Geographic Information for Disaster Management in Nigeria: Case Study of the Mud-beach Coast of Southwestern Nigeria

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Abstract

This paper demonstrates the importance of geographic information in disaster management. It examines the state of disaster management in Nigeria and presents a local area case study of the use of geographic information to establish the vulnerability to composite environmental threat and hazard of 605 communities around the mud-beach coast of southwestern Nigeria. Environmental threat and hazard factors interpreted from remote sensing imageries were integrated within geographic information systems with data that characterized the communities. The integrated data was further analyzed for indices of exposure (stressors which define damage potentials) and management (likely coping ability which defines severity) for each community. Vulnerability index for each community was evaluated by comparing the difference between the degree of exposure and management. In terms of exposure, the results suggest that 18 communities fall under high exposure, 129 under medium exposure and 458 under low exposure categories. For management, 41 communities fall under the high management-low severity, 131 under average management-average severity and 433 under the low management-high severity categories. In all, 70 communities, most of which are first-line settlements, are highly vulnerability to composite environmental hazard. 80% of the highly vulnerable communities are found around degraded ecosystems including permanently inundated lands and areas where active devegetation is being experienced, which confirms the connection between creeping environmental change process and vulnerability to disasters especially at local levels.

Keywords: disaster, exposure, management, vulnerability, geographic information, mud-beach coast, Nigeria

1. Background

We live today in a world that is fascinated by speed and instantaneous scenario. Sustained ecosystems degradation and injuries to the environment that occur in patches and increase the vulnerability of population do not attract as much attention as their utmost consequence. Under-investment in disaster preparedness cuts across the world, but it is more critical in the developing countries because political leaders and decision makers have been slow to recognize geospatial datasets as part of a country's infrastructure (Abiodun, 2000; Adeniyi, 2009). Natural and human induced hazards are part of the interaction of the human-environmental systems which are not totally preventable. But they can be acted upon to prevent their disastrous effects on vulnerable people and places. Geographic data and information are critically important in disaster management and in monitoring vulnerable hotspots (Stockholm Environmental Institute, 2001). Disaster preparedness is a key component of disaster management and it requires enormous spatial information including information that defines the risk of exposure and the degree of vulnerability of the population and for developing early warning systems. While inadequate and unreliable information is a serious constraint to sustainable development (Mwaikambo & Hagai, 2011), failure to integrate the fundamental spatial datasets and other information for disaster management can spell doom for a nation during an emergency (UNU-EHS, 2011).

Although Nigeria is located neither in an active geological fault nor around the part of the Atlantic where high sea surface temperature induces tropical cyclones and hurricanes, it is nevertheless not immune to tectonic and climate related threats (Omodanisi & Salami, 2011). Man-made drivers including agriculture and unsustainable resource exploitation and rapid urbanization has increased the threat of deforestation and land degradation, desertification, over-grazing, savannah fires and oil spills and pipeline fires. Climate change related threats including erosion, heat waves, drought and floods are also on the rise. Despite the low exposure, Nigeria ranked 50th among 173 nations on the world risk index released by the UNU-EHS in 2011 with high scores (i.e. low performance) in vulnerability (67.37%), susceptibility (54.94%), lack of coping capacities (86.93%) and lack of adaptive capacities (60.24%). The International Disaster Database (EMDAT) quoted in Gbadegesin *et al*, (2010) identified 12 episodes of epidemic outbreak, 11 flood events and one drought between 1900 and 2009 with over 5 million people affected and significant loss of economic assets. In the rainy months of June to September 2011 alone urban flooding in the major cities of Lagos, Ibadan, Abeokuta and Kano resulted in loss of lives, dislocation of communities and significant economic damage to residents. A critical missing element in disaster management in Nigeria is lack of integrated data and information for disaster preparedness and emergency response.

Coordination of disaster management activities in Nigeria is the responsibility of the National Emergency Management Agency (NEMA) established in 1999. Apart from formulating policy on all activities relating to disaster management and coordinating plans and programmes for efficient and effective response to disaster, NEMA is also expected to collate (and integrate) data from relevant agencies so as to enhance forecasting, planning and field operation of disaster management (Omodanisi and Salami, 2011). The national space policy specifically stated that Nigeria shall endeavour to use space technology for disaster prediction, warning and mitigation due to its cost effectiveness in the reduction of the impacts on both the short and long term. Evidence suggests that the organization still lacks the spatial infrastructure for disaster preparedness and risk reduction as the first and critical step in disaster management. Although NEMA now activates and coordinates (through the National Space Research and Development Agency) the International Charter for Space and Major Disasters with the United Nations Platform for Space-based Information for Disaster Management and Emergency Responses (UN-SPIDER) a visit to NEMA website (www.nema.gov.ng) suggests that in-house capability to integrate and manage geographic data for disaster management still needs considerable improvement.

