Geografia Malaysian Journal of Society and Space

The hazards of coastal erosion in Central Java, Indonesia: An overview

Muh Aris Marfai[1]

[1]Geography Faculty, Gadjah Mada University, Bulaksumur 55281, Yogyakarta, Indonesia

Correspondence: Muh Aris Marfai (email: arismarfai@gadjahmada.edu)

Abstract

As an archipelago country, Indonesian coastal areas are the most dynamic and strategic areas for development as they provide many resources for human livelihood. At the same time, however, coastal areas are also prone to environmental hazards such as erosion and sedimentation processes. Erosion along the coast may cause loss of coastal land and damage infrastructures and buildings. The Semarang City, Tegal Regency, and Demak Regency of the Central Java Province are especially vulnerable to coastal erosion. This paper examines both the phenomenon and mitigation of erosion hazards in Central Java. It was found that in Semarang City, for the past 100 years coastal erosion has threatened facilities and land use along the coast causing extensive loss of coastal land. The local government has embarked on several mitigating measures including the construction of dykes and sea walls. Similarly, coastal erosion and abrasion had damaged tourism infrastructures and diminished the coastal land of the Tegal Regency since 1994. In Demak it led to the relocation of settlement and damage of aquaculture. Given the significant role of the city of Semarang, Tegal and Demak in the ongoing development of Central Java the issues of coastal erosion should have garnered serious attention from local and provincial government. Needless to say, coordination between planning and implementation of mitigation measures need to be comprehensive and enhanced.

Keywords: Central Java Province, coastal erosion, coastal hazard, Indonesia, risk reduction, shoreline dynamic

Introduction

Indonesia has more than 17,500 islands with total shoreline of approximately 80,000 Km. The coasts are the most dynamic areas as these are very strategic locations with many natural resources. In fact many large cities with dense population such as Jakarta, Semarang, Surabaya, are located in coastal areas. Indonesia's coastal areas have geomorphologically complex processes including coastal environmental degradation due to natural hazards (see Figure 1).

Central Java, with an area of 32,548.20 Km² is situated between latitudes 6° -7°30'S and longitudes 108°30'-112°00'E and has complex geomorphological features i.e., lowlands near the northern and southern coasts, and mountain ranges in the centre of the region. Beside coastal inundation and flooding, some of the coastal areas in Central Java Province undergo erosion-sedimentation processes (Bird & Ongkosongo 1980, Sunarto 2004, Marfai *et al.* 2008) which caused damage to public facilities, tourism areas, agricultural plantations and coastal settlemenst. The coastal areas in Semarang City, Tegal Regency and Demak Regency may be considered as the most dynamic areas of erosion-sedimentation processes in Central Java (Marfai *et al.* 2008, Sartohadi et al. 2009, Maulina 2010). In this context, it is necessary to learn some facts about

these environmental hazards from the historical record of coastal erosion in some these areas in order to address the mitigation challenge at the provincial level.

