Quest Journals
Journal of Research in Environmental and Earth Science
Volume 2~ Issue 8 (2016) pp: 01-08
ISSN(Online) : 2348-2532
www.questjournals.org

Research Paper

Vulnerability Of Coastal Communities In The Niger Delta Region To Sea Level Rise

Oyegun C. U.[2], Lawal O.[3], Ogoro M[1].
1(Department of Geography and Environmental Management, University of Port Harcourt, Nigeria)
2(Department of Geography and Environmental Management, University of Port Harcourt, Nigeria)
3(Department of Geography and Environmental Management, University of Port Harcourt, Nigeria)

Received 12 March, 2016; **A**ccepted 10 May, 2016 **P**ublished with open access at **www.questjournals.org**

ABSTRACT:- *The dynamic nature of coastal environment makes for a vulnerability assessment of Niger Delta to inundation. Digital Elevation Map 30 by 30 meters was analyzed using Arc GIS 9.3 tools. Physical exposure was examined using seven variables of Geomorphology, Shoreline change, Relief, Regional Slope, Mean wave height, Relative Sea Level Change, and Tidal Range. Independent Sample Student t-test, and the Multiple Correlation Analysis tools were used. Findings revealed that the relief of the entire area falls within 0 to 7 meters along the coastal stretch while inland to north eastern and north western sections of the study area lies at elevation of 1,800 meter above sea level. Vulnerability classification shows that middle and eastern part of the study area falls within the CVI of very Highly Vulnerable, and High Vulnerability. The study recommend institutional framework for an integrated coastal zone management and future research in areas of infrastructure and species vulnerability to inundation. Vulnerability to inundation and sea level rise using a 1: 5 or 1:10 meter resolution DEM should be employed to enhance more detailed spatial analysis of vulnerability across the Niger delta region.*

Keywords:- *Environment, Vulnerability, Inundation, Coastal, Dynamic*

I. INTRODUCTION

The coastline is the continental edge demarcating land from the sea or ocean, hence the coastline is the interface between land and ocean or sea. The coastline of the Niger Delta is dynamic in nature and this dynamism has made it and the coastal communities who dwell on the shore-zone vulnerable to coastal erosion and oceanic surges accentuated by the rising sea level. Coastal vulnerability assessment is an estimation of coastal susceptibility to flooding and inundation based on number of factors such as geomorphology, shoreline change, relief, regional slope, mean wave height, relative sea level change and tidal range. It can be examined and analyzed in relation to the susceptibility of communities to natural events and the interaction between the dynamic beach process and human/anthropogenic alterations. Komar (1985[1]) observed that if the interaction produces a negative sediment balance the coastal area's vulnerability will be pronounced. This is because coastal flooding and inundation of communities is induced either by natural processes or anthropogenic alterations which result in a deficiency of material supply to the beach alongside the inundation of coastal areas. This depletion in sediment supply to the region of the Niger Delta is as a result of river modification by Dam construction at river sources, building of coastal structures like bank barrier/protection, jetties and the extraction of minerals from the coastal region such mineral include sand, gas, water and oil. Apart from mineral extraction, the rate of urbanization in the Niger Delta against the background of sea level rise can result in increase in flood magnitudes and changing conditions of the basin hydrology which could affect the stream morphology and shoreline dynamics of the region (Carter, 1961[2]; Anderson, 1970[3]; and Oyegun, 1994[4]). The recent variability in climate and its resultant global warning has resulted in increased coastal flooding and inundation (Douglas, 1997[5]). The trend in coastal flooding and inundation is seen as an issue that requires urgent attention as well as understanding of the dynamics of coastal flooding and inundation in the coastal regions in a bid to proffering solutions.

