AN INTEGRATION OF COASTAL EROSION MAPPING USING STATISTICAL APPROACH TO PREDICT SHORELINE CHANGES

ISHA BAIZURA BINTI ISMAIL

A thesis submitted in
fulfilment of the requirement for the award of the
Doctor of Philosophy in Civil Engineering

Faculty of Civil Engineering and Built Environment
Universiti Tun Hussein Onn Malaysia

JUNE 2023

This thesis is dedicated to;

my beloved husband Mr Ahmad Zaidi Bin Mispan,

my children Iman, Izzaty, Ilham, Izzara & Irfan,

my father Mr Ismail Bin Pitt and my family.

Thank you for your advice, your love, your sacrifice and

your support towards to complete this thesis.

To my supportive supervisor,

Assoc. Prof. Ir. Dr. Mohd Adib Bin Mohammad Razi,

your guidance, opinions and the knowledge you have shared

will always be remembered in the future.

To my beloved friends

Your advice and your care will always

be appreciated and remembered.

Thank you

ACKNOWLEDGEMENT

I would like to express my deep gratitude to Allah SWT for His grace and mercy. I managed to undergo 4 years of study and make this doctoral thesis a reality. The infinite contribution from government agencies such as MYSA, JUPEM, DID and PLAN Malaysia) by providing cooperation and supplying data and essential information of the study, is undoubtedly very helpful in the success of this study. Furthermore, individuals through generous assistance, guidance, encouragement, and proficiency of contributed to the preparation and completion the study.

Firstly, most profound gratitude to Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia (UTHM) for giving the opportunity to conduct and finish the PhD study entitled "An Integration of Coastal Erosion Mapping using Statistical Approach to Predict Shoreline Changes". I also would like to acknowledge the Ministry of Higher Education (MOHE) through *Hadiah Latihan Persekutuan* (HLP) scholarship program that provide me the financial support during my study.

Secondly, a huge thank you to my awesome supervisor, Assoc. Prof. Ir. Dr. Mohd Adib Bin Mohammad Razi his excellent guidance, criticism, lessons, suggestions, understanding and continuous support in my research work.

Next, I would like to express my thanks to all my friends for the wonderful friendship throughout my studies. It has been a pleasure to work in a positive circle even though we face different challenges in our study. Hopefully, we will succeed together and be friends forever.

Finally, I would also thank my parents, spouse, children and family members for always praying for my success. Thank you for the support and encouragement through my ups and downs and difficult times in my PhD journey. Thank you so much, and I am glad for your presence in my life.

ABSTRACT

Coastal erosion is a marine geological phenomenon that has a significant impact on the impacted regions. Globally, coastal changes are having a significant impact in certain regions. Predicting the ecological effects and magnitude of coastal changes such as erosion and population growth is essential. Some analyses indicate that by 2050, sea level rise and global climate change would impact some coastal cities. This study aims to determine the pace of change along Regency Beach, Port Dickson, and to predict shoreline change using the End Point Rate (EPR) mathematical model equation approach. Digital Shoreline Analysis System (DSAS) software was utilised to develop shoreline position predictions, which were subsequently validated using field-measured shoreline data. To identify changes in the shoreline of the study area, researcher analyzed images captured by unmanned aerial vehicles (UAVs) from 2019 to 2021 with satellite images from 1988 to 2019. Root Mean Square Error (RMSE) computations were used to determine the accuracy of the data collected by the UAV. This data set was tested to fulfil the 7.95 cm $RMSE_x$/$RMSE_y$ horizontal accuracy class of the ASPRS Positional Accuracy Standards for digital geospatial data (2014). $RMSE_x$ = 4.26 cm and $RMSE_y$ = 1.57 cm were found to be the actual positional accuracy. The maximum rate of erosion was determined to be -4.65 m/year for long-term analysis, -5.16 m/year for medium-term analysis, and -1.46 m/year for short-term analysis. Between 1988 and 2021, there was moderate to high erosion in the study area. Using the EPR mathematical model equation method, the coordinates of where the shoreline is expected to be in the years 2030, 2050, and 2100 have been calculated. GIS and UAV data from the research region can predict future shoreline changes. The study proved shoreline erosion between 1988 and 2021, and the mathematical equations are useful for future research.

ABSTRAK

Hakisan pantai merupakan salah satu fenomena geologi marin yang memberi impak besar kepada kawasan yang terlibat. Perubahan pantai pada masa kini memberi kesan yang besar di beberapa kawasan di seluruh dunia. Implikasi ekosistem dan magnitud perubahan pantai seperti hakisan dan pertambahan bagi penduduk pantai adalah penting untuk diramal. Menurut beberapa kajian, peningkatan paras laut dan perubahan iklim global akan melanda bandar berhampiran pantai tertentu menjelang tahun 2050. Matlamat penyelidikan ini adalah mengukur kadar perubahan di sepanjang Pantai Regency, Port Dickson dan meramalkan perubahan garis pantai menggunakan kaedah persamaan model matematik *End Point Rate (EPR)*. Perisian *Digital Shoreline Analysis System (DSAS)* telah digunakan untuk menghasilkan ramalan kedudukan garis pantai, yang kemudiannya disahkan menggunakan data garis pantai yang diukur di lapangan. Untuk mengenal pasti perubahan garis pantai di kawasan kajian, penyelidik membandingkan imej satelit dari tahun 1988 hingga 2019 serta imej kenderaan udara tanpa pemandu (UAV) garis pantai semasa dari tahun 2019 hingga 2021. Hasil analisis menunjukkan kadar maksimum hakisan didapati -4.65 m/tahun untuk analisis jangka panjang, -5.16 m/tahun untuk analisis jangka sederhana, dan -1.46 m/tahun untuk analisis jangka pendek. Kajian juga mendapati antara tahun 1988 hingga 2021, kawasan kajian menunjukkan hakisan sederhana tinggi hingga hakisan tinggi. Data GIS dan UAV dari kawasan penyelidikan boleh meramalkan perubahan garis pantai masa hadapan. Kajian ini juga membuktikan berlaku hakisan pantai antara tahun 1988 dan 2021, dan persamaan matematik berguna untuk penyelidikan masa depan.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