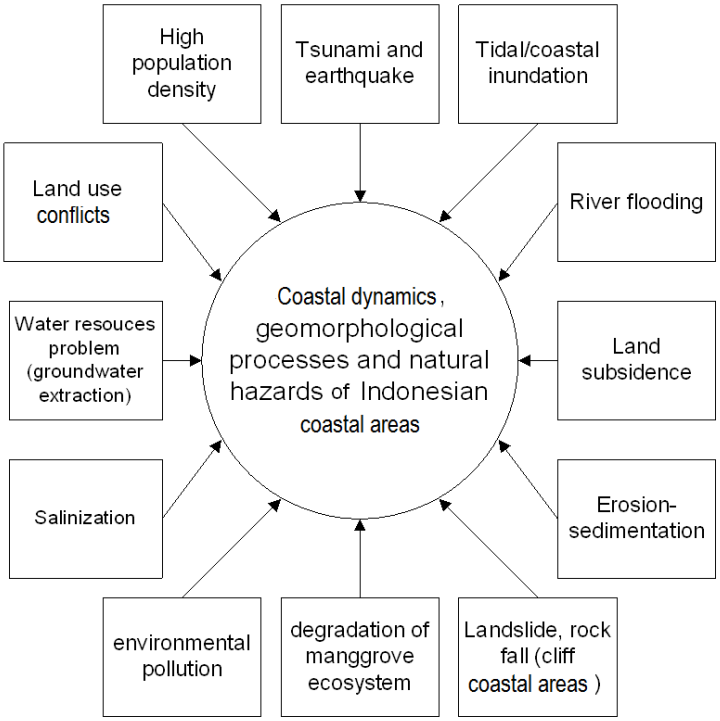

Figure 1. *Geomorphological processes and natural hazards in Indonesian coastal area (summarized from Marfai 2008)*

Data and methodology

Sources of data for this study include literature and previous researches on the study areas including the government policies and mitigation action plans. Primary data were obtained through field visits and observations of the coastal erosion process. In addition informal discussions with stakeholders and local governmental agencies were conducted to obtain data and information, especially pertaining to governmental action plan related coastal management.

Results and discussion

Coastal erosion in Central Java Province is mainly influenced by natural processes such as cross-shore and long-shore sediment movement and due to dynamic water levels at the coastal area, such as the wave action caused by winds, high tides due to astronomical tidal activity, and accelerated sea level rise due to global warming. In addition, coastal erosion may also give influence to shoreline change (Bagli and Soille, 2003; Sunarto, 2004; Mills et al. 2005, Marfai et al. 2008).

The most significant erosion process takes place in Semarang, Tegal and Demak areas. Semarang is one of the biggest cities in Indonesia with a total area of 373 Km^2, a population of more than 2 millions, and located at the northern coast of Java and about 500 km east of Jakarta (Figure 2). In general, Semarang coastal land use consists of agriculture and fishery, residential,

industrial, public and commercial land uses. The coastal erosion processes are most severe in Semarang as can be seen from their impact on the land use, coastal ecology, property and infrastructures the city's low lying areas (Sunarto *et al.* 2001, Marfai *et al.* 2008, Irwani *et al.* 2010).

Marfai *et al.* (2008) has monitored shoreline erosion using the visual interpretation of Topographic maps Year 1908, 1937, 1992 and Ikonos image Year 2003 as well as the digital number value analysis method of the spectral value of the Landsat images Year 1972 and 2001. Overlay techniques were adopted for all the segment maps from 1908 to 2003 to monitor the erosion-sedimentation process along the coast, and three profiles were selected across the shorelines for detail observations.

