MODELLING THE PROJECTION OF CLIMATE CHANGE IMPACT ON SHORELINE RETREAT: REMOTE SENSING APPROACH

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ABSTRACT: One of the climate change impact that should be alert by archipelagic state such as Indonesia, is the sea level rise. Sea level rise affects the existence of natural resources as well as human resources. Shoreline retreat and inundation are some impacts that can occur in the future along the coastline. Other problems derived as the impact of climate change such as tidal wave, and tidal flood can worsen the effects of sea level rise. Even, the human pressure on exploiting the nature system, such as urban development and ground water utilization will worsen the impact on existing shoreline. Therefore, taking a study area at Jakarta Bay, it is necessary to develop a spatial model to estimate the shoreline retreat along the coast. The model was developed based on remote sensing multi date analysis in comparison with shoreline retreat model developed using tidal data assessment. The result of remote sensing analysis indicates that the shoreline retreat and inundation occur within the area in contrast to the reclamation project. Reclamation project make the shoreline retreat assessment cannot be accurately examined. The other research on land subsidence justifies the inundation of the coastal area related to shoreline retreat. It seems remote sensing derived model is a good tool for depicting future scenarios of shoreline retreat not only caused by climate change but also by human induces factors.

I. INTRODUCTION:

One of the most pronounced effects of climate change has been melting of masses of ice around the world. It believes may cause the phenomenon of sea level rise. Sea-level rise can affect coastal communities and habitats in a variety of different ways, including submerging low-lying lands, eroding beaches, converting wetlands to open water, intensifying coastal flooding, and increasing the salinity of coastal and freshwater aquifers. It is caused by a number of natural and human-induced factors and can vary by region. Locally, sea-level rise is also influenced by changes to the geology of coastal land and human induce factors in utilize the resources beneath. This will worsen the effect of sea level rise on coastal area. As an archipelagic state that has more than 81.000 km coastline, the effect of sea level rise should be taken into account in planning the country development.

To study the impact of sea level rise to the coastal environment, the role of remote sensing data has been put into trial. In the manner how far the remote sensing data has been contributed such information regarding the shoreline retreat and in how it will be used for future projection. This information is urgently needed due to the remote sensing ability to capture the widely remote ground features with or without terrestrial test. Therefore, this study is aim to assess role of remote sensing data in supporting the shoreline retreat model. The Jakarta bay was used for the study area regarding the complexities of human activities in degrading the nature that will give ascent to the impact of sea level rise, especially in retreating and inundating the coastal area.

II. METHOLOGOGY

The development of the model may consist of: (1) Assessing the remote sensing method in determining the shoreline retreat, (2) Assessing the tidal gauge data for determining the shoreline retreat in compare to the remote sensing data, (3) Assessing the secondary data and the possibility of remote sensing data to become an input to the shoreline retreat projection.

2.1. Assessing the remote sensing method in determining the shoreline retreat.

Remote sensing may become a good tool to indicate the changes of earth features due to its synoptic and multi date coverage system. Indeed, it may give support to indicate the changes of coastal area not only by sea level rise but also other human or nature catastrophic. Dealing with the sea level rise, various methods for coastline assessment from optical imagery have been developed. Coastline can even be extracted from a single band image, since the reflectance of water is nearly equal to zero in reflective infrared bands. Experience has shown that of the six

reflective TM bands, mid infrared band 5 is the best for extracting the land-water interface (Kelley, *et al.*, 1998). Band 5 exhibits a strong contrast between land and water features due to the high degree of absorption of mid-infrared energy by water and strong reflectance of mid-infrared by vegetation and natural features in this range. Of the three TM infrared bands, band 5 consistently comprises the best spectral balance of land to water (Alesheikh *et al.*, 2007).

The dynamic and complex land-water interaction makes the discrimination of land-water features less certain. The mixed pixels and moisture regimes between land and water makes the coastline boundaries remain unclear. Therefore, to find the exact value, ratioing methods for selected bands were selected for this study. Band ratio between band 4 and 2 and also, between band 5 and 2 were being examined. With this method water and land can be separated directly.

