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THE USE OF SENTINEL-2 IMAGERY IN ASSESSING TEMPORAL COASTAL EROSION WITH IT'S VALIDATION BY GNSS TECHNIQUE

A Case Study of Raskazone Beach, Tanga

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BSc Geomatics

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A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of Science in Geomatics (BSc. GM) of Ardhi University

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University a dissertation titled "**The use of sentinel-2 imagery in assessing temporal coastal erosion with it's validation by GNSS technique, a case study of Raskazone beach, Tanga** " in partial fulfilment of the requirements for the award of degree of Bachelor of Science in Geomatics of the Ardhi University.

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(Main Supervisor)	(Second Supervisor)
Date………………	Date ………………………

DECLARATION AND COPYRIGHT

I, CHARLES ALENIUS, hereby declare that, the contents of this dissertation are the result of my own findings through my study and investigation, and to the best of my knowledge, they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning

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22759/T.2019

CHARLES ALLENIUS

(Candidate)

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DEDICATION

This thesis is dedicated to my beloved mother Praxeda Kurungi Charles, my lovely sister Agnetha Charles and his husband Mr Dickson, my lovely brother Avitus Charles and beloved Family the Kagombora's, also friends and relatives.

Thank you for all the support you have given me throughout my life

ABSTRACT

Coastal erosion involves the gradual removal and displacement of particles as the result of factors such as water, wind, or gravity. Coastal erosion leads to the loss of land and natural habitats, posing a threat to coastal infrastructure and ecosystems. It increases the vulnerability of coastal areas to flooding and storm events, impacting human settlements and economic activities. Efforts to mitigate erosion are crucial for preserving coastal environments, protecting valuable infrastructure and ensuring the long-term sustainability of coastal communities. To address the challenges of coastal erosion, this study utilized Sentinel-2 satellite imagery to analyze the temporal patterns of coastal erosion and verify the findings by comparing them with the Global Navigation Satellite System (GNSS) technique.

In this study, the Sentinel-2 satellite mission provides high-resolution multispectral imagery, which enables the monitoring of coastal areas with improved spatial and temporal coverage. In this research, a time-series analysis of Sentinel-2 imagery is conducted to evaluate coastal erosion patterns over a specific period (2017-2023), along Raskazone Beach in Tanga Region. The analysis includes the identification and quantification of shoreline changes, such as retreat or accretion, along the coast.

To validate the findings obtained from the satellite imagery, the GNSS technique is employed. GNSS receivers are deployed along the coastline to measure precise positions of reference points over time. By comparing the shoreline positions derived from satellite imagery with those obtained from GNSS measurements, the accuracy and reliability of the satellite-based erosion assessment and found to be 0.03m as the difference from the GNSS observed data and sentinel-2 imagery.

The integration of Sentinel-2 imagery and GNSS measurements provides a comprehensive approach to assess temporal coastal erosion. From the study, the coastline of Raskazone shore were extracted from sentinel-2 imagery, the rates were determined by which the general rate of change from the year 2017 to 2023 was 0.772m/year calculated from the baseline by DSAS tool, but it varied from year to year, and the current position of the shoreline was determined by producing a topographical map of the area and the features that can be easily destroyed by continual erosion.

Keywords: coastal erosion, Sentinel-2, time-series analysis, shoreline changes, GNSS technique, validation, coastal management.

LIST OF ABBREVIATIONS

DSAS	Digital Shoreline Analysis System
ESA	European Space Agency (ESA)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
NIR	Near Infrared
RTK	Rapid Time Kinematics
SWIR	Short-wave infrared

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CHAPTER ONE
INTRODUCTION

1.1. Background of the Problem

Coastal erosion is the washing away and the transportation of particles from one place to the other which can be a result of many factors including water, wind or gravity. (Paolo, 2016). The materials are washed away too easily as the result of many factors like loss of vegetation along the areas, the type of soil present, topography, climatic changes and even the increased level of water also results to the washing away of the materials along the coast thus leading to leaving the coast bare and destructed. Coastal erosion has been a global problem affecting almost every country having the coastline, something that is expected to be worse in the coming years if not studied and controlled in a given period of time, (Dahi, 2013).

Coastal erosion occurs due to the combination of factors that develop at different scales. Sea level rise, the intensity of storms and human interventions constitute the main parameters for coastal erosion (Hannah, 2004).

Coastal erosion can have a range of negative impacts on the environment, infrastructure, and communities in coastal areas, of which (Olayeni, 2017) states some results of erosion like; Loss of land, damage to infrastructure in nearby areas, increased flooding and also damage to the ecosystem and more so can lead to coastal retreat.

Therefore, the effects of coastal erosion can be very significant and far-reaching, it is important for communities and governments to take action to mitigate its impacts and adapt to changing coastal conditions.

Tanga beach, which is among coastal areas which may be affected by long-term erosion (McGranaham, 2007), by taking a look of Raskazone Coastal Area which is among the coastal areas that may be affected by coastal erosion. Raskazone area is more attractive for several investments and as per now it is occupied by several activities like harbor development, climate change construction along the beach and human activities are among the contributing factors of coastal erosion, thus if it is not well monitored and assessed on the issue of erosion, there can rise some effects related to coastal erosion., thus there is a need to use the current techniques which have more accuracy and can produce more reliable data for the long span of time and can easily be monitored Upon the utilization of techniques with greater accuracies like GNSS technique, and sentinel-2 imagery are assumed to be a good help in determining good results of coastal erosion assessment and hence may help in determining the current rates of coastal erosion along Raskazone beach in Tanga Region.

In the area, several groins have been built and this contributes to a modification of the hydrodynamics in the area.

1.1.2 Previous Research

Elineema (2008), used the aerial photographic scanning and image georeferencing to determine the coastal erosion process. The researcher concluded that remote sensing and GIS were the best tools for monitoring the coastal environmental and the resources around. And also recommended on the continual monitoring of the shoreline to determine and address the coastline changes.

Also, (Swai, 2006) did the assessment of coastal erosion using Thematic mapper TM of the previous years to determine the rate at which the coastline was changing for the past years. The use of thematic mapper entailed to show the rate at which erosion has been taking place, and the imagery used dated back in the past years of 1987 and 2002. The results shown there was continual erosion that had taken place for over 30 years (Swai, 2006), determined the coastline change in terms of area by using Analysis system to calculate the coastline changes.

Further, (Ndola, 2018), used Satellite Altimetry in assessing coastal erosion and its validation using tidal data. In his research he concluded that there is high correlation between sea level rise from altimetry data to coastal erosion. In his research, he analyzed that anomaly increased from year 2012 and became maximum in 2015 with maximum sea level of 0.218977m. Thus, from his analysis, sea level rise can be used as one of the major causes of coastal erosion and it is more likely to affect most coasts along the Indian Ocean. The researcher recommended that for further monitoring of coastal erosion, there is a need to use GNSS technique with validation to Lidar technique.