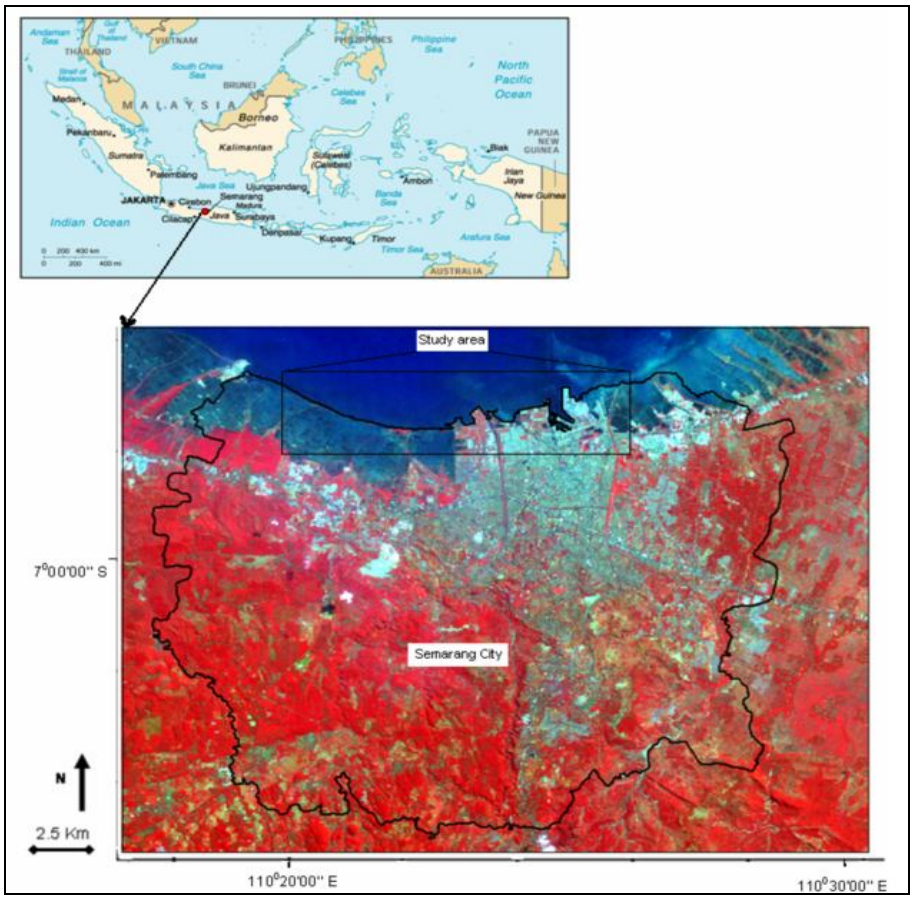

Figure 2. *Coastal areas of Semarang City, Central Java Province, Indonesia*

As mentioned in Marfai *et al* (2008), during the period 1937-1972 significant erosion occurred along the coast of Semarang and during 1972 and 1992 several places had eroded away about 500 meters of coastal land there. During the period of 1992-2001, a partial shift of the shoreline indicates the strong erosion occurred. The erosion process has changed the coastal landscape. As an example, the coastal erosion has occurred for about 461 m backward to the land and led to loss of land in 1972-1992. Several infrastructures, buildings and agricultural areas were damaged thereby.

In order to reduce the risk of coastal erosion in Semarang, the government has implemented structural measures, i.e. constructing walls and wave breakers along the coast. However this measures failed to solve the entire problem of coastal erosion in Semarang. In future, closer

cooperation between government and local community is needed to bring forth better structural and non structural measures to mitigate the erosion threats and protect the coastal environment from further degradation.

Meanwhile, coastal urban Tegal (Figure 3) was also experiencing the adverse impacts of erosion on its land use including fishery, residential, industrial, public and commercial land. According to Sartohadi *et al.* (2009) Tegal's coasts comprise sand larger in grain size and heavier than muddy materials. However, sand is less cohesive and therefore relatively easier to erode and thus leading to environmental degradation. The surface elevation of the Tegal Regency ranges from 0 m up to 925 m above sea level and in general, the shoreline slope is steep which allows for waves to break closer to the coast line and thus enhancing coastal erosion (Yudono 2008).