Yaw & Edmund (2006[6]) explored the assessment of environmental change using GIS and remote sensing (RS) technique in the tropical coastal environment. The author's emphasis was on the environmental impacts of developmental activities in the Niger Delta. Mixed scale approach was employed with the integration

*Corresponding Author: Ogoro M[1]

1(Department of Geography and Environmental Management, University of Port Harcourt, Nigeria)

of both primary and secondary data. The findings revealed some significant changes in the coastal environments as a result of developmental activities. Prince & Aifesehi (2013[7]) analyzed the vulnerability to flood hazard of Riverine communities in the Niger Delta, Nigeria, exploring the capacity of communities to live with or cope with floods thereby identifying the characteristics of societies that are regularly flooded, their vulnerability and resilience. Structured questionnaire, complemented by personal interviews and secondary data sources were employed. Findings revealed that people were not willing to move from flood-prone areas as they believed such areas where they had developed family ties had in the past sustained them and will continue to sustain them affordably. Although they employed some coping mechanisms which did not necessarily enhance their adaptation strategies but played some role in mitigating the impact of flooding on them. Also it was revealed that their level of income determined to some extent the kind of coping mechanisms employed. Olorunlana (2013[8]) examined the state of the environment in the Western Niger Delta area of Ondo State. The work identified environmental problems in the area alongside the socio-economic impacts of these problems. Findings revealed that the coastline in Awoye has receded by about 3.31km between 1974 and 1996 at annual rates which varied from 19m to 31m. By 1981, coastline recession in Awoye area had caused the incorporation of 487 hectares of the coastal plain into the Atlantic Ocean within a period of eighteen years: 1973 to 1991.

Gornitz (1990[9]) developed a coastal hazard database constructed to assess vulnerability of the U. S. East coast in the incident of an impact by potential rise in sea level. Seven variables known to influence the vulnerability of coastal areas to the impacts of sea level rise were integrated into the database. These variables are elevation, coastal rock type, geomorphology, relative sea level rise, erosion and accretion, tidal range and wave height (Gornitz, 1990). Based on this integrated analysis of highlighted variables, findings revealed that much of coastal New Jersey especially the barrier beach and coastal wetlands on the Atlantic coast were characterized as high risk to the impact of sea level rise. Thieler & Hammer-Klose (1999[10]) carried out an assessment of coastal vulnerability along the U. S. Atlantic Coast. They integrated six physical coastal variables; which included; geomorphology, coastal slope, relative sea level rise, shoreline erosion/accretion rate, mean tide range, mean wave height and coastal slope. These variables were ranked according to their potential contribution to shoreline changes. Findings revealed that over 80 percent of the New Jersey coast is highly or very highly vulnerable to the effect of sea level rise. Harrilik (1980[11]) affirmed that GIS is able to handle all spatial data in any format, be it raster or vector which has global properties and part of geographic entities.

Ogba & Utang (2008[12]) in their assessment of the vulnerability of the Niger Delta to sea level rise, employed primary and secondary data in their analysis. Findings revealed that the Niger Delta, its natural system and human activities are sensitive to the changing climate and associated rise in sea level. In addition to these approaches in assessing vulnerability of coastal regions, various analytical frameworks have been employed in studying vulnerability and are essential step towards the development of methods for measuring vulnerability and the systematic identification of relevant indicators (Downing, 2004[13]). The pressure release model views disaster as the intersection of two major forces: those processes generating vulnerability on the one hand and the natural or technological hazard event on the other hand. This model outlines how disaster occurs when natural and anthropogenic hazard affect vulnerability within three progressive levels; root cause, dynamic pressure and unsafe condition thereby stressing the fact that vulnerability and development of a potential disaster can be viewed as a process. It also addresses exposure to potential hazard from sea level changes by enhancing a proper understanding of the local context and setting in which potential risk unveils. This is paramount in appreciating the vulnerability of the study area. Communities' proneness to disaster is seen as the result of two major forces. The processes generating vulnerability on the one hand which include, exposure to shore line dynamics, elevation of communities above sea – level, and on the other hand, the hazard event such as sea level rise, inundation and the incidence of flooding this underlines how disaster occurs when hazards affect vulnerable people. Interestingly the pressure release approach stresses the fact that exposure leads to unsafe conditions which is therefore the specific form in which human vulnerability is revealed and expressed in a temporal and spatial dimension. Geo indicators measure geographical processes and phenomena that occur near the earth surface and are subject to change which is significant in the understanding of environmental alterations. Geo indicators when used to evaluate vulnerability, gives the possibility of obtaining quick result in the assessment of coastal risk. This is because of the fact that they are quantitative instruments with scientific validity for the rapid identification of potential risk which allows quick generation of mitigation management plan and environmental monitoring. This study assessed the vulnerable areas of the Niger Delta to flooding and inundation, rating its vulnerability and creating maps to illustrate the vulnerability of the region.

