International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Coastal Erosion and Land Degradation - A Study at Navaladi, Batticaloa, Sri Lanka

Rajaretnam Kiruparajah

Department of Geography, Eastern University, Sri Lanka

Abstract: ***In general, coastal erosion is one of the global level threats to coastal community and coastal resources. Sri Lanka is a coastal nation in the Indian Ocean, where the coastal zone is not stable and can change time to time in response to natural process due to the seasonal weather patterns and anthropogenic activities such as settlement, urban development, economic development and tourism. Locally,there are many forces like waves, winds, currents, tides, and storms thathave an effect on the coast of Sri Lanka. In that context, coast of Navaladi in Batticaloa District severely affected by the force of waves.This study approaches through remotely sensed data from Google Earth, interviews, and observation.The free satellite imagery provided in Google earth which can be used for many studies has certain limitations.Through the data analysis in ArcGIS environment, there are varieties of issues identified such as many acres of the land disappeared, coastal vegetation destroyed, certain amount of planted treescover destroyed, disturbance caused to coastal environment and habitual activities of the fishing and other communities affected in study area of Batticaloa district. Finally, this study states the people and environment affected seriously influenced by wave and human induced activities near the coast of Navaladi, Batticaloa. Coastal conservation is vital part of the respected authorities in the Nation, they should monitor the coastal areas periodically with the concern of global trend of climate change and population is dwelling very fast in the coastal environments today.***

Keywords: Coastal erosion, landuse change, Land degradation, GIS and Remotely sense data

1. Introduction

At present, coastal erosion is very common, and happens worldwide, and it has about 70% of the sandy coastmarked erosion in the world(China Ocean Press, 2017). Erosion is one of the most serious issues being faced by coastal system worldwide (Toimil et.al, 2017). The world's coastline extends for about 273,000 miles (440,000 km) and nearly half of the world's population lives within 60 miles (100 km) of the shoreline (Kusky, 2008). It is globally estimated that about 60% of the population is dwelling in the coastal environments (Prasad and Kumar, 2014). The coastal zone offers physical and biological opportunities for human use (Mitra, 2011).Worldwide, coasts are always valuable assets, but nowadays they undergo degradation process through coastal erosion by climatic anomalies and human activities. Coastal erosion can be defined as the removal of material from the coast by wave action, tidal currents and/or the activities of humans, typically causing a landward retreat of the coastline (British Geological Survey, 2012; McKibbin, 2016).

Sri Lanka, being a coastal Nation and an Island,is located in the Indian Ocean. It has a coastline over 1700 kilometers long (Swan, 1983). It's location and geographical features are providing immense support to economic development of the country. Coastal regions are habitat for a larger growing population in Sri Lanka. The high densities of coastal population have produced many economic benefits from coastal resources, in particular from fishing, tourism, and maritime activities. Environmentally, flora and fauna, mineral, sands, and estuaries are vital support for healthy environment and quality of life to people in Sri Lanka. Nowadays, the increasing beneficiaries towards the coast are main cause for degrading coastal environment. In this background, Sri Lanka faces severe challenges related to coastal erosion due to the manmade activities as well as complex behavior of land-ocean system. In fact, there are five factors namely; climate, coastal process, sea level, human activities and sediment budget interact to influenceerosion and accretion in the coastal regions (Williams, 2016).However,the erosion already identified as a longstanding problem in Sri Lanka but still continues(Lakmali, et. al, 2017). The shoreline characteristics of Sri Lanka are categorized such as sandy without headland, beaches and headlands, deltas, limestone shorelines, and corals shoreline, they have representation of 33%, 36%, 25%, 04% and 02% respectively in the total length of shorelines (Swan, 1983).

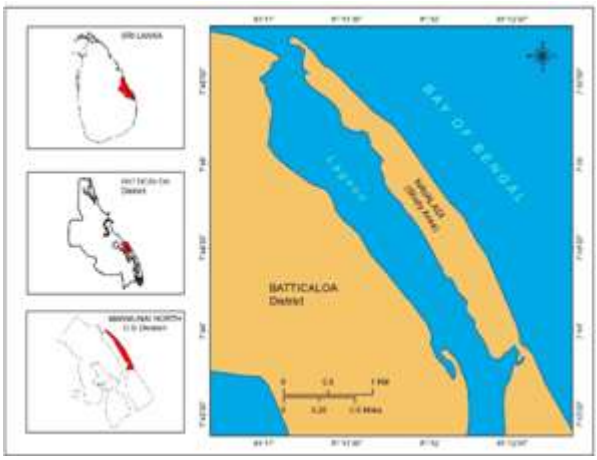
Batticaloa district possesses 121 kilometers longof coastline.Along the coast of Batticaloa district mainly sandy and rest of the coastline is rocky and coral beaches. The coastal zone consistsof diversity of landformsin different scales. In general,vegetation, sands, corals, and beaches are very significant features in particular coastal areas.Fishing and tourism are vital economic activities and immensely contribute to the economic development of the region as well as the Nation.