The method for coastline change detection was consisted of employing histogram threshold on one of the infrared band of multi date optical imageries. Follow by ratioing of infrared bands and visible green bands and subtraction of the derived ratioing images to indicate the coastline change or shoreline retreat. Finally, cross-examined the result with the shoreline retreat defined by tidal data assessment and so did other secondary data relating to the inundation of the coastal area.

The remote sensing data that were used for this study assessment Landsat MSS data of Jakarta Bay (1976), Landsat TM data of Jakarta Bay (2002), ETM^+ of Jakarta Bay (2006) dan ETM^+ of Jakarta Bay (2011). The process of remote sensing data for determining the shoreline retreat may describe as follow;

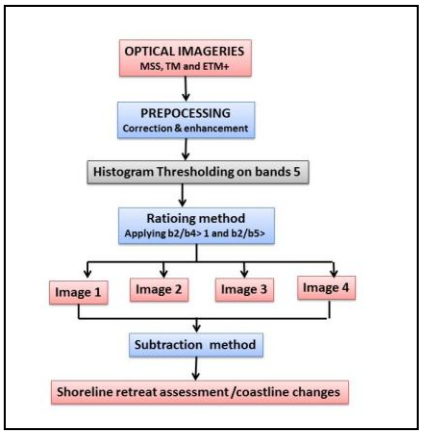

Figure 1. Flowchart of extracting shoreline retreat from images

2.2. Assessing the tidal gauge data for determining the shoreline retreat

The tide gauge data of at least 20 years was used for assessing the trend of sea level rise in Jakarta Bay. The study was exercised using Mean sea level (MSL) as the vertical references data. The MSL data were being obtained by calculating the daily average tidal data from Tanjung Priok tidal gauge station. Harmonic analysis with least square method was used to get the average MSL (Z_0),, trend of the rise (change) (a) and its regression formula.

The trend of sea level rise data then become an input for establishing the shoreline retreat within the study area. For finding out how far the shoreline retreat will be occur due to the sea level rise affect, the shoreline retreat model that was developed by Sutrisno (2005) was being exercised. The formula was explained as:

$$R = \left[(\Delta Z - \Delta S)L\right]\left(h + D + \Delta Z\right)^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

whereas R = shoreline retreat (m), ΔZ = sea level rise (m), ΔS= sedimentation and other factor based on field observation or other study (m), L = the length of sandbars up to the delta front (m), the depth in L (m), D= coastal elevation (m)

The data that was needed for this assessment is the base map of the study area, consist of topographic map of Jakarta bay scale 1: 25.000, bathymetry data from coastal map scale 1: 25.000 and field observation, geology map of Jakarta bay, sedimentation and land subsidence data from other study.

2.3. Assessing the secondary data and the possibility of remote sensing data to become an input to the shoreline retreat projection

The shoreline retreat data that was obtained from remote sensing analysis and shoreline retreat model that was developed from shoreline retreat model (Sutrisno 2005) were being compared. Other input dealing with the inundation data and other information were also engaged to achieve accurate information in utilizing the remote sensing data as an input to the shoreline retreat projection model.

III. RESULT AND DISCUSION

Jakarta is one of many other coastal cities in the world that needs to adapt to survive from the global warming. Despite of the rapid urban development, Jakarta look out several environmental problems including sea level rise, land subsidence and salt water intrusion. It means, the shoreline retreat along the Jakarta coastline is not a simply single factor but the combination of those. Therefore, the phenomenon of sea level rise in Jakarta bay was a constituted of the combination of relative and *eustatic* sea level rise rather than the simply *eustatic* one as a consequences of global warming.

The coastline change detection model using multi date Landsat data of Jakarta bay may indicate the problems of those. The threshold values have been chosen such that all water pixels are classified as water, and most of land pixels have been classified as land. In this case, water pixels are then assigned to one and land pixels to zero. Using the band ratio between band 4 and 2 for MSS, and also, between band 5 and 2 for TM and ETM can result in water-land discrimination. Figure 2 illustrates the result of land-water developed technique.