Cu	-	Uniformity Coefficient
Cc	-	Curvature Coefficient
D_{10}	-	Particle diameter (mm) that corresponds to 10% transparency
D_{30}	-	Particle diameter (mm) that corresponds to 30% transparency
D_{60}	-	Particle diameter (mm) that corresponds to 60% transparency
(x_i, y_i)	-	Image Coordinates
$(\overline{x_i}, \overline{y_i})$	-	Projected Coordinates
y_1, y_2	-	Shoreline movement distances
t_1, t_2	-	Dates of the two shoreline positions
(x, y)	-	Prediction Position
(x_i, y_i)	-	Intersection Position
(x_t, y_t)	-	Baseline Position
Δt	-	Date
d	-	Distance between the intersection and baseline
NCES	-	National Coastal Erosion Study
EPU	-	Economic Planning Unit
GIS	-	Geographic Information System
UAV	-	Unmanned Aerial Vehicle
LiDAR	-	Light Detection and Ranging
GPS	-	Global Positioning System
NCEC	-	National Coastal Erosion Control
CETC	-	Coastal Engineering Technical Centre
BMS	-	Beach Management System
ISMP	-	Integrated Shoreline Management Plan

ICZM	-	Integrated Coastal Zone Management
UKMO	-	United Kingdom Hydrographic Office
SLR	-	Sea Level Rise
DID	-	Department of Irrigation and Drainage
NAHRIM	-	National Hydraulic Research Institute of Malaysia
DSAS	-	Digital Shoreline Analysis System
CVI	-	Coastal Vulnerability Index
EPR	-	End Point Rate
LRR	-	Linear Regression Rate
RMSE	-	Root Mean Square Error
NEXC	-	NAHRIM Coastal Erosion Protection and Beach Expansion
DTM	-	Digital Terrain Model
DSM	-	Digital Surface Model
MYSA	-	Malaysian Space Agency
LL	-	Liquid Limit
PL	-	Plastic Limit
USGS	-	United States Geological Survey
SCE	-	Shoreline Change Envelope
NSM	-	Net Shoreline Movement
LMS	-	Least Median of Squares
JUPEM	-	Department of Survey and Mapping Malaysia
GCP	-	Ground Control Points
CP	-	Correction Points
GDM	-	Geodetic Datum Malaysia
3-D	-	Three-Dimensional
SFM	-	Structure Form Motion
GSD	-	Ground Sampling Distance

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Peninsular Malaysia has a shoreline of 3,771.5 km, whereas East Malaysia has a shoreline of 5,068.5 km. Clay, mud, and silt coasts may be found all along the west coast of Peninsular Malaysia and Sabah, and nearly all the coasts are made up of regularly eroding productive soil. East Peninsular Malaysia, Sarawak, and sections of west Peninsular Malaysia such as Pulau Pinang, Port Dickson, and Melaka have sandy coasts (DID, 2015). Because of the vast erosion along the shoreline, coastal erosion has become a national rather than a local issue in Malaysia. Coastal locations host a variety of vital economic and social activities that exacerbate the coastal erosion. The National Coastal Erosion Study (NCES) was undertaken in 1985 under the auspices of the Minister Department’s Economic Planning Unit (EPU) to assess the coastal erosion, and the results suggested that 30% of Malaysia’s coastal lands were threatened by erosion. Peninsular Malaysia (including Pulau Tioman, Pulau Langkawi, and Pulau Pinang), Sabah, Pulau Labuan, and Sarawak were all included in the study. The study categorised deteriorating coastal locations based on the urgency and severity of the erosion hazard to the existing infrastructure. The study’s foundation was the identification of critical erosion areas with a total length of 140 km where the facilities were in an urgent risk. The facilities that would be endangered in 5 to 10 years were found in significant erosion regions with a total length of 240 km.

Acceptable erosion regions of more than 900 km in length are generally underdeveloped and do not currently contain any facilities that will be jeopardised soon (DID, 2015). The receding shoreline covers 1,347 km or 15.2% of the country's shoreline. A comprehensive coastal zone planning and management system is definitely required for a systematic development along Malaysia's 8,840 km of shoreline. Natural processes and/or human activities can produce shoreline changes. Natural phenomena such as waves, currents, and winds are examples of natural processes. Coastal erosion is a destructive natural disaster that occurs frequently. Previous research by Genderen and Marghany (2014) has established that coastal erosion has both direct and indirect effects on coastal communities, culminating in the abandonment of beachfront properties, the modification of coastal infrastructure, and, in the worst-case scenario, the loss of life.

Coastal erosion is also relevant in the most recent issue namely the phenomena of high tides, which occur frequently today. The erosion occurs in the coastal areas because of a combination of natural and human forces. When the location is exposed to severe gusts and heavy waves, the erosion problem becomes more difficult to manage. Sandy beaches are always changing, posing a hazard to assets such as buildings and transportation infrastructure. Rising sea levels will worsen the coastal erosion in this climate. The changes in the sea levels have an impact on changes in shorelines. In the future decades, the impact of the rising sea levels on sandy beaches is worth considering. This is done so that global data of long-term shoreline positions may be used to help construct more coastal effect models (Le Cozannet *et al*., 2019).

This research focuses on assessing the coastal erosion utilising aerial digital images in conjunction with geographic information system (GIS) mapping and analysis to define accurate shorelines in terms of accessible and available beach area. The information on the current state of erosion and the study of the erosion impact are essential for coastal management decision making. Coastal GIS is an important part of the study since it gives scientific data and aids decision making. It is also used to track the coastal changes in the study area. Shoreline erosion monitoring, coastal engineering management, and coastal data inventory are the three design functions of GIS. For shoreline change detection, the shoreline should be measured frequently from images, and historical photographs can be used to reconstruct past shoreline positions and estimate shoreline changes. The shoreline changes will be detected by comparing satellite images such as photographs and maps. Spatial analysis, categorisation findings, and temporal analysis will all be parts of the investigation. For shoreline changes, this study combined GIS and unmanned aerial vehicle (UAV) technologies, while the numerical method was used to forecast the future outcomes. The government and private entities will benefit from the unique method of shoreline mapping for coastal erosion prediction utilised in this study for evaluating the coastal area, particularly for decision making and coastal erosion prediction.

1.2 Problem Statement

A few approaches can be used in the field to map and monitor the coastal erosion, such as Light Detection and Ranging (LiDAR) (Tak *et al.*, 2020), Global Positioning System (Smith *et al.*, 2021), Terrestrial Laser Scanning (TLS) (Hayakawa & Obanawa, 2020), manned aircraft (Green *et al.*, 2019), and remote sensing (Apostolopoulos & Nikolakopoulos, 2021). The remote sensing and aerial photogrammetry are effectively and widely being used to map the coastal erosion. Engineers can use the available geoinformation technologies to preserve the coastal areas from erosion.