Similarly in 2018, seeing the problem associated with coastline change, (Pardo, 2018), conducted a study that to observe coastline change with the use of sentinel 2 image.

The sentinel 2 image was used over Landsat image due to better spatial resolution of 10 x 10 meters which is better than the Landsat imagery.

According to (G, 2009) ocean waves and currents included in the oceanographic parameters are generated by surface wind so that the rate of erosion and increase that occurs is influenced by the named parameters.

From all the research conducted along the coastline, there is the need to validate the accuracy of the satellite images and GNSS in terms of operation and output.

Previous researches were based on Kunduchi beach but this research will focus on assessing the rate of coastal erosion along RASKAZONE SHORELINE as it is prone to tourist attraction, harboring and other developmental activities are more likely to be carried along the areas. Addressing the problem of coastal erosion along Raskazone will help in preserving the coastline.

Also, the validation will be of helpful in telling to which periods is the rate of erosion high by using the data collected using GNSS and the sentinel-2 imagery. The Sentinel-2 imagery will be corrected for geometric distortions, atmospheric effects and other errors. The validation on the methods will help in identifying which methods gives a clear insight on the problem of coastal erosion and which areas are affected by much erosion so as to have much insight by the people intended to invest in the area.

1.2 Problem Statement

The problem of coastal erosion is a growing concern as it results in the loss of land, property and habitat, as well as damage to infrastructure and displacement of coastal communities. The primary causes of coastal erosion being wave action, tidal currents, wind, seal level rise, increased storm activity, and human activities like construction and development along the coast. Raskazone Beach being affected by coastal erosion, requires broad and integrated approach to address the root causes and reduce it's impacts, which includes coastal defenses, land-use planning, and natural solutions such as beach nourishment and dune restoration. Several methods have been used to assess the rate of coastal erosion along beaches, like the use of Tide gauge data and satellite altimetry, the use of Thematic mapper (TM) and the use Quick bird methods, of which gave the results of erosion but may be differed in terms of accuracy and resolution.

Therefore, there is the need to use modern methods with higher accuracy and greater resolutions than the previous techniques. The use of GNSS technique gives real time data with greater accuracy unlike the application of thematic mapper (TM) and Quick bird methods. Also, Sentinel 2 imagery give high resolution and greater coverage that GNSS, which includes GPS (Global Positioning System), provides highly accurate positioning information, and when integrated with Sentinel-2 data, can serve as ground truth reference points for validation purposes. By comparing the information obtained from Sentinel-2 with GNSS measurements we can ensure actual assessment of the shoreline change.

1.2.1 Case Study

The study area, from Tanga Raskazone beach with latitude -5.0607427 degrees to -5.09412 degrees North and longitude 39.131158031 degrees to 39.489784 degrees East, along the Tanga coastal zone.

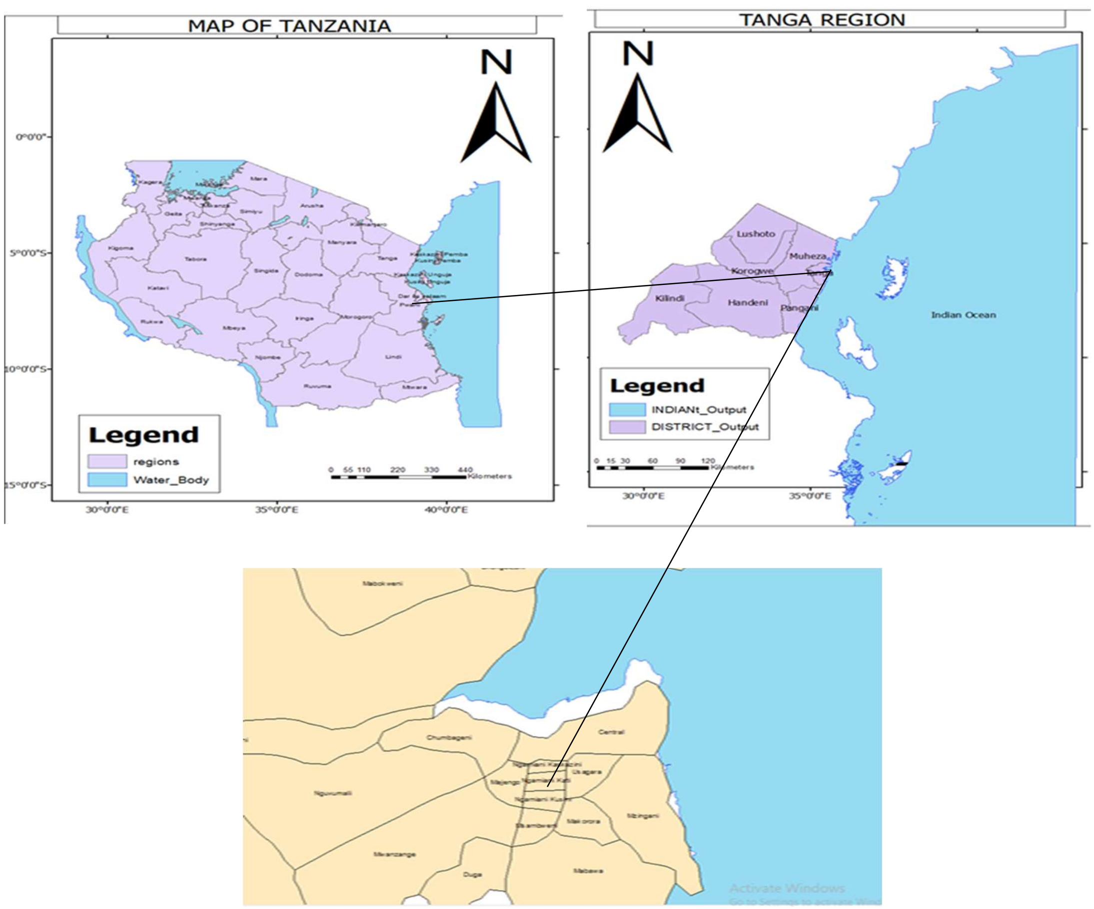

Figure 1.1: An Insert showing the shore of Tanga Raskazone Beach

1.3 Objectives of the Research

1.3.1 Main Objective

The main objective of the research is to assess the rate of coastal erosion using Sentinel-2 Imagery with it's validation by GNSS Technique.