The land use and land cover in the coastal areas are extremely experiencing substantial transformation due to waves, wind, tide, saltwater, saltation, sea level rise, storm surge, cyclones and human interference activities (Weismiller and Momin, 1977; Meyer and Turner, 1994; Nemani and Running, 1995; Muttitanon and Tripathi, 2005; Li et al., 2010; Mani Murali and Dinesh Kumar, 2015; Kaliraj et al., 2017).Although, coastal erosion is one of the major factors for degradation of land resources in coastal areas, where prime of fishing, tourism, infrastructural facilities get regularly threatened. Nearly 24% of the earth surface area is experienced decline in ecosystem function and productivity during last two decades (Meyer and Turner, 1994; Kalensky et al., 2003: Kaliraj, 2017), while the 43% of the earth surface area is experienced human-induced degradation (Daily, 1995; Kaliraj, 2017).Erosion and accretion are common process for maintaining equilibrium

itself on the coast. Accordingly, the natural system of coastal zone seriously disturbed via coastal erosion by natural and human phenomenon. It was adversely affected habitual activities of the community in the study area.The coastal lagoon of Batticaloa contributesa vital role in maintaining the balance between land and ocean itself. The lagoon has a Bar mouth (A gate where the excess water in the lagoon discharge into sea) which, connectswith ocean. The seasonal basis,if thatlagoon's water level is increased the outlet will open naturally, otherwise it will be closed. Some other times, the people of the village intentionally open it in advance. But, in December 2010, water level of the lagoon increased suddenly due to the heavy rain fall island wide influenced by South-west monsoonal season. The rain madeflash flood,most of the areasespecially in low-lying coast and plains inundated in Batticaloa district and also many part of the country too.In that scenario, the mouth of lagoon (Water outlet) openednaturally;inundated water was discharged through the lagoon to the sea. In the meantime, the Politicians of provincial council made a big role to open another new outletbetween lagoon and sea in different direction over the land in Navaladi without the collective decision or concern of the experts in the region or country for the purpose of discharging water quite quickly.As perthe decision by them,a new water outletwas opened and discharged excess water from lagoon to sea. Followed by, unexpected changes were observed in the particular coastal area very seriously.But still now, no one knows what happened to the natural coastal system after this decision in the particular area. The present study delivers the basic information for public and relevant authorities to understand that less known situation and what should be considered before making a decision pertaining to such activities in future to ensure the defense of coast, coastal environment and coastal community in Navaladi and so on.

2. Study area and its morphology

The areaproposed for the present study is Navaladi(People may call New Bar Mouth) in Batticaloa District, Sri Lanka. Batticaloa is located in the eastern province of Sri Lanka and bordered by the Bay of Bengal to the East, coastal lagoon to the West and Southern part connected to the headland of Batticaloa.



Map 1: The study area covers part of the coastal area of Batticaloa district

The geographical coordination of the study area isextend from 81 40 8.089 E to 81 42 50.933 E longitude and 7 43 23.636 N to 7 45 49.108 N latitude covering the total area of 297hectares with the length of 6943.5 meters along the shoreline. It is one of the GramaNiladhari level administrative divisions under the Manmunai North Divisional Secretariat, Batticaloa.

Morphologically, it has both steep-sloped and gentle-sloped seashore. They are unstable seashore,because of sand barrier is the major morphological aspects along the coast. The coastal and shoreline of Sri Lanka classified in four prime categories and four sub categories (Swan 1983) as follow;

Table 1: Principle coast and shoreline classes, Sri Lanka

Main Categories	Sub Categories
A- Bay and Headland	a- With beaches
B- Spit and Barrier	b- With beach and low dunes
C- Deltas and Saline Flat	b^1- With beach and high dunes
D- Limestone Coast	(t)- Structure transverse to coat

Based on the Swan's classification, the coast of Batticaloa district covers under main category "B" (Spit and Barrier) and sub category "a" (with beaches), sothe study area is classified as "Ba" (Spit and barrier with beaches). The Digital Elevation Model (DEM) (Map 2) covers an administrative division for Manmunai North Divisional Secretariat, it clearly illustrates morphological feature of study area and its surroundings.

Map 2: Digital Elevation Model (DEM) for Manmunai North Divisional Secretariat, Batticaloa.