II. THE STUDY AREA

The study area is the BRACED states of the Niger Delta. The region is mostly under tidal influence and falls within latitude 4^0 12' 30.892'' North through 4^0 50' 10.7'' North and longitude 4^0 56' 15'' East through 9^0 40' 2.654'' East. Six states of Akwa Ibom, Bayelsa, Cross Rivers, Delta, Edo, and Rivers state in the Nigeria Federation make up the study area and has adjourning boundary with the Atlantic Ocean. As shown in fig. 1

Note: Highlighted States Constitutes the Niger Delta BRACED States
Source: Adapted from NASRDA, 2010[14] and Digitized by Researcher
Figure 1Niger Delta (BRACED) States

The region consist of 20 barrier island ridges which borders the Atlantic Ocean, though with generally very low terrain comprised mostly of mud and sandy particles which provide no resistance to the waves of the Atlantic Ocean (Oyegun, 1993[15]). Morphologically, the region comprises geomorphic units of Strand Coast, Delta Flank, and the Arcuate Delta (Oyegun, 1993[15]). The region has an arc like protrusion into the Atlantic Ocean with 19 estuary opening which allows for distributaries outlet into the Atlantic Ocean.

The region is underlain by the Basement Complex and sedimentary rock most noticeably in the Oban and Obudu areas while the coastal areas consist mostly of sedimentary rock. Also around the coastal area is the hydromorphic and organic soils developed on alluvial marine and fluvial marine deposits of variable texture. The region is endowed with mangrove, fishery and mineral resources in its freshwater marsh and swamp interconnected with creeks. This is favoured by the equatorial climate with monsoonal precipitation which supports a relatively long wet season lasting between seven and eight months of the year from March through October. The average population density in the coastal Niger Delta Zone was reported as 77 person per sq km in 1990, 87 person per sq/km in 2000 and projected 99 person per/sq km in 2010 (Mahendra, Kulmar, Shenoi, Nayak, 2010[16]). This tremendous population and development pressure have been increasing in the coastal areas for the past four decades. The growing economic, social and environmental importance of coastal areas has increased the challenges associated with sustainable management of coastal resources. This has made the coastal areas more prone and vulnerable to natural and human induced hazards such as sea level rise, shoreline erosion, environmental degradation, and coastal inundation. Climate change, industrial perturbation and their systematic destruction of natural resources especially water, forest and marine resources undermine the people's ability to secure their livelihood. These dynamic pressures combine to adversely impact human health, food security and water supply.

Table 1 Ranking of Physical Variables for Relative Coastal Vulnerability

Variables	**CATEGORIES**				
	1	**2**	**3**	**4**	**5**
CVI (Coastal Vulnerability Index)	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Geomorphology	Rocky, high cliffs, seawalls, etc	Medium cliffs, indented coast, bulkheads and small sea walls etc	Low cliff, alluvial plain etc	Cobble beach, estuary, lagoon etc	Barrier beach, sand beach, mud flat, delta
Relief (m)	>6	4-6	3 - 4	1-3	0 - 1
Shoreline Erosion/Accretion (m/yr)	>2.0	1.0-2.0	-1.0-1.0	-2.0- -1.0	≤ -2.0
Coastal Slope (%)	>1.20	1.20-0.90	0.90-0.60	0.60 – 0.30	≥ 0.30
Mean wave height (m)	0 – 2.9	3.0 – 4.9	5.0 – 5.9	6.0 – 6.9	≥ 7.0
Relative Sea level Changes (m/yr)	<0.1	0.1-0.3	0.3 -0.6	0.6-1.0	1.0-2.0
Mean Tidal Range (m)	<0.1	0.1-0.3	0.3 -0.6	0.6-1.0	1.0-2.0

Source: Thieler & Hammer-Klose, (1999[10])
(*) Positive values indicate accretion, negative values indicate erosion

III. COASTAL VULNERABILITY INDEX (CVI)

The Coastal Vulnerability Index (CVI) is a most widely used method in assessing coastal vulnerability to inundation (Gornitz, 1990[9]). This is because the CVI makes for a numerical base which allows for the ranking of coastal areas in relation to their susceptibility to change which enables proper planning as high risk areas are properly identified. These CVI results can be shown or displayed as maps showing regions with vulnerable shoreline to shoreline retreat. Seven physical variables were ranked on a linear scale of 1 – 5 in an increasing vulnerability order due to sea level rise. The value 1 represent low risk and 5 represent high risk see Table 1 above.