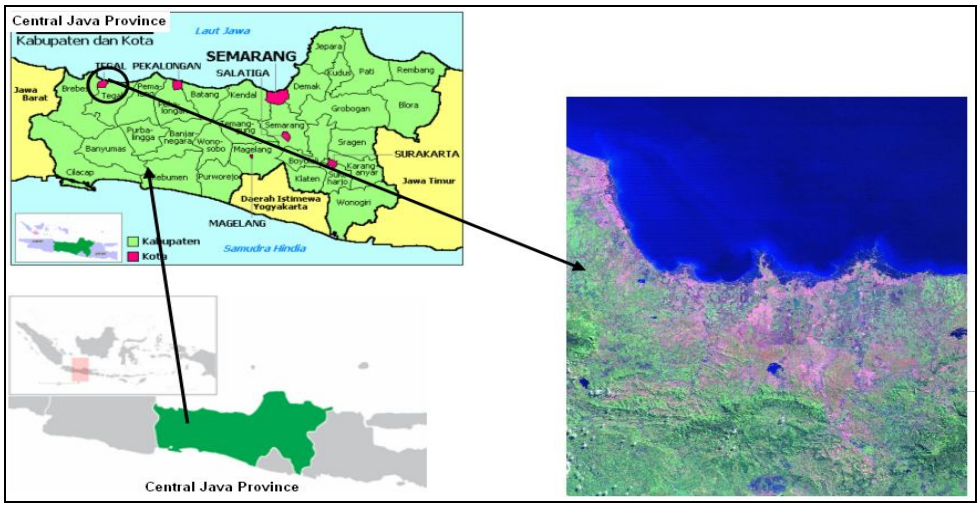

Figure 3. *Tegal coastal areas, Central Java Province, Indonesia (Modified from Yudono 2008)*

Sartohadi *et al.* (2009) has applied the same method adopted by Marfai *et al.* (2008) for coastal change monitoring whereby visual interpretation and delineation techniques of the satellite images detected the erosion along the coastal area of the Tegal city. The result revealed that during the period 1944 to 2005, the shoreline changed and moved landward leading to the increasing degradation on the coastal areas (Figure 4).

Intensive erosion process took place along the coastal area of Tegal. According to Yudono (2008), erosion occured up to 250 m towards the land. This posed a threat to the coastal community in the form of land loss and damage to coastal settlements. Figure 5 exposed the impact of the erosion along the Tegal coastal area. This is in line with the report of the Board of the Environmental impact monitoring / Bapedalda (2002) which put the loss of land due to coastal erosion along the northern coastline at 2,910 hectares in the last five years.

Coastal community in Tegal responded to the erosion problems by mangrove re-forestation and constructing structures such as ripraps, seawalls, jetties and groins. The groins, which the local government built in 2001, had been quite effective in reducing erosion at certain points along the coastline. They had also turned the area into a tourist attraction (Figure 6). Apart from that, forest (mangrove) rehabilitation would go a long way to reduce the erosion threat while producing food for the fish through the photosynthesis of organic matter .

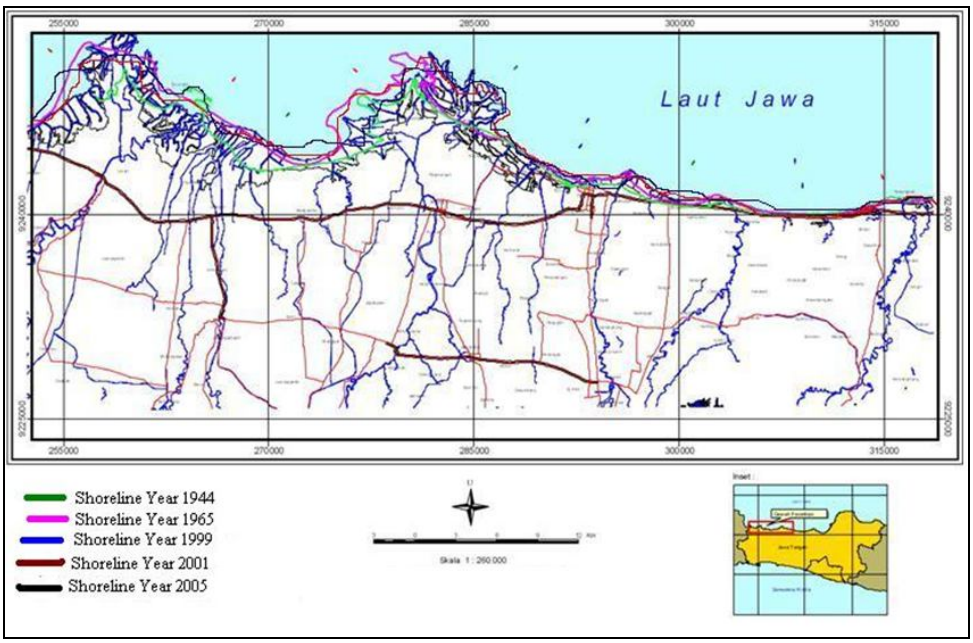

Figure 4. *The shoreline change during the 1944 to 2005 indicating the erosion process along the Tegal coastal area (summarized from Sunarto et al. 2001, Yudono 2008, Sartohadi et al. 2009)*