Lagoon is the special geomorphological feature of Batticaloa district. Coastal lagoon is an inland water body, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets (Map 2) (Kjerfv, 1994). Lagoons formed as a result of rising sea level during the Holocene or Pleistocene and the building of coastal barriers by marine processes (Kjerfv, 1994). Morphology of Sri Lanka hasbeen determined largely by its geological history, rock type and structure. Structurally, Sri Lanka is related to India to which it was

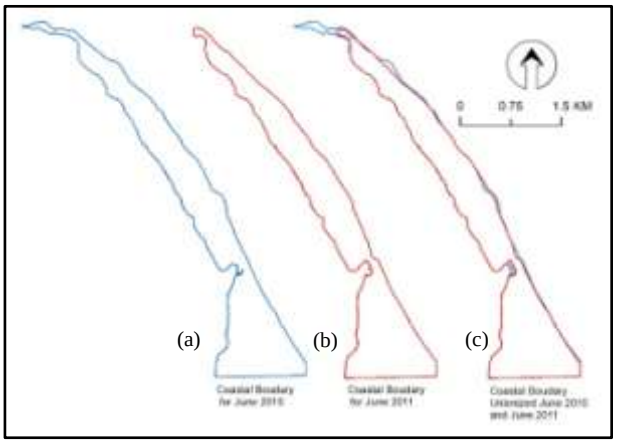
united in part of geological time. Indo-Lankan rift appeared in Jurassic times, opening pre-Cambrian fault, resulted in the creation of Palk Strait and Gulf of Mannar. This is the reason sediments which attain in different scales along the coast (Hatherton et al. 1978; Swan. 1983). In the Tertiary period around 5-2 million years ago, the land uplifted and eroded, after<2 million years ago, Quaternary period, in Pleistocene time due to the sea level fluctuation raised beach and dune deposit evolved along the coastal zone(Cooray, 1978; Swan, 1983).

3. Materials and Method

Satellite imagery is the prime datasource for this study. Many recognized websites provide satellite data free of cost to promote research by the use of remotely sensed data. However, some remotely sensed data have certain limitations in resolutions to obtain recent or current data. There is some possibilities of getting the latest and high resolution satellite imagery having spatial resolution less than or equal to 1m, from US based satellites like Worldview-2 or Quickbird, etc., but more expensive.An alternative solution is to download satellite images from Google Earth[1]. In recent years, most popular image processing and GIS software like ERDAS IMAGINE, ENVI, ArcGIS, etc. have provided tools to visualize and import Google earth images (Malarvizhi et. al. 2016).The Advantage of Google earth is that it provides the latest satellite imagery having spatial resolution in very high, clear view of features such as buildings, roads, and coast, etc., further Google earth provides temporal data which will be very useful for land use mapping and coastal change detection studies of the region of interest. The only limitation of Google earth is that it may not be possible to obtain the original multispectral band data. The present study is an attempt in this direction, in which 48 individual tiles of Google earth images covering Navaladi area in Batticaloa district, Sri Lanka were extracted using Terra Incognita for GPS mapping and management open source software. The advantage of Terra Incognita for GPS mapping and management software is that it downloads the images along with the coordinated information from Google earth. And these downloaded images can be directly utilized in GIS environment for spatial analysis without the need for geo-referencing (Map 3).

Map 3: The prime data sets acquiredfrom Google earth dated June 2010 (Left) and June 2011(Right) of the study area

But, some other images and maps were converted from geographic coordinate system (latitude/longitude) to projected coordinate system (northing/easting) using UTM[2] projection in Arc GIS 10.5. Two sets of cloud free satellite images were acquired for this study, and every set contains 48 images. One set (dated June 8, 2010) and another set (dated June 17, 2011) of images were collected from historical site in Google earth. The boundary of the study area as seen in Map 1 is digitized as polygon and has been converted from ArcGIS shape file format (.shp)[3]. There are two polygons 2010 and 2011 digitized separately for the boundary of the study areas from satellite images, each polygon representing those coastlines in respective years. The polygons processed to overlay operation, for detect eroded and deposited areas along the coast of study area, and then geo-processing tool used for union function and geometric calculation effectively (Map 4).



Map 4: The overlay of two different polygons in two periods of time. (a) The boundary represents study area in 2010, (b) Another boundary for 2011 and (c) An overlaying both periods of 2010 and 2011 coastal boundaries.

Finally, onscreen digitizing of various landuse classes were performed to prepare the land use map.

4. Results and Discussion

Coastal erosion is a major process for degradation of land resources in the coastal areas, where prime fishing, tourism, and infrastructural facilities get regularly threatened. In this study area, natural elements and human induced activities are accelerating along the shoreline. The inhabitants in the village are really surprised; this is the first time in their life; they never ever met this type of atrocious wave action in the village. The mechanism of the wave's action on the coast is different in seasonal wise. Actually, waves are generating by winds blowing over the sea in sandy beach, under the influence of weather patterns beach profile slightly change time to time(Thorp-2015).