1.3.2 Specific Objectives

- To extract coastline spatial change from sentinel 2 imagery
- To determine the rate of coastline, change from 2017 to 2023
- To determine the present position of coastline using GNSS
- To assess the performance of sentinel 2 and GNSS on coastal erosion using the rate of coastline change scenario

1.4 Significance of the Research

The research will be of great importance in providing the information on the rate at which the coastline of Tanga particularly Raskazone is being affected by erosion and its related factors, thus there will be a need to watch on the possible methods and ways to protect it from further erosion, help in protecting natural habitats and preserving cultural resources (Baron, 2018)

Also, the information obtained will help investors interested in the coast to know the kind of protective measures to use in order to control the rate of erosion occurring in the area.

1.5 Beneficiaries of the Research

- Environmentalists who are interested in monitoring the coasts and beaches (NEMC). This will help in preparing possible suggestions and guidelines on how to monitor the coastline.
- Investors, who are interested in construction of beach sports, hotels and other recreation activities along the ocean.
- Ministry of lands, settlement and Housing (MLSH) to be able to provide
- All related stake holders with interest to the coastal zone (Tourism Industry)
- Residents residing near the coastal areas who may be interested in knowing the rate coastal erosion changes.

1.6 Scope and Limitations

This research is limited to the use of satellite imagery from Sentinel-2 to assess temporal coastal erosion. It aims to validate the results obtained from the analysis of sentinel-2 imagery using the Global Navigation Satellite System (GNSS) technique.
The study covers the coastal area of Raskazone, that is likely to experience coastal erosion.

1.7 Dissertation Outline

Chapter one contains an introduction to the research. It sets the scene by giving a little relevant background information. It also clearly reveals the aims and objectives of the objectives of the project and the constraints that might affect the way in which the research is carried out. It specifies the problem to be solved and gives an overview of what follows in the next chapters. Chapter two covers the literature review by providing an overview of the research, it's contents, giving the reasoning behind why it is structured in a particular way. The main fall of the chapter is the review of relevant work by other authors and relationship between that work and the research that is being carried out. If several other people have done closely related work in different way, then the reasons for using this approach chosen are explained. The research area is identified and explanations of the terms used in the research presented. More so, Chapter three has the Methodology, it clarifies the trend of the whole research. The methods are chosen to carry out the research and how it is to be carried out clearly stated. The data collection methods are also described. It also states how the work was done and will be evaluated. Also, chapter contains the result, analysis and discussion. The main results of the research are presented together with critical discussion.
Finally, Chapter five contains the conclusion, problems, and recommendations for the research.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Coastal erosion is the wearing away of material from a coastal profile including the removal of beach, and sand dunes, or sediments by wave action, tidal currents, wave currents, drainage or high winds. Waves, generated by storms, wind or fast-moving motor craft, can cause coastal erosion, which may take the form of long-term losses of sediment and rocks, or merely the temporary redistribution of coastal sediments; erosion in one location may result in accretion nearby (Lee, 1905). This study of erosion and sediment redistribution is called coastal morph dynamics. It may be caused by hydraulic action, abrasion, impact and corrosion by wind, water and other forces, natural or unnatural (de Jong, 2002).

On non-rocky coasts, coastal erosion results in rock formations in areas where the coastline contains rock layers or fracture zones with varying resistance to erosion (Paula Marques Figueiredo, 2022). Softer areas become eroded much faster than harder ones, which typically results in landform such as tunnels, bridges, columns and pillars. Over time the coast generally evens out. The softer areas fill up with sediment eroded from hard areas, and rock formations are eroded away. Also, abrasion commonly happens in areas where there are strong winds, loose sand, and soft rocks. The blowing of millions of sharp and grains creates a sandblasting effect. This effect helps to erode, smooth and polish rocks. The definition of abrasion is grinding and wearing away of rock surfaces (from *https://en.wikipedia.org/wiki/Coastal-erosion).* There are many factors that may affect the coastal erosion, these factors are divided into two parts; natural causes and man induced factors.

2.2 Types of Coastal Erosion

2.2.1 Mechanical Erosion of Waves

This is the type of coastal erosion in which waves are the main factor through high waves in the coastal environment. Erosion is reduced or reduced or decreased in the low waves; however, they can contribute to the removal of weathered material, two conditions may result through the materials, which are abrasion of rock surfaces and the pressure fluctuations induced on rocks by the waves (Lisitzin, 1974).

2.2.2 Weathering

Weathering is the main erosive mechanism in which the waves are responsible for removing the weathered materials (Ingham A. , 1994). In weathering, the coastal cliffs and internal coastal platforms are exposed to alternating wetting and drying from salt spray (Maibach, 2014).Weathering processes are controlled by climatic factors such as temperature and precipitation.

The two types of weathering can contribute to coastal erosion which are physical weathering and chemical weathering. Physical weathering can be derived from frost action and alternating cycles of hydration. Hydration and chemical weathering is mainly then result of various cooperating chemical reactions, such as hydrolysis, oxidation, hydration and dissolution (Maibach, 2014).

2.2.3 Bio-Erosion

In the tropical regions, rocks are being removed from organisms. The crucial factor in the efficiency of bio erosion is the spatial distribution of marine organisms along the rock surface (de Jong, 2002).

2.3 Natural Causes of Coastal Erosion

Coastal erosion may be caused by the following factors; rise and fall of the sea level, tectonic movement, climate change, coastal processes and physical conditions.

2.3.1 Rise of the sea level

Rise of the sea level may cause coastal erosion, when the water level increases to the maximum will push up or shift the landward by eroding the upland area (Fenoglio, 2014). This is because when water level increases to the maximum causing pressure of the water also to increase and causing the water waves to increase thus leading to the rise of coastal erosion.

2.3.2 Tectonic Movements

Tectonic movements is defined as the movement that is associated with faulting to cause them to occur In which these movements include broad, gentle unwrapping or down warping of large coastal areas (Morner,2016). Therefore, these movements may result to the result to rise of coastal erosion.

2.3.3 Climatic Change

The wind has contribution to the effect on the ocean circulation, waves and sea level, therefore the climatic conditions in the coastal zone are a significant factor for the intensity of coastal erosion. The climatic regime defines the weather conditions of an area and therefore the physical phenomena of the coastal zone, such as waves, underwater currents, coastal currents and storm surges. This wind regime is the most important climatic variable for coastal erosion processes (Lisitzin, 1974).

The wind defines wind waves and the resulting coastal currents. The stronger the wind in the in the coastal zone, the larger is the wave height and therefore the erosive action. The influence of wind on the waves is owed to the drift of the surface of the sea water through friction (PSMSL, 2010). Gradually, this movement of water molecules is extended to the deeper layers, resulting in the development of wind waves. The later ones, as they move towards the shore, impacts on the coast with great velocity, causing intense erosion on existing cliffs with undercutting, or by sweeping coastal sediments offshore.

Storm conditions also bring about intense on coastal environments. The resulting storm surges are much larger in height than the average wave height of an area, as on the latter one an additional height is added, to the disturbance of the sea mass because of the storm and the related barometric low Omuombo, Olago, and Odada, “Coastal Erosion”.