Figure 5. *Coastal erosion leading to loss of land and permanent inundation in Tegal*

In Demak coastal erosion has become a national issue. Demak is part of Central Java Province , is located side by side with Semarang, and covers an area of approximately 88,743 ha comprising 14 districts and 249 villages (Figure 7).

Here, intensive land use changes of mangrove forests to fishponds and other aquaculture activities had removed the natural barrier of coastal erosion. Moreover, Maulina (2010) mentioned that an extended harbour and beach reclamation in Semarang was also believed to have accelerate Demak's shoreline change. The study detected several points of damage due to Demak's coastal erosion and the shoreline change. At least 200 families had had to be relocated and 300 ha of fishponds had sunk in the process.

Figure 6. *Structure measure/groin (A) and protected coastal area for tourism activity (B)*

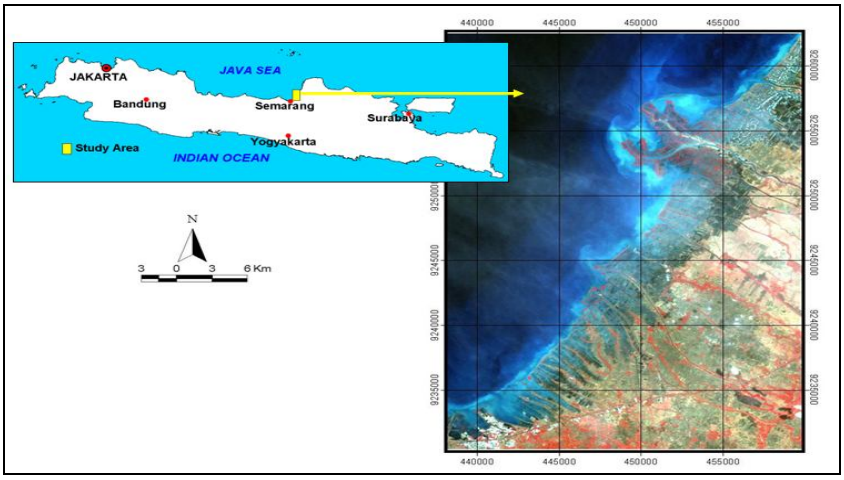

Figure 7. *Demak coastal area from Landsat satellite image (modified from Maulina 2010)*

Maulina (2010) has conducted shoreline monitoring to observe the dynamics of coastal erosion in Demak. Using statistic based approach, she calculated the shoreline change rate and shoreline prediction with the assumption that the shoreline grew linearly. Table 1 lists the scenario and prediction of change of shoreline as impact of coastal erosion and sedimentation during 1972 – 2032.

Local government had strengthened the coordination among governmental agencies to cope with the issue of coastal erosion. Environment Affairs Office of Demak Regency (Kantor Lingkungan Hidup/KLH), Ministry of Marine Affairs and Fisheries Republic of Indonesia (Kementrian Kelautan dan Perikanan), and the Ministry of Agriculture Republic of Indonesia (Kementrian Pertanian) are involve on the coastal mitigation action against erosion process. Local government had also built the dike along the coastal area to block the tide and wave action (Figure 8).