[1] Google: Google earth ver.6.0.1.2032 (beta), https://www.google.com/earth/

[2] UTM-Universal Transverse Mercator

[3] Environmental System Research Institute (ESRI)

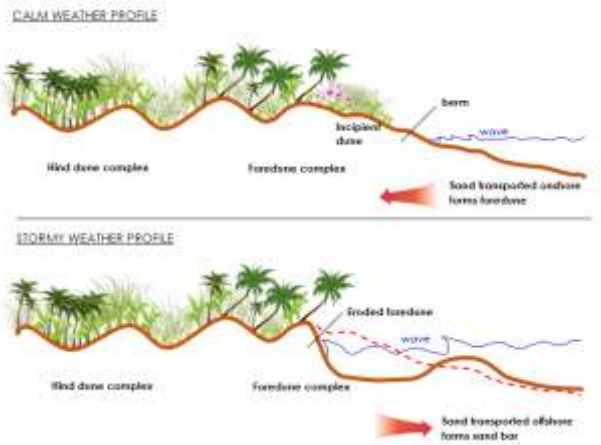
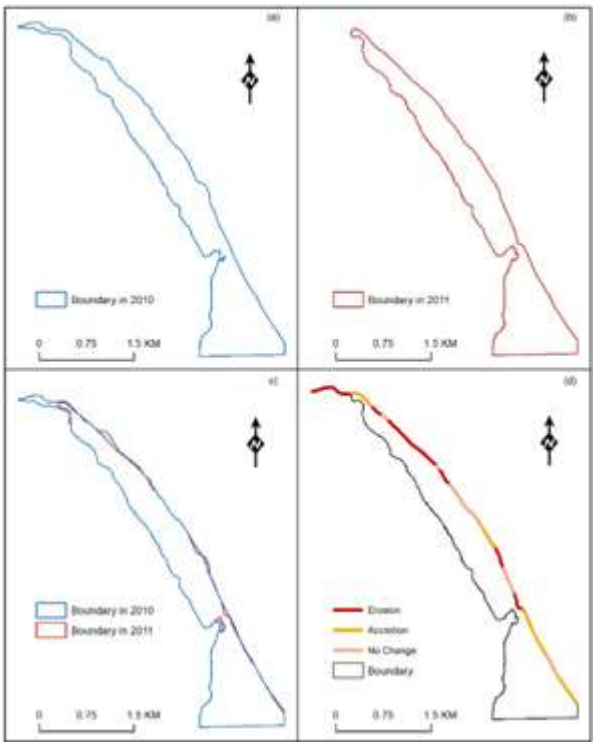


Figure 1: Seasonal variation of waves action. Beaches and foredunes undergo major cycles of change, as storm waves drag sand out to the surf zone and calmer swells bring the sand back onshore. The beach, foredune and offshore sandbar are all part of the one dynamic system. (After Thorp-2015)

In winter season the beach profile become steeper due to strong wave action, which removes sand from the shore and deposit it on offshore sand bars. In summer, calmer waves brings sand back to the shore from offshore sand bar. As a result, coastal environment in sandy beach is constantly changing as they seek to achieve and maintain equilibrium among the natural process of the particular coast (Figure 1)[4].In contrast to this, in thewinter season, the beach profile changed suddenly and it became steeper and the stronger wave action influenced very aggressively nearby new bar mouth area of the coast.

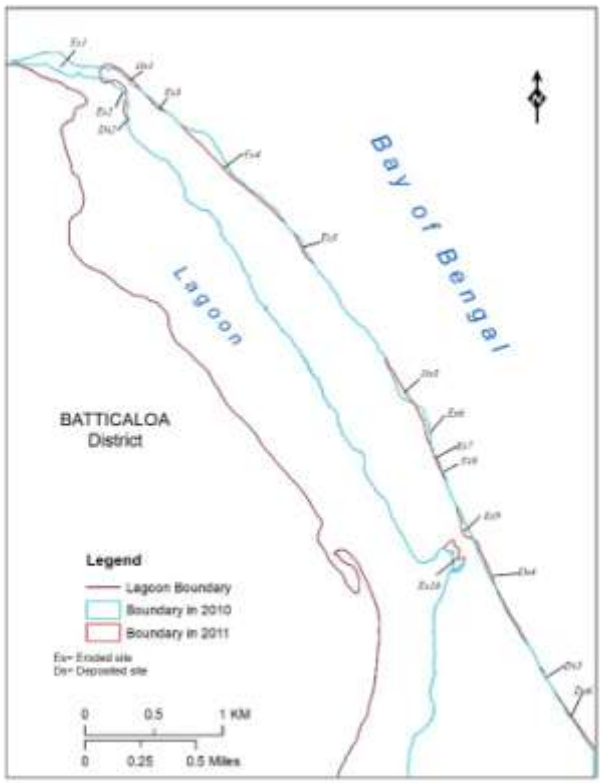


Map 5: The condition of the coastline in study area. Map (a) boundary in 2010, (b) boundary in 2011, (c) An overlapped map both 2010 and 2011, and (d) Coastal condition in lengthwise