2.3.4 Coastal Processes

The currents that are generated along the near shore zone will cause coastal erosion when the waves reach the coast (NOAA, 2000). Waves generated currents tend to dominate water movements in the near shore zone and also are important in the dispersal of sediments, pollutants and biological nutrients. The currents can also carry the sediments when their speed reaches the threshold speed at which sediment of seabed can be moved. Therefore, erosion will occur as the quality of the sediment carried away by such currents exceeds the amount supplied to beach.

2.3.5 Physical Conditions

The geomorphology, geology and topography are the physical conditions that may result in different erosion and accretion. The ways are determined along the near shore bathymetry and topography in which they depend on the geological properties of the beach material. The response of the shoreline will in turn depend on the geological properties of the beach material (USACE, 2002).

When the rock are hard and strong, the susceptibility to erosion is very low and with the soft sedimentary rocks the rates of the cliffs retreat are, and where the rocks are poorly compacted, faulted, long-term retreat is expected causing the erosion to occur when elevated sea levels are large waves attack the base of the cliff during the storms, resulting in un determining and failure (NOC, 2006).

2.4 Man-Induced Factors

The human's activities may cause the rise of the rate of coastal erosion and therefore the human activities can increase in the rate of coastal erosion at higher rate than natural causes. Therefore, the rate of coastal erosion can be affected by; damage or loss of sand dunes, global warming, coastal removal of coastal plants and trees, sand mining and construction of shoreline structures.

2.4.1 Global Warming

Global warming is the effect that results from the influence of the greenhouse gases. Global warming is contributed by the clearing of plants and trees in order to view the properties of the owners. Also, an industrial activity produces the heat and fumes making the ozone layers to heat and causes holes on it when the heat and fumes produced by industrial activities reaches the ionosphere. This situation will make the radiation of the ultra violet and other unwanted electromagnetic rays to reach the earth's surfaces without being absorbed by the ozone layer. As the result temperature will rise causing the rise in sea level. Therefore, this situation will change the natural vegetation of beach causing the rise of coastal erosion and exposing the shoreline to the effect of global warming (Hannah, Sea Level Change, 2014).

2.4.2 Sand Mining

During the construction activities being carried out along the coast areas, there is a need of high demand of sand (over exploitation of sand along the coast) in which the sand mining on the beach will remove sediments from beach system leading to beach narrowing and deflection (University, 1999).

2.4.3 The removal of coastal plants and trees

The loss of coastal plants is caused by increased population which will cause the rise of destroying natural vegetation along the coast (Lee, 1905), Also, the increase of industrial and urban development has caused the natural vegetation along the coast to be destroyed. Natural plants, like mangrove trees play the role for preventing coastal erosion.

When the vegetation is removed then leaves the bare sand which cause erodes due to wind erosion, therefore vegetation helps to trap and bind sediments and, in some cases, improves slope stability (Morner, 2003).

2.4.4 Damage or Loss of Sand Dunes

When the sand dunes have lost, then the sea walls or other shoreline protection structures along the front of their land are built by the government or the owners in some parts along the coast areas (Neugebauer, 1945).

2.4.5 Construction of Shoreline structures

When constructing the sea walls for the purpose of controlling the coastal erosion, in turn will contribute to the effect of beach erosion (Mahongo, 2009).Most people who build their houses along the coast areas in order to protect their homes with sea walls and rock walls are crashing against the wall, instead of the beach, and because the wall is not sediment, no sand is being deposited with the worn-down wall and ocean currents will move sand along the coast to build beaches.

2.5 Processes Causing Coastal Erosion are:

2.5.1 Corrosion is when waves pick up beach materials (e.g pebbles) and hurl them at the base of the cliff.

2.5.2 Abrasion occurs as breaking waves which contain sand and larger fragments erode the shoreline or headland. It is commonly known as the sand paper effect.

2.5.3 Hydraulic Action is when waves hit the base of the cliff air is compressed into cracks. When the wave retreats the air rushed out of the gap. Often this causes cliff material to break away.

2.5.4 Attrition is when waves cause rocks and pebbles to bump into each other break up.

2.5.5 Corrosion/Solution is when certain types of erode as a result of weak acids in the sea.

2.6 Main Parameters that define Coastal Erosion

2.6.1 Climate

The climatic conditions in the coastal zone are a significant factor for the intensity of coastal erosion. The climatic regime defines the weather conditions of an area and therefore the physical phenomena of the coastal zone, such as waves, underwater currents, coastal currents and storm surges. This wind regime is the most important climatic variable for coastal erosion processes (Fenoglio, 2014).

The wind defines wind waves and the resulting coastal currents (Hunter, 2003).The stronger the wind in the coastal zone, the larger is the wave height and therefore the erosive action. The influence of wind on the waves is owed to the drift of the surface layer of the sea water through friction. Gradually, this movement of water molecules is extended to the deeper layers, resulting in the development of wind waves. The later ones, as they move towards the shore, impacts on the coast with great velocity, causing intense erosion on existing cliffs with undercutting, or by sweeping coastal sediments offshore.

Storm conditions also bring about intense erosion on coastal environments. The resulting storm surges are much larger in height than the average wave height of an area, as on the later one an additional height is added, owed to the disturbance of the sea mass because of the storm and the related barometric low (Moffat, 2017).

2.6.2 Wave Regime

Wave action is the defining parameter in the configuration of coastal geomorphology (Hemmed, 2018). Marine waves are periodic mechanical oscillations of water molecules, by which energy is transferred. A large part of this energy is consumed by breaking of waves on the coast. Waves have a double part, as they are not only undercut coastal cliffs, but they also transport the weathering products that are accumulated at their base.

The wave regime is directly related to the wind conditions in a coastal area. The more intense the wind the more erosive is their action, as they break on the coast, (Ally, 2014).

2.6.3 Coastal Currents Regime

Coastal currents transport loose sediments of the coastal zone, which derive either from fluvial process inland and are deposited on the coast or from the weathering of coastal cliffs (Hunter, 2003).In this way, they are a significant factor in the sediment balance in the coastal zone and therefore in coastal geomorphology.

Coastal wind currents owe their genesis to the waves that approach the shore and are responsible for the moving of large volumes of sediments along shoreline.

2.6.4 Global Sea Level Rise

In this case when global temperature increases cause the rise of sea level. As the sea level rises during an interglacial period, it appears that this rise is amplified by the anthropogenic global warming. The continuous global warming results to the continuous sea level rise, due to the thermal expansion of ocean water in combination with ice sheet melting. Global warming is attributed to the increasing atmospheric concentrations of greenhouse gases (mainly CO_2), due to fossil combustion. Since humanity is unlikely to stop burning fossil fuels in the near future, gas concentrations of greenhouse effect in the atmosphere are expected to continue to increase over the next century (Hannah, 2014).

