Shoreline Change Detection using Geospatial tools including GIS and Remote Sensing

Coastal Engineering CVG5124

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1-Primary Article Selamat, S. N., Abdul Maulud, K. N., Jaafar, O., & Ahmad, H. (2017). Extraction of shoreline changes in Selangor coastal area using GIS and remote sensing techniques. Journal of Physics: Conference Series, 852, 012031

1-1 Abstract

Coastal processes including actions of the natural forces on the shoreline is a subject which should be considered to figure out the patterns of these changes during the time to be used in costal management. This can be done by the help of geospatial tools and technologies such as Geographical Information System (GIS) and Remote Sensing (RS) which are able to gather information, analyze, display data and predict the trend of changes along shorelines. In this study specific coastal area Selangor was under investigation between the years of 1984 to 2013 to identify the accretion rate and categorise this area from level of erosion risk aspect.

1-2 Introduction

Keeping track of changes in coastal areas is a core in environmental management; particularly for protecting shorelines. Coastal cities and countries are under direct influence of shoreline changes and risk of serious coastal hazards including "sea level rise (SLR), tidal flooding, land subsidence, erosion, and sedimentation" that are rising phenomena caused by climate change. Shoreline Changes can be monitored by GIS and RS and the collected data can be stored, analyzed, integrated and mapped to identify the areas that have experienced movements or changes. GIS integrates and model the spatial information of different locations and their other related information and temporal dimensions. The historical shift from the regular line, aerial survey, coastline profiles and topography of the shorelines is being calculated through GIS and RS to evaluate the spatial changes through satellite images. In this study the shoreline changes at several Selangor coastal area was detected with the help of SPOT 5 satellite images and topographic map of the area.

1-3 Objectives

Malaysia has around 4809 km coastal area which comprises of sandy beaches in east and muddy areas in west. Most of them are used for industrial, agricultural, tourism and construction purposes. The study area is located in west coast of Peninsular Malaysia and is about 276 km which are known as being potentially hazardous area of coastal erosion, flooding and technological hazards. This research focused on extraction of shoreline erosion and accretion at Selangor coastal area with the total length is 276 km from Kuala Langat to Sabak Bernam.

1-4 Methodology

The study area is consisting of 3 management units. These units are defined by national administration based on use of land, and ecological characteristics.

Figure 1. Study area and management units

As mentioned before, SPOT 5 satellite imagery and topographic map from 1984 to 2013 were used for this study to detect the shoreline changes along the Selangor coastal area. Rectified Skew Orthomorphic (RSO) projection system were used in this study to enter the collected data into ArcGIS software which is a local cylindrical projection in Malaya and Borneo. Using ArcGIS Model builder (a visual programming language for building geoprocessing workflows), the 1984 shoreline topographic map with resolution 1:50000 was used as a baseline and SPOT 5 satellite imageries with resolution 2.5m were used to extract shorelines in 2013.

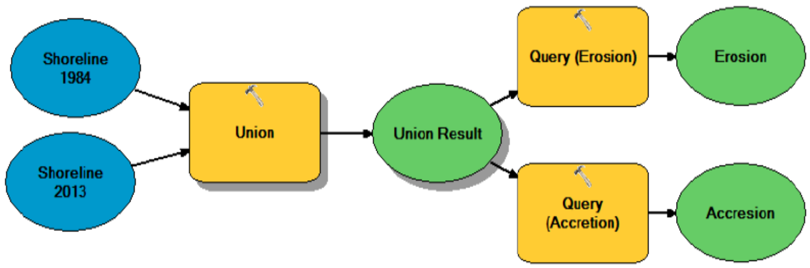

Figure 2.Spatial Model to classify the coastal change in Model builder-ArcGIS

1-5 Results

The changes rate is different for different management units based on their specific area and the dynamic process.

Eroding and accretion shoreline in Selangor coastal area on 1984 to 2013				
Management Unit (MU)	**Location**	**Shoreline Length (km)**	**Eroding (Ha)**	**Accreting (Ha)**
MU1	Sungai Bernam - Northern border sub-district of Kapar.	114.727	813	960
MU2	Northern border sub-district of Kapar– Sothern border sub-district of Kelanang	293.675	1549	1523
MU3	Southern border sub-district of Kelanang -Southern border district of Kuala Langat	29.858	196	100

About 2558 hectare was eroded from the area and 2583 hectare was accreted between 1984 until 2013. The highest erosion area occurred at MU2 compare to the MU1 and MU3. Erosion in MU1 is more than MU3. As a result, MU2 indicates facing the higher erosion rate and identified as the high-risk erosion area.

