopted from Setyawan et al. (2015).

For the purposes of developing coastal tourism areas in the coastal area of Ujunggebang, it is proposed to create a CBZ that has three zones in the area. The zones are a coastal front zone, a vegetation zone or green line, and a support zone (**Table 3**; **Figure 16**).

Table 3 Suggestions for the division of zones within the CBZ for the coastal area of Ujunggebang.

	Coastal front open zone	Vegetation zone or green line	Support zone
Width (relative, m)	50	50	50
Description	Open zone.	This zone should be planted with shade vegetation and/or fruit trees. This zone must be free from buildings used for trading or other purposes except for shelter buildings.	Zone for various supporting activities or facilities for tourism activities, such as trading activities (stalls, shops, and so on), vehicle parking areas, and access roads to enter and exit tourism areas.
Function	Playground for tourism activities in open area.	Green zone or barrier zone.	Supporting facilities provider.

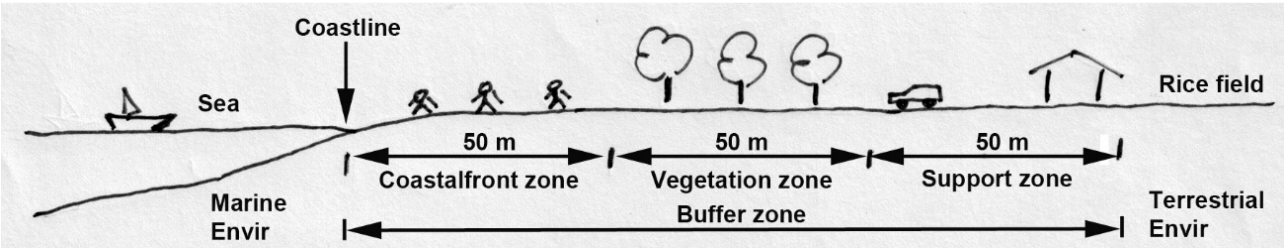

Figure 16 Proposed Ujunggebang CBZ for coastal tourism development. Drawing based on Setyawan et al. (2015). Not to scale.

In 2015, a study was conducted on the development of coastal hazard mitigation efforts in Eretan Bay which focused on coastal segments of coastal villages that have residential areas near the coast. The study was a continuation of a study conducted in 2007. In the study, field observations were conducted: (1) to update data on coastal geomorphological conditions and land use near the coast, and study sediment transport along the coast; (2) to collect primary data on coastal hazards and buffer zone development plans; (3) to make field observations to find out the various activities of residents on land near the coast and land conditions near the coast; (4) for socialization of research results and adaptation plans (Setyawan et al., 2015). Furthermore, based on the results of the study, to deal with the problem of coastal hazards in UV, Setyawan et al. (2015) provided three recommendations, namely: (1) maintaining the coastline by constructing a groin field and/or maintaining existing CDS, (2) improving the utilization of coastal land that cannot be used as rice fields or ponds, and (3) mobilizing local villagers to work voluntarily to mitigate coastal hazards in their own village coastal areas. The advantages and disadvantages of these recommendations are summarized in **Table 4**.

The recommendations given by Setyawan et al. (2015) inspired the Head of UV at that time to develop the Pantai Plentong tourism area in Pegagan Hamlet in an effort to adapt to the hazard of erosion (Kusnato, August 26, 2021, personal communication). More about the development of Pantai Plentong will be elaborated further in the upcoming section.

Table 4 Advantages and disadvantages of coastal adaptation recommendations provided by Setyawan et al. (2015).

Recommendations (Setyawan et al., 2015)	Advantages	Disadvantages
Maintain coastline by constructing groin field and/or maintaining existing CDS.	Most of the body of the CDS is still in good condition. If efforts to maintain the coastline are successful, then no more coastal front land is lost due to erosion.	The cost of repairing the CDS and groin field construction is still too high for the village government.
Improving utilization of deteriorated coastal land (changing land use).	If this idea is realized, unproductive waterfront land will increase in value, and productive rice fields will be protected from overtopping.	This needs agreement from many waterfront landowners, which is not easy because there could be economic, social, and political barriers at the village level.
Mobilizing local villagers to work voluntarily to mitigate coastal hazards.	If this effort is successful, light physical work to care for CDS can be done independently by villagers.	It takes time to be able to invite citizens to willingly work, and there may be village-level social and political barriers.

5.2.5 Recommendation for maintaining the coastline

Until 2015, the problems faced in the coastal area of UV related to coastal erosion were (1) continued coastal erosion in the east coastal cells that have not been reinforced with CDS, and (2) damage in some parts of CDS that occurs in west coastal cells due to wave activity.

Protection of coastlines eroded by wave activity can be done by changing the environmental conditions of coastal zones from erosional to depositional. Such efforts can be made, among other methods, by lowering the strength of waves that hit the coast or by controlling sediment transport along the coast. In determining the choice of coastal protection methods, in addition to paying attention to local environmental conditions, it is also necessary to take into account what objects will be protected, and for what purposes the protection is carried out (Pilarczyk, 2017). In the case of Ujunggebang coastal area, coastal protection is carried out to prevent coastal erosion and damage to the body of CDS due to wave activity, and defense efforts are also carried out for recreational purposes. Meanwhile, the presence of sandy beaches is one of the aspects that are important for the achievement of these recreational goals. The results of visual observations along the coast of the study area, or analysis of sediment loads trapped using sediment traps (Setyawan et al., 2015), show that there is a large amount of sediment transport along the coast (**Figures 15** and **17**). Therefore, in order to maintain the coastline and to obtain sandy beaches simultaneously in the coastal area of Ujunggebang, it is recommended to build groin or groin fields, both in front of the existing CDS and on the coast that has not been strengthened with CDS (W.H. Sulistyawan, Sept 26, 2021, personal communication). Groins are structures built jutting into the sea from the shoreline, in various forms, with the aim of maintaining the coastline or controlling the amount of sand moving along the coast (Montanari, 2020; Pilarczky, 2018; Rahobisoa et al., 2014; U.S. Army Corps of Engineers, 1984, 2011). Groins are very efficient on coasts with a constant direction of littoral transport (Rahobisoa et al., 2014). Groin fields can be constructed on coasts with longshore transport to form sandy beaches (Claudio-Sales et al., 2019; Barbaro, 2016). Changes to the coast that will occur due to groin fields are predictable (Uda et al., 2014). The construction of groin structures is a method that is widely used in the world to overcome the problem of coastal erosion,

and groin structures can be made of wood, concrete, geotextiles, steel, or stone (Tereszkiewicz et al., 2018).