2.7 Monitoring and Management of Coastal Erosion

Assessing coastal erosion can be done by visual observation. Common visual indicators to identify erosion are summarized in the table below. However, determining the causing of coastal erosion and which coastal protection options should be used requires a comprehensive study of coastal processes that work on a regional scale (not only on sites) through every season.

Options for combating coastal erosion are traditionally two-fold, namely hard structural/engineering options and soft structural/engineering (Allii, 2010).These solutions have at least two hydraulic functions to control waves and littoral sediment transport in applying the solutions, their underlying principles should be well-understood, otherwise they will fail. A combination of hard and soft options has become more popular recently for optimum results because they have weakness when used signally. Many schemes have failed and resulted in environmental and socio-economic problems owing to improper design, construction and maintenance, and were often only implemented locally in specific places or at regional or jurisdictional boundaries, rather than at system boundaries that reflect natural processes. The factors can be shown in Table 2.1.

Table 2.1: Common visual indicators for identifying erosion problem (Maibach, 2014)

All coastlines	Cliff and platform (hard coast)	Clayey banks and muddy coast(semi-hard coast)	Sandy coast (soft coast)
Object (eg,fence, shed or tree) which fall into sea	Very steep cliff faces	Tree angle	Stable back dune vegetation in the active zone
Presence of existing coastal erosion management works (particularly poor condition of structure)	Sea caves, notches, stacks	Slumping slopes	Erosion scarps
	Debris at toe of cliff	Dislodged vegetation in the coastal area	Discontinuous vegetation cover on fore dunes
	Tree angle at the top of the cliff	Erosion scarps	Irregular fore dune crest, blows out
			Very steep dune
			Formation

2.7.1 Hard Structural/Engineering Options

Hard structural/ engineering options use structures constructed on the beach (sea walls, groynes, breakwaters). These options influence coastal processes to stop or reduce the rate of coastal erosion (Ingham A. , 1994)

2.7.2 Groyne

A coastal structure constructed perpendicular to the coastline from the shore into the sea to trap longshore sediment or control longshore currents (Newton, 1687). This type of structure is easy to construct from a variety of materials such as wood, rock or bamboo and is normally used on sandy coasts. It has the following disadvantages

i. Induced local scour at the toes of the structure
ii. Causes erosion down drift; requires regular maintenance

2.7.3 Seawall

A seawall is a structure constructed parallel to the coastline that shelters the shore from wave action. This structure has many different designs; it can be used to protect a cliff from wave attack and improve slope stability and it can also dissipate wave energy on sandy coasts (Neugebauer, 1945). The disadvantages of this structure are;

i. It creates wave reflections and promotes sediment transport offshore
ii. Scour occurs at the toes of eroded beaches
iii. It does not promote beach stability
iv. It should be constructed along the whole coastline; if not, erosion will occur on the adjacent coastline

2.7.4 Coastal Revegetation

Based on studies and scientific results, the presence of vegetation in coastal areas improves slope Stability, consolidates sediment and reduces wave energy moving onshore; therefore, it protects Shoreline from erosion (Hannah, 2004). However, its site-specificity means that it may be successful in estuarine.

Conditions (low energy environment), but not on the open coast (high energy environment). In some cases, revegetation fails because environmental conditions do not favor the growth of the species at the particular site or there is ignorance as to how to plant properly given the same conditions. It is also possible that anthropogenic influences have completely altered the natural processes in the area. The most obvious indicator of site suitability is the presence of vegetation already growing. This can be extended by other factors such as slope, elevation, tidal range, salinity. Substrate and hydrology.

2.7.5 Dune Building/Reconstruction

Sand dunes are unique among other coastal landforms as they are formed by wind rather than moving waters; they represent a store of sand above the landward limits of normal high tides where their vegetation is not dependent on the inundation of sea water for stability. They provide an ideal coastal defense system; vegetation is vital for the survival of dunes because their root systems bind and facilitate the build-up of dune sediment via wind baffle.

During a storm, waves can reach the dune front and draw the sand onto the beach to form a storm beach profile; in normal seasons the wind blows the sand back to the dunes. In dune building or reconstruction, sand fences and mesh matting in combination with vegetation planting have successfully regenerated dunes via sediment entrapment and vegetation colonization. The vegetation used should be governed by species already present, such as marram, sand couch grass and Lyme grass (Morner, 2003).

2.8 GNSS Technique in Assessing Coastal Erosion

According to several literatures done on the use of GNSS technique to assess coastal erosion, there are several steps that are to be taken into consideration; the steps include;

The first step is to establish a network of reference stations. These reference stations are typically placed on stable ground away from the coast and are used as a baseline for comparison with other locations along the coast. The reference stations continuously collect data on the positions of GPS satellites and transmit this data to a central processing facility (Liu, 2017).

Next, GNSS receivers are placed at various locations along the coast that are prone to erosion. These receivers are used to measure the position of the coastline and the rate at which it is changing over time. The data collected from the receivers is then compared to the data from the reference stations to determine the extent of coastal erosion, (Liu, 2017).

GNSS can also be used to measure changes in sea level, which can be a factor in coastal erosion. In this case, GNSS receivers are placed on offshore buoys or other stable structures and used to measure the height of the sea surface. By comparing these measurements to historical data, changes in sea level can be identified and assessed (Wang, 2018).

Also, GNSS data gives the real time data with the actual position of the given shoreline, unlike other methods for monitoring and assessing coastal erosion.

CHAPTER THREE
METHODOLOGY

3.1 Introduction of the Chapter

This section describes the methods that are used in assessing coastal area in Tanga city using data from GNSS technique and Sentinel-2 imagery at **Raskazone Beach.**
Also, this section describes the methodology which involves data types and sources, data preparation, devices and software used in order to achieve the objectives of this research.

The methods that will be described in the assessment of coastal erosion along Raskazone beach in Tanga are the GNSS technique, by determining the position changes on the ground, and also the use of sentinel-2 imagery to determine the position changes in relation to the current image of 2023 imagery.

The position changes obtained from GNSS measurements with those sentinel-2 images can be proved by creating different maps describing the change of position.

3.2 Data Types

Sentinel 2A satellite image data from 2017-2023 by the image with resolution of 10m x 60m data per year.

3.3 Research Methods

3.3.1 Image downloading and processing

The downloading of sentinel 2 imagery involved the use of sentinel scientific data whereby the image was downloaded basing on the locality, defining the cloud covers available for proper clarity of the image basing on the specific day and date.

3.3.2 Preprocessing Image

Preprocessing image data is a pre-analysis of satellite image data that aims at removing noise, improve image, transform images and determine part of the image to be used. The preprocessing stage in satellite image data includes resampling data images, geometric correction, masking and subset image data.

