Geospatial Approach for Coastal Vulnerability Assessment of Selangor Coast, Malaysia

F A Mohd1, A A A Rahman2,3,* , K N Abdul Maulud4,5, M K Kamarudin1, N A Majid1 and A Rosli1

1Center of Studies Surveying Science & Geomatics; Faculty of Architecture, Planning & Surveying Universiti Teknologi MARA (Perlis).
2Centre of Studies Surveying Science & Geomatics, Faculty of Architecture, Planning & Surveying, Universiti Teknologi Mara Shah Alam, Selangor Darul Ehsan, Malaysia.
3Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia (UKM), 43600 UKM Bangi, Selangor, Malaysia.
4Earth Observation Centre, Institute of Climate Change (IPI), Universiti Kebangsaan Malaysia
5Department of Civil and Structural Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

*aziz121@uitm.edu.my

Abstract. The length of the coast of peninsular Malaysia is approximately 4,809 km long. Coastal erosion is recognized as the permanent loss of land and habitats along the shoreline resulting in the changes of the coast. Thus, the aim of this study is to determine the vulnerability of erosion of the Selangor coast caused by sea level rise events. In this paper, by using satellite imagery, both manual methods and coastal extraction processing have been examined. Six variables consist of the coastal vulnerability index (CVI), which are coastal geomorphology, coastal slope, erosion and accretion rate, mean wave height, mean tidal range, and the increase in sea level. Vulnerability levels are classified into five vulnerabilities for 8 management units along the Selangor coast which are very medium, medium, moderate, high and very high. The finding reveals that the level of vulnerability of MU 7 Pantai Jeram & Bagan Sungai Janggut is very high because the rate of erosion in the area is higher compared to other areas. Finally, the outcome of this study provides a framework that can be used by decision makers, and relevant authorities to implement mitigation and adaptation measures in the effort to deal with the impacts of climate change on coastal regions.

1. Introduction
Malaysia is situated in Southeast Asia between 1 ° and 7 ° North latitudes and 100 ° and 119 ° East longitudes. The length of the Malaysian coastline is approximately 4,809 km, which means that Malaysia’s coastal resources are rich in natural biodiversity [17] & [13]. The west coast facing the Melaka Strait in peninsular Malaysia is longer compared to the straighter east coast of the South China Sea. It seems that this richness is an advantage for the county. To maximize the use of such properties, it is very important to manage the coastline itself. The population density tends to grow worldwide along the coast because of the importance of the coastline itself. Coastal erosion has now become a major issue where 29% of the coastline since 1984 has been eroded [8] & [4].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
According [1] mentioned that field survey techniques are conventionally used to map coastal patterns in small areas. The coastline mapping and extraction methods were also labour-intensive and time-consuming operations using conventional methods. Other than that, in traditional shoreline surveillance, aerial image and ground survey methods may also be combined. It is more practical and cost-effective due to the vast operational area and the high resolution of satellite imagery ([14],[11], [10] & [13]).

To map the relative sensitivity of the coast to future sea-level rises, a coastal vulnerability index (CVI) was used [14]. This method is very helpful for long-term coastal planning in the decision-making process. As for the research on this coastal erosion, the recently used methods had been improvised and have developed some additional data verification and data collection techniques. Therefore, the present study is to highlight that the vulnerability of erosion of the Selangor coast to sea level rise by using six parameters. Thus, proper planning and protection strategies for the Selangor coast must be taken by coastal management and policy makers to sustain the coastal ecosystem and livelihood.

2. Study Area
The study area focuses on the coastal area from Bagan Nakhoda Omar to Port Klang, seen on the Malaysian map Figure 1. The distance covered is approximately 196 km and is split into eight management unit (MU) regions. MU is the division focused on the coastal relationship with the beach's natural process and land use activities. The MU, separated by a river, encounters another coastal river. In the western part of Peninsular Malaysia, coastal regions are well known for their muddy coastal areas.

