The Implication of Shoreline Changes on Spatial Planning -A Case Study in Semarang Municipality and Demak Regency Coastal Area-

The Implication of Shoreline Changes on Spatial Planning - A Case Study in Semarang Municipality and Demak Regency Coastal Area-

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Abstract

A Shoreline recession that occurred in both Semarang Municipality and Demak Regency, two adjacent administrative areas, causes in physical, economic, and social influences, such as the loss of many fish ponds, rice fields, and the damage to settlements, buildings, and infrastructures. This study set three objectives to have sustainable land use planning on both study areas. 1) Analyze the shoreline change and the coastal land use conversion in the study area. 2) Analyze the suitability of the actual coastal land use and the current regional spatial planning documents. 3) Propose a strategic direction toward the suitable coastal spatial planning policy. This study used both quantitative and qualitative approaches. In the quantitative approach, the shoreline change and the coastal land use conversion were analyzed by using satellite image data. This approach also analyzed the suitability of the actual coastal land use based on the current regional spatial planning documents. In the qualitative approach, SWOT analysis was employed to formulate the strategic direction of the coastal spatial planning policy. This study cleared that the shoreline recession has implicated the coastal land use change on Semarang Municipality and Demak Regency. Their actual land use are inconsistent with the current spatial planning documents that have been formulated before. Based on these discussions, this study proposed a strategic direction for suitable coastal spatial planning.

Keywords: shoreline change, land use change, remote sensing, spatial planning, strategic direction

1. INTRODUCTION

The shoreline change caused by coastal erosion or accretion is one of the concerns relating to a coastal land use planning. Some reasons cause the shoreline change, such as coastal developments or the increase of wave action due to climate change[1), 2), 3)]. Many pressures come from natural phenomena and human activities will continue to influence landscape dynamics on coastal area[4)].

Semarang Municipality and Demak Regency, the research area of this study, are suffering from the problem caused by the shoreline change, because the shoreline change is generating physical, economic, and social influences, such as the loss of many fish ponds, rice fields, and the damage to settlements, buildings, and infrastructures[5)].

Some administrative problems often appear when the shoreline change causes a conflict between the existing spatial plan and a future land use. In the study area, the shoreline change is proceeding at a higher rate per year, and this situation makes the conflict more serious, and it also makes the optimization of coastal spatial planning difficult.

Through the above background, this study set three objectives. Firstly, shoreline changes and coastal land use conversions in the study area are analyzed by using satellite image data that were taken in 1991, 2011, and 2019. Secondary, this study analyzes the suitability of actual coastal land use with current spatial planning documents. Thirdly, this study proposes a strategic direction to renew the coastal spatial planning policy in the study area.

Many previous researches have been studying relations between shoreline changes and land use planning. Ferdiansyah used a quantitative method to clear the shoreline change from satellite image data[6)]. The result includes some implications for the problem between shoreline changes and spatial planning in Brebes Regency.

2. RESEARCH DATA AND METHODS

2.1 Research area

This study set two research fields on Central Java Province, Indonesia, one is Semarang Municipality and Demak Regency (Figure 1). They are bordered physically and administratively, and have potential as a strategic zone for the economy in Central Java. The fields are divided into eight coastal sub-districts, named as Tugu, Semarang Barat, Semarang Utara, Genuk, Sayung, Karang Tengah, Bonang, and Wedung.

The ground level of each district is ranged from 0 m to 10 m above the sea level, they are vulnerable against the coastal erosion. Besides, they are experiencing land subsidence and tidal inundation[7)]. Each administration shows the guideline for their land use, but unexpected land uses are proceeding especially in the protection zone and buffer zone. Also, land use conversions lead to the increase of pollution, and it further accelerate inappropriate land use, too.

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Semarang Municipality and Demak Regency had already issued their regional spatial planning from 2011 to 2031, but the concept of them seems weak in controlling the planning.