The mud-beach coast of Nigeria has experienced large-scale oil exploration and unsustainable land management leading to modification of the natural systems and concomitant loss of mangroves and forests that formerly acted as buffer between the land and the sea. This has resulted in permanent inundation and saline water inflow into land areas (Fasona and Omojola, 2009). Such ecosystems disruption and environmental decline increases the vulnerability of communities to hazards (PRB 2003; UNEP/GRID-Arendal 2005; German Advisory Council on Climate Change, 2000; White, 1974). As noted by UNU-EHS (2011), the risk that a natural event will develop into a disaster depends only partially on the strength of the event itself. A substantial cause lies in the living conditions of people in the affected area and the opportunities to quickly respond and help. Those who are prepared and who know what to do during an extreme natural event have higher survival chances. Anticipation of natural hazards and preparation for the consequences of environmental change with better mobilization make society better equipped for the future.

Disaster risk arises when hazards interact with physical, social, economic and environmental vulnerabilities (ISDR, 2006). The critical element in disaster is the vulnerability of people. Vulnerability refers to conditions determined by physical, social, economic, and environmental factors or processes that increase the susceptibility of a community to the impact of hazards (McBean, 2006; ISDR, 2006). Vulnerability assessment is carried out to recognize, measure, understand and predict risk as information basis for mitigation and prevention strategies (Taubenbock *et al.*, 2007). Elements of disaster management essentially include preparedness, response, recovery and mitigation. Effective disaster preparedness has the propensity to reduce vulnerability. In a disaster context vulnerability has two basic elements: exposure and susceptibility to harm (Taubenbock e*t a*l., 2007).

There are several conceptual frameworks of vulnerability including the climate and environmental change (IPCC, 2001), double structure (Bohle 2001), pressure and release model and the

BBC framework (Bogardi & Birkmann, 2004; Cardona 2003). The commonalities include hazard, stressors, exposure, coping capacity and responses which are the essential ingredients for building vulnerability. Regardless of how vulnerability is viewed (physical, social, economic, environmental, political, or human security perspectives) it requires geographic information that needs to be integrated and stored in an easily accessible platform and retrievable format. The UN-SPIDER makes spatial data available for recovery efforts during disaster, but Nigeria has no disaster preparedness plan that has established and documented the hazardousness of places and vulnerability of populations throughout the country at high spatial resolution required for quick response to disaster.

In this paper, we argued that the environmental change process including submergence or permanent inundation of land, saline water intrusion into land areas, active devegetation, canalization, land excavation which leaves open burrow pits, coastal erosion, and loss of mangrove and wetland that act as coastal buffer increases the vulnerability of communities in the mud beach coast of southwestern Nigeria to coastal disaster. We also argued that lack of integrated spatial data to assess the level of vulnerability and the coping capacity of these rural communities presents a clear danger if disaster occurs. Such integrated geospatial information driven by the requisite technology makes geospatial information accessible to and effectively used by a broad range of users especially for disaster management and local emergency management. This paper thus attempts to demonstrate the importance of geographic information to decipher the pattern of exposure to composite environmental threat that can induce disaster and the vulnerability of rural coastal communities in the mud beach coast.

2. Methodology

2.1 Study Area

The study area in the mud-beach coast of southwestern Nigeria extends from Latitudes 5°45ʹ to 6°30ʹ North and Longitudes 4°30ʹ to 5° 07ʹ East (Figure 1).