![Study Area](image-url)

Figure 1. Study area

3. Methodology
Collection of research data collected from fieldwork and secondary information by the Management Unit Division (MU) along the Bagan Nakhoda Omar coast to Port Klang. The methodology adopted in the present study is in accordance with the procedure set by the United States Geological Survey (USGS) [6] & [7]. Six variables were selected to calculate the CVI, and each variable represents a specific characteristic of coastal vulnerability. Most of the variables are dynamic in nature along the coastal region and vast amounts of data and information have to be gathered from different sources, then processed and analysed.

The CVI parameters are based in accordance with the USGS procedure published by [18], which outlines the specific characteristics of coastal vulnerability based on the coastal conditions of the study area. The management units (MU) within the study area were assigned a risk rating for each variable, and the CVI was then calculated as the square root of the results of the ranked variables divided by the total number of variables [14] as shown in Equation 1:
$CVI=\sqrt{((a*b*c*d*e*f)/6)}$ (1)

Where $a$ = geomorphology, $b$ = coastal slope, $c$ = rate of shoreline change, $d$ = rate of sea level rise, $e$ = Mean Significant wave height, and $f$ = mean tidal range. The composite index of the selected study area was calculated by their weighted averages by combining the individual parameters [3]. In the present vulnerability analysis, equal weight is assigned to each variable, an approach that is the commonly used in the literature [2] & [18]. The selected parameters of CVI divided and ranked into five categories based on the level of risk, namely very low, low, moderate, high and very high risks using natural break classification technique which indicates that class boundaries tend to place large numbers of similar values in the same class [15].

4. Results and Analysis

4.1. Geomorphology

The results of the analysis show that the morphology of the Selangor coast is quite varied. Only four areas in the Selangor coast are highly vulnerable while four areas, i.e. MU2, MU3, MU7 and MU8, have high vulnerability respectively as shown on Table 1. The colour indicates highly vulnerable (red colour), high vulnerable (brown colour), moderate vulnerable (yellow colour), low vulnerable (green colour) and very low vulnerable (cyan colour).

| No | MU  | Location          | Geomorphology                                                                 | Vulnerability Level |
|----|-----|-------------------|-------------------------------------------------------------------------------|---------------------|
| 1  | MU1 | Bagan Nakhoda Omar | Throughout the area, the coastline features covered by mudslides. The soil is grayish brown, and the surface is smooth in texture. Coastline topography is sloping gently. During low tide this section of the coast is visible. A concrete structure (1-1.5 m) in height is covered at the back of the beach. There are mangrove trees to both the right and left of the beach. | High |
| 2  | MU2 | Bagan Sungai Pulai | The front of the beach was erected with a "T" shaped rock protection structure to reduce the impact of waves on the coast for 1-2km. The back of the beach is protected by 1m high fort. At the river estuary and on the right and left of the coast there is a small mangrove tree. The coastal geomorphology of this coastal area is characterized by muddy soil and sloping gently. | High |
| 3  | MU3 | Kampung Hj Dorani | A sandy beach mixed with mud and sand. Coastal erosion occurs on the right side of the coast, which causes many mangrove trees to die. The soil is grayish gray and has a smooth texture on the surface. The back of the beach is a bit sandy and gray and brown and the sand is a bit dense. The slopes of the coast are very low. | High |
| 4  | MU4 | Sungai Nibong      | The coastline is characterized by dense, grayish-gray mudstones with a fine texture on the surface. Rocky cliffs along the coast protect the back of the beach. The gradients of the beach are very low. | Very Low |
The front of the beach has muddy grey soil and the texture is delicate. Low slope beach conditions. The coastline has coarse sand beaches that are light grey. Plants such as coconuts and mangroves grow along the coast. The gradients of the beach are very sluggish. The movement of the waves parallel to the beach.