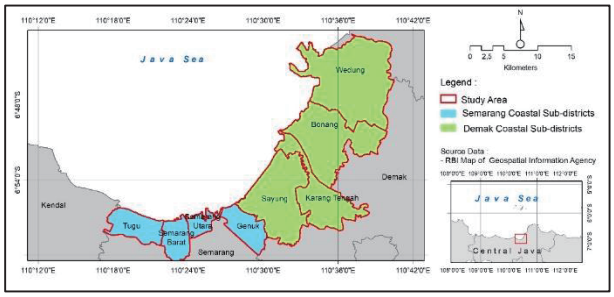

Fig. 1. Location of Semarang Municipality and Demak Regency

2.2 Data

As the primary data, this study uses Landsat Satellite Imagery taken in 1991, 2011, and 2019 provided by the U.S. Department of The Interior U.S. Geological Survey, USGS[8]. Also, the Regional Spatial Planning Document from 2011 to 2031 issued by Semarang Municipality[9] and Demak Regency[10]. The interview survey was conducted for local government agencies, academic specialists, NGOs, and local people to investigate concerns about the current spatial planning.

There are many researches that investigate the coastal topography change using satellite image data and numerical analysis. Tarigan *et al*. applied three formulas, BILKO, AGSO, and Tresholding, to determine the shoreline position by using Landsat image data[11]. Meilistya *et al.* also applied a numerical analysis to detect waves and current that explain coastal erosion conditions[12].

Meanwhile, the secondary data include tidal data and sea wave data in 1991, 2011, and 2019 provided by Indonesian Agency for Meteorological, Climatological and Geophysics, Document of Zoning Plan of Coastal Area and Small Islands of Central Java Province 2018-2038, supporting data from the Central Bureau of Statistics, and RBI Map from Geospatial Information Agency[13), 14].

The sea wave data were obtained at two stations, Station No.1 at Sayung Sub district, Demak 110° 29' 39.560"E 6° 53' 14.070"S, and station No.2 at Tugu Sub district, Semarang 110° 20' 17.510"E 6° 56' 33.430"S. The observation was carried out for two days at each station for 24 hours with a record every 20 minutes. This survey determines the significant wave height, H_s, and significant wave period, T_s. The wave data are used to calculate the longshore current velocity[15].

2.3 Methods

This study uses quantitative and qualitative approaches. In quantitative approach, the shoreline change and the coastal land use conversion were analyzed by using satellite image data in 1991, 2011, and 2019. The radiometric calibration and geometric correction were done by using image processing software. The shoreline position was detected by digitizing the boundary between sea and land on images. The land use was also detected by investigating the difference of colors on images. These methods are common for monitoring the coastal environment and development [16), 17].

The shoreline positions were extracted by BILKO algorithm provided by Training and Education in Marine Science Programme, UNESCO[18]. This method takes the temporal tidal level into analysis. The shoreline position on all images was corrected to H.H.W.L, Highest High Water Level, based on the tidal component analysis[19]. Table-1 shows the tidal elevation when the images were recorded.

Table-1. Tidal elevations when the images were taken

No	Type of Landsat	Image Recorded Elevation (cm)	H.H.W.L. (cm)
1	5 TM 1991	179	247
2	5 ETM+ 2011	184	246
3	8 OLI 2019	208	255

This study analyzes the suitability of the actual coastal land use and the current regional spatial planning documents by overlaying them.

The qualitative approach was carried out by conducting the hearing survey to stakeholders who are engaged in the coastal land use and its planning, where 9 from local government agencies, 2 from academic specialists, 2 from NGOs, and 3 from local people. There were 7 categories in this hearing survey, and each category consisted of some questions. The hearing category is showed in Table-2.

Table-2. Category of hearing survey in this study

No.	Category of hearing survey	Number of questions
1	Spatial planning in coastal area	4
3	Issues in coastal spatial planning	3
2	Conservation and mitigation	3
4	Community empowerment	3
5	Policy and law enforcement	3
6	Integrated coastal management	4

Based on the analysis of hearing survey, this study proposes the formulation of a strategic direction to renew the coastal spatial planning policy. The study employs SWOT analysis, where it investigates Strengths, Weaknesses, Opportunities, and Threats observed in a project. This study lists the strengths, weaknesses, opportunities, and threats observed in the research area, where all items are picked up from hearing survey and field observation.

3. RESULTS AND DISCUSSIONS

3.1 Shoreline changes along study area

From the analysis of satellite images data in 1991, 2011, and 2019, the shoreline changes at Semarang Municipality and Demak Regency are shown in Fig. 2 and Fig. 3.