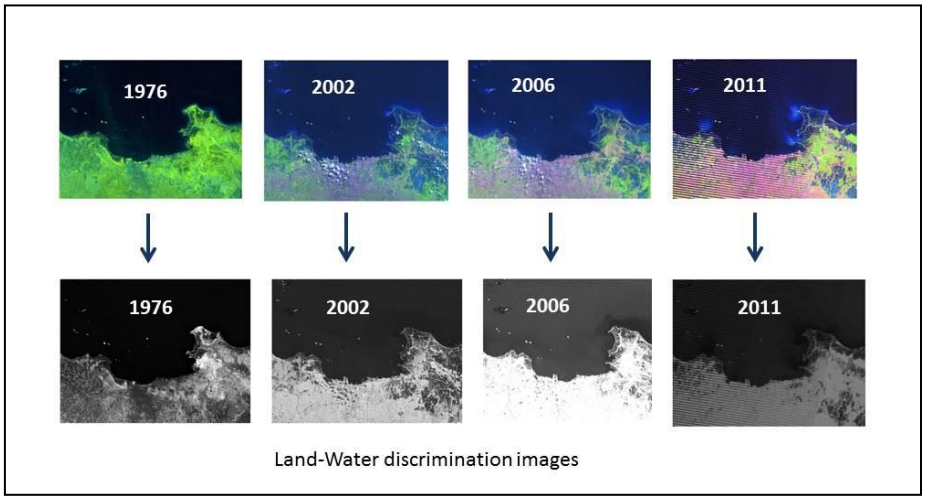

Figure 2. Land-water discrimination results

Those land-water discrimination images then were being composited for shoreline retreat assessment. Differences method was applied for this purpose. Figure 3 illustrates the coastal area changes between the years of data acquired, 1976 – 2011. The dark area (black) indicates the changes while the grey area indicates the unchangeable earth surface coverage. However, shoreline retreat was not ensued along the coastline of Jakarta bay. Inundation of coastal area that was signing as indication of shoreline retreat only can be seen at the Jakarta bay sider, not in the city due to the reclamation project.

Meanwhile, the tidal data assessment from Tanjung priok tidal gauge station indicates that the sea level rise has been arising in Jakarta. Using The *least square linier regression* concerning to bivariate value, the trend of sea level rise can be obtained as about 0.58 to 0.73 cm /year. Figure 4 illustrates the results of the projection of sea level rise in Jakarta bay based on tidal data analysis. This sea level rise data initiated the shoreline retreat at about 61 - 103 cm in 2002, 63 - 107 cm in 2006 and 65 – 112 cm in 2011. Figure 5 illustrates the projection of shoreline retreat related to the projected sea level rise in Jakarta Bay.

The spatial model to illustrate the result of the two models, i.e remote sensing model and shoreline retreat model by Sutrisno (2005) can be seen in Figure 6. The shoreline retreat model simply describes the inundation along the low lying area along the coast. Meanwhile, the remote sensing derived model note some advance area regarding the reclamation project and reforestation of mangrove instead of retreat. It seems shoreline retreat model derived from

remote sensing analysis are questionable to be implemented. Other information regarding the inundation should be examined to justify the remote sensing derived data