A grayish gray mud characterizes the front of the beach. The coastline is composed of forts (1.5-2 m in height), boulders and tires to prevent overflowing of the beach. Shoreless beach conditions. The movement of the waves parallel to the coast.

The sandy beaches have relatively coarse sand (light gray and slightly brown) and a dense soil texture. The beach has a wave-reflecting movement in line with the beach and is protected by beach protection structures, including forts and rock blocks. Plants such as mangroves and shrubs grow along the shoreline. At the Janggut River Chart there is a beach erosion at the mouth of the river that causes mangrove trees to die.

The coastline is composed of grayish-gray mudstones and coarse-grained sand. Shoreless beach conditions. On the shores of the coast there are mangrove trees. The coast also comprises the harbor as a Protected Area (Limited).

4.2. Coastal Slope
The data on the coastal slope is collected from the Google Earth application where it contains a slope reading tool at any spot. Five readings were taken for coastal slope readings for each area and would be combined to calculate the slope for each area. In the MU6 Bagan Pasir and MU7 Pantai Jeram & Bagan Sungai Janggut areas, the areas with the highest slope measurements ranged from 2.3 to 2.6 percent. The level of coastal vulnerability in an area where the area is heavily sloping and not easily affected is limited. Furthermore, due to the usual gradient of the coast, the MU4 Sungai Nibong and MU8 Pelabuhan Klang areas are at moderate levels, while the level of beach vulnerability in the MU2 Bagan Sungai Pulai region is high. Finally, there are gently sloping beach areas in the MU1, MU3 and MU5 areas, creating high levels of coastal vulnerability within these regions as shown on Table 2.

| MU  | Location                      | Coastal Slope (%) | Vulnerability Level |
|-----|-------------------------------|-------------------|---------------------|
| MU1 | Bagan Nakhoda Omar            | 1.20              |                     |
| MU2 | Bagan Sungai Pulai            | 1.57              |                     |
| MU3 | Kampung Hj Dorani             | 1.29              |                     |
| MU4 | Sungai Nibong                 | 1.92              |                     |
| MU5 | Sungai Burong                 | 1.18              |                     |
| MU6 | Bagan Pasir                   | 2.37              |                     |
| MU7 | Pantai Jeram & Bagan Sungai Janggut | 2.58  |                     |
| MU8 | Port Klang                    | 2.01              |                     |
4.3. Rate of Erosion and Accretion

The data acquired by the SPOT satellite image digitization process for erosion and accretion readings. Based on Table 3, MU1 Bagan Nakhoda Omar, MU3 Kg. Hj. Dorani, MU4 Sg Nibong and MU5 Sungai Burong provide examples of areas of low vulnerability. This is because, relative to erosion, the area has a lot of development. Moreover, at MU 2 Bagan Sungai Pulau, there is a region of medium vulnerability. The erosion rates and accretion rates are not high in the MU2 Bagan Sungai Pulai region. Finally, MU6 Bagan Pasir and MU7 Pantai Jeram & Bagan Sungai Janggut are two areas of great vulnerability. This is because a high erosion rate compared to accretion has been experienced in the region. These two places are, in other words, at high risk.

| MU     | Location                  | Rate of Erosion and Accretion (m/yr) | Vulnerability Level |
|--------|----------------------------|-------------------------------------|---------------------|
| MU1    | Bagan Nakhoda Omar        | -                                   | (+)                 |
| MU2    | Bagan Sungai Pulai        | 1.4                                 | 0.3                 |
| MU3    | Kampung Hj Dorani         | 3.6                                 | 9.7                 |
| MU4    | Sungai Nibong             | 0.6                                 | 1                   |
| MU5    | Sungai Burong             | 0.5                                 | 3.9                 |
| MU6    | Bagan Pasir               | 0.05                                | 5.3                 |
| MU7    | Pantai Jeram & Bagan Sungai Janggut | 19.2 | 7.1 |
| MU8    | Port Klang                | 5.8                                 | 5.5                 |