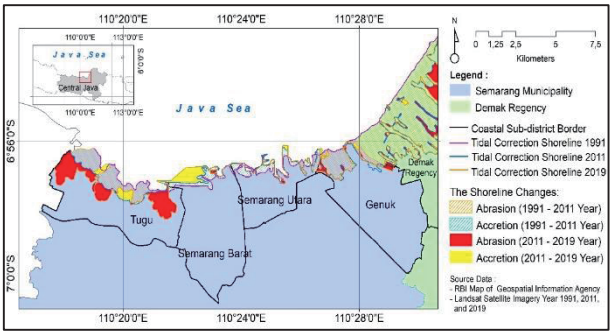

Fig. 2. Map of shoreline change in Semarang Municipality from 1991 to 2019

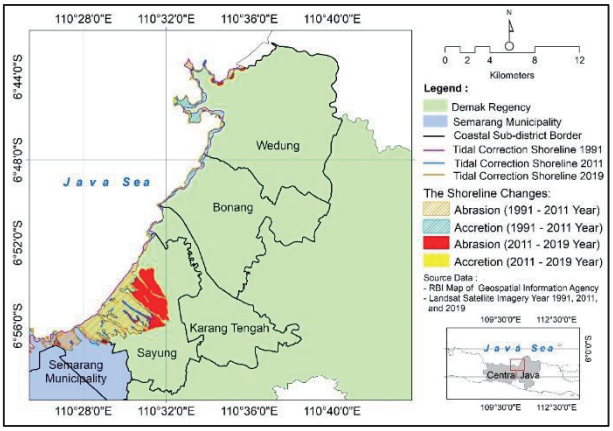

Fig. 3. Map of shoreline change in Demak Regency from 1991 to 2019

From the wave measurements at St.1 and St.2, H_s=0.95m and T_s=3.57s. and H_s=1.07m and T_s=3.29s., respectively. The kinds of sediment at two stations were reported silt and sand based on Document of Zoning Plan of the Coastal Area and Small Islands of Central Java Province 2018-2038[20]. From these data, it is assumed that the study area has the potential to abrasion.

Semarang Municipality had the shoreline change due to the abrasion of 1416.38ha from 1991 to 2019, where an annual abrasion rate was 50.58ha/year. The accretion was 597.48ha and the rate was 21.39ha/year. The most severely affected area was Tugu Sub-district, during the 1991-2011 and 2011-2019, there were about 489.61ha and 485.57ha abrasion, respectively.

From 1991 to 2019, Demak coastal area had 2947.75ha abrasion with the rate of 105.28ha/year. The accretion was 746.75ha and the yearly rate was 26.67ha/year. Sayung Sub-district showed considerable erosional from 1991 to 2011 and from 2011 to 2019. About 92.43% of total abrasion, 2724.51ha, had lost in Demak Regency.

The abrasion and accretion in these coastal areas are due to natural factors and human activities, where natural factors relate to waves, tide, longshore currents. Human activities relate to reclamation of Marina beach in Semarang, the development of the Tanjung Mas port area, and the development of the industrial area in Tugu Sub-district. Anthropogenic affected the coastal dynamics in these regions[21), 22)].

3.2 Land use changes

The existing satellite images data of 1991, 2011, and 2019 were used to analyze the actual land use area and land use conversion. The land use area of each category at Semarang Municipality and Demak Regency from 1991 to 2019 are reported in Table-3 and Table-4.

Table-3. Land use area of each category at Semarang Municipality from 1991 to 2019

No	Category of Land use	Area (ha)		
		1991	2011	2019
1	Airport	44.79	154.09	201.37
2	Port	172.41	347.03	332.91
3	Industry	476.79	779.97	888.49
4	Mangrove	9.19	59.12	204.64
5	Settlement	2918.18	4189.71	4359.87
6	Rice field	1846.89	849.99	687.05
7	Fish pond	2604.10	1726.149	993.61
8	River	52.98	59.63	59.95
9	Vacant land	802.19	196.446	374.54
10	Sand	38.09	0	0

Table-4. Land use area of each category at Demak Regency from 1991 to 2019

No	Category of Land use	Area (ha)		
		1991	2011	2019
1	Industry	112.10	272.99	347.52
2	Mangrove	128.89	181.26	569.21
3	Settlement	2377.50	3169.76	3443.19
4	Rice field	24742.22	18075.16	16296.24
5	Fish pond	8002.44	12903.58	12563.70
6	River	472.19	539.13	417.51
7	Sand	303.77	303.42	32.08

A validation test was performed by using an accuracy test matrix[23] to verify the accuracy and validity of land use maps generated from the satellite image data. The result showed that the image deviation was 7.3%, and 92.7% accuracy rate was confirmed.