The authors under reference put forward a vulnerability index formula viz:

$$VI = \sqrt{\frac{Rx_1 \,.\, Rx_2 .\, Rx_3 \,.\, Rx_4 \,.\, Rx_5 \,.Rx_6 .Rx_7}{Count_{Var}}} \quad ....(1)$$

where VI = vulnerability index, R = rated value, x_1= geomorphology, x_2 = Relief, x_3 = shoreline erosion/accretion, x_4 = coastal/regional slope, x_5 = mean wave height x_6 = relative sea level changes, x_7 = mean tidal range, $^{Count}{}_{Var}$ - represents the sum of the variables that are taken in to account.

1. Geomorphology: this expresses the relative erodibility of a landform type as cliffs are less prone to erosion especially when it is rocky. This determines the response of coast to sea level rise and its resistance to the impact of wave (Hammar-Klose and Thieler, 2001[17]). The 30meter Shuttle Radar Topographic Mission (SRTM) digital terrain model (DEM) was used to classify the study region into relief classes showing region of high to low relief. Community elevation was extracted in the ArcGIS environment and the information was used to understand the geomorphology of each community's environment whether cliff or beaches.
2. Shoreline Change: this is expressed as shift in the intersecting zone between the land and water over time. Its rate of change (m/yr) was calculated as the rate of change for each transect within a 1 – minute grid cell and was averaged to determine the shoreline change rate where positive numbers indicate accretion and negative numbers indicate erosion. This was possible as the Image of the study area for the year 1986 and 2010 was classified to enable the extraction of the shoreline within the study time.
3. Relief; this is expressed as the high and low lands of the region and helps to assess the relative vulnerability of a place to inundation and the pace at which the shoreline will either retreat or advance as it is constantly impacted by the action of wave (Pilkey and Davis, 1987[18]). Sites that are averagely above mean sea level (MSL) are at lower risk of being inundated than sites that are low – lying or at par with MSL. Elevation plays an important role in identifying and estimating the extent of land threatened by future climate change scenarios. The relief of the communities was extracted using geo spatial and statistical tools in the ArcGIS environment alongside the DEM.
4. Regional Slope: this is expressed as the steepness or flatness of the region. Thieler and Hammer – klose, (1999[10]) presented that the susceptibility of a coast to inundation is a subject and function of the coastal slope. The regional slope mostly referred to as the steepness or flatness of a coastal region calculated as the ratio of altitude change to the horizontal distance between any two points on the coast perpendicular to the shoreline. The susceptibility of a coast to inundation by a rise in sea level and its impact on coastal land loss is a function of coastal slope (Thieler & Hammer-Klose, 1999[10]). Hence a coastal region associated with steep coast would record lower consequence of sea level rise, in contrast to a gently sloping coast. The regional slope of the region was calculated using geo spatial and statistical tools in the Arc GIS Environment.
5. Mean Wave Height: this describes the amplitude of a wave and determine the energy that drives the coastal sediment as the waves make for the mobilization and transportation of coastal sediments. According to the NIOMR (2010[19]) the wave height for the western to middle Niger delta is 1.5meters while that of the eastern Niger Delta is 0.5 to 1.5 meters. Hence the average wave height for the eastern Niger Delta is 1.0 meter with an average of 1.25 meters across the region.
6. Relative Sea Level Changes: describe the rate of rise in sea level over time/years. This enables the calculation of exposure, vulnerability level over the years. It is one of the widely known consequences of climate change. It is described as a tidal datum that is calculated as the arithmetic mean of hourly water elevation observed over a specific 19 year cycle (Murali, Amrita, Vethamony, 2013[20]). The variable was derived from the increase or decrease in annual mean water elevation over time as measured at tidal gauge stations along the coast. This enables exposure, vulnerability level to be calculated over the years of predicted sea level changes.
7. Tidal Range: viewed as the measured difference vertically in meters between the recorded high tide and the consecutive recorded low tide. This gives the extent of temporal inundation over the years. Gornitz,

(1990[9]) suggested that high tidal range is associated with stronger tidal currents, which have the capacity to cause erosion and transport sediment. Tidal range data was obtained from the Nigeria Navy Tide Tables / WXTide software and was used to analyse the tidal range of the study area.