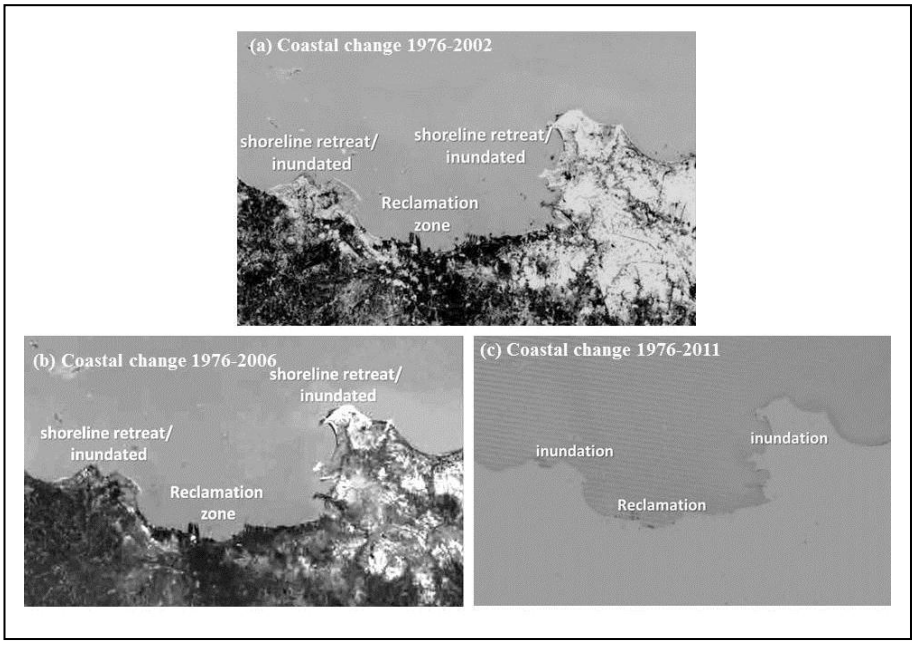

Figure 3. Illustration of inundation (*black*) initiated by shoreline change, (a) 1976-2002, (b) 1976–2006 and (c) 1976-2011

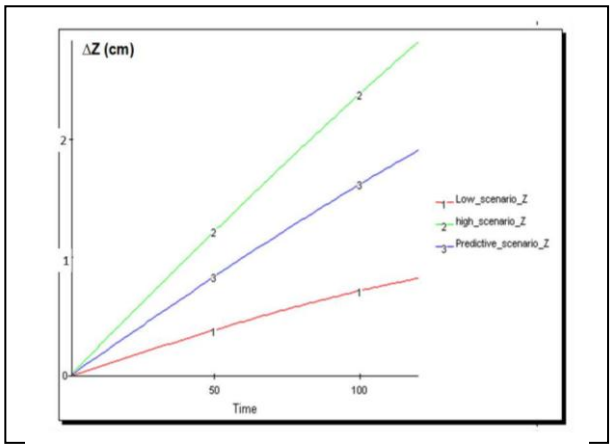

Figure 4. The projection of Sea level rise Based on Jakarta tidal gauge station assessment

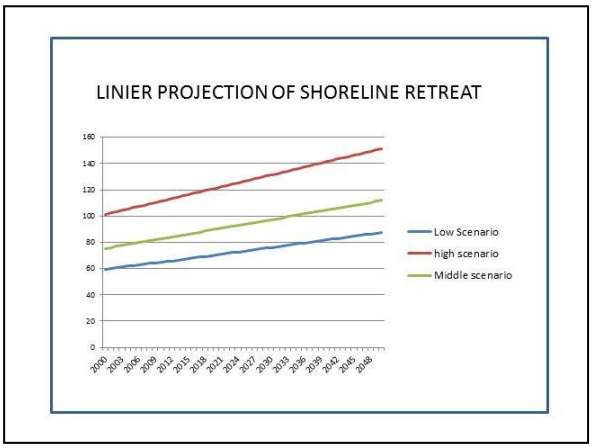

Figure 5. Projection of shoreline retreat along Jakarta coast based on tidal data analysis

Sea-level rise is not the only threat to the vulnerability of Jakarta due to the climate change. Bigger storms make Jakarta which lies in the lowlands, near the sea, and is crossed by 13 rivers flowing down from the south even more vulnerable. Many urban developments such as sea port, coastal resort, golf course, residential areas, industries, condominiums, malls, hotels, commercials and office buildings has been established in Jakarta coastal area. This urban development in synchronization with the population growth that was related to the ground water withdrawal may initiate land subsidence almost along the Jakarta lowland area. Land subsidence has been the basis of relative sea level rise that dominantly occur along the Jakarta coast. The eustatic sea level rise that was generated by the climate change forms escalation rise to this catastrophic.