The land use conversions at Semarang Municipality and Demak Regency from 1991 to 2019 are depicted in the Fig. 4 and Fig. 5. From 1991 to 2019, Semarang coastal area had significant land use changes in the category of fish pond, mangrove, and rice field. The fish pond area decreased 1610.49ha from 1991 to 2019 due to 1156.41ha abrasion. The

interview with some fish farmers in Tugu Sub-district said that the conversion of rice fields into fish ponds during 1991-2011 and 2011-2019 of 381.16ha and 82.28ha, respectively caused by fish pond preference, and saltwater intrusion. The mangrove area was increased to 195.45ha from 1991 to 2019 in Tugu Sub-district. This was due to the community awareness in coastal protection, as well as many coastal rehabilitation programs by governments and NGOs.

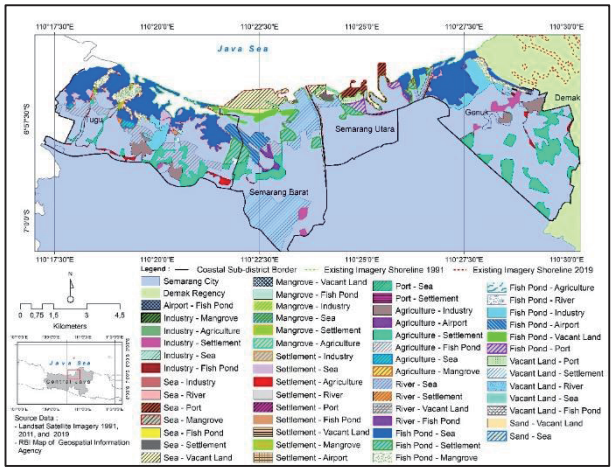

Fig. 4. Land use conversion at Semarang Municipality from 1991 to 2019

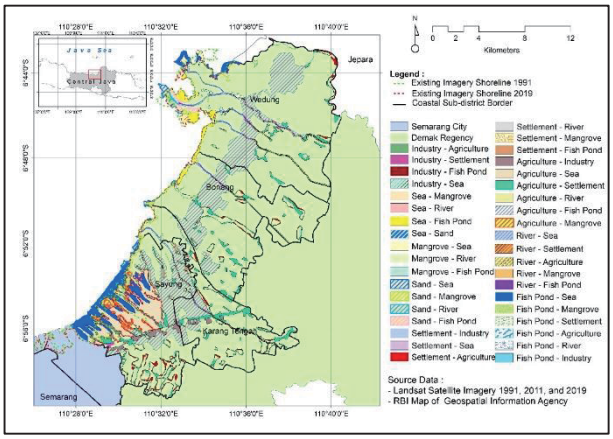

Fig. 5. Land use conversion at Demak Regency from 1991 to 2019

In Demak Regency, the land use change can be seen in the category of fish pond, rice field, and mangrove. Fish pond area had been increased about 4561.26ha from 1991 to 2019. The rice field was decreased 8445.98ha in the same period. This is due to the land use conversion into fish ponds, 5220.10ha from 1991 to 2011 and 1609ha from 2011 to 2019.

A large scale of land use conversion from rice field to fish pond had occurred since 1980s with economic reasons. Also, the rice field inundated by sea water due to sea level rise and land subsidence that resulted in conversion. The increase of mangroves area is 440.32ha from 1991 to 2019, and this is due to the people's awareness of their environment conservation.

3.3 Implication on spatial planning

Fig. 6 and Fig. 7 show the suitability maps of the actual land use based on current spatial planning document in Semarang Municipality and Demak Regency, respectively. The maps were drawn by regarding both the actual land use and how to use land in future.

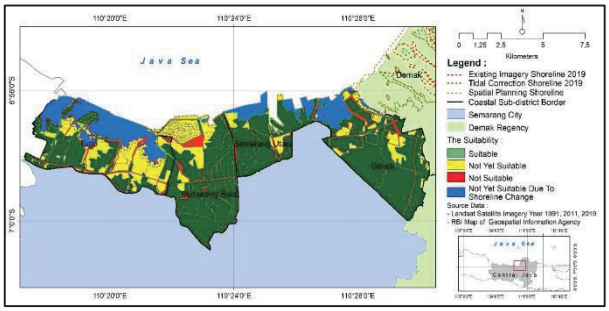

Fig. 6. Suitability map of actual land use based on current spatial planning document in Semarang Municipality