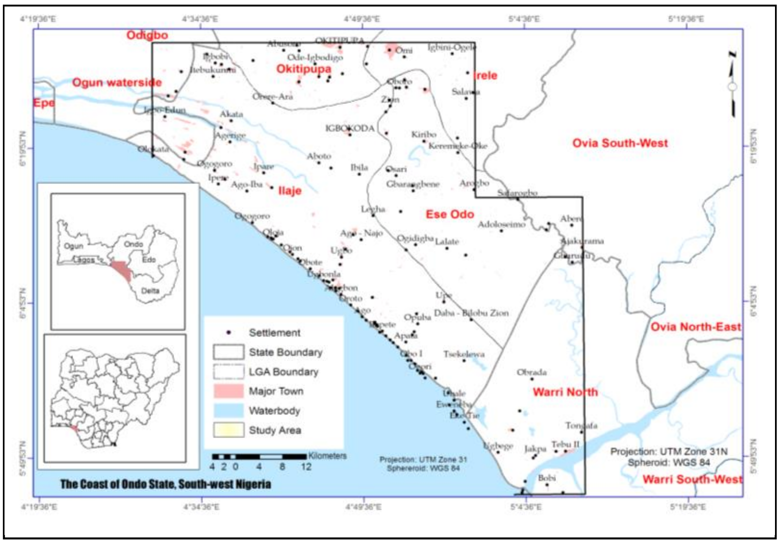

Figure 1: The Mud-beach coast of southwest Nigeria

It covers about 3,300km^2, stretching 88km along the Gulf of Guinea coastline and varying between 19km and 50km inland (Figure 1). Geologically, the mud beach coast evolved from the growth of the Niger delta into the Gulf of Guinea following gradual retreat of the sea after a short-lived Paleocene transgression on to the late cretaceous coal measures (Wright et al, 1985) and consists of general alluvium, lagoonal marshes, abandoned beach ridges and coastal plains sand. Elevation rises from less than 1m along the coastline to 55m around Okitipupa.

The soils consist of very deep poorly drained hydromorphic soils and mud in the lower parts, and deep, drained to well drained soils in the upland areas. Mean annual rainfall is about 3000mm, mean relative humidity is between 70% and 80% and mean annual temperature is about 27.8^{0}c. The original vegetal cover (which is much altered now) consists of heavy forests and creepers, a mosaic of forest and raffia complexes, and some red mangrove (*rhizopora*) around the coast. The mud-beach coast is second only to the Lagos barrier coast with regards to the density of population. It is inhabited by rural peasants that depend on the coastal resources for livelihood. About 600 communities with an estimated population of over 400,000 inhabitants are found within the study area.

2.2 Data utilized and adopted procedure

The types and sources of data accessed and analyzed for this study is shown on Table 1.

Table 1: Data and data sources

Data	Identification and Coverage	Scale/resolution	Date	Source(s)
Landsat ETM^{+} imagery from Landsat 7	Path 190 ROW 056	Spatial resolution – P – 15m B-IR 30mx30m TIR – 60m Spectral resolution – 8bands	29/12/2005	2005 GLS data from www.landcover.org
Population of communities			2006	National Population Commission
Administrative Status of communities			As at 2006	Local Government Offices, Gazetteers

Identification, delineation and classification of features from the imageries were done at a consistent scale of 1:25,000 with a minimum mapping unit of 0.25ha (2mm by 2mm). The direct interpretation approach where features were identified, digitized and allocated into information classes within desktop GIS software was adopted. The image interpretation process was greatly aided by field reconnaissance which was carried out in the area in 2006. Land use and cover classes interpreted from the imageries were validated for accuracy with field observations carried out in 2006/2007 with handheld global positioning system (GPS) equipment. A total of 585 points were captured on the field with their attributes recorded. These points were downloaded, analyzed, and used to compute error matrices using the method of omission and commission errors described by Jensen (1986) for quantitative assessment of attribute accuracy for the image-derived maps. The computed overall map accuracy was 87.4%, with average omission and commission errors of 11.1% and 9.1% respectively. Average user and producer accuracies were also estimated at 88.9% and 90.9% respectively. The land cover data directly provided the input data such as the health of the ecosystems and area extent of communities and indirectly, the distance of communities to the ocean and degraded lands for the simplified vulnerability analysis.

2.2.1 Generation of simplified vulnerability indices

The exposure and management (coping) variables

The variables that define vulnerability can be grouped into the exposure variables and the management variables. The exposure variables define the stressors i.e. the probability of a community being impacted by a hazard. The composition of the exposure variable include: present condition of the land (healthy or degraded), the presence of a hazard (i.e. the likelihood of a disaster), the population at risk, and the economic and social assets at risk. These variables together defined the overall damage potential of an impending disaster. The management variables define the present or likely expected capacity of a community to contain the impacts of a hazard i.e. to prevent or contain a disaster. These variables, which include presence of early warning and response infrastructure, intervention policies of government and political authorities, etc, qualify the severity of the impending impacts. Incidentally, the two sets of variables can be generated from the same set of indicators when subjected to multi-criteria analysis. These variables are also consistent with the commonalities in the vulnerability frameworks, which define the hazard, stressors, exposure, coping capacity and responses.