Malaysia's coastal erosion rate varies between 1 m/year and 100 m/year, with some regions degrading much faster (DID, 2015). The residential areas, recreation theme parks, and resorts are among the development projects in the coastal zone that are rising in numbers year after year. Although there are methods for controlling or at least reducing the erosion, such as implementing structural measures such as revetments, sea walls, gabions, breakwaters, and groins, the waves and mean high water could have an impact on the developed buildings. Therefore, it is necessary to gain a better understanding of the erosion process and lay the groundwork for planning and managing activities and facilities in the coastal areas. In 1987, the National Coastal Erosion Control (NCEC) and the Coastal Engineering Technical Centre (CETC) were established to regulate the coastal development initiatives.

Up to now, several studies have shown that coastal vulnerabilities such as shoreline shifts and coastal flooding affect the majority of the world's coasts and are accountable for property and infrastructure devastation. Long-term and short-term shoreline changes are influenced by a variety of factors including sediment supply, littoral transport, secular sea-level variations, nearshore hydrodynamics, river mouth processes, storm surges, and the type of coastal landforms (Scott, 2005; Kumar & Jayappa, 2009).

According to Luijendijk and Vries (2020), 31% of the world's ice-free shorelines are sandy, and 24% are degrading at rates more than 0.5 m/year. The property and urban infrastructure damages that result in environmental and economic losses may lead to significant issues for the local communities, decision makers, and government agencies (Silveira *et al.*, 2021). For example, despite the development of different coastal defence measures in Tanjung Piai, Johor, the coastal area faced serious erosion issues for several decades, according to the research by Nor Aslinda Awang in 2014. The pace of shoreline retreat was found to be between 2 and 4 m/year. This demonstrates the need of shoreline change monitoring that utilises satellite images combined with GIS for coastal management. Malaysia must respond to the urgent need for a thorough scientific study for national coastal planning. GIS and UAV integration can analyse an exact and true database for each year. This model can be used by the authorities as a decision maker to manage the coastal and tourist areas. These coastal erosion monitoring model and coastal management plan entail increasing coastal zone management in an integrated manner so that the coastal erosion incidences do not grow in terms of database usefulness. Thus, a viable technique for achieving the study's purpose should be created.

The research region's shoreline area is assessed to be 174m x 627m, and erosion is projected to be roughly 450 m long. The remnants of certain banks created with rubble wall structures show the effects of erosion. Erosion in the research area has been caused by wave action on those structures. The rate of erosion along the coast will rise as current velocity and wave height change, and this rate will rise even more during the monsoon and High Astronomical Tide (HAT) when strong currents, high waves, and tidal activities have a great influence on the area's existing shoreline. Coastal erosion has been present in this area since the beginning of 2002 until 2018 (DID, 2018). Since 2004, several solutions have been developed to combat erosion in the study region, including the Beach Management System (BMS), sandbag and geotextile, groin, erosion barrier structure, and coastal reclamation. However, majority of the geobags were found to be punctured, even though they were employed to reduce erosion. Figures 1.1 to 1.3 show the most recent erosion that occurred in the study area. Although numerous approaches have been used, coastal erosion are still happening.

DID has produced an Integrated Shoreline Management Plan (ISMP), which is a non-structural, long-term solution to coastal erosion issues. It is based on the same principles and characteristics as Integrated Coastal Zone Management (ICZM). The ISMP, on the other hand, has been created to be more specialised and to consider the local factors in the coastal area, and it is a management plan that covers all aspects of coastal management. This study combined the data from ISMP with new information gathered by academics. Furthermore, Ab Rahman *et al.* (2017) urged more research to be conducted using the statistical technique because of its usefulness in predicting coastal changes. As a result, a numerical model for the predicted future shoreline has been created to support the study.

Malaysia witnessed the worst natural disaster in its history on December 26, 2004, when a tsunami struck the northwest regions of Peninsular Malaysia. The tsunami affected several places and exposed the coast to the open sea, thus resulting in the worst coastal erosion consequences ever recorded. Figure 1.1 to 1.3 shows the erosion at the study area. The Malaysian government created the Third National Physical Plan on New Planning Guidelines (GPP) for Disaster Resilient Cities (DRC) in response to the tsunami disaster. According to these guidelines, coastal erosion is one of Malaysia's top five natural disasters. According to a study conducted by Kulp & Strauss (2019), global temperatures and sea levels are anticipated to rise by 2050.

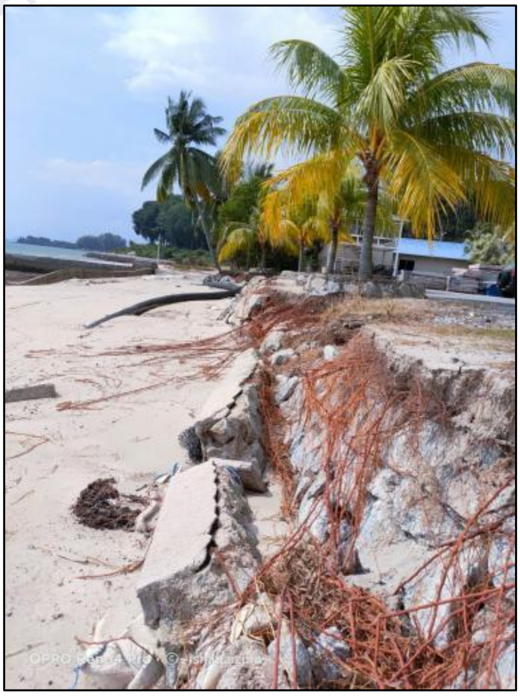

Figure 1.1: Erosion at the study area

Figure 1.2: View from the front of the hotel

Figure 1.3: Erosion in the parking area in front of the hotel

The Malaysian government is currently exerting all its available resources to address the problem of shoreline erosion. The Malaysian government is utilising the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030, which was approved at the third United Nations World Conference on Disaster Risk Reduction. Henceforth, urgent research is required to avoid even worse consequences in the future. According to previously completed studies, no research has been done on the integration of remote sensing techniques, UAVs, and statistical modelling in predicting the predicted shoreline. The majority of conducted research focus entirely on determining historical shorelines, the most recent shoreline, or predicted sea level rise (Quang *et al.*, 2017; Sarhan *et al.*, 2020; Bagheri *et al.*, 2019; Qiao *et al.*, 2018; Maiti and Bhattacharya, 2009; Galgano and Douglas, 2000).