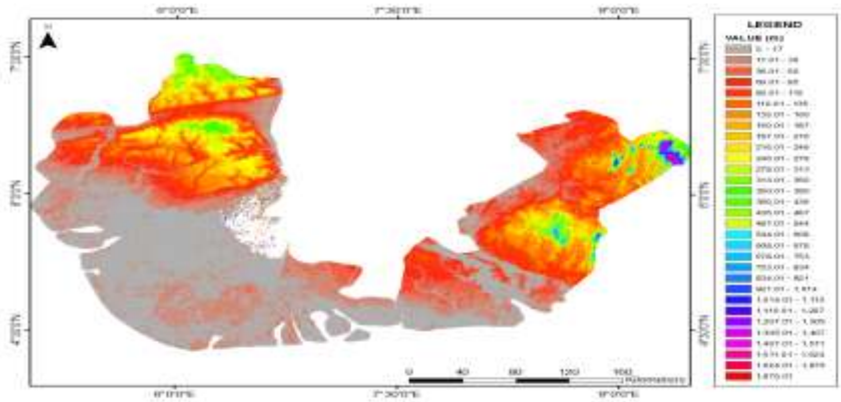
IV. METHODOLOGY

The elevation parameters were derived using the Shuttle Radar Topographic Mission (SRTM) data to generate the 30 meter digital topographic map of the study area which has an absolute horizontal and relative vertical accuracy of 90% confidence level (USGS, 2006[21]). Karwel (2008[22]) stated that the SRTM data serve and could do better than specified therefore could serve in varying geospatial applications. The WXtide 32 software developed by the US National Ocean Service with a study base year of 1995 was used to generate the tidal model from 1 station (Takoradi, Ghana) out of the 149 station computing for the 4996 surge point.

The coastal vulnerability index (CVI) by Hammar-klose and Thieler, (2001[17]) was employed alongside the physical variables in Table 1 to weigh the vulnerability of the coastal area. This was supported using the Geographic Information System (GIS) and Remote Sensing Technology to identify vulnerable areas within the Niger Delta coastal communities in line with the outcome of the vulnerability rating for each variable. This enhanced the identification of communities of the Niger Delta vulnerable to flooding, inundation and its vulnerability rating index.

V. RESULTS

With the present environmental concern of low lying settlements in coastal region, the need to map vulnerability of coastal people to flooding and inundation becomes paramount. This is an effort in contingency preparedness in the event of shoreline inundation due to sea – level rise.



Source: Extracted from SRTM DEM and classified by Authors

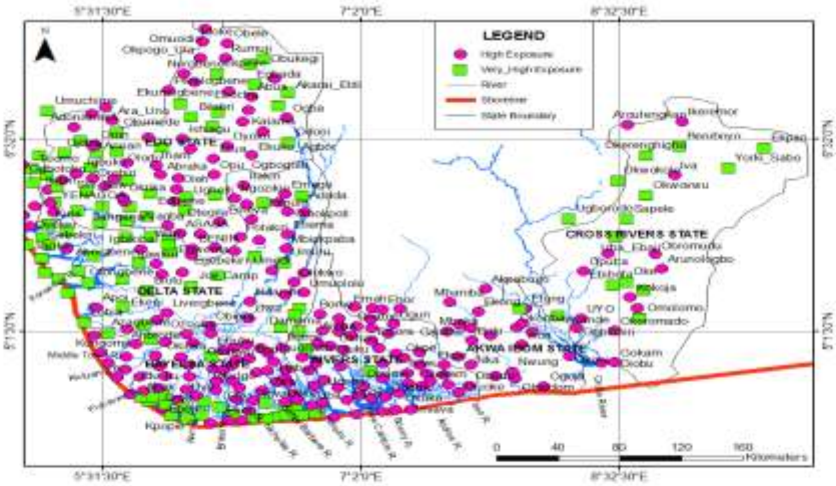
Figure 2 Digital Topographic map of the study area