Damage potential and severity indices

The data used include the population of communities, extent of built up areas, distance of communities to already degraded lands, distance of communities to the ocean, and administrative status of communities. Some of these indicators were analyzed both factors and constraints to generate indicators for both the exposure and management variables as indicated on Table 2. Scores (weights) were generated for exposure and management likelihood using multi-criteria evaluation as indicated on Tables 3 and 4. The choice of variables used was based on availability of data derivable from remote sensing sources, fieldwork and administrative sources. Allocation of weights to the respective variables (and intra-class variables) was based on their perceived importance in contributing to the risk of exposure and in mobilization for pre-disaster, during-disaster and post disaster management.

Table 2: Indicators of exposure and management

S/N	Data/Indicators	Exposure (stressors)	Management (severity)
1	Population from 2006 population census	Communities with large population imply large exposed population, large impact or high casualty should hazard occur.	Communities with large population will likely attract government attention to buffer impact than faster than smaller communities. Large communities can also pull more resources through communal cooperation (synergy) either to buffer impact or mitigate spread of hazard. Smaller communities may not be able to do this
2	Area coverage (for each settlement generated from the 2005 land cover data)	Larger communities naturally have higher area than smaller ones which indicate higher damage potential for social and economic assets.	Large communities have more probability for mobilization of resources and other management issues such as early warning infrastructure and refuge platforms.
3	Distance of communities to already degraded lands – generated within the GIS	The nearer the community is to a degraded ecology, the higher its exposure to the associated composite risks	Geographic distance decay function
4	Settlement's distance to the ocean - generated from GIS	In case of hazard emanating from rapidly evolving scenario from the ocean such as strong and turbulent waves, coastal flooding, sea level rise, etc, distance may play a difference. The closer a settlement is to the ocean, the higher its exposure. For slowly evolving degradation processes such as salt water inflow into land areas, communities that are nearer the ocean will naturally be more exposed	Geographic distance decay function
5	Settlement status - generated by combining administrative and GIS data	Administrative headquarters and bigger settlements will have more exposed population and economic and social assets at risk	Administrative centers will attract more mobilization - governmental attention and communal synergy - for mitigation and relief and are exposed to more information

Table 3: Risk exposure (damage potentials) indices

S/N	Variable	Total Score	Intra Class Score
1	Population	20	>5000 = 20 2000-5000 = 15 1000-1999 = 10 500-999 = 7

			<500 = 5
2	Area extent	15	>50ha = 15 25-50ha = 10 5-24ha = 5 <5ha = 3
3	Settlement Administrative status	10	1 = 10 (Admin Hq) 2= 7 (Settlements With Area Apart From Admin Headquarters) 3 = 3 (No Area)
4	Distance to Degraded Land	20	Less Than 0.5km = 20 0.5-1km = 15 1.1 - 2km = 10 >2km = 5
5	Distance to Ocean	20	Less Than 0.5km = 20 0.5-0.75km = 15 0.76 – 1km = 10 > 1km = 5
	Total Score	85	

Table 4: Management Likelihood (Severity Indices)

S/n	Variable	Total Score	Intra Class Score
1	Settlement administrative status	20	1 = 20 (Admin Hq) 2= 15 (Have Area) 3 = 10 (No Area)
2	Population	20	>5000 = 20 2000-5000 = 15 1000-1999 = 10 500-999 = 7 <500 = 5
3	Area	20	>50ha = 20 25-49ha = 15 5-24ha = 10 <5ha = 5
	Total Score	**60**	

Scores were also generated for each of the variables and intra-variables for exposure (damage potential) and severity (management likelihood). The assignment of score was based on perceived ability to either drive or contain exposure to hazards. The total score for the exposure index is 85 and 60 for the management index. The processing of the data was done in a GIS environment. Vulnerability index for each community was evaluated by:

$$VI = (Rs-Ms) \text{------------------} (1)$$

Where:

VI = vulnerability index, Rs = total score for risk exposure (damage potential) and Ms = total score for management likelihood (severity indices).