4.4. Mean Tidal Range

Tidal readings were obtained from JUPEM’s tidal station provided by the Tidal Book near the study area of Bagan Datuk, Permatang Sedepa and Port Klang. Bagan Datuk and Permatang Sedepa tidal stations are used in the MU 1 to MU 7 areas, while MU 8 is near Permatang Sedepa and Port Klang tidal stations. The vulnerability rate is high for coastal areas in Selangor. Visual Ship Observation (SSMO) waveforms obtained using SSMO data for directions 150°, 180°, 210°, 240°, 270°, 300° and 330° from the Department of Irrigation and Drainage Malaysia were generated using MIKE-21 software. The coastal area of Selangor has a low degree of vulnerability based on the results obtained from wave height measurements, where the wave height only records between 0.91 meters and 0.99 meters [9]. However, there is only one area, Bagan Pasir (MU 6), which has a very low level of coastal vulnerability. Overall, for the Selangor coastal areas, the wave height factor only has a low effect. This finding shows that the wave height is lower than that of the east coast of the west coast.

4.5. Rate of Sea Level Rise

One of the indicators used to assess the extent of coastal risk is the amount of sea level rise. By the process of interpolation, the readings of sea level rise are obtained by Inverse Distance Weight (IDW). The higher the increase in sea levels, the greater the visibility and marking of high value to coastal areas [5]. The level of coastal vulnerability in the Selangor region falls within the lower class of parameters of sea level rise.

4.6. CVI Mapping Along Selangor Coastal

For all regions, the CVI solution range is between 3.65 and 11.31, while the percentage outcome range is between 6.25 and 81.25, as shown in Table 4. The total region of the coast of Selangor faced moderate levels of coastal vulnerability. MU 1 Bagan Nakhoda Omar, MU 5 Sungai Burong and MU 8 Pelabuhan Klang are the areas with Level 3 CVI. Looking at it, only one or two parameters show a high level of vulnerability and a low level of vulnerability is shown by the other parameters. There are also areas with
a low to very low level of risk at a decent level. For areas with low vulnerability levels, MU 3 Kampung Haji Dorani and MU 4 Sungai Nibong and MU 6 Bagan Pasir are areas of very low vulnerability levels. The area at MU 7 Pantai Jeram & Bagan Sungai Janggut shows a high level of coastal vulnerability with the score is 10.33. In this region, reference to the erosion and accretion parameter is higher compared to others. Then the region with the highest level of coastal vulnerability is at MU 2 with a CVI score of Bagan Sungai Pulai 11.31. This is because there are 3 parameters with high vulnerability levels in this area, which are geomorphology, coastal slope and mean tidal range.

Although geomorphology and coastal slope parameters are highly vulnerable in some areas, CVI values are not necessarily at high levels. This is because the beach's vulnerability relies on the location's overall CVI parameters. As in Bagan Sungai Pulai (MU 2), there are several triggers that cause a location to be at a very high level of coastal vulnerability based on CVI parameters that have been used in this study. According [5] revealed that the wave of builders triggered the development of the long coastline. Destructive waves cause erosion along the coast and destroy the coastal strip that the building waves have built.

Using ArcMap software, the mapping of CVI was performed. This map showing all parameters involved in determine CVI level for each MU. For local authorities and public awareness, this map is significant. Several measures should be taken to prevent or control the erosion of the coastline. The CVI map of coastal Selangor is shown in Figure 2.