Figure 17 Sandy beach at Pegagan coast without CDS in 2015. The sand deposits were formed in the west monsoon after the embankments eroded during the previous east monsoon; then, they were transported again in the next east monsoon. Photographed facing westward. Adopted from Setyawan et al. (2015).

Beaches formed by a groin field will, at some stage, be able to protect the coastal plain or coastal cliffs or CDS from waves that can cause erosion. Therefore, groin field need to be constructed on coasts that have been reinforced with or without CDS. By creating a groin field, it is hoped that the sediment load in these coastal waters can be captured and form deposits in front of the coastal cliff or CDS, to prevent waves hitting the coastal cliff or CDS directly. Furthermore, in addition to maintaining the coastline, the sand deposits can be used for tourism activities.

The construction of groins in a coastal segment can cause erosion in other segments that are in the direction of downdrift, due to reduced supply of sediment load to that segment (Komar, 1976; U.S. EPA, 2009; U.S. Army Corps of Engineers, 1984, 2011; Rangel-Buitrago et al, 2015). However, in the case of the UC, the construction of groins or groin fields along the coastal segment, although causing a reduction in the supply of sediment load, is not expected to have a negative impact on the downdrift area, due to the following two circumstances. First, to the west of the Ujunggebang coastal segment, there is the mouth of the Sewo River, or Truntum River Mouth, which serves as a port for local fishing boats. Reduced supply of sediment load towards the estuary means that it helps reduce sedimentation problems in the port entrance. Second, further west, or downdrift, at a distance of about 2 km from Truntum River Mouth, there is an area of Patimban Port that is still in the process of development. The port still requires dredging to obtain sufficient port flow depth, which is a depth of 10 m (Sukarno, 2021). For this port, the reduction of sediment load transport from the UC contributes to reducing the port siltation problem.

5.2.6 Mobilizing local villagers

The involvement of local residents is important in the management of their villages' coastal areas. Their opinions or views on efforts to manage the coastal areas need to be known. It is necessary to know whether or not they support the planned coastal area management activities. They need to be involved from planning and decision-making activities to program implementation.

Socialization activities and field studies were carried out for representatives of UV residents in 2015 with aims to involve local communities in participating in managing their coastal areas. Socialization was done with the following stages (Setyawan et al., 2015):

1) Recommendations regarding coastal hazard mitigation efforts were submitted to the Village Head, or Kuwu, for his approval. The recommendations were packaged in the form of final research reports, booklets, brochures, and posters. After the recommendations were approved by the village head, the second phase was implemented.

2) Socialization was made of research results and adaptation recommendations or concepts of coastal area management to the UV community. Socialization meetings was held at the village hall and attended by representatives of hamlets and village officials. Socialization activities were carried out in the form of oral presentation, discussions, distributing brochures and booklets, and displaying posters (**Figure 18**).

3) Conducting field studies for representatives of local residents was done in selected locations to see various models of coastal area management, especially tourism areas. Field study activities were carried out by visiting several tourism sites in the Regencies of Brebes, Tegal, and Pemalang, and the City of Tegal (**Figure 19**). The purpose of the field studies was so that they could see firsthand the practice of managing tourism areas and give rise to the idea of managing coastal areas in their villages.

The result of this series of activities was the establishment of a tourism destination on the coast of UV with the name *Pantai Plentong* in 2016 (**Figure 4**), which is now one of the main tourism destinations in Indramayu Regency.

Figure 18 Socialization activities of Ujunggebang coastal zone management ideas for Ujunggebang communities in 2015. A: The head of Sukra district and the head of UV see the booklet; B: The head of Sukra district and the head of UV look at the poster; C and D: The atmosphere of socialization to representatives of residents of UV. Adopted from Setyawan et al. (2015).

Figure 19 Field study activities or comparative studies on coastal zone management with representatives of the UV community in 2015. A: Representatives of UV community in field at Pantai Alam Indah, Tegal; B: Activity in vegetated coastal zone at Mintaragen, Tegal; C: Activity on sandy beach at Pemalang; D: Activity on coastal structure at Purwahamba Coastal Tourism Site, Tegal. Adopted from Setyawan et al. (2015).

5.3 Pantai Plentong tourism area

The coastal tourism area *Pantai Plentong* is located in the coastal area of Pegagan Hamlet, UV, Sukra District, Indramayu Regency, and West Java Province. This tourism area began being built in 2016 (Handayani, 2021; Prawira et al., 2020). The name "Plentong" comes from the name of a hamlet in UV which has been lost due to coastal erosion, the Plentong Hamlet that used to be directly adjacent to the sea (Handayani, 2021; Cahyadi, 2019a). When the tourism area began being built in 2016, the western segment of the coastline which was managed as a tourism area had previously been strengthened by CDS, and the other part, the eastern segment, was still unprotected.

The idea of building the Pantai Plentong tourism area in UV was proposed by Mr. Kusnato who, in 2015, was the Head of UV. The idea came about after comparative study activities based on the thought that "The coastal zone should not only be a source of problems for residents (because of its erosion), but also can provide direct benefits for the surrounding residents" (Kusnato, August 26, 2021, personal communication). Furthermore, Mr. Kusnato explained that, initially, Pantai Plentong was built on the remaining land of former ponds controlled by fishery companies whose Right to Business permits had expired, and the remaining ponds were controlled by residents. The acquisition of the former pond land was carried out after obtaining permission to use the former farm land from the company's manager, as well as paying compensation to the residents who controlled the land. Then, the expansion of the tourism area to the south was done by utilizing Mr. Kusnato's privately owned land.

The Pantai Plentong tourism area is managed by the village through a Village-Owned Enterprise (BUMDES), "Madiri Sejahtera Utama", whose scope of work includes visitor arrangement, human resource management, and business operations by involving elements of the village community, such as the Youth Community, who are members of the Clean Ujunggebang Community (**Figure 20**). This tourism site offers tourism attractions in the form of playing activities, enjoying the sea and coastal scenery, and photography. Visitors to this tourism spot mainly come from the surrounding regencies which are within a radius of about 100 km, such as Indramayu, Karawang, Subang, and Purwakarta, with an average number of visitors of 300 people per day on weekdays, and around 1,000 people per day on weekends (Handayani, 2021; Prawira et al., 2020).