3.3.3 Image Processing

The process of processing pixels in a digital image to obtain information contained in an image is called image processing. Image processing is grouped into two types, namely processing information contained in the image and improving the image in accordance with the requirements.

Stages of image classification that will be used in this study are unsupervised classification, pixel classification learner and shoreline change model.

Pixel classification using Google earth engine is one of the classification models using machine Learner, where the classification uses band in satellite imagery used for sand classification. The bands used in the classification of sands in Sentinel 2A are band 8 (NIR), band 8A (Narrow NIR), band 11 (SWIR)) and band 12 (SWIR). After that, Google earth software will study the pixel values and classify them based on the range of values for the type of black sand and white.

3.3.4 Post Processing image

A stage that aims to increase the accuracy of processing results from satellite image data is called the post processing stage. Post processing stages included in this study are tidal correction in the analysis of shoreline change.

3.4 GNSS Observations

3.4.1 Reconnaissance

Reconnaissance involved the visiting of the area, to determine the nature of the area, see the availability of control points in the nearby area, of which my shoreline extraction could just begin at the identified benchmarks.

Also, under reconnaissance, it involved determination of time spans for both low and high tides. In studying the nature of the area, came up to know that low tides occur in the morning at around 8 AM to around 11AM, and high tides occurs at around 4 pm to 6 PM, these times helped to know when to pick the shoreline, for easy assessment of the shoreline change.

Figure 3. 1: Raskazone shoreline

3.4.2 Shoreline Observation by Using GNSS technique

Shoreline was surveyed by using RTK method with (Leica), were by base was set up at known point (HDR1) and receiver roving checked at HDR2, and then roving was done at different spot heights and details around Raskazone beach and record its position. The recorded positions involved the observation during low tide specifically around 9 am to 12 noon, by considering all the changes of the water level and the effect on the nearby areas.

Also, present bounding features like groins, fences were also observed and seen to be limiting further entrance of water. Figure 3.2 elaborates the way the shore was observed by GNSS along various places and at different intervals at Raskazone Beach in Tanga Region. All the positions of the shoreline were observed not based on the interval but on the basis of the shoreline change.

Further the data was then downloaded after survey and uploaded on AutoCAD for processing to begin.

Figure 3.2: Shows data collection along Raskazone shoreline using GNSS technique

3.5 Devices and software used

The devices used in this research are, set of Leica GNSS Receiver (GS15), for Shoreline observation, AutoCAD software, ArcGIS (ESRI) software with DSAS input in the ArcGIS for shoreline analysis.

3.6 Digital Shoreline Analysis System (DSAS)

3.6.1 Creating a personal Geodatabase in DSAS

Upon the determination of rate of shoreline change, there was the need to create a personal database, this is because the DSAS tool requires all DSAS input data must be imported and managed with personal database, which also serves as the storage location for the program generated transect feature class and related statistical output files. DSAS also requires that data be in meter units in a projected feature coordinate system (Such as Universal Transverse Mercator or state Plane). All shorelines and baselines files used in analysis must reside in the same geodatabase, or rates will not calculate, and a warning message will be generated.

3.6.2 Creating a baseline and shoreline feature class.

After creating a personal geodatabase, a new two new polyline feature classes where created namely baseline and shoreline were created which each contained different attribute fields as shown in *table 3.2* and *table 3.3*. The created feature was projected on the same coordinate system which was UTM 37S. It should be noted that both the baseline and shoreline must be features created within a personal geodatabase or else they DSAS will not produce results. On the date attribute field, the data format must be the one of English United State (i.e. MM/DD/YY

Table 3.1: Shoreline attribute field required on the shoreline class

Field name	**Type**	**Assigned value after Digitization**
DATE_	Text	MM/DD/YY
UNCERTAINTY	Double	1
SHAPE_Length	Double	Automatic Generated

Table 3.2: Baseline attribute field required on Baseline Class

Field name	Type	Assigned Value after digitization
ID	Long integer	1
GROUP_	Long integer	1
OFFshore	Shorter integer	2
CastDir	Shorter integer	2
SHAPE_Length	Double	Automatic generated

3.6.3 Shoreline and baseline digitization

After creating feature classes digitization of both shoreline and baseline being, on this process each year image is digitized individually and on the shoreline attribute table the field were assigned as in *Table 3.2.* On the baseline point of view the baseline was digitized Offshore and the attribute table assigned value as shown in the above tables.

3.6.4 Creating Transects

In DSAS tool transects are line which returned with rate information spatially joined, that is transects show the change of two difference shoreline at a given point of time interval using the baseline as a reference line to assessment and compute the changes. But in order to produce these transect several baseline and shoreline parameter must be inserted refer to such as;

- Baseline ID field.
- Baseline Group.
- Shoreline date field.
- Uncertainty.

- Transect spacing where on this research was 500m.
- Transect smoothing; on this was set as 100m for easy and accurate maintenance of the trend
- Maximum baseline distance; on this research it was 1000m

CHAPTER FOUR
DATA ANALYSIS AND RESULTS

This chapter presents the outcomes obtained from the methods employed and the analysis of the collected data. It shows the processed images showing the changes in shoreline

Shoreline analysis using sentinel-2 imagery based on the determination of distance change between years.

4.1 Shoreline Analysis Using GNSS Technique

The use of GNSS technique to determine shoreline change, involved the determination of shoreline as per March 2023, and the output obtained was the topographical map of the area. The obtained topographical map will be used as the base for other epochs to be carried out in monitoring the rate of coastal erosion at Raskazone beach in Tanga region for after four years (2023-2027) or more.

The topographic map displayed the actual shoreline, nearby features like roads and other infrastructure that could be destroyed by the increased extent of coastal erosion.

Table 4.1: Rates of erosion can be summarized in the table below

YEAR	RATE
2017-2018	0.05m/year
2017-2019	0.065m/year
2017-2020	0.157m/year
2017-2021	0.271m/year
2017-2022	0.539m/year
2017-2023	0.772m/year

The results are obtained only from one portion as identified basing on the DSAS tool