1-6 Conclusion

Using SPOT 5 satellite imagery the assessments shows that the study area has a high rate of erosion and accretion along the different coastal zone during 1984 to 2013. All effecting aspects of the coastal processes should be monitored and focused on to get accurate result to be used in coastal management. Therefore, it is needed that Coastal zones be divided into sub-sections that is known as management units which are defined based on the natural coastal processes and land use activities. As a result, development planning at coastal zone is vital to ensure that area is not threatened. This study denotes as a preliminary study to investigate the shoreline changes in Selangor coastal area.

2- Similar studies

Three other experimental studies on coastline erosion and accretion detection using GIS and Remote Sensing (RS) were considered for a comprehensive review of the presented paper.

1- Din Hashmi, S. G. M., & Ahmad, S. R. (2018). GIS-Based Analysis and Modeling of Coastline Erosion and Accretion along the Coast of Sindh Pakistan. Journal of Coastal Zone Management, 21(1)
2- Ciritci, D., & Türk, T. (2019). Automatic Detection of Shoreline Change by Geographical Information System (GIS) and Remote Sensing in the Göksu Delta, Turkey. *Journal of the Indian Society of Remote Sensing*, *47*(2), 233–243.
3- Zagórski, P., Jarosz, K., & Superson, J. (2020). Integrated Assessment of Shoreline Change along the Calypsostranda (Svalbard) from Remote Sensing, Field Survey and GIS. *Marine Geodesy*, *43*(5), 433–471

2-1 Din Hashmi, S. G. M., & Ahmad, S. R. (2018)

Spatial and temporal dynamics coastline changes along Keti-Bunder and Kharo-Chann in Indus Delta- Pakistan were studied in this research using GIS and modeling techniques.
Multi Spectral Scanner (MSS), Thematic Mapper (TM) and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER images) were used to extract coastlines' data for various time periods starting from 1973 to 2011. Coastlines were extracted from Landsat MSS, TM for the time periods of 1973, 1977, 1992, 2000 and ASTER image for 2011. Then, all images were projected in UTM Zone 42N. Before the coastlines were extracted from the satellite images, through digital image processing software called Earth Resources Data Analysis System (ERDAS), the researcher reviewed several coastline extraction and change detection techniques including Normalized Difference Water Index (NDWI), Threshold level slicing, Density slicing, Tasseled, Cap Transformation, Morphological segmentation algorithms, Band rationing, Modified Normalized Difference Water Index (MNDWI) and Object based image analysis. Finally, researchers came up using different techniques for different resolution of the satellite images to improve the accuracy of the results.

Therefore, NDWI, MNDWI and threshold level slicing algorithms were selected to extract the water from MSS, TM and ASTER sensors and object-based image analysis technique (OBIA) was used to extract the water on the criterion of NDWI, MNDWI and threshold level slicing. Topographic maps were also used to extract the topographic information. Digital Shoreline Analysis System (DSAS) which is and ArcGIS extension was used to analyse and predict rates of coastline change based on statistical details of the coastlines. Multiresolution segmentation algorithm was used to create the segment for the automatic extraction of water. Binary data was converted into vector line format using the ArcGIS 10. Coastline of 1973 was used as the baseline and an extrapolation of a constant rate of change was applied to predict future shoreline position.
Linear Regression Rate (LRR) of coastlines was calculated through the change statistics window in DSAS to account for the trend in extrapolating historical and future coastline positions. A linear regression rate-of-change statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect.

