Spatial Planning Based on Carrying Capacity: Study of Sustainable Coastal Area Management

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Abstract. The rapid development of industrial sectors, tourism, transportation, and ports, along with human settlement in coastal areas, leading to the deterioration of its environmental qualities. Hence, it requires a plan that able to balance between the development and the environmental conservation of the coastal area to achieve its sustainability, which is to consider the coastal carrying capacity. The purpose of this study is to create an alternative for spatial planning based on the carrying capacity for the space utilization for the sustainability of the coastal area. This study conducted using geographic information system (GIS) based on the land use data in 2008, 2012, and 2017 in the coastal area at Serang Regency, Indonesia. Based on the data, the significant changes shown in the industrial sector, seen from 17% in 2008 to 40% in 2017. The rapid development arises some problems that lead to environmental stress, such as the increase of industrial waste, a reclamation that potentially changes the land structure, as well as the seawater contamination in groundwater. Therefore, best alternative planning is to promote the development of natural tourism by utilizing the existing potential and at the same time conserving the environment quality.

Keywords: Coastal Area; Management; Environmental Conservation; Spatial Planning; Sustainability

1. Introduction

The importance of coastal area existence in recent years has been recognized along with the increasing of populations, rapid urbanization, development of human activities, which exert enormous pressure on the vulnerability of its ecosystem [1]. Coastal and marine ecosystem have 4 fundamental functions for human activities, namely providing natural resources, life support services, amenities, and also natural wastewater treatment [2]. Currently, the coastal and marine area has become the priorities for the development of industry, settlement, tourism, transportation, and ports [3]. The existence of such development due to the coastal area ability to support the dynamic interaction between land, sea, and the atmosphere can change deliberately either naturally or because of the human activities [4]. However, some of the development tend to ignore the issues of its environmental qualities, ultimately lead to the degradation of the coastal environment itself [3].

The ecosystem in the coastal areas known as dynamic natural systems due to its nature to store various advantages as well as the vulnerabilities within [5]. The vulnerability mentioned is climate change related natural disaster such as storm surges, hurricanes, and tsunamis [6]. Human activities can also cause the vulnerability due to the increase in population, uncontrolled development and urbanization that resulted in inevitable conflicts between competing stakeholders to explore the natural resources within the environment [7], collectively pose considerable stress on fragile coastal ecosystems [6]. Despite their potentially life-threatening vulnerabilities, many communities continue to choose to settle in coastal areas due to the highly rich biodiversity,

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abundant fisheries resources, and high mineral content with various benefits [8].

There are two fundamental factors related to land use in the coastal area. The first factor is determination priorities consisting of natural structure, ecological specifications, qualification and potential of its utilization structure. The second factor is the ability to accommodate all activities within, which called the carrying capacity of the coastal area [9].

The concept of coastal carrying capacity based planning will able to determine how well the quality of the users of a coastal area based on natural resources, culture, and location, in order to prevent the degradation of physical, ecological, economic, and socio-cultural structures in the coastal area based on its location and structural type [9]. Towards a low-carbon society's vision in strategy and planning, it is necessary to balance the development and the protection of the environmental quality, particularly in a strategic area such as coastal [10,11].

This Paper discusses the alternative for the coastal area development planning based on the carrying capacity to achieve the balance between development and coastal environmental protection, as a strategy to mitigate vulnerabilities in coastal area in terms of climate change that cause by the rapid development of human activities. This paper using case study of Serang Regency that located in Banten Province, indonesia. The reason for choosing this area because the majority of Serang area consist of coastal that up until now is utilized as industrialization area, beside of tourism and settlement.

2. Methods

This study uses a quantitative approach with the case study in western part of Serang Coastal Area, Indonesia. The shoreline length of this study area ± 177.3 km facing the Sunda Strait, with the limitation of the study location is land use from coastline up to 500 m from the coast.The map of study area location shown in figure 1.

The data used are digitalized data based on Satellite Imagery. All data are plotted in 2008, 2012, and 2017 with the GIS method using ArcGIS 10.3 software. It utilized to analyze the direction of land change. Literature studies and related references are used to support alternative analysis of appropriate utilization based on their carrying capacity.