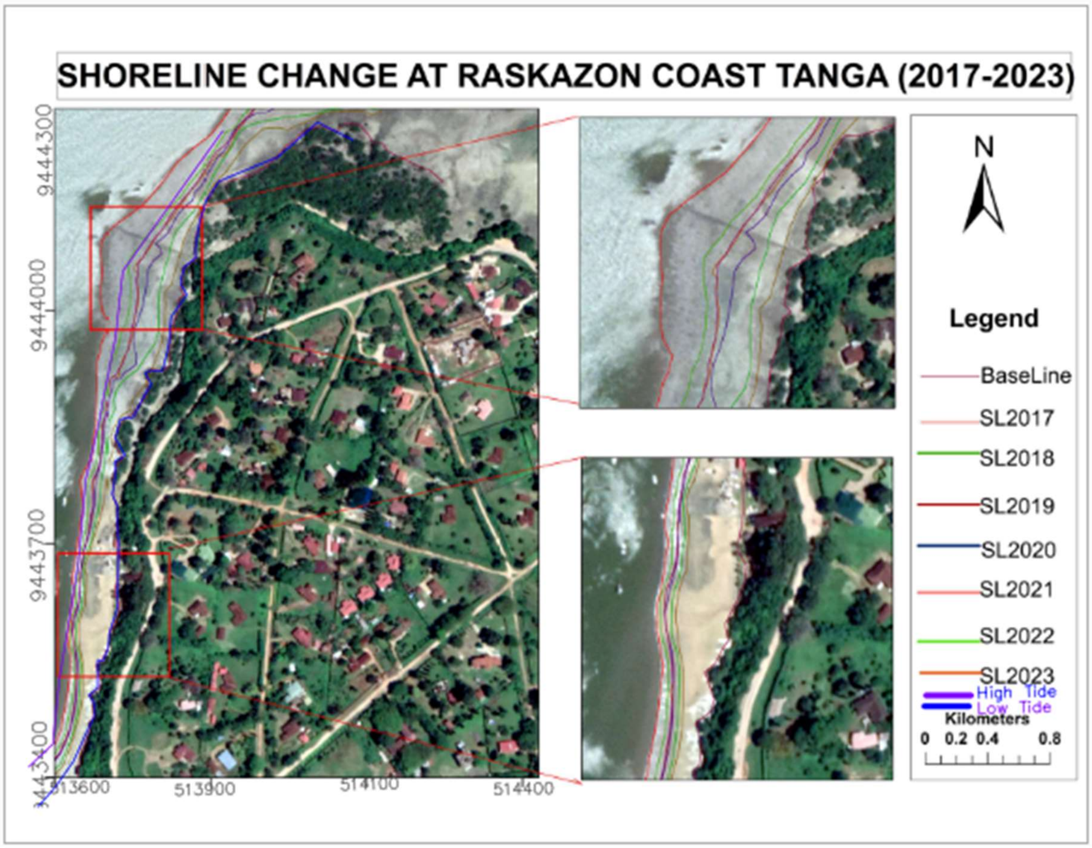

Figure 4.1 Sentinel-2 imagery representing the rate of shoreline change at Raskazone beach from the year 2017-2023 overlaid with GNSS data as per 2023

Figure 4.2: Rate of shoreline change at Raskazone beach from 2017-2021 being overlaid with the GNSS shoreline as per 2023

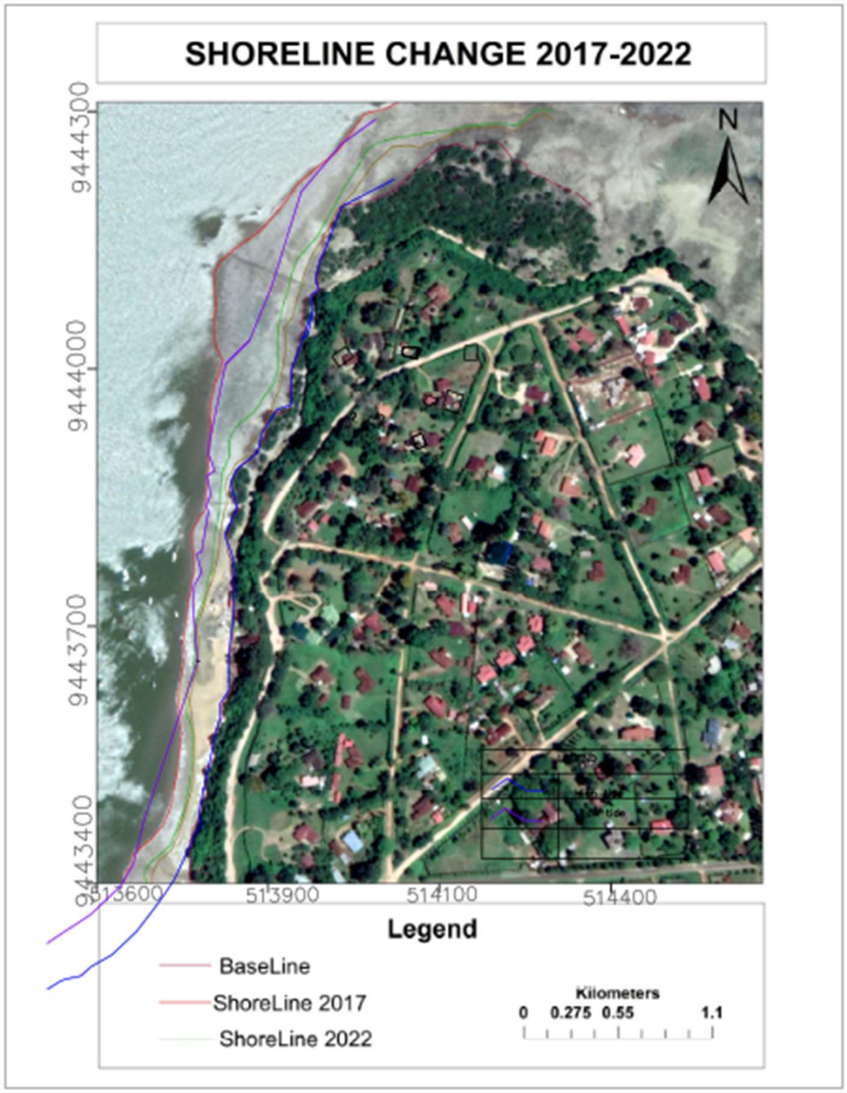

Figure 4.3: Rate of shoreline change at Raskazone beach from 2017-2022 showing the GNSS shoreline with blue color being overlaid to the Sentinel-2 imagery.