The land subsidence in Jakarta was exacerbated by the decreasing water catchment areas both in Jakarta and the outskirts of Jakarta. The decreasing water catchment areas will reduce the volume of water that sink into the ground for recharging the groundwater. The mismatch between the intensive groundwater withdrawal and recharge of groundwater is the major cause of land subsidence. Over the period of 1982–1997, subsidence ranging from 20 to

200 cm is evident in several places in Jakarta. In general the land subsidence exhibits spatial and temporal variations, with the rates of about 1 to 15 cm/year (Abidin *et al.*, 2009).

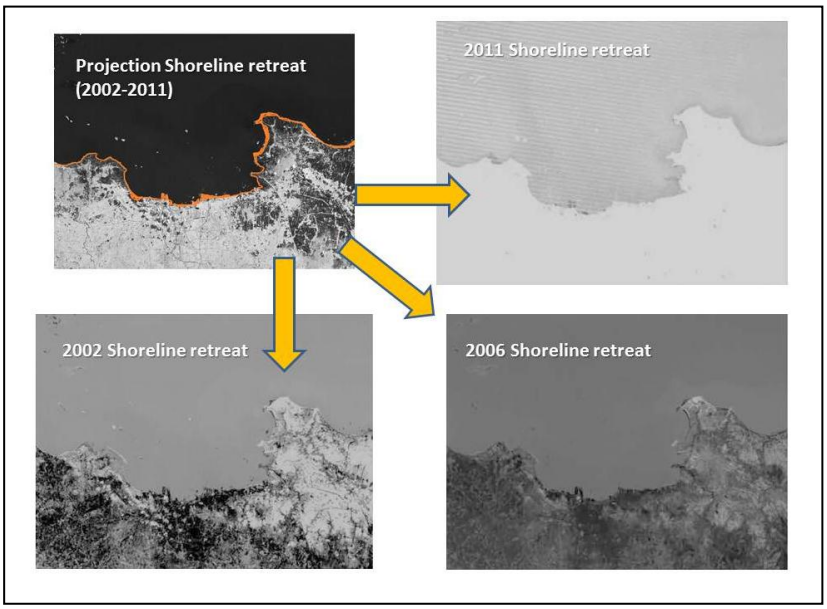

Figure 6. Shoreline retreat projection based on tidal data (*orange*), Shoreline retreat based on images analysis *(black)*

In contrast to the advance coastline, land subsidence in northern part of Jakarta detected by InSAR over the period of June 2006 to February 2007 (Abidin *et al.*, 2009). Figure 7 shows that subsidence along the coastal zone of Jakarta has a spatial variation, with subsidence rates can reach about 12 cm/year whereas the deepest subsidence is located in Pantai Mutiara housing complex, which is actually a land reclamation area (Abidin *et al.*, 2009). The result justifies the shoreline retreat data derived images that excluding the reclamation, the coastline of Jakarta is slowly sunk. This meant, the shoreline retreat still slowly occurs even within the reclamation zone

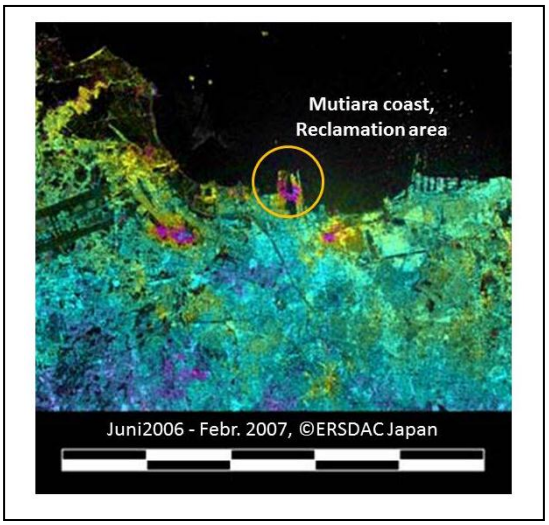

Figure 7. Subsidence in Reclamation area (Abidin *et al.*, 2009).