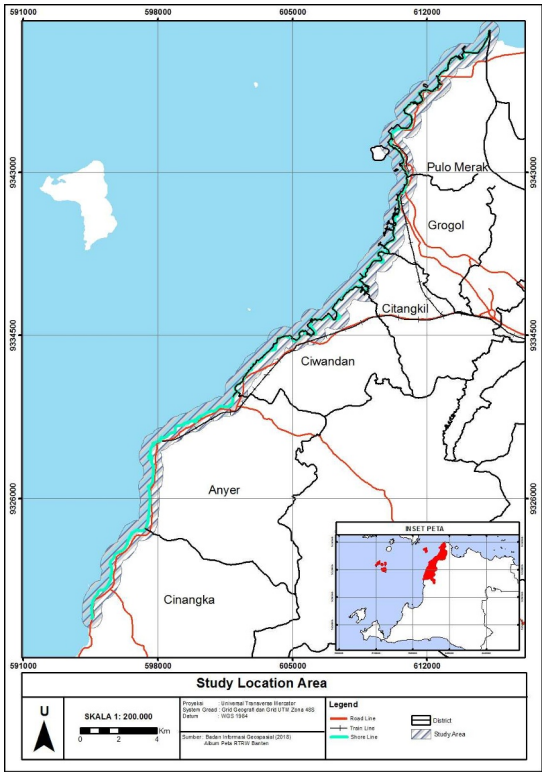

Fig. 1. Map of the study area location

This map represents the western part of Serang coastal Area. It consist of Pulau Merak District, Ciwandan District, Anyar District, and Cinangka District. Anyar and Cinangka is famous for its tourism sector, while Pulau Merak, Ciwandan, and part of Cilegon is famous for the development of industrial sector.

3. Result and Discussion

The coastal area in Banten Province based on its morphology consists of three different group namely the plains, mid-slope hills, and steep hills. Serang region itself mostly consists of mid-slope hills that has 25% of slope and medium-low rough ground texture, a small part of a plateau with a slope of 0-15% on its coast, and steep hills with a slope of > 25% in its southern region [12]. Serang western coastal area (from Bojonegoro to Anyer district) divided into three zones based on its land use, i.e semi-enclosed coastal seas area that dominated by aquaculture, Petrochemical Industry area (from Bojonegoro, Merak, Cilegon, and Ciwandan district), also tourism and agricultural area (from Anyer to Cinangka district) [13]. Figure 2 shown the land use utilization of Serang western coastal area in 2008, 2012, and 2017.