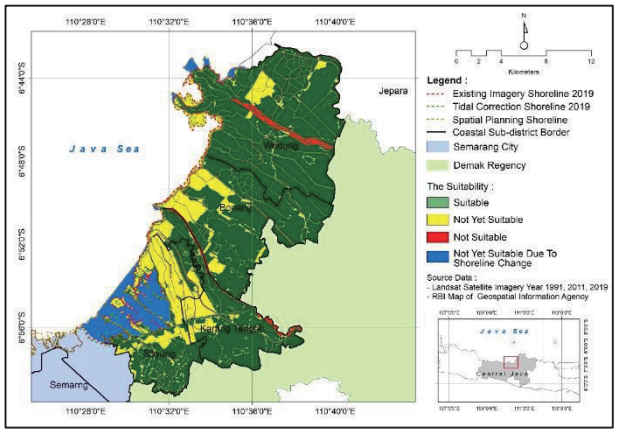

Fig. 7. Suitability map of actual land use based on current spatial planning document in Demak Regency

Table-5 and table-6 show the unsuitability of land use in comparison with the current spatial planning document due to shoreline change.

Table-5. Unsuitability of land use in comparison with the current spatial planning document in Semarang Municipality

Category of land use in spatial planning	Area (ha)	Percentage (%)
Industry	233.21	15.52
Fisheries	197.68	13.15
Agriculture	0.58	0.04
Trade and services	9.33	0.62
Settlement	110.82	7.37
Tourism	319.96	21.29
Transportation	274.36	18.25
Road plan	27.58	1.83
Local conservation	142.65	9.49
Protected conservation	125.73	8.37

Table-6. Unsuitability of land use in comparison with the current spatial planning document in Demak Regency

Category of land use in spatial planning	Area (ha)	Percentage (%)
Horticulture	1.48	0.05
Industry	2130.64	77.14
Fisheries	136.48	4.94
Settlement	182.17	6.60
Beach buffer zone	224	8.11
River buffer zone	32.95	1.19
River	54.24	1.96

The discrepancy of the land use can be seen between actual land use and the land use described in the current spatial planning document. In Semarang Municipality, 59.09% of the actual land use matches the land use described in the current spatial planning document. In Demak Regency, 66.71% of the actual land use matches the current spatial planning.

The significant shoreline changes in both regions generated the inconsistency of the land use., In Tugu, Semarang Utara, and Genuk Sub-districts in Semarang Municipality, the land use categories in industrial, fisheries, tourism, local conservation, transportation, and protected conservation areas showed larger rate. The land use for fisheries, industrial, and tourism were affected by 197.68ha, 233.21ha, and 319.96ha. The protected conservation areas along the coastline was also affected 125.73ha. Tanjung Mas Port and Ahmad Yani Airport Semarang indicated 274.36ha due to their development.

In Demak Regency, Sayung Sub-district had impacted 2130.64ha by industrial development. The coastal buffer zone and fisheries zone were affected about 224ha, and 136.48ha, these occupied the largest portion of land use inconsistency in Sayung and Wedung Sub-districts.

The reason of above land use changes was spread to improve the economy in those areas. For example, increase of regional income, provide prosperity of coastal communities, and increase of business opportunity. The coastal development to achieve above purposes generates the inconsistency of land use condition. Furthermore, some of the urban villages in Semarang and Demak were determined as the Environmental Services Center, such as Mangunharjo Village (Tugu Sub-district), Terboyo Wetan Village (Genuk Sub-district), and Gemulak Village (Sayung Sub-district), to serve economic activities in sub-district scale. The threat of shoreline changes will affect the optimization of the environmental services in these regions.

3.4 Strategic direction of coastal spatial planning

To formulate the strategic direction for the policy of coastal spatial planning, SWOT analysis was used to identify various factors that should be included in the policy. The strategic direction covers four dimensions of sustainable development, including technical-ecological, socio-economic-cultural, socio-political, law and institution aspects (See Table-7).