The maximum obtainable score for exposure is 85. A community that scores 51 (60%) and above is considered very highly exposed, which indicates a high damage potential. A score of between 34 and 50 (40%-59%) is considered medium exposure (medium damage potential) and a score less than 34 (<40%) is considered low exposure (low damage potential). The total obtainable score for management is 60. A score of 36 (60%) and above indicates high management (i.e. low severity), 24-33 (40-59%) indicate average management (average severity) and less than 24 (<40%) indicates low management (high severity). The optimum *VI* score (difference between high exposure risk and high management risk) is 15. A close gap (<15) between exposure and management indicates that exposure is high and possibility of management is equally high, hence vulnerability is low. On the other hand, since management cannot be greater than exposure, a wider gap between exposure and management suggests that while exposure is high, management is low, which implies high vulnerability. A settlement with *VI* >15 is therefore classified as having a high vulnerability, while a settlement with *VI* <15 is classified as having a low vulnerability.

This methodology is consistent with the approach used by the UNU-EHS (2011) to derive the world risk index. It is also consistent with the demonstration of the capability of remote sensing to create vulnerability and risk framework by Taubenbock et al (2008). The departure (which is also an advantage) of the approach used here is that it is community-centered i.e. it evaluates the exposures/stressors and ability to manage these at the level of individual community rather than taking the total landscape as one single entity for analysis. The use of remote sensing and GIS permits indexing which enables a multilayer analysis of the spatial differences in stressors and other indicators across communities that would have been lost in a total landscape analysis approach.

3. Results and Discussions

3.1 Performance of indices of exposure (damage potential) and management (severity) indices

The study area consists of 605 communities. Figure 2 presents the spatial perspectives of risk exposure of the communities. The computation suggests that 18 communities fall under high exposure, 129 under medium exposure and 458 under low exposure categories. Figure 3 presents the management categorization for all settlements. The results suggest that 41 communities fall under the high management-low severity, 131 under average management-average severity and 433 under the low management-high severity categories.