1.3 Objectives

The main objective of this study was to develop and validate a model for predicting future coastal shoreline changes in Port Dickson, Malaysia. This model would aid in the modelling of shoreline changes for future forecasting. The following specific objectives can help attain the main objective:

i. To evaluate the rate of coastal erosion at the Regency Beach, Port Dickson shoreline using a spatial-temporal scale.
ii. To quantify rate-of-change statistics based on various historical shoreline positions.
iii. To develop prediction shoreline using a mathematical model.

1.4 Significance of Study

Sea level rise has substantial long-term consequences for coastal communities, and the degree of those impacts depends on how exposed and vulnerable such areas are. Storm surges and flooding can have devastating consequences on coastal communities, especially in low-lying locations. People and property in coastal areas are at risk from the rising sea levels. A rise in sea levels will exacerbate these consequences and may lead to long-term economic and social disruptions at the coastal areas in the future (Tacoli, 2009; Tol, 2020; Ehsan *et al.*, 2019). According to the NCES (2015), the impacted coastal areas are classified according to the severity of erosion threats to the existing facilities. The study's findings have identified major erosion regions with a total length of 140 km where facilities are in jeopardy. The facilities in a large erosion area with a total length of 240 km will be jeopardised in the next 5 to 10 years. An acceptable erosion area of more than 900 km in length is generally undeveloped and

REFERENCES

Ab Rahman, A. A., Maulud, K. A., Mohd, F. A., Jaafar, O., & Tahar, K. N. (2017, December). Volumetric calculation using low cost unmanned aerial vehicle (UAV) approach. In *IOP Conference Series: Materials Science and Engineering* (270, 1, p. 012032). IOP Publishing.

Ab Razak, M. S., Jamaludin, N., & Nor, N. A. Z. M. (2018). The planform stability of embayed beaches on the west coast of Peninsular Malaysia. *Jurnal Teknologi*, *80*(4).

Adams, P. N., Inman, D. L., & Lovering, J. L. (2011). Effects of climate change and wave direction on longshore sediment transport patterns in Southern California. *Climatic Change*, *109*(1), 211-228.

Addo, K. A., Jayson-Quashigah, P. N., & Kufogbe, K. S. (2011). Quantitative analysis of shoreline change using medium resolution satellite imagery in Keta, Ghana. *Marine Science*, *1*(1), 1-9.

Aedla, R., Dwarakish, G. S., & Reddy, D. V. (2015). Automatic shoreline detection and change detection analysis of netravati-gurpurrivermouth using histogram equalization and adaptive thresholding techniques. *Aquatic Procedia*, *4*, 563-570.

Agueera-Vega, F., Carvajal-Ramirez, F., Martínez-Carricondo, P., López, J. S. H., Mesas-Carrascosa, F. J., García-Ferrer, A., & Pérez-Porras, F. J. (2018). Reconstruction of extreme topography from UAV structure from motion photogrammetry. *Measurement*, *121*, 127-138.

Ahmad, M. B. A., Bahiah, B., Rasib, A. W., & Saifullizan, M. B. (2021). GIS and Multi-criteria Analysis for School Site Selection (Study Case: Malacca

Historical City). *International Journal of Integrated Engineering*, *13*(4), 234-241.

Airoldi, L., Abbiati, M., Beck, M. W., Hawkins, S. J., Jonsson, P. R., Martin, D., & Åberg, P. (2005). An ecological perspective on the deployment and design of low-crested and other hard coastal defence structures. *Coastal engineering*, *52*(10-11), 1073-1087.

Alkhalidi, M. A., Al-Dabbous, S. K., Neelamani, S., & Aldashti, H. A. (2019). Wind energy potential at coastal and offshore locations in the state of Kuwait. *Renewable Energy*, *135*, 529-539.

Anfuso, G., & Martinez del Pozo, J. A. (2005). Towards management of coastal erosion problems and human structure impacts using GIS tools: case study in Ragusa Province, Southern Sicily, Italy. *Environmental Geology*, *48*(4), 646-659.

Apostolopoulos, D., & Nikolakopoulos, K. (2021). A review and meta-analysis of remote sensing data, GIS methods, materials and indices used for monitoring the coastline evolution over the last twenty years. *European Journal of Remote Sensing*, *54*(1), 240-265.

Ariffin, E. H., Sedrati, M., Akhir, M. F., Norzilah, M. N. M., Yaacob, R., & Husain, M. L. (2019). Short-term observations of beach Morphodynamics during seasonal monsoons: Two examples from Kuala Terengganu coast (Malaysia). *Journal of Coastal Conservation*, *23*(6), 985-994.

Awang, N. A., & Hamid, M. R. A. (2013). Sea level rise in Malaysia. *Sea level rise adaptation measures. Hydrolink*, *2*, 47-49.

Awang, N. A., Jusoh, W. H. W., & Hamid, M. R. A. (2014). Coastal Erosion at Tanjong Piai, Johor, Malaysia. *Journal of Coastal Research*, (71 (10071)), 122-130.

Bagheri, M., Zaiton Ibrahim, Z., Bin Mansor, S., Abd Manaf, L., Badarulzaman, N., & Vaghefi, N. (2019). Shoreline change analysis and erosion prediction using historical data of Kuala Terengganu, Malaysia. *Environmental Earth Sciences*, *78*(15), 1-21.

Bathrellos, G. D., Skilodimou, H. D., Chousianitis, K., Youssef, A. M., & Pradhan, B. (2017). Suitability estimation for urban development using multi-hazard assessment map. *Science of the Total Environment*, *575*, 119-134.

Bay, N., & Park, N. (2005). UAV Monitoring Of Dune Dynamics-Anna Bay Entrance, Stockton Bight.

Beluru Jana, A., & Hegde, A. V. (2016). GIS based approach for vulnerability assessment of the Karnataka coast, India. *Advances in Civil Engineering*, *2016*.

Bheeroo, R. A., Chandrasekar, N., Kaliraj, S., & Magesh, N. S. (2016). Shoreline change rate and erosion risk assessment along the Trou Aux Biches–Mont Choisy beach on the northwest coast of Mauritius using GIS-DSAS technique. *Environmental Earth Sciences*, *75*(5), 1-12.

Bird, E. C. (2011). *Coastal geomorphology: an introduction*. John Wiley & Sons.

Boak, E. H., & Turner, I. L. (2005). Shoreline definition and detection: a review. *Journal of coastal research*, *21*(4), 688-703.