Fig. 2 shows the elevation classes of the study area/the relief nature of the study area. Within the coastal area are relief classes of 1 to 17 meters above sea level with a gradual change and increase as distances increases inland. Relief above 300 meters above sea level is noticeable within the eastern and western 'horn' of the study area. These areas ('horns of the study area') also enjoy relative lower vulnerability in relation to the south – south section of the study area.

Source: Authors

Figure 3. Isoline Joining Communities of Equal Elevation

Fig. 3 above shows the isolines created from the raster surface DEM of 30 meters resolution. The lines were generated above the base value over the entire range of the raster surface showing the elevation of communities of the study area and the isolines joining communities of equal elevation. This enabled the analysis of exposure index which is a prerequisite of a community's risk and potential hazard in relation to communities' exposure to coastal dynamics. Each community vulnerability index was analyzed in line with criteria/classification applied by the US National Park (Thieler and Hammar-klose, 1999[10]), Orissa State Coast, East Coast of Indian (Kumar *et al*, 2010[23]), Andalusia Coastline (Emiliano *et al*, 2011[24]), that a region values for vulnerability falls within the classes; Low – 1 (2.2 < CVI < 6.3), Medium – 2 (6.4 < CVI < 10.00), High – 3 (10.1 < CVI < 14.1), Very High – 4 (CVI > 14.2).



Source: Authors

Figure 4 Spatial Exposures of Communities to Shoreline Dynamics

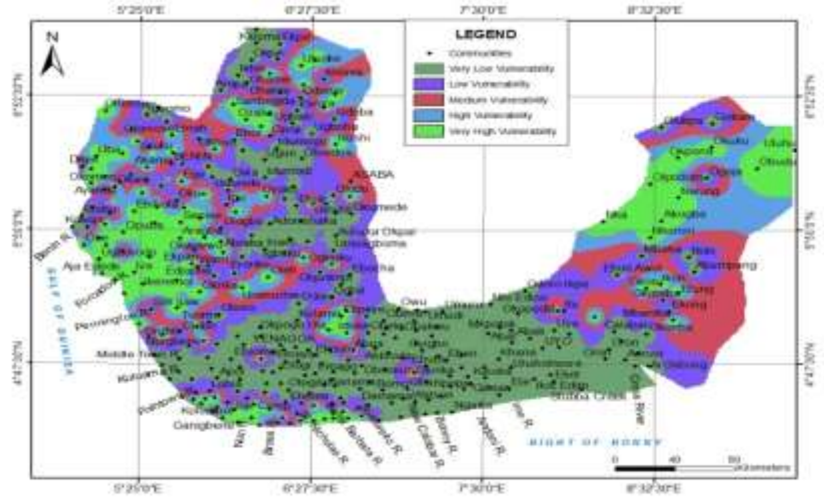
The fig. 4 shows the communities that are spatially exposed to shoreline dynamics as classified in line with Table 1**.** Though, the spread of vulnerability from the fig. is not linear in relation to the shoreline rather spatially scattered across the study region. When the Niger Delta shoreline is inundated, the coastal region of the Niger Delta and its drainage pattern would allow the inward flow of ocean water inland with the potential of inundating inland communities of lower elevation than that of higher elevation. Therefore, communities along river/water ways with low elevation/relief, gentle slope and close distance to shoreline influences their vulnerability to coastal dynamics such as flooding and inundation. This has resulted in the use of all factors listed to calculate the vulnerability of individual communities to determine vulnerable and non vulnerable communities and the extent to which they are vulnerable. Table 2 below shows summary statistics of community exposure to shoreline dynamics in the Niger Delta. From the table, Cross Rivers and Edo states enjoy a very high distance from the shoreline which resulted in a lower value in terms of exposure to shoreline dynamics in relation to other states in the study area. States like Bayelsa, Rivers and Delta are almost 50 percent exposed to shoreline dynamics and other coastal perturbations which are mostly attributed to their distance from the shoreline with a mean distance of 16.10, 14.86 and 16.79km respectively.