When comparing the boundaries for two different periods of time, obviously understands the differences of changes on the coastline. According to this, coastline was subjected to severe erosion in several locations, and accretion was happened in a few areas. Based on different action,the coastline categorized into 3 type of coastlinessuch as erosional coastline, depositional coastline and stable coastline. Erosion process happened in 2828.42 meters long, accretion in 2207.59 meters long and unchanged 1907.48 meters of the shoreline out 6943.5 meters in total length.

Table 2: Details of coastal changes in lengthwise

Type of Changes	Length (Meter)
Erosion	2828.42
Accretion	2207.59
Stable	1907.48
Total Length	6943.49



Map 6: The boundaries are overlapped for the years 2010 and 2011. It shows how coast lines deviate one to other. Boundary in read is below the blue line indicate erosion, whereas above the blue line indicate deposition.

Total extend of the study area is 305.7 hectares in 2010. In 2011, total area was 298.4 hectares. The land area is decreased by 7.3 hectares between 2010 and 2011. There are 10 locations identified along the coast, and from these locations 13.36 hectares of land eroded by the influences of natural and human induced activities. This is 4.11% of total land area. The accretion sites are identified in 6 locations and total area of accretion is 5.74 hectares along the coast. Scale of erosion and accretion of the study area, is stated below in tables 3 and 4 clearly. Scale of erosion and accretion of the study area, the tables 3 and 4 clearly stated

[4]Coast physical factor, Department of Primary Industries, Parks, Water and Environment., Tasmanian Government: www.tas.gov.au

below. The accretion sites are identified in 6 locations and total area of accretion is 5.74 hectares along the coast.

Table 3: Eroded land areas along the coast

Eroded sites	Code	Area (Hectares)
Site-1	*Es1*	4.90
Site-2	*Es2*	0.54
Site-3	*Es3*	0.50
Site-4	*Es4*	3.31
Site-5	*Es5*	0.45
Site-6	*Es6*	0.88
Site-7	*Es7*	0.12
Site-8	*Es8*	0.22
Site-9	*Es9*	0.80
Site-10	*Es10*	1.64
Total Area		13.36

Table 2: Deposited land areas along the coast.

Eroded sites	Code	Area (Hectares)
Site-1	*Ds1*	0.55
Site-2	*Ds2*	0.36
Site-3	*Ds3*	0.92
Site-4	*Ds4*	3.31
Site-5	*Ds5*	0.07
Site-6	*Ds6*	0.53
Total Area		5.74

The photograph (Plate 1) below, a great example to severe erosion on coast in Navaladi.

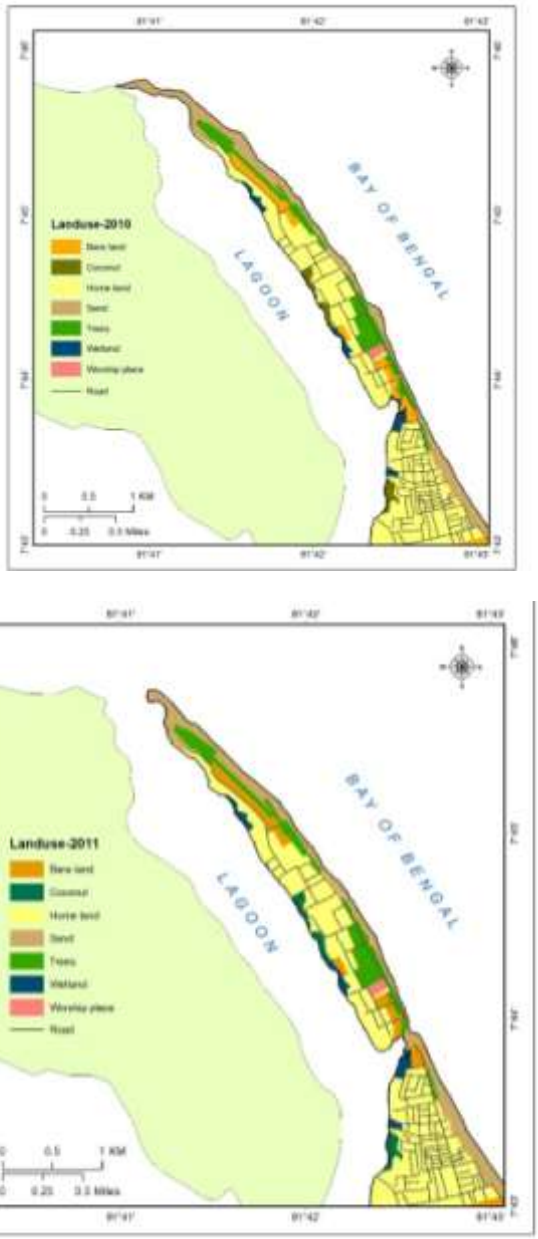
Plate 1: A severe wave action observed along the coast due to the sudden change of beach profile as steeper