Breckenridge, R. P., & Dakins, M. E. (2011). Evluation of bare ground on rangelands using Unmanned Aerial Vehicles: A case study. *GIScience & Remote Sensing*, *48*(1), 74-85.

Bruun, P. (1962). Sea-level rise as a cause of shore erosion. *Journal of the Waterways and Harbors division*, *88*(1), 117-130.

Carrasco, A. R., Ferreira, Ó., & Roelvink, D. (2016). Coastal lagoons and rising sea level: A review. *Earth-Science Reviews*, *154*, 356-368.

Carrivick, J. L., & Smith, M. W. (2019). Fluvial and aquatic applications of Structure from Motion photogrammetry and unmanned aerial vehicle/drone technology. *Wiley Interdisciplinary Reviews: Water*, *6*(1), e1328.

Carvalho, R. C., Kennedy, D. M., Niyazi, Y., Leach, C., Konlechner, T. M., & Ierodiaconou, D. (2020). Structure-from-motion photogrammetry analysis of historical aerial photography: Determining beach volumetric change over decadal scales. *Earth Surface Processes and Landforms*, *45*(11), 2540-2555.

Casella, E., Rovere, A., Pedroncini, A., Stark, C. P., Casella, M., Ferrari, M., & Firpo, M. (2016). Drones as tools for monitoring beach topography changes in the Ligurian Sea (NW Mediterranean). *Geo-Marine Letters*, *36*(2), 151-163.

Cenci, L., Disperati, L., Sousa, L. P., Phillips, M., & Alve, F. L. (2013). Geomatics for Integrated Coastal Zone Management: multitemporal shoreline analysis and future regional perspective for the Portuguese Central Region. *Journal of Coastal Research*, (65 (10065)), 1349-1354.

Chao, H., Cao, Y., & Chen, Y. (2010). Autopilots for small unmanned aerial vehicles: a survey. *International Journal of Control, Automation and Systems*, *8*(1), 36-44.

Collins, B. D., & Sitar, N. (2008). Processes of coastal bluff erosion in weakly lithified sands, Pacifica, California, USA. *Geomorphology*, *97*(3-4), 483-501.

Crowell, M., Honeycutt, M., & Hatheway, D. (1999). Coastal erosion hazards study: phase one mapping. *Journal of Coastal Research*, 10-20.

Dahm, J. (2000). Natural character: concept development in New Zealand planning law and policy. *Environment Waikato, Hamilton*.

Darwish, K., Smith, S. E., Torab, M., Monsef, H., & Hussein, O. (2017). Geomorphological changes along the Nile Delta coastline between 1945 and 2015 detected using satellite remote sensing and GIS. *Journal of Coastal Research*, *33*(4), 786-794.

Das, B. M. (2011). Principles of Foundation Engineering. 7th. *Pacific Grove: Brooks/Cole-Thomson Learning*.

Dean, R. G., & Dalrymple, R. A. (2004). *Coastal processes with engineering applications*. Cambridge University Press.

Department of Irrigation and Drainage Malaysia. (2015). *National Coastal Erosion Study*. Malaysia

Dewi, R. S., & Bijker, W. (2020). Dynamics of shoreline changes in the coastal region of Sayung, Indonesia. *The Egyptian Journal of Remote Sensing and Space Science*, *23*(2), 181-193.

Dolan, R., Hayden, B., & May, S. (2018). Erosion of the US shorelines. In *CRC handbook of coastal processes and erosion* (pp. 285-300). CRC Press.

Drummond, C. D., Harley, M. D., Turner, I. L., Matheen, A. N. A., & Glamore, W. C. (2015, September). UAV applications to coastal engineering. In *Australasian Coasts & Ports Conference* (2015, p. 22nd).

Dupré, W. R., & Evans, I. (2000). Attempts at improving quantitative problem-solving skills in large lecture-format introductory geology classes. *Journal of Geoscience Education*, *48*(4), 431-435.

Ehsan, S., Begum, R. A., Nor, N. G. M., & Maulud, K. N. A. (2019). Current and potential impacts of sea level rise in the coastal areas of Malaysia. In *IOP*

Conference Series: Earth and Environmental Science (228, 1, p. 012023). IOP Publishing.

Eschmann, C., Kuo, C. M., Kuo, C. H., & Boller, C. (2012). Unmanned aircraft systems for remote building inspection and monitoring.

Esmail, M., Mahmod, W. E., & Fath, H. (2019). Assessment and prediction of shoreline change using multi-temporal satellite images and statistics: Case study of Damietta coast, Egypt. *Applied Ocean Research*, *82*, 274-282.

Fenster, M. S., Dolan, R., & Smith, J. J. (2016). Grain-size distributions and coastal morphodynamics along the southern Maryland and Virginia barrier islands. *Sedimentology*, *63*(4), 809-823.

Ghazali, N. H. M., Awang, N. A., Mahmud, M., & Mokhtar, A. (2018). Impact of sea level rise and tsunami on coastal areas of north-West Peninsular Malaysia. *Irrigation and Drainage*, *67*, 119-129.

Gonçalves, J. A., & Henriques, R. (2015). UAV photogrammetry for topographic monitoring of coastal areas. *ISPRS Journal of Photogrammetry and Remote Sensing*, *104*, 101-111.

Gopikrishna, B., & Deo, M. C. (2018). Changes in the shoreline at Paradip Port, India in response to climate change. *Geomorphology*, *303*, 243-255.

Green, D. R., Hagon, J. J., Gómez, C., & Gregory, B. J. (2019). Using low-cost UAVs for environmental monitoring, mapping, and modelling: Examples from the coastal zone. In *Coastal management* (pp. 465-501). Academic Press.

Gross, M. G. (1990). Oceanography; A View of Earth Prentice Hall. *Inc. Englewood Cliff. New Jersey*.

Hakkou, M., Maanan, M., Belrhaba, T., El Ouai, D., & Benmohammadi, A. (2018). Multi-decadal assessment of shoreline changes using geospatial tools and automatic computation in Kenitra coast, Morocco. *Ocean & Coastal Management*, *163*, 232-239.

Harwin, S., & Lucieer, A. (2012). Assessing the accuracy of georeferenced point clouds produced via multi-view stereopsis from unmanned aerial vehicle (UAV) imagery. *Remote Sensing*, *4*(6), 1573-1599.

Hassan, M. I., & Rahmat, N. H. (2016). The effect of coastline changes to local community's social-economic. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*, *42*.