| MU   | Location                      | Geomorphology | Coastal | Erosion & Accretion Rate | Mean Tidal Range | Mean Wave Height | Rate of Sea Level Rise | CVI   | Percentile (%) | Coastal Vulnerability Index |
|------|-------------------------------|---------------|---------|--------------------------|------------------|------------------|------------------------|-------|----------------|-----------------------------|
| MU1  | Bagan Nakhoda Omar            | 5             | 5       | 1                        | 4                | 2                | 2                      | 8.16  | 50             | 3                           |
| MU2  | Bagan Sungai Pulai            | 4             | 4       | 3                        | 4                | 2                | 2                      | 11.31 | 81.25          | 5                           |
| MU3  | Kampung Hj Dorani             | 4             | 5       | 1                        | 4                | 2                | 2                      | 7.30  | 31.25          | 2                           |
| MU4  | Sungai Nibong                 | 5             | 3       | 3                        | 4                | 2                | 2                      | 6.32  | 18.75          | 1                           |
| MU5  | Sungai Burong                 | 5             | 5       | 1                        | 4                | 2                | 2                      | 8.16  | 50             | 3                           |
| MU6  | Bagan Pasir                   | 5             | 2       | 1                        | 4                | 2                | 2                      | 3.65  | 6.25           | 1                           |
| MU7  | Pantai Jeram & Bagan Sungai Janggut | 4         | 2       | 3                        | 4                | 2                | 2                      | 10.33 | 68.75          | 4                           |
| MU8  | Port Klang                    | 4             | 3       | 3                        | 4                | 2                | 2                      | 9.8   | 56.25          | 3                           |
5. Conclusion
To conclude, all the goals in this analysis have been accomplished successfully. It is possible to evaluate the coastal vulnerability index parameter along the coast of Selangor according to the first objective of defining it. For this analysis, six parameters were calculated, namely geomorphology, coastal slope, erosion and accretion rate, mean tidal range, mean significant wave height, and sea level rise rate. The result shows that the level of vulnerability of MU 7 Pantai Jeram & Bagan Sungai Janggut is very high because the rate of erosion in the area is higher compared to other areas. There are 3 areas with a high level of vulnerability, and the remaining four areas have a very low level of vulnerability. The coastal areas in Selangor indicate that the level of coastal vulnerability is at a normal level, based on the CVI study conducted as a whole, since the amount of very high and high levels of coastal vulnerability in the class is low compared to the level of moderate and below vulnerability. Finally, the outcome of this study provides a framework which can be used by researchers, decision makers, and relevant authorities to formulate and implement mitigation and adaptation measures in the effort to deal with the impacts of climate change on coastal regions.

References
[1] Ashraful Islam, M., Mitra, D., Dewan, A., & Akhter, S. H. Coastal multi-hazard vulnerability assessment along the Ganges deltaic coast of Bangladesh-A geospatial approach. Ocean and
Coastal Management. 2016, 127, 1–15. https://doi.org/10.1016/j.ocecoaman.2016.03.012.

[2] Boak, E. H., & Turner, I. L., 2005. Shoreline Definition and Detection: A Review. Journal of Coastal Research. 214, 688–703. https://doi.org/10.2112/03-0071.1.

[3] Boruff, B. J., Emrich, C., & Cutter, S. L. (2005). Erosion hazard vulnerability of US coastal counties. Journal of Coastal Research, 932–942.

[4] Fazly Amri Mohd, Khairul Nizam Abdul Maulud, Rawshan Ara Begum, Siti Norsakina Selamat, & Othman A. Karim. Impact of Shoreline Changes to Pahang Coastal Area by Using Geospatial Technology. Sains Malaysiana. 2018, 47(5), 991–997.

[5] Gill, J. A., Anwar, A. M., & Omar K., S., 2014. Towards the implementation of continuous coastal vulnerability index in Malaysia: A review. Jurnal Teknologi. 71(4), 1-10. https://doi.org/10.11113/jt.v71.3819.

[6] Gornitz, V., White, T. W., & Cushman, R. M. (1991). Vulnerability of the US to future sea level rise. Proceedings of the 7th Symposium on Coastal and Ocean Management, 2354–2368. https://doi.org/10.1017/CBO9781107415324.004.