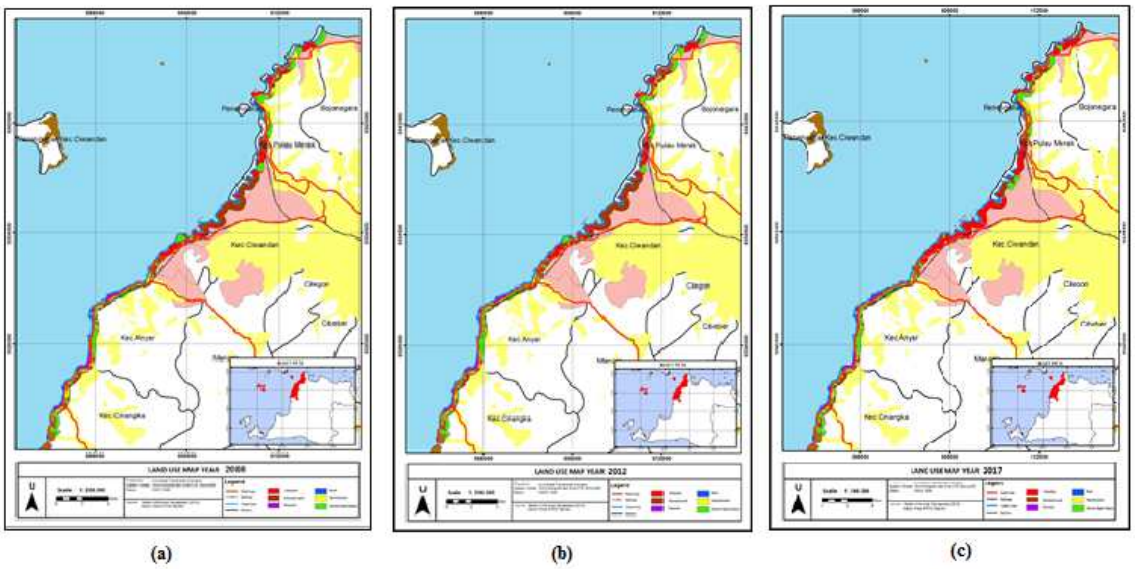

Fig 2. Maps of Land utilization in Serang's Western Coastal area (a) year 2008 (b) year 2011 (c) year 2017

The utilization in Serang western coastal area in recent years has been different and complex, where the shoreline changes due to reclamation that occurs for human activities (i.e., making port or dock) or abrasion and erosion of the sea that visible [13]. Based on the fig.2, changes of the land utilization in the coastal area will be described in table 1 based on its total area per sector.

Table 1. Changes in land utilization at the Western part of Serang Coastal Area in 2008, 2012, and 2017

No	Type of Land Utilization	Total Area in Year (Hectare)		
		2008 (Ha)	2012 (Ha)	2017 (Ha)
1	Industry	424.16	480.85	1,014.62
2	Tourism	204.57	203.84	203.84
3	Green Open Space	670.34	633.63	557.99
4	Unused Land	733.12	701.52	312.08
5	Port	17.76	24.54	32.01
6	Settlement	412.14	430.43	387.20
Total		2462.09	2474.72	2507.74

The significant changes of land utilization based on the table was occurred due to the development of industrial sector, marked by the change from previously 17% (424.16 Ha) in 2008 to 19% (480.85 Ha) in 2012 and becoming 40% (1014.62 Ha) in 2017. The development of the industrial sector also caused a reduction in green open space total area from previously 27% (670.34 Ha) to 22% (557.99 Ha) in 2017. While most of the green open space has also decreased due to deforestation or clearing land for industrial development. This condition was seen from the differences of the total amount of unused land (or clear land) versus green open space, which is 733.12 Ha versus 670.34 Ha in 2008, and decreased into 312.08 Ha in 2017, while the total area of the industrial sector dramatically increased.

The rapid development of industrial sector in coastal area potentially arise some problems that lead to environmental stress, such as the increase of industrial waste (both emission and liquid waste), potential for reclamation that changes the land structure of the region [14], as well as the possibility of seawater contamination in groundwater [15]. The possibility of reclamation occurrence in Serang coastal area has shown in table 1, where there was an expansion of total land area from previously 2462.09 Ha in 2008 to 2507.74 Ha in 2017. Fransisca (2011) study about the level of pollution substances in water based on space utilization in Cilegon (one part of Serang western coastal area) found that the water was contaminated with detergent with the average from 0.283 ± 0.008 mg/l to 0.433 ± 0.018 mg/l, Total Solid Suspended (4.4 ± 0.5 mg/l to 9.9 ± 1.2 mg/l), also industrial waste such as ammonia (from 3.86 ± 0.56 mg/l to 31.43 ± 6.11 mg/l), Nitrite (from 0.36 ± 0.05 mg/l to 8.62 ± 2.39 mg/l), and Zinc (from 27.06 ± 1,80 mg/l to 37.29 ± 0.97 mg/l) [16]. This indicates that the most substances that pollute the water comes from industrial waste within the area. Martosuparno et al. (2017) found a presence of seawater contamination in some of the surface groundwater in Serang western coastal area [17], due to excessive groundwater pumping in the certain area that caused friction in seawater and

freshwater transition zone beneath the soil surface [17,18]. Tresnadi (2014) also stated that the intrusion of seawater caused by an excessive groundwater use in Cilegon, Ciwandan, Citangkil, and Pulo Merak districts, which are well-known as the industrial areas in western part of Serang [18].

Based on its structural area, Serang has a potential to be developed as a natural marine-based tourism destination [19]. But this potential has not fully explored yet, shown by a stagnant development of tourism area from 2008 to 2017 in table 1. Coastal natural tourism is one of the destinations that in great demand, while enhancing local economic growth, creating jobs, improving infrastructure and transportation, also providing comfortable, fresh experience for body and mind to the tourists [20,21]. With good planning and execution, the development of natural tourism would able to protect its natural landscape and preserve the local plants and animals in the ecosystem [21].