2-2 Ciritci, D., & Türk, T. (2019)

Ciritci, D. & Türk, T. (2019) aimed to reveal the shoreline change occurring in the Go¨ksu Delta by using satellite images and GIS-based analyses. They examined the shoreline changes based on shoreline change envelope (SCE), end point rate (EPR), and linear regression rate (LRR) techniques and digital shoreline analysis system extension program running on ArcGIS software during 27 years from 1984 to 2011. First, they corrected the Landsat images from atmospheric aspect by ENVI software (FLAASH). Then, they converted raster data to vector using ArcGIS. Then used the SCE method to estimate the magnitude of changes in the shoreline, and the EPR and LRR methods were used to calculate the change rates. Not to mention that the events that may have an effect on the shoreline change were taken into account in the selection of the dates of the satellite images used in the study. Moreover, they tried to reduce the negative effects of topographic and atmospheric changes, such as slope, aspect, shadow, sun angle and intensity, atmospheric conditions, with image processing. For instance, If satellite images are captured in different years or on different days, the sun angle between these two images will be different, which will result in different enlightenment and shadow effects which may lead to incorrect results in the way that there is also change in the areas where there is actually no change.

The SCE and EPR methods work based on the location of at least two shorelines, while LRR needs the location of three or more shorelines. The LRR method takes all shorelines belonging to the region under consideration. Therefore, the change rates of shorelines were calculated by EPR and LRR methods. The EPR method makes a calculation using shoreline on two different dates. EPR is an easily applicable method. The least-squares method is used for the calculation of the most appropriate regression line for each transect crossing all shorelines. Therefore, the annual changes of the shorelines were calculated using the SCE, EPR, and LRR methods in 95% confidence interval.

2-3 Zagórski, P., Jarosz, K., & Superson, J. (2020)

This study represents the changes of the Calypsostranda coastline in Svalbard (High Arctic) between 2007 to 2017 through using Shoreline Change Envelope (SCE) which measured the total changes in all position of considered shoreline, Net Shoreline Movement (NSM) which describes the distance between the oldest (2007) and youngest (2017) shorelines, end point rate (EPR) which shows the distance of shoreline movement by the considered time period and Linear Regression Rate (LRR) which determines a rate-of-change statistic by fitting a least square regression to all shorelines methodology. In this study the Calypsostranda coastline were made part into eroding and aggrading zones. Results show that the changing pattern of 2 areas are similar during the studied period and the erosion rate increases in recent interval of the years. GPS field measurement was done to find the difference of the shorelines to a reference station point in Calypsobyen (CALY point) and identify the trends of changes. Then, the collected information projected to the UTM system zone 33. Different observations were made during various dates. Then, the position of the coastline was processed through ArcGIS for the whole period of 2007-2017. Zagórski et al., (2020) digitised shorelines and then they used the Digital Shoreline Analysis System (DSAS) to facilitate the process which was the “calculation of the statistics of the rate of changes in the shoreline from different temporal series of shoreline locations”. The confidence for each of the transect was 95%. As a result, various driving variables including wind-wave climate, variations in sea ice extent, etc., impact the pattern of coastline change during this period. In the studied period the Calypsostranda was generally subject to erosion.

3- Discussion

Three supporting papers were presented in this report to assess the achievement and contributions made by Selamat et al. (2017).Some key elements that were discussed in the supporting articles are summarized in the table below:

	Selamat et al. (2017)	Din Hashmi & Ahmad (2018)	Ciritci, D. & Türk, T. (2019)	Zagórski et al. (2020)
Studied Period of time to identify erosion	1984-2013 =29 years	1973-2011=38 years	1984-2011= 27 years	2007-2017= 10 years
Resolution of the used images	SPOT 5: 2.5 m	1. Terra- Aster: 15 m 2. Landsat-TM: 30 m 3. Landsat MSS :60m	Landsat TM : 30m	1. LandInfo(GPS) :0.5m 2. Sattelite Images 2013,2017: 0.5m 3. Orthophotomap 2011: 0.4m 4. Orthophotomap 2016 : 0.02m
Applied Methodologies	Erosion & Accretion query-ArcGIS-Model builder, based on Management units	NDWI, MNDWI, OBIA, LRR, based on various resolution off available imageries	SCE, EPR, LRR, based on the date of the collected imageries	SCE, NSM, EPR, LRR, based on the date of the collected imageries
Degree of Confidence	N/A	92%	95%	95%
Applied Image Processing techniques before using images to minimize biases	-	Used	Used	-