(A)

(B)

Figure 20 Youths who work in the tourism area of Pantai Plentong. (A) Admission ticket clerk, (B) Parking attendant. Photo: W B Setyawan, 03 April 2019.

The financial income of this tourism area is still only from entrance tickets and vehicle parking fees for visitors. Meanwhile, traders are still given a place to trade for free. According to the management of the tourist area, Mr. Kusnato (Oct 23, 2018, personal communication), this policy was a promotion, so that traders who want to sell in tourism areas which are still in the early stages of development are able to do so (**Figure 21**).

Figure 21 Talking with Pak Kusnato (in gray T-shirt, second from right); in 2018. Photo: W B Setyawan, 23 October 2018.

Based on the data that has been collected, the stages of developing this tourism area can be described as follows:

1) The first stage, or the initial stage. This stage begins with the Clean Ujunggebang Movement, which was carried out by the youth of UV who are members of the Clean Ujunggebang Community. This movement held a coastal land cleaning activity, which was carried out twice a week, with the aim of making Ujunggebang coastal area clean and comfortable to visit. This movement began in 2015 after it was initiated by Mr. Kusnato, the new head of Ujunggebang village at the time (Handayani, 2021).

2) The second stage was marked by the movement to beautify the village. At this stage, the village government of Ujunggebang initiated the establishment of Kampung Bintang (Star Village). In this program, village roads and houses in the village were cleaned and decorated. The goals were for residents to feel that they own the coast, and to be willing to keep it clean and to feel sorry if their village is dirty. The success of this program further motivated the village government to make the coastal area a tourism site (Handayani, 2021). The Kampung Bintang program was carried out independently by local residents (Berwisata ke Pantai Plentong Ujunggebang Sukra Indramayu, 10 September 2017). In 2016, for freedom of business and as a managerial forum for Pantai Plentong, a Village-Owned Enterprise (BUMDES) was formed, which was named “Mandiri Sejahtera Utama” (Prawira et al., 2020; Achdi, 2019).

3) The third stage began when Pantai Plentong was declared as tourism site in 2017 (Handayani, 2021). In that year, the management of Pantai Plentong began to collaborate with PT

Pembangkit Jawa Bali, Operation and Maintenance Services Business Unit (PJB UBJOM) for the Steam Power Plant (PLTU) Indramayu (Cahyadi, 2019a).

4) The fourth stage began when the manager of the PLTU Indramayu (**Figure 22**) was willing to help the development of Pantai Plentong through the provision of CSR (Community Social Responsibility) funds from 2018 onwards every year with a development plan until 2022 (Handayani, 2021; Cahyadi, 2019a).

Figure 22 Information poster of Pantai Plentong. Photo: W B Setyawan, 03 April 2019.

The presence of the Pantai Plentong tourism site influences the lives of the residents of UV, especially the residents of Pegagan Hamlet, which is where this tourism area is located. For the residents of the village, the tourism area has provided a new identity, new jobs, and a new atmosphere of life. Before there was a tourism area in the village, the village coastal land was dirty, with garbage and shrubs, and was not maintained. Near coast rice fields and ponds were damaged due to wave activity and become unproductive. The development of the tourism site on the coastal land has succeeded in changing the poor and unprofitable land conditions into productive, beautiful, and comfortable coastal land, and attracts many people to visit (Handayani, 2021; Prawira et al., 2020; Achdi, 2019; Gandarasa, 2019; Lia, 2019).

The presence of the Pantai Plentong tourism area in UV has caused changes in the economic activities of some of the villagers. Kusnato (August 26, 2021, personal communication) explained that, before the existence of Pantai Plentong, the economic activities of Ujunggebang villagers centered only on the agricultural sector, as farmers in rice fields, and fisheries, as coastal fishermen. The presence of Pantai Plentong fosters new economic activities in UV, namely economic activities in the tourism sector. Many villagers work in the tourist area. This reduces the number of unemployed villagers. The number of employees working at Pantai Plentong reached 58 people (before the Covid-19 Pandemic). There are as many as 32 people who are settled traders, and there are also traders who are not fixed or who are mobile, whose numbers are difficult to calculate. Of

the 32 traders who are settled, as many as 5 people were previously fishermen, a small percentage were farmers, and the rest were residents who did not work. Meanwhile, Handayani (2021) noted that there are many village youths who initially did not work have become workers in the tourism area, and many villagers have become producers of handicrafts or food, or traders in the tourism area.

Managing Pantai Plentong is one of the activities of the Ujunggebang Village-Owned Enterprise (BUMDES), which is very prominent and is seen as being able to influence the people's economy, so that the enterprise received the title of the second best Village-Owned Enterprise at the West Java Province level in 2018 (Achdi, 2019). This achievement has made the people of UV proud of their village, and they were determined to make it a tourist village. Furthermore, in 2019, UV won an award from the Indramayu Regency Government as the First Winner of the Best Village at the Indramayu Regency level (**Figure 23**) for its achievements in developing the Pantai Plentong tourism area, which was seen as having an effect on the economy of its residents (Gandarasa, 2019; Lia, 2019).

Figure 23 UV received an award as the best village at the Indramayu Regency level because it was considered successful in activating the economy of its population through the development of the Plentong Beach tourist area. Adopted from Lia (2019).

Although it is growing continuously, the Pantai Plentong tourism area still faces one main problem, namely, coastal erosion on the part of the coastline that has not been protected by CDS. Erosion that occurred along the coastal segment in the period 2013 to 2020 was very significant (**Figure 24**). Efforts to protect the coast by making breakwaters with used tires and bamboo in 2020 have not yielded satisfactory results. The building was damaged by waves blown by the east monsoon in April 2021, and the erosion that occurred damaged several tourism facilities built on the coast (Sung Tv, 2021; 2020).