Therefore, the possible alternative is focusing on the natural tourism redevelopment in Anyer and Cinangka District. The tourism object in Anyer regency consists of Anyer-Kidul Lighthouse, Sanghiyang Island (marine tourism and cultural/ archaeological reserve), Patra Jasa tourism Park (natural and beach scenery tour), and Anyer Beach [13]. While in Cinangka regency, consist of Karang Bolong Beach, Karang Suaga, Umbul Tanjung (White Sand Beach), Kamasan Fisherman Village, Curug Cikotak and Curug Betung Waterfall [13]. Tabel 2 represent the capability and carrying capacity for tourism development sector in Serang western coastal area based on the study in 2011.

Table 2. Carrying capacity of the Serang Western Coastal Area in Anyer and Cinangka for Tourism Development Sector [13]

No	Criteria	Anyer	Cinangka
1	Ecological Footprint (ha/capita)	1.6928	0.0943
2	Biocapacity (ha/capita)	2.9348	2.9899
3	Carrying capacity in the Area (people/area/day)	1215	4378
4	Total area for tourism sector (ha)	3.038	10.945

Another natural tourism alternative would possible located in Tanjung Lesung Beach. Based from Cahyo (2017) study of coral reef damage in four location in Banten marine area, although has been classified into very bad sub-criteria (between 0 – 24.9%) based on coral reef damage standard criteria by Indonesian Ministry of Environment year 2002, Tanjung Lesung area has the biggest percentage of live coral substrate (16.81%) compared to other area (Liwungan Islan 0.10%, Karang Pamecahan 8.40%, Karang Gundul 11.14%) [22]. Furthermore, with the water condition quality in Tanjung Lesung (table 3) was very ideal to be potentially for coral reef re-growth based on Indonesian Ministry of Environmental standard criteria year 2004, i.e average temperature 25 – 29 ^{o}C, salinity 33 – 34 ppt, pH 7 – 8.5, Dissolved Oxygen (DO) > 5 ppm.

Table 3. Water Quality Measurement in Tanjung Lesung [22]

No	**Parameter**	**Result**
1.	Depth (m)	4 - 8
2.	Temperature (^{o}C)	28.8
3.	Salinity (ppt)	32
4.	pH	7.97
5.	DO (ppm)	12.3

This condition can be adequate for the proposal of coral reef conservation tourism or diving tourism in Tanjung Lesung as another coastal area natural tourism. However, the idea of diving tourism proven to be riskier that the conservation, due to the vulnerability of coral reef itself that potentially will be disturbed by the presence of divers. Several studies of the impact of diving tourism show that activity of divers can cause a raising in sediment, and also frequent contact to the coral reef (by the divers) have caused stress to the reef that leads to its deterioration [23]. Also, the use of sunscreen and insect repellant by divers causes coral reefs infected with viruses that cause coral bleaching [24].

4. Conclusion

Based from the data, it can be concluded that the significant changes of land utilization based on the table was occurred due to the development of industrial sector, marked by the change from 17% in 2008 to 40% in 2017. The development caused a decrease in green open space due to clearing land for the development of the industry, shown by the total amount of unused land (or clear land) versus green open space, which is 733.12 Ha versus 670.34 Ha in 2008, and decreased into 312.08 Ha in 2017, while the total area of the industrial sector dramatically increased.

The rapid development of industrial sector in coastal area potentially arise some problems that lead to environmental stress, such as the increase of industrial waste proven by the high concentration of chemical substances (i.e ammonia, nitrite, and Zinc) in some area near the coast, a reclamation that potentially changes the land structure and qualities within (proven by the addition of total land area in 2008 (2462.09 Ha) to 2017 (2507.74 Ha), as well as the seawater contamination in groundwater.

Therefore, preferable alternative development based on the carrying capacity in Serang coastal area including the redevelopment of tourism in Anyer and Cinangka regency, and also the coral reef conservation tourism in Tanjung Lesung Beach.

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