Elevations of communities are believed to play a very vital role in their vulnerability to inundation (IPCC, 1996[25]; Oyegun, 2007[26]; Tol, Klein and Nicholla, 2008[27]; and Vaughan, 2008[28]). Therefore, the study area was classified in relation to elevation classes as adapted from (Thieler and Hammer-Klose 1999[10]) as shown in Fig. 5 below.

Table 2 Community Exposure to Shoreline Dynamics

States	No of Communities	Mean Distance to Shoreline (km)	Percentage Exposed	
			Very High Exposure	High Exposure
Bayelsa	95	16.10	49.4	50.6
Rivers	58	14.86	46.5	53.5
Akwa Ibom	24	34.87	12.5	87.5
Cross River	31	146.83	6.5	93.5
Edo	73	105.95	1.4	98.6
Delta	68	16.79	45.5	54.5

Source: Authors



Source: Authors

Figure 5 Vulnerability ranking of the Study Area

The analysis of fig. 5, shows communities in the study area that are classified as having high and very high vulnerability to sea-level rise. This analysis was done using the inverse distance weighing technique in the GIS environment and shows the interpolated vulnerable surface from communities' vulnerability class showing the spatial trend of vulnerability of the study area and its communities. The colour represented in the legend as Medium Apple signifies Very high vulnerability while the colour represented by the unit Green represents very Low vulnerability.

VI. CONCLUSION

The present environmental concern of low lying settlements in the coastal region calls for concern in mapping vulnerability of coastal communities to flooding and inundation sequel upon a rise in sea level. This will build effort in contingency planning and preparedness in the event of flooding and inundation due to sea level rise. From the analysis, communities' elevation above sea level plays a very vital role in their vulnerability. The study revealed that 25.9km^2 of the study area fell within 0 to 1 meter above sea level and was classified as area of very high vulnerability. High vulnerability areas in the Niger Delta were delineated to represent a total of 14.58km^2 land area within the relief of 2 to 3 meters above sea level. While relief ranges of 4 to 5 meters above sea level representing 35.87km^2 of land was classified as moderately vulnerable. Low and very low vulnerable area fell within relief corridor of 6 to 7 meters and above 7 meters above sea level occupying a total land area of 43.52km^2 and 71.738km^2 respectively.

Finally from the physical exposure of the study area using the seven variables of Geomorphology, Relief, Shoreline change rate, Regional slope, Relative sea level, Wave height and Tidal range. Geo information and remote sensing techniques using the SRTM DEM identified the geomorphology of the study area as mostly dominated by low lying relief which Oyegun (1993[15]), identified as barrier islands. The relief of the entire area falls within 0 to 7 meters along the coastal stretch while inland to north eastern and north western sections of the study area lies at elevation of 1,800 meter above sea level. The analysis of the physical / coastal exposure index of the area as shown in this study shows that the middle and eastern part of the study area falls within the CVI of very high vulnerability while the industrial areas of Bonny, Forcados and Excravos fall within the class of high vulnerability. The study therefore recommends that institutional framework should be put in place to mitigate the impact of inundation of shore-zone occasioned by oceanic surges induced by sea level rise. This should be aimed at mainstreaming resilience and proactive planning into an integrated coastal zone management system for the Niger Delta region.

REFERENCES

[1]. Komar, P.D. (1983) - Beach processes and erosion: an introduction. *In*: Komar, P.D. (Ed.), *CRC Handbook of coastal processes and erosion*, CRC Press, Boca Raton, Florida, USA:

[2]. Carter, R.W. (1961). Magnitude and frequency of floods in suburban Area. U.S*Geological society profession* Paper, Vol. 424 – B – B9 – 11.Climate Change Impact Vulnerability and Adaptation, Viale Aldo Moro44, Italy

[3]. Anderson, D.G. (1970). Effects of urban development on floods in northern Virginia: United States Geol. Survey water supply Paper 2001C.