[7] Hammar-Klose, E. S., & Thieler, E. R., 2001. Coastal vulnerability to sea-level rise: a preliminary database for the US Atlantic, Pacific, and Gulf of Mexico coasts. US Geological Survey.

[8] Hayrol Azril Mohamed Shaffril, Nurani Kamaruddin, & Siti Zobidah Omar. The coastal community awareness towards the climate change in Malaysia. International Journal of Climate Change Strategies and Management. 2015, 7(4), 516–533.

[9] Jeofry, M. H., & Rozainah, M. Z., 2013. General observations about rising sea levels in Peninsular Malaysia. Malaysian Journal of Science. 32, 363–370.

[10] Kumar, A. A., & Kunte, P. D. Coastal vulnerability assessment for Chennai, east coast of India using geospatial techniques. Natural Hazards. 2012, 64(1), 853–872.

[11] Kumar, T. S., Mahendra, R. S., Nayak, S., Radhakrishnan, K., & Sahu, K. C. Coastal Vulnerability Assessment for Orissa State, East Coast of India. Journal of Coastal Research. 2010, 263(3), 523–534. https://doi.org/10.2112/09-1186.1.

[12] Mohd, F. A., Maulud, K. N. A., Karim, O. A., Begum, R. A., Awang, N. A., Hamid, M. R. A., Razak, A. H. A. (2018). Assessment of coastal inundation of low-lying areas due to sea level rise. IOP Conf. Series: Earth and Environmental Science, 169(012046): 1–9.

[13] Mohd, F., Maulud, K., A Karim, O., Begum, R., Awang, N., Ahmad, A., Azhary, W., Kamarudin, M. Khairul Amri, Jaafar, M., & W An Mohtar, H. (2019). Comprehensive coastal vulnerability assessment and adaptation for Cherating-Pekan coast, Pahang, Malaysia. Ocean & Coastal Management, 182, 104948. https://doi.org/10.1016/j.ocecoaman.2019.104948.

[14] Pendleton EA, Thieler ER & Williams SJ. (2010). Importance of coastal change variables in determining vulnerability to sea level change. Journal Coastal Research, 26:176–183. doi:10.2112/08-1102.1.

[15] Pendleton EA, Thieler ER & Williams SJ. (2004). Coastal vulnerability assessment of Cape Hatteras National Seashore (CAHA) to Sea Level Rise. 2004, USGS Open File Report 2004-1064. Available online: http://pubs.usgs.gov/of/2004/1064/images/pdf/caha.pdf.

[16] Pramanik, M. K., Biswas, S. S., Mondal, B., & Pal, R. (2016). Coastal vulnerability assessment of the predicted sea level rise in the coastal zone of Krishna–Godavari delta region, Andhra Pradesh, east coast of India. Environment, Development and Sustainability, 18(6), 1635–1655. https://doi.org/10.1007/s10668-015-9708-0.

[17] Tangang, F. T., Juneng, L., Salimun, E., Sei, K. M., Le, L. J. & Muhamad, H. (2012). Climate Change and Variability over Malaysia: Gaps in Science and Research Information. Sains Malaysiana 41(11): 1355–1366. Retrieved from http://www.scopus.com/inward/record.url?eid=2s02084867519723&partnerID=40&md5=70163afaba2a90143167dfe890cd872e.

[18] Vousdoukas, M. I., Voukouvalas, E., Annunziato, A., Giardino, A., & Feyen, L. (2016) Projections of extreme storm surge levels along Europe. Climate Dynamics, 47(9–10), 3171–3190. https://doi.org/10.1007/s00382-016-3019-5.
Acknowledgment

The authors acknowledge the funding for this study from Trans Disciplinary Research Grant Scheme (TRGS/1/2015/UKM/02/5/1) and (TRGS/1/2015/UKM/02/5/3). In addition, the authors acknowledge the funding for this paper from TABUNG AGIHAN PENYELIDIKAN (TAP) and also the contribution by all colleagues that involve in this study.