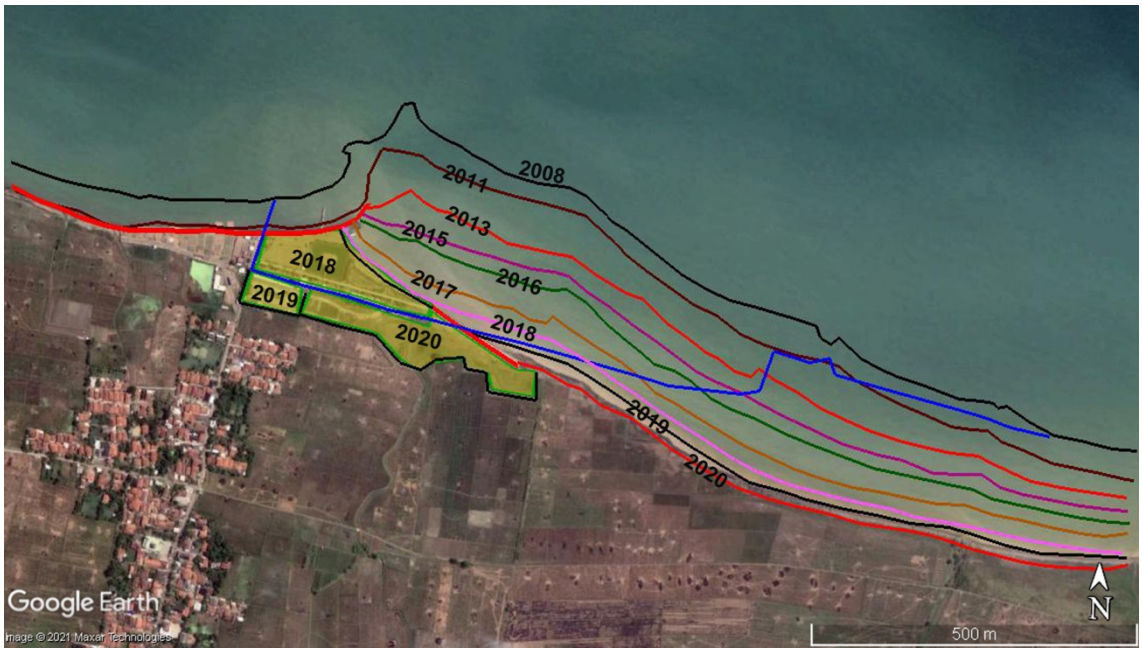

Figure 24 Coastline changes around Pegagan Headland, showing differences between protected and unprotected coastline in the period 2008 - 2020. Blue line: land boundary of formerly coastal ponds in 2008. Yellow shade land is Pantai Plentong tourism site. Images from Google Earth; Image axis: 6° 15' 22.88"S and 107° 56' 16.14"E.

6. Discussion

6.1 Land use change as an adaptation strategy for coastal erosion

Overcoming erosion problems with a structural planning approach is an activity that requires high costs, due to the construction of coastal protection structures. Meanwhile, the non-structural approach, or management approach, such as land use planning and zoning, is a relatively inexpensive one, especially for communities (Jarungrattanapong & Manasboonphempool, 2009). However, in general, the decision to choose structural or non-structural protection will be determined by financial capacity or physical feasibility, priority of object to be protected, cost-benefit analysis, financial capacity of various levels of government for sustainable protection, and the manager's view of the issues or wider impacts, such as ecological or aesthetic impacts (Moser et al., 2012). Limitations of financial and engineering skills are faced by the residents of UV concerning the problem of coastal erosion that occurs in their village.

Adaptation efforts to reduce erosion hazards in UV were carried out by building a CDS along the coast in 2006 and 2013 by the government. However, some parts of the extended CDS were damaged in 2015. Damage to the CDS caused the coastal rice fields to be splashed with seawater and become damaged or unable to be planted with rice. Meanwhile, on the coast where the CDS is still good, it can be seen that seawater overtopping occurs when the waves hit the coast, so that seawater enters the rice fields behind it (Setyawan et al., 2015). This situation illustrates that the CDS construction has not been carried out properly, such as the height of the structure not being sufficient to prevent overtopping, the weight of the stone used to build the structure being inadequate to deal with the wave energy, or the parameters of the oceanography, such as wave height and sediment transport, not being calculated properly (W H Sulistyawan, September 29, 2021, personal communication).

Nevertheless, the presence of the CDS remains useful, at least in inhibiting the rate of coastal erosion. Furthermore, land use changes made by locals to the waterfront land behind the CDS can improve the economic value of that land that has deteriorated due to overtopping. Land

that was originally deteriorated and did not provide economic value became land of economic value. That is because the changes in land use can eliminate the impact of overtopping, even though overtopping still occurs at certain times or certain seasons, such as those in Pantai Plentong. This is because the land that is splashed with sea water is land that has changed its use into a playground for visiting tourists. In this case, the activity of changing land use is a measure that complements the coastal defense structure (Baills et al., 2019).

The Pantai Plentong tourism area was built on coastal front land in Pegagan Hamlet, UV, which was a previously abandoned pond. The change in land use does not cause conflict. It is possible that this is because no one is harmed by the land use changes. As mentioned earlier, the success of the effort to develop the tourism area has also been recognized by the Regional Government of Indramayu Regency, because it has succeeded in driving the economy of the community in UV by recognizing it as the best village in the Regency (**Figure 14**). Although there is no numerical data that describes the changes that have occurred, the acknowledgment shows that land use changes can be a complementary measure to adapting to coastal hazards due to wave activity causing coastal land quality degradation.

Previously, it was also stated that the Pantai Plentong tourism area was built on coastal land with two different coastline conditions, namely, a segment that has been reinforced with CDS in the west, and a segment that has not been reinforced with CDS in the east. In such circumstances, coastal hazards in the form of coastal erosion still exist in the eastern part of this tourism area. The choice of location for the development of the Pantai Plentong tourism area, thus, exposes the tourist area to the main coastal hazard in the area, namely, that of coastal erosion. A summary of changes that have occurred over several parameters in Pegagan Hamlet, from before and after the existence of Pantai Plentong, is presented in **Table 5**.

Table 5 Coastal zone conditions of Pegagan Hamlet before and after Pantai Plentong tourism site development.

	Before Tourism Activity Development		**After Tourism Activity Development**	
	Before Revetment	**After Revetment**	**With Revetment**	**Without Revetment**
Coastal Hazards				
• Coastline erosion	Yes	No	No	Yes
• Overtopping	-	Yes	Yes	-
Tourism Activities	No	No	Yes	Yes
Small Business Activities	No	No	Yes	Yes
Land use	Deteriorated Ponds	Deteriorated Ponds	Tourism	Tourism
Scenic value	No	No	Yes	Yes

Coastal erosion can be seen to become a major hazard to an area because of its threat to economic activity (Rahobisoa et al., 2014). Such a situation is currently being faced by Pegagan Hamlet, with coastal erosion occurring in the segment without CDS in the Pantai Plentong tourism area, because the tourism area has become their economic asset and provides socioeconomic benefits for the village. What has happened in the hamlet of Pegagan shows that land use changes are also changing the levels of danger.