Hayakawa, Y. S., & Obanawa, H. (2020, September). Volume Measurement of Coastal Bedrock Erosion Using UAV and TLS. In *IGARSS 2020-2020 IEEE International Geoscience and Remote Sensing Symposium* (pp. 5230-5233). IEEE.

James, M. R., & Robson, S. (2012). Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application. *Journal of Geophysical Research: Earth Surface*, *117*(F3).

JPBD. Report Rancangan Fizikal Zon Pesisiran Pantai Negara; Federal Town and Country Planning Department: Kuala Lumpur, Malaysia, 2012; ISBN 9789832839354

Kaamin, M., Daud, M. E., Sanik, M. E., Ahmad, N. F. A., Mokhtar, M., Ngadiman, N., & Yahya, F. R. (2018, September). Mapping shoreline position using unmanned aerial vehicle. In *AIP Conference Proceedings* (Vol. 2016, No. 1, p. 020063). AIP Publishing LLC.

Kallepalli, A., Kakani, N. R., James, D. B., & Richardson, M. A. (2017). Digital shoreline analysis system-based change detection along the highly eroding Krishna–Godavari delta front. *Journal of Applied Remote Sensing*, *11*(3), 036018.

Kim, J. O., & Lee, J. K. (2017). UAV Application for process control of the reclamation project. *Journal of Coastal Research*, (79 (10079)), 309-313.

Kolednik, D. (2014). Coastal monitoring for change detection using multi-temporal LiDAR data. *Proceedings of the CESCG*, 73-78.

Kuleli, T., Guneroglu, A., Karsli, F., & Dihkan, M. (2011). Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. *Ocean Engineering*, *38*(10), 1141-1149.

Kulp, S. A., & Strauss, B. H. (2019). New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nature communications*, *10*(1), 1-12.

Kumar, A., & Jayappa, K. S. (2009). Long and Short-Term Shoreline Changes Along Mangalore Coast, India. *Int. J. Environ. Res*, *3*(2), 177-188.

Kumaravel, S., Ramkumar, T., Gurunanam, B., Suresh, M., & Dharanirajan, K. (2013). An application of remote sensing and GIS based shoreline change studies–a case study in the Cuddalore District, East Coast of Tamilnadu, South

India. *International Journal of Innovative Technology and Exploring Engineering*, *2*(4), 211-215.

Landry, C. E., Shonkwiler, J. S., & Whitehead, J. C. (2018). Economic values of coastal erosion management: Joint estimation of use and passive use values with recreation demand and contingent valuation data. *Available at SSRN 3215484*.

Le Cozannet, G., Bulteau, T., Castelle, B., Ranasinghe, R., Wöppelmann, G., Rohmer, J., ... & Salas-y-Mélia, D. (2019). Quantifying uncertainties of sandy shoreline change projections as sea level rises. *Scientific reports*, *9*(1), 1-11.

Li, R., Keong, C. W., Ramcharan, E., Kjerfve, B., & Willis, D. (1998). A coastal GIS for shoreline monitoring and management-case study in Malaysia. *Surveying and Land Information Systems*, *58*(3), 157-166.

Li, X., Zhou, Y., Tian, B., Kuang, R., & Wang, L. (2015). GIS-based methodology for erosion risk assessment of the muddy coast in the Yangtze Delta. *Ocean and Coastal Management*, *108*, 97–108.

Lin, D., & Li, B. (2018, August). Application of GIS in Campus Navigation. In *8th International Conference on Education, Management, Information and Management Society (EMIM 2018)* (pp. 356-360). Atlantis Press.

Liu, Q., & Trinder, J. C. (2018). Sub-pixel technique for time series analysis of shoreline changes based on multispectral satellite imagery. *Advanced Remote Sens. Technology for Synthetic Aperture Radar Applications, Tsunami Disasters, and Infrastructure*.

Lucieer, A., Jong, S. M. D., & Turner, D. (2014). Mapping landslide displacements using Structure from Motion (SfM) and image correlation of multi-temporal UAV photography. *Progress in physical geography*, *38*(1), 97-116.

Lucieer, A., Turner, D., King, D. H., & Robinson, S. A. (2014). Using an Unmanned Aerial Vehicle (UAV) to capture micro-topography of Antarctic moss beds. *International Journal of Applied Earth Observation and Geoinformation*, *27*, 53-62.

Luijendijk, A., & de Vries, S. (2020). Global beach database. In *Sandy Beach Morphodynamics* (pp. 641-658). Elsevier.

Luijendijk, A., Hagenaars, G., Ranasinghe, R., Baart, F., Donchyts, G., & Aarninkhof, S. (2018). The state of the world's beaches. *Scientific reports*, *8*(1), 1-11.

Mancini, F., Dubbini, M., Gattelli, M., Stecchi, F., Fabbri, S., & Gabbianelli, G. (2013). Using unmanned aerial vehicles (UAV) for high-resolution reconstruction of topography: The structure from motion approach on coastal environments. *Remote sensing*, *5*(12), 6880-6898.

Marfai, M. A. (2011). The hazards of coastal erosion in Central Java, Indonesia: An overview. *Geografia-Malaysian Journal of Society and Space*, *7*(3), 1-9.

Maulud, K. N. A., & Rafar, R. M. (2015, August). Determination the impact of sea level rise to shoreline changes using GIS. In *2015 International Conference on Space Science and Communication (IconSpace)* (pp. 352-357). IEEE.

Mentaschi, L., Vousdoukas, M. I., Pekel, J. F., Voukouvalas, E., & Feyen, L. (2018). Global long-term observations of coastal erosion and accretion. *Scientific reports*, *8*(1), 1-11.

Modava, M., Akbarizadeh, G., & Soroosh, M. (2018). Integration of spectral histogram and level set for coastline detection in SAR images. *IEEE Transactions on Aerospace and Electronic Systems*, *55*(2), 810-819.

Mohamed Rashidi, A. H., Jamal, M. H., Hassan, M. Z., Mohd Sendek, S. S., Mohd Sopie, S. L., & Abd Hamid, M. R. (2021). Coastal structures as beach erosion control and sea level rise adaptation in malaysia: A review. *Water*, *13*(13), 1741.

Mokhtar, N. M., Darwin, N., Ariff, M. F. M., Majid, Z., & Idris, K. M. (2019). The apabilities of unmanned aerial vehicle for slope classification. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*.

Moussaid, J., Fora, A. A., Zourarah, B., Maanan, M., & Maanan, M. (2015). Using automatic computation to analyze the rate of shoreline change on the Kenitra coast, Morocco. *Ocean Engineering*, *102*, 71-77.