Table-7. Identification of Strengths, Weaknesses, Opportunities, and Threats elements

Ecological	Socio-economic-cultural	Socio-politic	Law and Institution
S: land potential for fish pond allocation, settlement, industry, and conservation	S: coastal community awareness to shoreline protection	S: stakeholders involvement in coastal spatial planning	S: Semarang and Demak regional spatial planning documents
W: high rate of shoreline changes	W: budget constraints to coastal protection	W: there is no mechanism for stakeholders involvement	W: ineffectiveness of spatial planning documents
O: Semarang and Demak as National Strategic Area	O: strong support in coastal management program	O: Law Number 23 Year 2014 On Local Government	O: Presidential Regulation Number 78 Year 2017 On Spatial Planning For Urban Area of Kendal, Demak, Ungaran, Salatiga, Semarang, and Purwodadi (Kedungsepur)
T: natural phenomena and human activity	T: high in demand for coastal land use	T: sectoral and regional ego	T: no regulations related legally agreed shoreline

Table-8. Grand strategy formulation of SWOT elements

	Strengths	Weaknesses
Opportunities	SO: 1. Implementation of integrated coastal spatial planning, and active involvement of all relevant stakeholders; 2. Space allocation for fish pond, conservation, settlement, and industry which integrated into the regional spatial planning document;	WO: 1. As National Strategic Area, the development focused to open opportunities for private investors, and conservations; 2. Provide participation, and control mechanisms for stakeholders in coastal spatial planning;
Threats	ST: 1. The use of legally agreed shoreline in regional spatial planning documents to avoid conflicts between activities and regions; 2. Regional governments coordination in anticipating global climate change, high demand for coastal land use, and irresponsible development;	WT: 1. As National Strategic Area is expected to solve budget constraints, global climate change, and the high needs of coastal land; 2. Provide an integrated mechanism for stakeholder participation to reduce sectoral and regional egos; 3. Law establishment on the use of legally agreed shoreline.

Table-8 shows the process of arranging SWOT elements by cross technique of the four factors to

formulate grand strategy. Base on the Table-8, the functional strategy will be formulated to generate final strategies[24]. This study leads following main aspects, from (1) to (5), to conclude the strategic direction of spatial planning in study area.

(1) Legal aspect:
   1) Development of integrated coastal spatial planning model and active stakeholder engagement refer to the Kedungsepur (Kendal, Demak, Ungaran, Salatiga, Semarang, and Purwodadi) Spatial Planning.
   2) Establish a law that treats the ownership of the lost land by the shoreline change.
   3) Establish a policy that facilitates a license for investors who prioritize the environment.
   4) Recommend to the central government to establish a new policy that relates to a legally agreed shoreline in regional spatial planning.

(2) Physical aspect:
   1) Allocation of coastal area for various development purposes (fish pond, settlement, industry, and conservation) which integrated into the City of Semarang and Demak Regency Spatial Planning Documents, and consistently implemented with the clear support of rules to avoid conflict.
   2) Provide facilities and infrastructures for coastal protection against disasters.

(3) Institutional aspect:
   Provide a transparent mechanism for the regional government, and stakeholder in participation and supervision towards Regional Spatial Planning Documents implementation, in anticipating global climate change, also avoid conflict of sectoral and regional activities, and egos.

(4) Socio-cultural aspect:
   Provide a coastal community agency to accommodate coordination between the government and the coastal community in deal with conservation programs, environmental sustainability, environment awareness campaign, and the future risk in coastal area.

(5) Financing aspect:
   As national strategic area, it is expected to become primary priority in budgeting, and to open investment opportunities for the private sectors to attract funding, especially in order to develop and protect the coastal area of Semarang Municipality and Demak Regency.

The main aspects of legal, physic, institutional, socio-cultural, and financing play an important role to identify the specific strategy. The strategic direction of the spatial planning on coastal area can be derived as items listed in above main aspects. The direction is including the integration of sectors between land, coastal and marine, integration of stakeholders and coastal administrative. Also, it is including preparation of integrated spatial management mechanisms, environmental conservation, coastal community empowerment, budgeting, legally agreed shoreline, resolution of land status problems, and law enforcement. These strategic directions are expected to be included in the next spatial planning to optimize the current plan.

4. CONCLUSIONS

This study identified the shoreline changes in the coastal areas of Semarang Municipality and Demak Regency from 1991 to 2019. The results indicate a large shoreline change along the coastal areas of Semarang Municipality and Demak Regency.

The shoreline changes affected the land use conversion in study area. The actual land use showed the significant inconsistency with the land use that was defined in the current spatial planning document. The shoreline changes were caused by many coastal developments that were required from some sectors to facilitate their economic growth. This indicated the necessity of strategic direction for an appropriate coastal land use planning.

This study conducted SWOT analysis to show the strategic direction for the appropriate land use on coastal area. Five main aspects were derived in this study, and formulated the items of recommendation for the strategic direction of spatial planning in study area.

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