Table 1. Coastal erosion and prediction of the shoreline change dynamic in Demak (1972-2032) (Summarized from Maulina 2010)

Year	Shoreline Length (km)	Length of Change (km)
1972	55	
1982	63	8
1992	56	-7
2002	65	9
2032	56	-9

Figure 8. *Structural coastal defense in Demak*

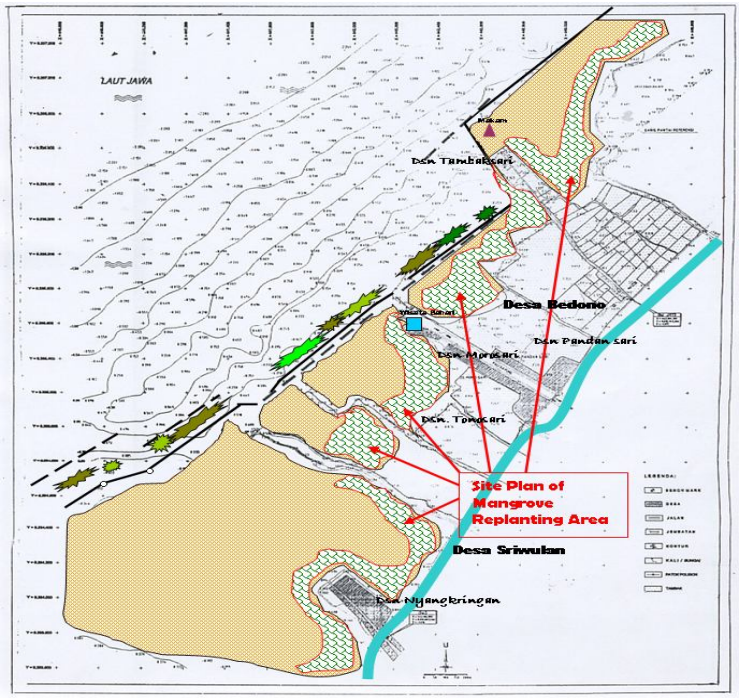

Figure 9. *Mangrove replanting area sketch in part of Demak coastal area (modified from PEDAL Demak 2007)*

Moreover, community and local government had also taken actions to cope with coastal erosion hazard by implementing mangrove replanting even years before the abrasion and coastal erosion got worse. Mangrove replanting programme can revitalize the eroded coastal land by holding the sediment material and reducing the wave energy. However mangrove replanting had been implemented in several areas, and today the local government intends to increase this application of soft engineering by planting the mangrove on the entire Demak coastal zone (Figure 9).

Table 2. Proposed model for coastal zone management against erosion (Summarized from Sartohadi et al. 2009)

Nu	Approach	Function	Structure	Type
1	Hard engineering	Breaking waves and reduce the waves energy	Revetment	Permeable revetment: Rip-rap (open filter material) Stone pitching Concrete block Impermeable revetment
			Seawall	Vertical wall structure
			Breakwater	Overtopping Non-overtopping
		Reduce erosion and suspend the sediment	Jetty	Mono Multi
			Groin	Permeable (over passing) Impermeable (end passing)
2	Soft engineering	Coastal stabilization		Mangrove Reforestation
3	Social engineering	Community development		Community based management and Capacity building Stakeholders coordination and consultation Empowerment of the local groups, etc

In addition, measures were taken to enhance the engagement of community participation in mitigation actions. Increasing the people environmental awareness would also increase their participation in successive management plans. This was being accomplished by conducting training for coastal communities, providing the mangrove seeds to them, explaining the benefits of proper coastal management, and highlighting success stories of abrasion management (Table 2).

Conclusion

Three important Central Java cities of Semarang, Tegal and Demak were facing serious coastal erosion problems. Historical shoreline change analysis provides valuable information on erosion and sedimentation trends, permits limited forecasting of shoreline movement, and contributes to the analysis of the coastal erosion morphological dynamics and processes. While physical and structural mitigation measures have proven effective in Semarang, Tegal and Demak, they could not answer the entire problem of coastal erosion there. The future calls for an integration of hard engineering mitigation measures such as dyke and sea wall construction, soft engineering such as mangrove replanting, and social engineering such as coastal community participation . In other words, the challenge of coastal erosion in Central Java should no longer be treated as merely a city issue but that of provincial government so that mitigation programmes could integrate, coordinate, and engage all stakeholders.

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