In the development of the tourism area, efforts to protect the coastline from the hazard of erosion have been carried out by Pantai Plentong management, but have not succeeded as expected,

so that the hazard remains a problem for the development of the tourism area in its fourth year of development. As acknowledged by Mr. Kusnato, lack of funds is an obstacle for the development of a coastal protection system, and financial assistance from the government for coastal protection measure is highly expected (Sung Tv, 2021). The construction of coastal defense structures requires very high costs (Rangel-Buitrago et al., 2015). Cost constraints are indeed a problem for the management of coastal areas that need to find solutions (Ibrahim & Hezagy, 2013). In addition, to promote coastal zone management, the concept of Local Coastal Partnerships (LCPs), which is the main stakeholder cooperation forum (Booth et al., 2013), needs to be considered for implementation. Furthermore, the ability to obtain financial strength independently also needs to be developed.

The perpetrators of land use changes affect the amount of profit coverage obtained. If the change is made by the individual, then the greatest benefit is only felt by the individual. However, if the changer is an organized community, then the benefits of change are felt not only by the residents of that community but more broadly, including by other villagers. Changes in land use in the form of tourism area development as an effort to adapt to environmental conditions or erosion hazards have occurred in Ujunggebang coastal zone. The benefits of such changes are not only felt by individual residents who are directly involved in tourism activities, but also by other villagers who are not directly involved and by residents outside the village. **Table 6** provides an overview of these changes.

Table 6 Coastal land use change, operator, and benefits in UV.

Current Coastal Land Use	Previous Coastal Land Use	Operator	Who gets the Benefits	Remarks
Tourism site at Pegagan Hamlet (Pantai Plentong)	Deteriorated ponds	BUMDES	Communities	Benefits are not limited to the person directly involved.
Tourism site at Tanjungpura Hamlet.	Deteriorated land	Personal, Unorganized individual.	Personal	Benefits are limited to those directly involved.

6.2 Evolution of adaptation action

The results of this study provide an overview of an evolution of strategies to deal with the problem of coastal erosion in the coastal area of Ujunggebang, with the following stages identified:

1) Stage 1: Loss Acceptance or Sacrifice. This stage occurred in the period before 2006. In this stage, significant erosion occurred in all parts of the Ujunggebang coastal segment, and there was no recorded active action to inhibit the rate of erosion, or the erosion process was allowed to occur. Faced with erosion that hit residential areas, residents moved to areas further from the coastline within the village by getting permission to occupy land owned by the village, or to move to another village. This situation is explained by Mr. Kusnato (02 October 2021, personal communication).

2) Stage 2: Defense. This stage lasted from 2006 to 2015. This stage was characterized by the presence of efforts to maintain the coastline by building CDS carried out by central government. CDS were built in stages and were not been built across the coastal segments that are experiencing erosion. The first phase in 2006 built CDS along about 600 m and continued in 2013 by adding CDS along about 800 m. This stage lasted from 2006 to 2015. In this stage, the built CDS

successfully inhibited the rate of erosion in protected segments of the coast. The erosion process continued significantly in coastal segments that were not protected by CDS.

3) Stage 3: Accommodation. This stage lasted from 2016 until now. This stage was characterized by the emergence of initiatives at the local level to survive by taking adaptation measures or complementary measures by changing land use as an additional action for CDS that had been built by central government. In this stage, the local population managed to change the conditions of coastal land near the coast damaged by erosion and overtopping into land of economic value by building tourism areas, even though the problem of coastal erosion was not successfully resolved.

6.3 Local character adaptation action

Adaptation actions for coastal erosion carried out by the residents of UV, who made changes to land use as complementary measures for CDS built by central government, were small-scale and local adaptation efforts, although these acts of adaptation could cause changes in their daily lives. To be able to provide an overview of the situation, here are given three examples of cases from three countries.

The coastal area of Bang Khun Thian district, Bangkok, Thailand, is a mud coast that is situated along the Upper Gulf of Thailand. Coastal aquaculture is a major economic activity in the area. Coastal erosion is a major problem for the district, causing the loss of aquaculture areas (Jarungrattanapong & Manasboonphempool, 2009). Coastal areas that are seaside wetlands make it impossible for partial action to maintain the coastline and change the land use as done in Ujunggebang coastal land, which is dry coastal land.

On the Columbian Caribbean coast, coastal erosion is also a major problem. The coastline experienced erosion reaching a length of about 1182 km, the causes varying from those arising naturally to those due to human activities, and stakeholders are severely affected by the erosion. Along the coastal area are concentrated four commercial and tourism areas. Tourism activity contributes enormously to the economy, with about 1,900,000 international visits, and nearly 6,000,000 domestic visits. These circumstances give rise to various acts of adaptation that are seen to suit their respective needs, all of which are defense actions. The most preferred adaptation actions are “hard structure”, in the form of groin and breakwater. The act of maintaining the coastline is carried out on the basis of “action-reaction or post-disaster”. Coastal defense measures are carried out based on the pressures faced by stakeholders when their property is exposed to erosion processes, without analysis of potential hazards or evaluation of potential for the surrounding environment (Rangel-Buitrago et al., 2015). Under such environmental conditions, adaptation measures such as those carried out in the Ujunggebang region cannot be applied due to the problems faced on a very large scale, while those carried out in Ujunggebang are only for a small and local scale.

In island nations on small islands in the Pacific Ocean that are reef islands, coastal erosion and land loss are major coastal hazards. The character of the area is reef islands or atolls with very limited land and a very small population. Coastal communities have social and cultural activities that are very close to coastal areas or coastlines. Coastal erosion threatens their important natural assets. The preferred and applied adaptation measures can protect coastlines and shore-front assets and can be implemented immediately and easily using local knowledge and resources. Communities on the islands prefer adaptation based on ecosystems to building coastal defense structures, although they are less effective. Coastal ecosystems are seen as more profitable, in the form of fishery production, agriculture, and firewood. Commonly applied adaptation measures are planting coastal vegetation, building traditional seawall, or elevating land by using timber from coastal plants, rocks mined from islands, or naturally dying corals (Naraya et al., 2020). The physical environmental condition of small islands in the Pacific Ocean is very different from the environmental conditions in the coastal area of Ujunggebang. Making land use changes such as

those made in the coastal areas of Ujunggebang can be unimaginable in areas of small islands that are remote and have very small populations, as well as local communities that have a close relation to the coastal ecosystems where they used to live. This condition causes the idea of land use changes to be incompatible, especially that of the development of tourist areas.