According to land use, there are 7 types of land usecategorized in study area such as Home land, bare land, planted tree area, worship area, coconut area, sand area and wetlands (Map-7).Quantity differences of land use in different periods of time are as follows;

Table 5: Landuse pattern in Navaladi - 2010 and 2011

Landuse Type	In 2010	In 2011	Changes
Bare land	21.79	21.46	- 0.33
Coconut	7.88	7.88	=
Home land	174.22	174.22	=
Sand	57.34	52.33	- 5.02
Tree	34.33	32.60	- 1.73
Worship area	2.06	2.06	=
Wetland	8.07	7.85	- 0.22
Total	305.70	298.40	- 7.30

The prepared land use map 7 atNavaladi for the year 2010 and 2011illustrateshow that land use patterns was changed over the time in various scales. Erosion and accretion have been crucial factors to change the land use of coastal area of Navaladi. The main reason was an opened a new bar mouth across the land cover without the future concern.

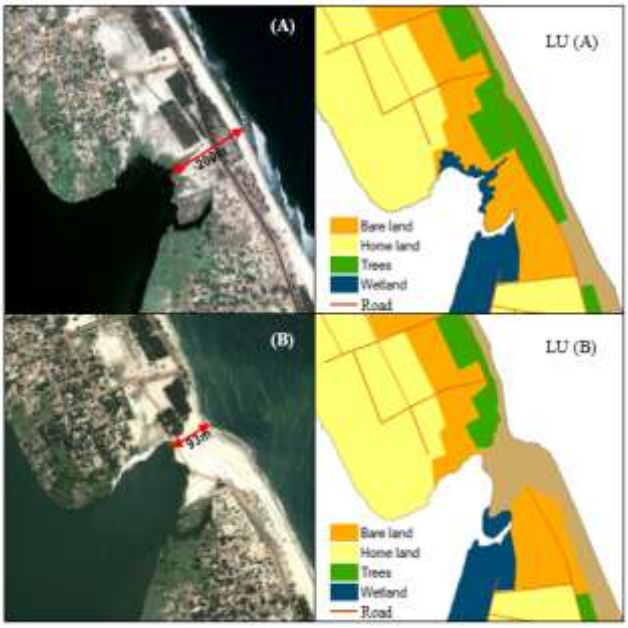


Map 7: The Land use map for 2010 and 2011

According to changes, bare land decreased by 0.87 hectare it is 3.9% of total bare land, the sand along the coast decreased by 5.02 hectares it is 8.8% of the total sands and tress in this area planted by coastal conservation department with support of the NGOs it was lost by 1.73 hectares and the percentage of 1.64 in total area.

The extreme weather condition inducednatural phenomena on the sea and unnatural activities in coastal area in the latter part of 2010 and the early part of 2011. Natural phenomena triggered severe erosion in shoreline on the northern part, and sand deposited in southern part of the study area. Likewise, in the middle part of study area, infrastructure facilities (road, electricity, telecommunication), planted tree covers and bare lands were threatened.The following map 8

is a good example to understand the real situation regarding coastal erosion and land degradation in the study area.



Map 8: Satellite images and landuse maps for certain area, representing 2010 and 2011. (A) Satellite image for 2010 and LU-(A) is the landuse map for it. (B) Representing for 2011 image and LU-(B) is landuse map prepared based on that

Plate 2: Water discharge toward sea via opened new mouth of lagoon (Photograph dated on Feb 12, 2011)

Plate 3: Coastal land degradation by wave and running water. (Photograph dated on July 2, 2011).

The satellite imagery (A) is portraying the earlier condition and it shows the length between lagoon and sea 200 meter (indicate red line), but the imagery (B) is later one, in this image shows the same direction as 93 meter the length between lagoon and sea reduced by 107 meter. Based on the scenario, there have been a change to land that will be broken as two parts and a small new island will form in future. In addition to that, the photographsare representing as plate 2 and 3 for same place but photographs were taken in two different time of study area. These are the evidences for land degradation due to the human activity in this site.When comparing with 2010 land use map with 2011, some of the land use portions are disappeared, in a few portion of land use chanced from one to another, the sea water entered into land, someone reduced in their scale and some land use extended from previous scale.