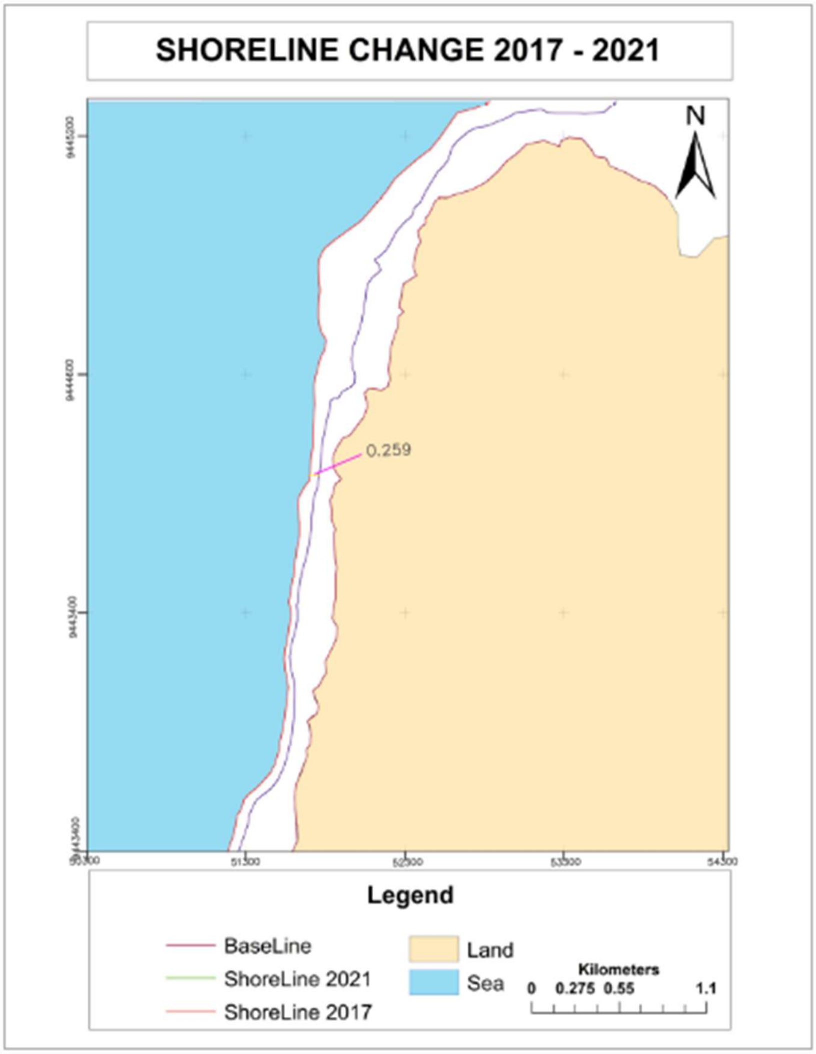

Figure 4.4: Rate of shoreline change at Raskazone beach from 2017-2021 & 2017-2022

Figure 4.5: Sentinel-2 imagery showing the rate of shoreline change showing the features that can be destroyed due to erosion

4.2. Analysis and discussion

Shoreline analysis using Sentinel 2 imagery resulted to the determination of various results basing on the images from 2017-2023, the rate of change was observed basing on the sentinel imagery of 2017 following the imagery of the following year, ie.by taking the imagery of 2017 relative to the imagery of 2018 the rate was 0.05m/year, 2017 relative to 2019 the rate was 0.115m/year, also from 2017 to 2020 the rate was 0.157m/year, More so, from 2017 to 2021 the rate of coastline change was 0.271m/year and finally from the year 2017 to 2022 the rate of change was 0.539m/year. The general change from 2017 to 2023 by the time of data collection by GNSS, was 0.772 m/year.

The changes were shown in table 4.1 of which the figure 4.1 shows the general change from the year 2017 to 2023 and figure 4.5 shows general changes of the shoreline from 2017 to 2023 with the visible features around Raskazone beach. The changes vary from year to year as they can be seen from the results. Through the continued rise and fall of sea level, human activities along the shoreline and other natural causes of erosion, there are seen trends that show the possibility of continued erosion along the shore of Raskazone. The projected area is highly accompanied by several activities particular beach sports, prolonged beach cleaning of which may have led to erosion along the shore.

From the results obtained, sentinel 2 is seen as a valuable tool for monitoring environmental changes, but its spatial and temporal resolutions might have limitations in capturing fine-scale erosion changes in the coastline as the shore was determined by actual digitization by Digital Shoreline Analysis System (DSAS).

More so, there are uncertainties that occurred during the overlaying of the GNSS data with the Sentinel 2 imagery as the data observed during high tide overlays with the baseline for the sentinel 2 imagery for the year 2023, and the data observed during low tide crosses through various years as seen in figure 4.1.

Furthermore, the study has employed Sentinel-2 imagery consistently over multiple years, allowing for a temporal analysis of coastal erosion. This demonstrates the usefulness of remote sensing data in monitoring and quantifying erosion rates over extended periods.

More so, temporal coastal erosion may have resulted from both natural causes and human influenced factors such as coastal development, sea-level rise, or changes in sediment supply, which have contributed to the observed erosion rates.

Further, temporal scale chosen (2017-2023) provided the insight on coastal erosion but there is a need to use longer periods which will lead to obtaining different erosion trends.

CHAPTER FIVE
CONCLUSION, PROBLEMS AND RECOMMENDATION

5.1 Conclusion

The shorelines were automatically extracted from five (5) sentinel 2 images using DSAS software, so when overlaid with shoreline from GNSS, it was found that the rates of shoreline change were ranging from 0.05m/year and 0.772m/year as shown in Table 4.1. The high rate of 0.772m/year was between 2017-2023 which may be unrealistic due to the limitations of DSAS. Usually, the DSAS extracts the shorelines of the images by referring to the commanded baseline of the base image.

Based on the rates of coastline change, Raskazone beach seems to have undergone erosion which may be influenced by ongoing human activities and sea level changes

The utilization of GNSS techniques enabled the determination of the current position of the coastline accurately. This information is essential for coastal management and planning, as it helps identify areas at higher risk of erosion and facilitates appropriate decision-making.

The combination of Sentinel-2 imagery and GNSS technique may be a promising technique in assessing the rate of shoreline change and coastal erosion regardless the limitations of DSAS tool. For more analysis and assessment of coastline change and erosion, other tools may be utilized with appropriate in situ measurements and high-resolution satellite or aerial images.

This is because, the combination of Sentinel-2 imagery and GNSS technique has demonstrated its potential for coastal erosion assessment in a temporal context. The integration of these technologies provides a comprehensive and reliable monitoring solution for coastal managers, researchers, and policy makers. The findings from this study can be utilized to inform coastal erosion mitigation strategies, aid in decision-making processes, and contribute to the sustainable management of coastal areas.

5.2 Recommendations

From the results and conclusion obtained above, the following recommendations are being made

Through the ongoing advancements in satellite technology and the integration of other complimentary techniques, such as LiDAR (Light detection and ranging), may further enhance the capabilities and accuracy of coastal erosion assessment due to it's higher data density and minimum human dependence.

Also, collaboration and data sharing is highly recommended. Collaboration among researchers, government agencies, and coastal management stakeholders. Foster data sharing initiatives to enhance the availability of Sentinel-2 imagery and GNSS data for coastal erosion assessments. This collaboration can contribute to a broader understanding of coastal dynamics and support evidence-based decision making for coastal developments.

Sea walls should be constructed along the coastline and monitored frequently to at least prevent further shoreline destruction

Most of the activities taking place along the coastal areas should be monitored frequently in order to minimize the effects of coastal erosion that may occur in future.

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APPENDICES

List of Appendices

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