Mujabar, P. S., & Chandrasekar, N. (2013). Shoreline change analysis along the coast between Kanyakumari and Tuticorin of India using remote sensing and GIS. *Arabian Journal of Geosciences*, *6*(3), 647-664.

Nahon, A., Molina, P., Blázquez, M., Simeon, J., Capo, S., & Ferrero, C. (2019). Corridor mapping of sandy coastal foredunes with UAS photogrammetry and mobile laser scanning. *Remote Sensing*, *11*(11), 1352.

Nassar, K., Mahmod, W. E., Fath, H., Masria, A., Nadaoka, K., & Negm, A. (2019). Shoreline change detection using DSAS technique: Case of North Sinai coast, Egypt. *Marine Georesources & Geotechnology*, *37*(1), 81-95.

Natesan, U., Parthasarathy, A., Vishnunath, R., Kumar, G. E. J., & Ferrer, V. A. (2015). Monitoring longterm shoreline changes along Tamil Nadu, India using geospatial techniques. *Aquatic Procedia*, *4*, 325-332.

National Hydraulic Research Institute of Malaysia (2008). *Integrated Shoreline Management Plan of Negeri Sembilan*.

National Hydraulic Research Institute of Malaysia (2010). The study of Impact of Sea Level Rise in Pulau Langkawi. p3-1.

Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding-a global assessment. *PloS one*, *10*(3), 0118571.

Ngoc, G. P., Moon, K. S., Lee, S. H., & Kwon, K. R. (2016, December). GIS Map Encryption Algorithm for Drone Security Based on Geographical Features. In *2016 International Conference on Computational Science and Computational Intelligence (CSCI)* (p. 1422-1423). IEEE.

Nguyen, H. H., McAlpine, C., Pullar, D., Johansen, K., & Duke, N. C. (2013). The relationship of spatial–temporal changes in fringe mangrove extent and adjacent land-use: Case study of Kien Giang coast, Vietnam. *Ocean & coastal management*, *76*, 12-22.

Nor, N. A. M., Tahar, K. N., Suprijo, T., & Sulaiman, S. A. H. (2020, August). Shoreline changes analysis along the coast of Kuala Terengganu, Malaysia using DSAS. In *2020 11th IEEE Control and System Graduate Research Colloquium (ICSGRC)* (pp. 276-281). IEEE.

Paiman, T., & Asmawi, M. Z. (2015). The Practice of Coastal Management Initiatives in Using Geographical Information System in Selangor, Malaysia. In *3rd Int. Conf. Biol. Chem. Environ. Sci.* (pp. 23-8).

Pandian, P. K., Ramesh, S., Murthy, M. V. R., Ramachandran, S., & Thayumanavan, S. (2004). Shoreline changes and near shore processes along Ennore coast, east coast of South India. *Journal of Coastal Research*, *20*(3), 828-845.

Pereira, E., Bencatel, R., Correia, J., Félix, L., Gonçalves, G., Morgado, J., & Sousa, J. (2009). Unmanned air vehicles for coastal and environmental research. *Journal of Coastal Research*, 1557-1561.

Pettijohn, F. J. (1975). *Sedimentary rocks* (Vol. 3, p. 628). New York: Harper & Row.

Pollard, J. A., Spencer, T., & Brooks, S. M. (2019). The interactive relationship between coastal erosion and flood risk. *Progress in Physical Geography: Earth and Environment*, *43*(4), 574-585.

Popielarczyk, D., & Templin, T. (2014). Application of integrated GNSS/hydroacoustic measurements and GIS geodatabase models for bottom analysis of Lake Hancza: the deepest inland reservoir in Poland. *Pure and Applied Geophysics*, *171*(6), 997-1011.

Prajwal, M., Rishab, J., Vaibhav, S., & Karthik, K. S. (2016). Optimal number of ground control points for a UAV based corridor mapping. *Int. J. Innov. Res. Sci. Eng. Technol*, *5*(9), 28-32.jun

Radoglou-Grammatikis, P., Sarigiannidis, P., Lagkas, T., & Moscholios, I. (2020). A compilation of UAV applications for precision agriculture. *Computer Networks*, *172*, 107148.

Rajendra, E. (2016, April 13). Coastal erosion cause for concern. *The Star.*

Ramli, N. I., Majid, T. A., Chik, F. W., Muhammad, M. K. A., & Deraman, S. C. (2014). Assessment of pull-through failure of nail connection for rural roofing system under wind load in Malaysia. *Journal of Civil Engineering Research*, *4*, 135-137.

Rashidi, A. M., Ab Ghani, N. H., Sendek, S. S. M., Jamal, M. H., & Hamid, M. R. A. (2018). Beach Protection System Using Nahrim Coastal Erosion Protection And Beach Expansion (NEXC) Block at Pantai Batu 5, Port Dickson, Negeri Sembilan, Malaysia. In *Proceedings of the 4th International Conference on Water Research*.

Rebelo, L. M., Finlayson, C. M., & Nagabhatla, N. (2009). Remote sensing and GIS for wetland inventory, mapping and change analysis. *Journal of environmental management*, *90*(7), 2144-2153.

Romine, B. M., & Fletcher, C. H. (2013). A summary of historical shoreline changes on beaches of Kauai, Oahu, and Maui, Hawaii. *Journal of Coastal Research*, *29*(3), 605-614.

Ryan, J. C., Hubbard, A. L., Box, J. E., Todd, J., Christoffersen, P., Carr, J. R., ... & Snooke, N. (2015). UAV photogrammetry and structure from motion to assess calving dynamics at Store Glacier, a large outlet draining the Greenland ice sheet. *The Cryosphere*, *9*(1), 1-11.

Sahin, O., Stewart, R. A., Faivre, G., Ware, D., Tomlinson, R., & Mackey, B. (2019). Spatial Bayesian Network for predicting sea level rise induced coastal erosion in a small Pacific Island. *Journal of environmental management*, *238*, 341-351.

Scott, D. B. (2005). Coastal changes, rapid. *Encyclopedia of coastal sciences. Springer, the Netherlands*, 253-255.

Serafin, K. A., Ruggiero, P., Barnard, P. L., & Stockdon, H. F. (2019). The influence of shelf bathymetry and beach topography on extreme total water levels: linking large-scale changes of the wave climate to local coastal hazards. *Coastal Engineering*, *150*, 1-17.