These are exactly, 1.73 hectares of trees are lost, 0.55 hectare of wetland destroyed and it became permanent water body now, bare land reduced by 0.33 hectare in this highlighted study area. It is representing percentage of degradation 66%, 21%, and 13% respectively in amount of total degradation land. The road access in this area altogether was 25,920 meters in 2010. In 2010, it was reduced by 230 meter and damaged 425 meters in long, these are the main access connected to Navaladi and Batticaloa city (Plate 4).

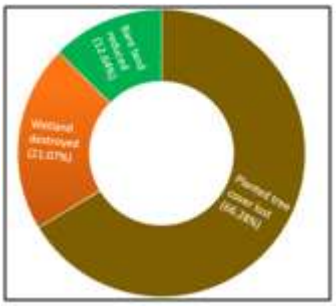


Figure 2: The proportion of Degraded land and its types.

Plate 4: The Main access along the coast of Navaladiwasseverely affected.

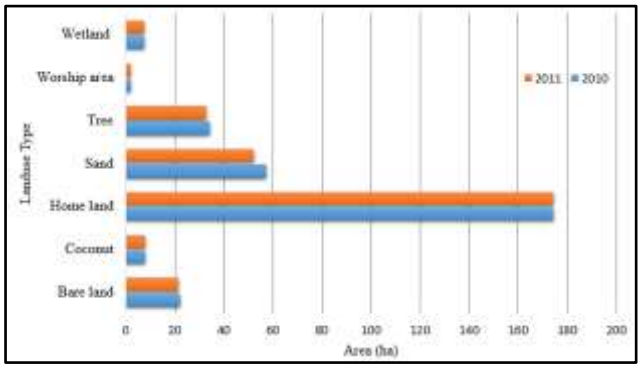


Figure 3: Trend of Landuse changes compare with 2010 and 2011.

The bar chart shows, the overall changes of land use in the study area. In fact, wetland, bare land, trees' cover and sand are changed, but settlement, coconut area and worship area did not change significantly because these are laying in 300 meter away from the coast.

The Coastal Conservation Department of Sri Lanka made steps to inhibit the coastal erosion in the study area. For an example, the Government representatives in different levels came with heavy machinery, laborers and other accessoriesat right time to the spot, and they were preparing thousands of sand bags to placein identified coastline to prevent the erosion.Few days after, most of the sand bags were transported from onshore to offshore by waves. Because, at the moment beach profile wassteeper and the wave action was very aggressive, the inhibiting force for coastal erosion had beyond their management. However, few days later they achieved their task in certain coast lines (photograph (B).

Plate 5: There are two photographs, prevention measure for coastal erosion by government authority. Photograph (A) sand bags arranged with heavy machinery, and photograph (B) completion of prevention works in study area.

5. Conclusion and Recommendation

The result emphasizes, the coastal environment has been great asset to people to gain facilities in various level in Navaladi area. There were many activities lying on the particular coastal zone, mainly, fishery, transport, agriculture, vegetation, settlement, recreation, and tourism. All the activitieswereadversely affected along the coast inthe study area. In Navalady, 351 people who are living in 172 families[5],and among the people fisher folk community was affected severely. The Navaladi coast is a valuable sandy landform, it is naturally beautiful, and the vibrant beauty of this place is attracting people at the regional level as well as island wide.

However, coastal erosion was very serious phenomena in this area. Even though, respective authoritiespromptly acted to inhibitfrom coastal erosion on time, but it was unsuccessful because, they havelack of an integrated and coordinated decision-makingsystem, it should be rectified. For an example, a Bar Mouth openedin a new location across the land area to discharge the flood water to sea, in addition to natural Bar Mouth of lagoon was on functioning in the natural mechanical system within the lagoon and ocean. In contrast, beach profile became steeperlike a storm weather condition and coastal erosion and land degradation induced severely.The particular area narrowed by erosion, the both coasts in lagoon and sea eroded severely. Due to this action, there is a possibility of Navaladibeingse parated in two parts of land.

Geographic Information System (GIS) and Remote Sensing are an effective platform to assess the coastal erosion, accretion and land use changes over time. In the study area, the tree covers, bare land, and wetlands decreased and infrastructure facilities have been affected significantly.

With any kind of development in the study area, the socio-economic activities should be secured from coastal erosion in sustainable manner. The public participation is very much needed continuously, all affected groups should involved in the decision making process for better results[6],andthe respected authorities should be implemented appropriate remedial measures in this coastal area it would support to minimize the degree of erosion hazard and shall be adopted to survive from vulnerability for erosion. Tree plantation is very essential of this coastboth lagoon as well as sea coast.