- Din Hashmi & Ahmad (2018) studied a wider range of time period in their study compare to other articles.
- Each study used images with different spatial resolutions as shown in the table above. It seems that Zagórski et al. (2020) used images with the highest resolution for their study.
- Din Hashmi & Ahmad (2018) tried different techniques based on the different resolution of the satellite images that they had as data to extract and detect coastline changes. However, Ciritci, D. & Türk, T. (2019) and Zagórski et al. (2020) used different techniques based on the date of the captured satellite images.
- Din Hashmi & Ahmad (2018) applied the most statistically strong quantitative method which is least square regression to minimize the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) and find the slop of the change rates of coastlines with 92% accuracy. Similarly, both Ciritci, D., & Türk, T. (2019) and Zagórski et al. (2020) used DSAS and linear regression rate (LRR) methods to detect shoreline change rates with 95% confidence. Therefore, the accuracy of the Ciritci, D., & Türk, T. (2019) and Zagórski et al. (2020) articles are higher than Din Hashmi & Ahmad (2018). However, the primary article

(Selamat et al. (2017)) did not use any statistical techniques for extracting the changes instead, it queried the erosion and accretion in Model Builder- ArcGIS and as a result it did not give any information for confidence degree to identify the accuracy of its method.

- Ciritci, D. & Türk, T. (2019) used black and white (Binary) images from Landsat 5 TM satellite for their study purpose. However, the other studies used RGB images to extract coastline erosion.
- Din Hashmi & Ahmad (2018) applied Digital Image Processing to rectify the images geometrically and correct the images radio-metrically before extracting shoreline changes. Similarly, Ciritci, D. & Türk, T. (2019) applied image processing techniques on satellite images to minimize the effect of sun angle, slope and other topographic phenomena on the final result which is identifying the shoreline changes. Other studies didn't use such techniques before using satellite images for their study purpose.

4- Conclusions

Selamat et al. (2017) is a preliminary study to identify the shoreline changes in Selangor coastal area. It used SPOT 5 satellite imagery and topographic map from 1984 to 2013 to illustrate the shoreline changes along the Selangor coastal area with the help of ArcGIS Model builder. It put the 1984 shoreline topographic map as a baseline to the study and used SPOT 5 satellite imageries to identify the shorelines in 2013. Although dividing the study area into regions by this article gave a good interpretation of the results, in this critical review we focused on 3 other research which applied various methodologies to obtain shoreline changes. With this review we expected to get a better understanding of other methodologies, required data and satellite images and defects of primary article from those aspects which are recommended below:

- In terms of the available satellite images to use for the study Selamat et al. (2017) only used SPOT 5 satellite imageries to detect the shoreline changes. The result and the accuracy of the study could be improved, if they had used different satellite images like Landsat and Terra for their special management units along the Selangor coastal area.
- In terms of resolution, using a higher resolution imagery could give a better result which Selamat et al. (2017) can apply to improve the research accuracy.
- Details about the Erosion and Acieration query in ArcGIS are not given in the Selamat et al. (2017) study, so it is not possible to estimate degree of confidence and the accuracy of the methodology used in the research. The research can improve from this respect by giving more details about the methodology and equations which were used in calculating coastline change rate in the study area.
- The other three secondary studies detect the shoreline changes and erosion based on the time intervals during considered period or based on the resolution of the collected data. The primary article did not use any of those methods instead it considered the study area based on the location of the management units. It seems that it would be more beneficial if the authors had used another method addition to this to improve the accuracy.
- Image processing techniques could be applied to the primary article to improve the images which were used as the collected data to minimize the impact of geographical biases such as slope and the angle of sun.

5- References

Ciritci, D., & Türk, T. (2019). Automatic Detection of Shoreline Change by Geographical Information System (GIS) and Remote Sensing in the Göksu Delta, Turkey. *Journal of the Indian Society of Remote Sensing*, *47*(2), 233–243. https://doi.org/10.1007/s12524-019-00947-1

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Zagórski, P., Jarosz, K., & Superson, J. (2020). Integrated Assessment of Shoreline Change along the Calypsostranda (Svalbard) from Remote Sensing, Field Survey and GIS. *Marine Geodesy*, *43*(5), 433–471. https://doi.org/10.1080/01490419.2020.1715516