Sesli, F. A., Karsli, F., Colkesen, I., & Akyol, N. (2009). Monitoring the changing position of coastlines using aerial and satellite image data: an example from the eastern coast of Trabzon, Turkey. *Environmental Monitoring and Assessment*, *153*(1), 391-403.

Silveira, P. G., Venâncio, M. D., & Leite, J. R. M. (2021). Brumadinho's Disaster, Mine Tailing Dams and the Environmental Licencing in Brazil: Preventing Risks to Human Wellbeing, Soils, and the Environment. In *International Yearbook of Soil Law and Policy 2019* (pp. 241-259). Springer, Cham.

Smith, D., & Heidemann, H. K. (2015). New standard for new era: Overview of the 2015 ASPRS positional accuracy standards for digital geospatial data. *Photogrammetric Engineering & Remote Sensing*, *81*(3), 173-176.

Smith, K. E., Terrano, J. F., Pitchford, J. L., & Archer, M. J. (2021). Coastal wetland shoreline change monitoring: A comparison of shorelines from high-resolution WorldView Satellite imagery, aerial Imagery, and field surveys. *Remote Sensing*, *13*(15), 3030.

Štroner, M., Urban, R., Reindl, T., Seidl, J., & Brouček, J. (2020). Evaluation of the georeferencing accuracy of a photogrammetric model using a quadrocopter with onboard GNSS RTK. *Sensors*, *20*(8), 2318.

Sutherland, J. (2007). Inventory of coastal monitoring methods and overview of predictive models for coastal evolution. *Netherlands. Retrieved January*, *20*, 2017.

Sytnik, O., & Stecchi, F. (2015). Disappearing coastal dunes: tourism development and future challenges, a case-study from Ravenna, Italy. *Journal of Coastal conservation*, *19*(5), 715-727.

Tacoli, C. (2009). Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and urbanization*, *21*(2), 513-525.

Tak, W. J., Jun, K. W., Kim, S. D., & Lee, H. J. (2020). Using drone and LiDAR to assess coastal erosion and shoreline change due to the construction of coastal structures. *Journal of Coastal Research*, *95*(SI), 674-678.

Tavares, K. D., Fletcher, C. H., & Anderson, T. R. (2020). Risk of shoreline hardening and associated beach loss peaks before mid-century: Oʻahu, Hawaiʻi. *Scientific reports*, *10*(1), 1-10.

Thankappan, N., Varangalil, N., Kachapally Varghese, T., & Njaliplackil Philipose, K. (2018). Coastal morphology and beach stability along Thiruvananthapuram, south-west coast of India. *Natural Hazards*, *90*(3), 1177-1199.

Thieler, E. R., & Danforth, W. W. (1994). Historical shoreline mapping (II): application of the digital shoreline mapping and analysis systems (DSMS/DSAS) to shoreline change mapping in Puerto Rico. *Journal of coastal research*, 600-620.

Thieler, E. R., Himmelstoss, E. A., Zichichi, J. L., & Miller, T. L. (2005). *The Digital Shoreline Analysis System (DSAS) version 3.0, an ArcGIS extension for calculating historic shoreline cange* (No. 2005-1304). US Geological Survey.

Tol, R. S. J. (2009). The economic effects of climate change. *Journal of economic perspectives*, *23*(2), 29-51.

Toure, S., Diop, O., Kpalma, K., & Maiga, A. S. (2019). Shoreline detection using optical remote sensing: A review. *ISPRS International Journal of Geo-Information*, *8*(2), 75.

Tran Thi, V., Tien Thi Xuan, A., Phan Nguyen, H., Dahdouh-Guebas, F., & Koedam, N. (2014). Application of remote sensing and GIS for detection of long-term mangrove shoreline changes in Mui Ca Mau, Vietnam. *Biogeosciences*, *11*(14), 3781-3795.

Tunji, L. A. Q., Hashim, A. M., & Wan Yusof, K. (2012). Shoreline response to three submerged offshore breakwaters along Kerteh Bay coast of Terengganu. *Research Journal of Applied Sciences, Engineering and Technology*, *4*(16), 2604-2615.

Turner, I. L., Harley, M. D., & Drummond, C. D. (2016). UAVs for coastal surveying. *Coastal Engineering*, *114*, 19-24.

US Army Corps of Engineers. (2002). Coastal engineering manual. *Engineer manual 1110–2-1100*.

V Genderen, J., & Marghany, M. (2014, February). A three-dimensional sorting reliability algorithm for coastline deformation monitoring, using interferometric data. In *IOP Conference Series: Earth and Environmental Science* (Vol. 18, No. 1, p. 012116). IOP Publishing.

Vitousek, S., Barnard, P. L., & Limber, P. (2017). Can beaches survive climate change? *Journal of Geophysical Research: Earth Surface*, *122*(4), 1060-1067.

Vousdoukas, M. I., Ranasinghe, R., Mentaschi, L., Plomaritis, T. A., Athanasiou, P., Luijendijk, A., & Feyen, L. (2020). Reply to: Sandy beaches can survive sea-level rise. *Nature climate change*, *10*(11), 996-997.

Westoby, M. J., Brasington, J., Glasser, N. F., Hambrey, M. J., & Reynolds, J. M. (2012). 'Structure-from-Motion'photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*, *179*, 300-314.

Williams, S. J. (2013). Sea-level rise implications for coastal regions. *Journal of Coastal Research*, (63 (10063)), 184-196.

Wong, P. P., Losada, I. J., Gattuso, J. P., Hinkel, J., Khattabi, A., McInnes, K. L., ... & Sallenger, A. (2014). Coastal systems and low-lying areas. *Climate change*, *2104*, 361-409.

Wright, W., Dutta, D., & Rayment, P. (2010). Flood vulnerabillity analysis in coastal zones: a comparative analysis across five asia-pacific countries. In *International Symposium on Coastal Zones and Climate Change 2010* (pp. 433-443). Monash University Publishing.

Xu, N. (2018). Detecting coastline change with all available landsat data over 1986–2015: A case study for the state of Texas, USA. *Atmosphere*, *9*(3), 107.

Yanalagaran, R., Ramli, N.I., & Ramadhansyah, P.J. (2019). Overview of Monsoon Induced Coastal Erosion Disaster in Peninsular Malaysia Based On Mass-Media Reports. *IOP Conference Series: Earth and Environmental Science*.

Yoo, C. I., Oh, Y. S., & Choi, Y. J. (2018). Coastal mapping of Jinu-Do with UAV for Busan Smart City, Korea. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*, *42*(4), 725-729.

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.