Nowadays, the respected authority shows good sign (Plate 5) specially the Coastal Conservation Department of the country aware regarding this issues and attempting several steps to inhibiting coastal erosion temporarily.The setback system in the coastal defense and management shall be improved by the Government authority in regional level.

[5] Statistical Handbook, Kachcheri, Batticaloa, 2016.

[6] Beach Erosion Control: Public Issues in Beach Stabilization Decisions, Florida, (David W. Fischer, 1986).

References

[1] British Geological Survey, (2012), Coastal Erosion, available from: http://nia1.me/39x2
[2] China Ocean Press, (2017) Coastal Erosion, Marine Geo-Hazards in China, China, Elsevier Inc.
[3] Dayananda.H.V., (1986), Shoreline Erosion in Sri Lanka's Coastal Areas, Coast Conservation Department of Sri Lanka.
[4] Fischer, D. W., (1986). Beach erosion control: public issues in beach stabilization decisions, Florida. Journal of Coastal Research, 2(1), 51-59. Fort Lauderdale, ISSN 0749-0208.
[5] Google: Google earth ver.6.0.1.2032 (beta), https://www.google.com/earth/
[6] Kachcheri, (2016), Statistical Handbook, Batticaloa, Planning Division.
[7] Kaliraj.S, Chandrasekar,N, Ramachandran.K.K, Srinivas.Y, and Saravanan.S, (2016), Coastal landuse and land cover change and transformations of Kanyakumari coast, India using remote sensing and GIS, The Egyptian Journal of Remote Sensing and Space Sciences.
[8] Kjerfv.B., (1994), Coastal Lagoons, Kjerfv.B, Coastal Lagoon Process, Amsterdam - London - New York – Tokyo, Elsevier Science B.V.
[9] Kusky.T., (2008), Hazardous Interactions within the Coastal Environment, An imprint of Infobase Publishing, U.S.A.
[10] Lakmali.E.N, Desapriya.W.G.A., Jayawardane.K.G.A., Ishara., Raviranga.R.M.P., Ratnayake.N.P., Premasiri.H.M.R. and Senanayake.I.P., (2017), Long term coastal erosion and shoreline positions of Sri Lanka, Journal of Survey in Fisheries Science, Sri Lanka.
[11] Malarvizhi.K, Vasantha.S, Kumarb, and Porchelvanc.P, (2016), Use of High Resolution Google Earth Satellite Imagery in Landuse Map Preparation for Urban Related Applications, International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015), ScienceDirect
[12] McKibbin.D, (2016), Legislative and policy response to the risk of coastal erosion and flooding in the UK and Ireland, Research and Information Service Research Paper, Northern Ireland Assembly
[13] Mitra.D., (2001), Remote Sensing and GIS for Coastal Zone Management: Indian Experience. S Anbazhagan S. K. Subramanian and X.Yang, Geoinformatics in Applied Geomorphology. U.S., CRC Press.
[14] Page.L and Thorp.V., (2010), Tasmanian Coastal Works Manual: A best practice management guide for changing coastlines, Department of Primary Industries, Parks, Water and Environment – Tasmania.
[15] Prasad, D.H. and Kumar, N.D. (2014) Coastal Erosion Studies—A Review. International Journal of Geosciences, 5, 341-345. http://dx.doi.org/10.4236/ijg.2014.53033
[16] Swan.B., (1983), Introduction to the coastal geomorphology of Sri Lanka, The National Museum of Sri Lanka.
[17] Tasmanian Government., (2014), Coast physical factor, Department of Primary Industries, Parks, Water and Environment, www.tas.gov.au, Accessed on: 8 February 2018.
[18] Toimil.A, Losada.I.J, Camus.P, and Díaz-Simal.P, (2017), Managing coastal erosion under climate change at the regional scale, An international journal for coastal, harbor, and offshore engineers, Universidad de Cantabria, Isabel Torres 15, 39005 Santander, Spain.
[19] Training Symposium Proceedings Gulf Shores State Park, AL
[20] Williams. S.J., (2001), Coastal Erosion and Land Loss Around the United States: Strategies to Manage and Protect Coastal Resources- Examples from Louisiana, Coastal Ecosystems and Federal Activities Technical

Author Profile

Rajaretnam Kiruparajah is a senior lecturer at the Department of Geography, Eastern University, Sri Lanka. He obtained his M.Phil.degree from University of Jaffna, Sri Lanka in Geography (Geoinformatics in applied Geomorphology) in 2013. His main research interests are application of geoinformatics, geomorphology, environ -mental studies and Disaster Management.