Therefore, the shoreline retreat data derived from remote sensing analysis can be further implemented to assess the projection of shoreline retreat cause by both relative (land subsidence) and eustatic sea level rise (climate change). Indeed, the methods above can be used to validate the result of tidal data projection in the near future. During high tides, tidal flooding is already affecting some of these coastal areas. The extent and magnitude of subsidence and sea level rise will worsen the coastal area of Jakarta. By utilizing the InSAR derived subsidence as shown in and

the sea level rise rate of 2 mm/year [*Gornitz*, 1995; *IPCC*, 2007 *in* Abidin *et al*., 2009], the possible inundated areas can be obtained (Abidin *et al*., 2009). Figure 8 illustrates the projection of shoreline retreat that was assessed from the average shoreline retreat of images added by the subsidence/ relative sea level rise from secondary information, in compare to the (Abidin *et al*., 2009) projection. Noted that the projection model derived by Abidin *et al*. (2009) has considered the flooding while the shoreline retreat model of landsat images assessment was not.

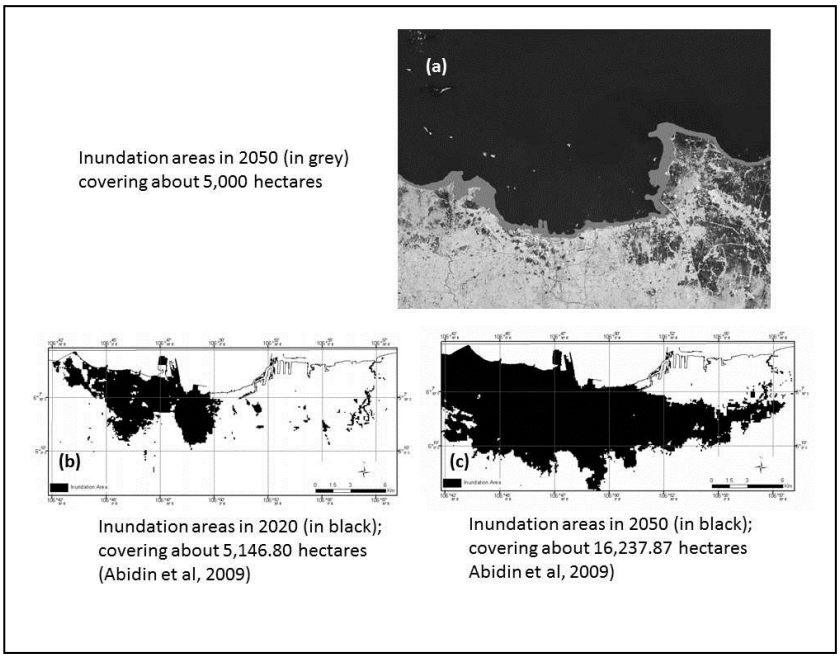

Figure 8. Comparison of inundation caused by shoreline retreat (a) the model, (b) and (c) Abidin et al.,(2009)

IV. REMARK:

Multi date analysis of remotely sensed data may become good source for shoreline retreat assessment. This data can be employed to develop a model of shoreline retreat, to validate the result of shoreline retreat model that was developed using tidal data analysis and as an input for determining the projection of shoreline retreat. However, the implementation of remotely sensed data for this model need more ancillary data since some contrast and mistaken information can be occurred in this study, such as the case in Jakarta coast. Urban area are the most complicated to predict since there are some implementation of development program to protect the land from catastrophic. However, the remote sensing data will give benefit to the decision makers in such methods in order to adapt and mitigate the impact of sea level rise, i.e relative or eustatic, and other climate change or human induced factor catastrophic

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