7. Conclusions

This study shows that adaptation to coastal hazards can be carried out at the village or local level as a complementary measure for coastal defense structures built by central government. The presence of a leader who acts as a driver, and support from villagers, are very important for the success of hazard adaption efforts at the village or local level. Financial and technical support from other parties for the success of these activities is also very important.

Another thing that this study shows is that land use change can be an alternative for coastal hazard adaptation efforts as a complementary measure. Nevertheless, the main hazards faced must still be a top priority in adaptation actions. Furthermore, program compatibility between central and local governments is very important for the success of a coastal area management program.

Changes in land use by developing tourism areas as an adaptation option such as that carried out in the coastal area of Ujunggebang are very site specific and very local. Its application elsewhere in Indonesia, or in other countries, needs to be done with a very careful study of physical and social environmental conditions, in order to find out whether the idea can be applied or not.

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References

Achdi, U.P. (2019). *Dikelola profesional, Pantai Plentong mampu angkat ekonomi warga* (*in Indonesian*). RadarCirebon.com, Headline. Retrieved from https://www.radarcirebon.com/2019/03/06/dikelola-profesional-pantai-plentong-mampu-angkat-ekonomi-warga

Adams, P. N., Inman, D. L., & Lovering, J. I. (2011). Effect of climate change and wave direction on longshore sediment transport in Southern California. *Climate Change, 109*, S211-S228. http://dx.doi.org/10.1007/s10584-011-0317-0

Anfuso, G., Martinez-del-Pozo, J. A., & Rangel-Buitrago, N. (2012). *Bad practice in erosion management: The Southern Sicily case study*. *In*: Cooper, J. A. G., & Pilkey, O. H. (Eds.). Pitfall of shoreline stabilization: Selected case study, coastal research library 3. https://doi.org/10.1007/978-94-007-4123-2_13

Baills, A. Garcin, M., & Bulteau (2019). Assessment of selected climate change adaptation measures for costal area. *Ocean and Coastal Management, 185*, 105059. https://doi.org/10.1016/j.ocecoaman.2019.105059

Barbaro, G. (2016). Master plan of solutions to mitigate the risk of coastal erosion in Calabria (Italy): A case study. *Ocean & Coastal Management, 132*, 21-35. http://dx.doi.org/10.1016/j.ocecoaman.2016.08.001

Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E., & Hurlimann, A. (2014). A local coastal adaptation pathway. *Nature Climate Change, 4*, 1103-1108. https://doi.org/10.1038/nclimate2383

Berwisata ke Pantai Plentong Ujunggebang Sukra Indramayu. (2017). *BloggerMangga: Komunitas Blogger Indramayu (in Indonesian)*. Retrieved from https://www.bloggermangga.com/2017/09/berwisata-ke-pantai-plentong.html

Biro Komunikasi dan Informasi Publik. (2020). *Pelabuhan Patimban, Pelabuhan Strategis Masa Depan. Laporan Khusus (in Indonesian)*. Kementerian Perhubungan Republik Indonesia. Retrieved from http://dephub.go.id/post/read/pelabuhan-patimban,-pelabuhan-strategis-untuk-masa-depan?language=id

Boateng, I. (2012). An application of GIS and coastal geomorphology for large scale assessment of coastal erosion and management: A case study of Ghana. *Journal of Coastal Conservation, 16*(3), 383-397. http://dx.doi.org/10.1007/s11852-012-0209-0

Booth, L., Milne, F. D., & Duck, R. W. (2013). Sectoral interaction in the Scottish coastal zone: Measuring sustainability in theory and practice. *Ocean & Coastal Management, 85*, 39-45. http://dx.doi.org/10.1016/j.ocecoaman.2013.09.003

Cahyadi, R. (2019a). *Abrasi pantai lahirkan wisata Plentong Ujunggebang (in Indonesian).* Fokus Pantura, Pariwisata. Retrieved from https://www.fokuspantura.com/pariwisata/2582-abrasi-pantai-lahirkan-wisata-plentong-ujunggebang

Cahyadi, R. (2019b). *Pembangunan pengaman pantai Ujunggebang ditangguhkan (in Indonesian).* Fokus Pantura, Fokus Indramayu. Retrieved from https://www.fokuspantura.com/fokus-indramayu/2970-pembangunan-pengaman-pantai-ujunggebang

Choi, Y. E., Jin, J. Y., Chang, Y. S., Jang, B., & Chon, J. (2018). Role of official development assistance in enhancing resilient coastal community in Small Island Development States. *Journal of Coastal Research, 85*, 1466-1470. http://dx.doi.org/10.2112/s185-294.1

Claudio-Sales, V., Wang, P., Vasconcelos, F. P., & Silveira, A. P. (2019). *Environmental problems and coastal mitigation in South America: Examples from Northeast Brazil and Northern Colombia*. IntechOpen. http://dx.doi.org/10.5772/intechopen.87959

Coastal Resources Management Council (n.d.). *CRMC: Rules and regulation governing the protection and management of freshwater wetland in the vicinity of the coast*. Retrieved from http://www.planning.ri.gov/documents/LU/legtask/CRMC_Coastal-wetland-Rules_2013.pdf

Duguma, L. A., Minang, P. A., & van Noordwijk, M. (2014). Climate mitigation and adaptation in the land use sector: From complementary to synergy. *Environmental Management, 54*, 420-432. https://doi.org/10.1007/s00267-014-0331-x

Dyer, K. R. (1986). *Coastal and estuarine sediment dynamic* (p. 342). John Wiley & Sons, Chichester.