[4]. Oyegun, C.U. (1994). Sediment yield, channel capacity and urbanisation. *Nigerian geographical journal* New series Vol. 2 and 3

[5]. Douglas B. C (1997). Global Sea Rise: A Redetermination Survey in Geo physis. Survey in Geophysics, Vol 18, Issue 2

[6]. Yaw, A. T., & Edmund, C. M. (2006). GIS and Remote Sensing Application in the Assessment of Change within a Coastal Environment in the Niger Delta region *International Journal of Environmental Research and Public Health*.
[7]. Prince, C. M., & Aifesehi, P. E. E. (2013). Vulnerability and Resilience of Niger Delta Coastal Commuities to Flooding. *IOSR Journal of Humanistic and Social Sciences, 10*(6).
[8]. Olorunlana, F. A. (2013). *State of the Environment in the Niger Delta Area of Ondo State.* Paper presented at the 1st Annual International Interdisciplinary Conference Proceeding.
[9]. Gornitz, V. M. (1990). Vulnerability of the East Coast, USA to furture Furture Sea Level Rise. *Journal of Coastal Research, Special Issue*.
[10]. Thieler, E. R., & Hammer-Klose, E. S. (1999). National Assessment of Coastal Vulnerability to Future Sea Level Rise:Preliminary Result for the U. S. Atlantic Coast (G. S. O.-F.Report, Trans.). U.S.
[11]. Harrilik, R. M. (1980). *A Spatial Data Structure for Geographic Information System*. New York: Academic Press Inc.
[12]. Ogba, O., & Utang, P. B. (2008). Biophysical and the Socio-Economic Vulnerability of the Niger delta coast to effective sea level rise, . *Africa journal of Contemporary issues, 18*.
[13]. Downing, 2004 Downing, T. (2004). *What have we learned Regarding a vulnerablity Science? In science support of adaptation to climate change.* . Paper presented at the Framework Convention on Climate Change, Buenos Aires.
[14]. National Space Research and Development Agency, 2010
[15]. Oyegun, C. U. (1993). Land Degradation and the Coastal Environment of Nigeria, *CATENA Integrated Journal of SOIL SCIENCE HYDROLOGY GEOMORPHOLOGY.* Vol 20
[16]. Mahendra R. S., M. P. C., Kulmar T. S., Shenoi S. S., and Nayak S. R. (2010). Coastal Multi- Hazard Vulnerability Mapping. A case Study Along the Coast of Nellone District, East Coast of Indian. *Rivista Italliana Di Telerilevamento*.
[17]. Hammer-Klose and Thieler, E. R. (2001). Coastal Vulnerability to Sea Level Rise. *In Science News line Nature*.
[18]. Pilkey, O. H., & Davis, T. W. (1987). *An Analysis of Coastal Recession Model* (Vol. 41). North Carolina SEPM Special Publication.
[19]. NIOMR: Marine Geology/Geophysics, available at: http://www.niomr.gov.ng.
[20]. 20 Murali M. R., A. M., Amrita S., and Vethamony P. (2013). Coastal Vulnerability Assessment of Puducheriy Coast, Indian using Analytical Hierarchical Process. *Natural Hazard Earth System Science, 13*.
[21]. USGS (2006). Shuttle Radar Topography Mission (SRTM) 3Arc Second (30 meter).
[22]. Kumar, T. and Kunte, P.(2010): Coastal Vulnerability Assessment for Chennai, East coast of India using Geospatial Techniques, J. Natural Hazards, 64.
[23]. Emiliano R, Andrew H, Andrea B, Anipe D, Ana G, Mikeel H, pasi L (2011).
a. *Climate Change Impact Vulnerability and Adaptation*, Viale Aldo Moro44, Italy
[24]. IPCC (1996) The Science of Climate Change in Oyegun C U. Climate Change and Nigeria Coastal Resources, UPPL, 2007 Komar (1985)
[25]. Oyegun, C. U. (2007). *Climate Change and Nigeria Coastal Resourcees*. Nigeria: UPPL.
[26]. Tol R, Klein R, and Nicholla J (2008) *Towards Successful Adaptation to Sea Level Rise along Europe's Coast.* Journal of Coastal Research Vol 24
a. united states Geol. Survey water supply Paper 2001C
[27]. Vaughan D. G. (2008) *West Antarctic Ice Sheet Collapse – The Fall and Rise of a Paradigm*, Journal of Climate Change