Forbes, D. L., James, T. S., Sutherland, M., & Nichols, S. E. (2013). Physical basis of coastal adaptation on tropical small islands. *Sustainability Science, 8*(3), 327-344. https://doi.org/10.1007/s11625-013-0218-4

Gandarasa, G. (2019). *Menengok keindahan wisata Pantai Plentong Indramayu (in Indonesian)*. PikiranRakyat.com, Jawa Barat. Retrieved from https://www.pikiran-rakyat.com/jawa-barat/pr-01322556/menengok-keindahan-wisata-pantai-plentong-indramayu

Handayani, L. S. (2021). *Plentong Reborn, membangun desa wisata dari dusun terkubur (in Indonesian)*. Republika Online, Nusantara. Retrieved from https://www.republika.co.id/berita/qolsvg396/plentongem-rebornem-membangun-desa-wisata-dari-dusun-terkubur

Hedge, A. V. (2010). Coastal erosion and mitigation methods: Global state of art. *Indian Journal of Geo-Marine Sciences, 39*(4), 521-530. https://www.researchgate.net/publication/264848811

Herrington, T. O. (n.d.). *Manual for coastal hazard mitigation.* New Jersey Sea Grant Collage Program. Retrieved from https://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf

Ibrahim, H. S., & Hezagy, I. (2013). *The important of the financial resources in applying effective Integrated Coastal Zone Management (ICZM): The Egyptian experience*. In Proceedings of

the Global Congress on Integrated Coastal Management: Lessons Learned to Address New Challenges. Marmaris, Turkey. https://doi.org/10.13140/RG.2.1.1557.8326

Jaafar, S. N., Yusoff, M. M., Hu, A. K., & Ping, O. W. (2018). How possible the coastal erosion and coastal deposition to influenced on the life quality of Kemeruk residents? A structural equation model study. *International Journal of Academic Research in Environment and Geography, 5*(1), 59-69. http://dx.doi.org/10.6007/IJAREG/v5-i1/4216

Jarungrattanapong, R., & Manasboonphempool, A. (2009). *Adaptation Strategies to Address Coastal Erosion/Flooding: A case study of the communities in Bang Khun Thian District, Bangkok, Thailand* (p. 35). Economy and Environment Program for Southeast Asia, Climate Change Technical Reports. Retrieved from https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/45445/131906.pdf

Jonah, F. E., Mensah, E. A., Edziyie, R. E., Agdo, N. W., & Adjei-Boateng, D. (2016). Erosion in Ghana: causes, policies, and management. *Coastal Management, 44*(2), 116-130. http://dx.doi.org/10.1080/08920753.2016.1135273

Klein, A. H. F., Viera da Silva, G., Taborda, R., da Silva, A. P., & Short, A. D. (2020). *Headland bypassing and overpassing: Form, processes and application* (pp. 557-591). Elsevier, http://dx.doi.org/10.1016/b978-0-08-102927-5.00023-0

Komar, P. D. (1976). *Beach processes and sedimentation* (p. 429). Prentice-Hall, New Jersey.

Kriesel, W., & Friedman, R. (2003). Coping with coastal erosion: Evidence for community wide impacts. *Shore & Beach, 17*(3), 19-23.

Li, Y. T., Lan, Y, J., & Hsu, T. W. (2010). *The study of coastal buffer zone in Taiwan for conception of coastal environmental recovery and protection*. In Proceedings of the European Geophysical Union General Assembly 2010, Retrieved from https://meetingorganizer.copernicus.org/EGU2010/EGU2010-39.pdf

Lia, E. (2019). *Pantai Plentong, kisah kebangkitan dusun yang hilang di Indramayu (in Indonesian).* AyoCirebon.com. Retrieved from https://www.ayocirebon.com/read/2019/11/01/3708/pantai-plentong-kisah-kebangkitan-dusun-yang-hilang-di-indramayu

Ma, M. (2016). *Riparian buffer zone for wetlands.* The Wetland Book. http://dx.doi.org/10.1007/978-94-007-6172-8_53-7

Montanari, A. (2020). *Design of Groins*. University of Bologna Home Page. Retrieved from https://www.albertomontanari.it/?q=node/122

Moser, S. C. (2005). Impact assessment and policy responses to sea-level rise in three US states: An exploration of human-dimension uncertainties. *Global Environmental Change, 15*, 353-369. http://dx.doi.org/10.1016/j.gloenvcha.2005.08.002

Moser, S. C., Williams, S. J., & Boesch, D. F. (2012). Wicked challenges at land's end: Managing coastal vulnerability under climate change. *Annual Review of Environment and Resources, 37*(1), 51-78. http://dx.doi.org/10.1146/annurev-environ-021611-135158

Mulyana, E., Prayoga, M. B. R., Yananto, A., Wirahma, S., Aldrian, E., Harsoyo, B., Seto, H., & Sunarya, Y. (2018). Tropical cyclones characteristic in southern Indonesia and the impact on extreme rainfall event. *MATEC Web of Conference, 229*, 02007. https://doi.org/10.1051/matecconf/201822902007

National Academy of Sciences. (2014). *Reducing coastal risk on the east and gulf coast*. Report in Brief. Retrieved from http://www.nap.edu

National Research Council. (2014). Reducing coastal risk on the east and gulf coast. Washington, DC: The National Academic Press. Retrieved from https://doi.org/10.17226/18811

Norris, V. (1993). The use of buffer zone to protect water quality: a review. *Water Resources Management, 7*, 257-272. https://doi.org/10.1007/bf00872284

Office for Coastal Management. (2021). *Hazard mitigation value*. NOAA. Retrieved from https://coast.noaa.gov/states/fast-facts/hazard-mitigation-value.html

Oh, J. E., Chang, Y. S., Jeong, W. M., Kim, K. H., & Ryu, K. R. (2020). Estimation of longshore sediment transport using video monitoring shoreline data. *Journal of Marine Science and Engineering, 8*(8), 572. https://doi.org/10.3390/jmse8080572

Pearce, L. (2013). Disaster management and community planning and public participation: How to achieve sustainable hazards mitigation. *Natural Hazards, 28*, 211-228. https://doi.org/10.1023/a:1022917721797

Pilarczyk, K.W. (2003). *Alternative systems for coastal protection: An overview* (pp. 409-419). In Proceedings of the International Conference on Estuaries and Coasts. Hangzou, China.

Pilarczky, P. (2018). *Remarks on coastal stabilization and alternative solutions* (pp. 743-773). Handbook of Coastal and Ocean Engineering. https://doi.org/10.1142/9789813204017_0027

Prawira, N. G., Johari, A., Prawira, M. F. A., & Susanto, E. (2020). Sumberdaya alam dan kearifan lokal sebagai rasional dalam workshop Visual Branding kawasan wisata Pantai Plentong Kabupaten Indramayu Jawa Barat (*in Indonesian*). *Jati Emas (Jurnal Aplikasi Teknik dan Pengabdian Masyarakat), 4*(2), 49-54. https://doi.org/10.36339/je.v4i2.307

Rahobisoa, J. J., Ratrimo, V. R., & Ranaivoarisoa, A. (2014). *Mitigating coastal erosion in Fort Dauphin, Madagascar* (pp. 147-164). In Kaneko, N., Yoshiura, S., & Kobayashi, M. (Eds.). Sustainable Living with Environmental Risk, Springer Open, Tokyo. https://doi.org/10.1007/978-4-431-54804-1_13

Rangel-Buitrago, N., Williams, A., & Anfuso, G. (2017). Hard protection structures as a principal coastal erosion management strategy along the Caribbean coast of Columbia. A chronicle of pitfalls. *Ocean & Coastal Management, 156*, 58-75. https://dx.doi.org/10.1016/j.ocecoaman.2017.04.006

Rangel-Buitrago, N. G., Anfuso, G., & Williams, A. T. (2015). Coastal erosion along the Caribbean coast of Columbia: Magnitude, cause and management. *Ocean & Coastal Management, 114*, 129-144. http://dx.doi.org/10.1016/j.ocecoaman.2015.06.024

Richardson, G. R. A., & Otero, J. (2012). *Land use planning tool for local adaptation to climate change* (p. 38). Ottawa: Government of Canada. Retrieved from http://www.coastalchange.ca/download_files/external_reports/Richardson_Otero(2012)_Land_Use_Planning_Tools.pdf

Setyawan, W. B., Hasanudin, M., Kusmanto, E., Witasari, Y., Winardi, & dan Hasanudin, M. (2007). *Studi Geomorfologi Pesisir dan Model Penanggulangan Erosi di Perairan Utara Jawa. Bagian 1: Studi Geomorfologi Pesisir untuk Penanggulangan Erosi di Eretan* (*in Indonesian*). Laporan Akhir Penelitian, Program Penelitian dan Pengembangan IPTEK, Pusat Penelitian Oseanografi, Jakarta.

Setyawan, W. B., Kusmanto, E., & dan Hasanudin, M. (2015). *Strategi pembangunan terpadu untuk kawasan pesisir yang mengalami erosi: Studi kasus di kawasan pesisir Ujung Gebang – Bugel, Indramayu, Jawa Barat* (*in Indonesian*). Laporan Akhir Penelitian, Riset Unggulan Kedeputian Ilmu Pengetahuan Kebumian. Pusat Penelitian Oseanografi LIPI, Jakarta.

Sukarno, P. A. (2021). *Jelajah Pelabuhan 2021, Ini Progres Terbaru Pelabuhan Patimban (In Indonesian)*. Bisnis.com: Ekonomi. Retrieved from https://ekonomi.bisnis.com/read/20210410/98/1379140/jelajah-pelabuhan-2021-ini-progres-terbaru-pelabuhan-patimban

Sung Tv. (2020). *Pemandangan ban bekas menumpuk di tepi pantai Plentong, Ujunggebang (in Indonesian)*. Youtube. Retrieved from https://www.youtube.com/watch?v=-76hSECQ0K8

Sung Tv. (2021). *Kodisi Pantai Plentong memprihatinkan (in Indonesian)*. YouTube. Retrieved from https://www.youtube.com/watch?v=rm4aQ_GMGfE

Tempfli, K., Kerle, N., Huurneman, G. C., & Janssen, L. L. F. (2009). *Principles of remote sensing: An introductory textbook* (p. 591). 4th eds. The International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands. Retrieved from https://webapps.itc.utwente.nl/librarywww/paper_2009/general/principlesremotesensing.pdf

Tereskiewecz, T., McKinney, N., & Meyer-Arendt, K. J. (2018). Groins along the Northern Yucatan Coast. *Journal of Coastal Research, 34*(4), 911-919. http://dx.doi.org/10.2112/JCOASTRES-D-17-00062.1

The Heinz Center. (2000). *Evaluation of erosion hazards*. Federal Emergency Management Agency, Washington, D.C. Retrieved from https://www.fema.gov/pdf/library/erosion.pdf

Uda, T., Serizawa, M., & Miyahara, S. (2014). Development of sand spits and cuspate forelands with rhythmic shape and their deformation by effects of construction of coastal structures. *Computational and Numerical Simulation, 19*, 419-450. http://dx.doi.org/10.5772/57043

U.S. Army Corps of Engineers. (1954). *Topographic Map of Indonesia, Djakarta Sheet, Sheet SB 48-12, Series T503, Edition 1-AMS, scale 1:250,000*. Retrieved from https://maps.lib.utexas.edu/maps/ams/indonesia/txu-oclc-21752461-sb48-12.jpg

U.S. Army Corps of Engineers. (1984). *Shore Protection Manual Vol. 1, Coastal Engineering Research Center, Department of the Army*. Vicksburg, Mississippi. Retrieved from https://ia802604.us.archive.org/34/items/shoreprotectionm01unit/shoreprotectionm01unit.pdf

U.S. Army Corps of Engineers. (2011). *Coastal Engineering Manual - Part VI. EM 1110-2-1100 (Part VI)*. Washington, DC, Department of the Army.

U.S. EPA. (2009). *Synthesis of Adaptation Option for Coastal Area.* Washington, DC, U.S. Environmental Protection Agency, Climate Ready Estuaries Program. EPA 430-F-124. Retrieved from https://www.epa.gov/sites/default/files/2014-04/documents/cre_synthesis_1-09.pdf

Widiyantoro, S., Gunawan, E., Muhari, A., Rawlinson, N., Mori, J., Hanifa, N. R., Susilo, S., Supendi, P., Shiddiqi, H. A., Nugraha, A. D., & Putra, H. E. (2020). Implications for megathrust earth-quakes and tsunamis from seismic gaps south of Java Indonesia. *Scientific Reports, 10*, 15274. https://doi.org/10.1038/s41598-020-72142-z

Williams, A. Rangel-Buitrago, N. G., Pranzini, E., & Anfuso, G. (2017). The management of coastal erosion. *Ocean & Coastal Management, 156*, 4-20. https://doi.org/10.1016/j.ocecoaman.2017.03.022