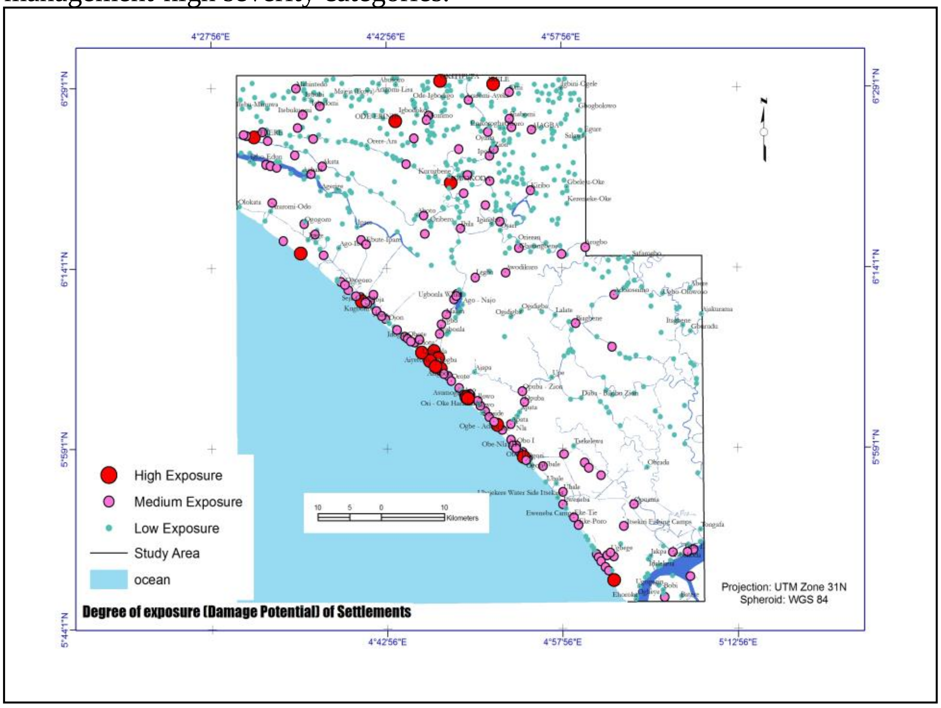

Figure 2: Risk exposure of communities in the Mud-beach coast

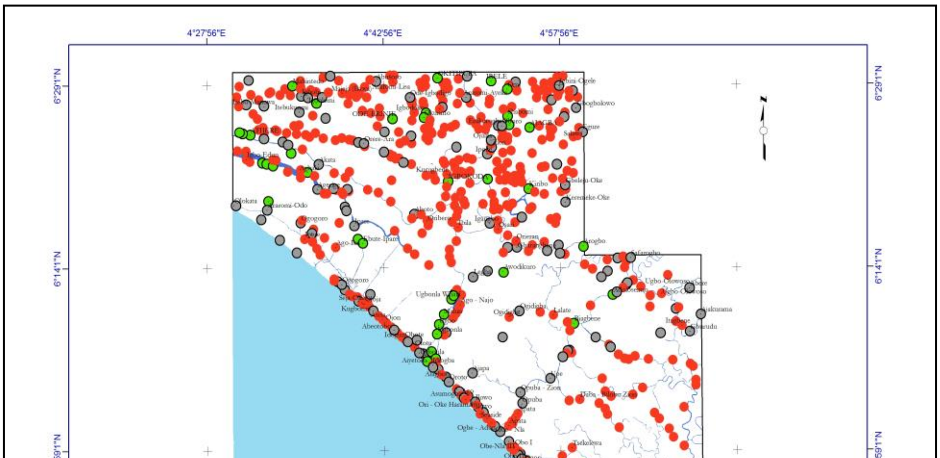

Figure 3: Management indices for communities in the Mud-beach coast

3.2 Spatial vulnerability index

Figure 4 presents the spatial pattern for vulnerability categorization for all communities and hotspots of highly vulnerable settlements. Communities with high exposure and low management typically have the highest vulnerability. Those with high exposure and high management tend to have low vulnerability while at the middle are those communities with medium exposure and medium severity indices. In all, 70 settlements fall under the high vulnerability category and 535 communities under the low vulnerability category. The geographic distribution of the vulnerability scenario suggests that most of the coastline communities have medium exposure but low management, which results in high vulnerability.

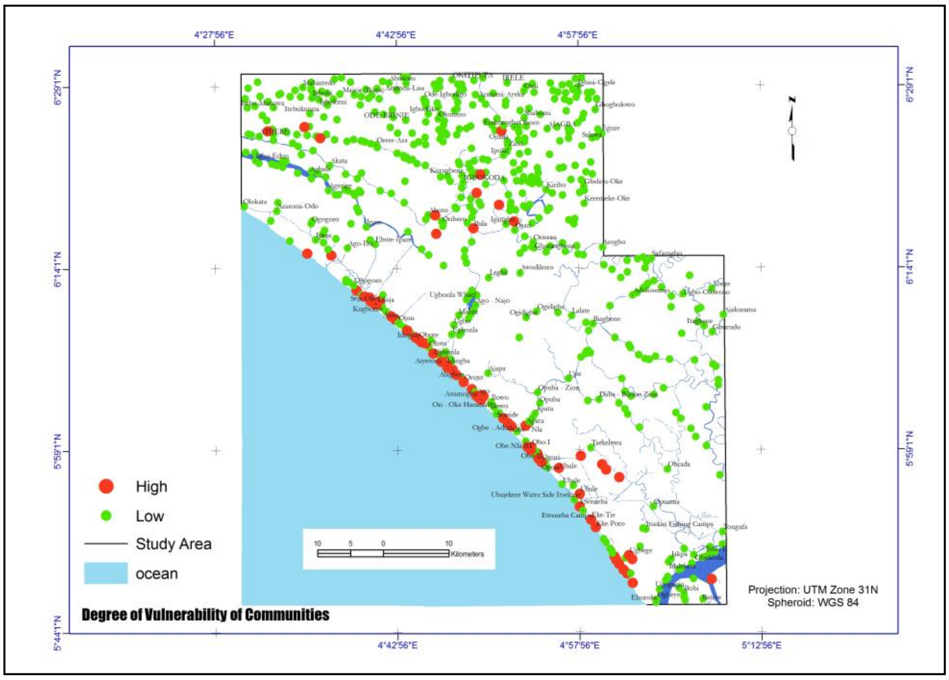

Figure 4: Spatial Pattern of Vulnerability categorization in the Mud-beach coast

Hence, 60 of the 70 communities with high vulnerability index are first-line communities. The most vulnerable large to medium population communities include Aiyetoro, Oke Iwamimo, Ilowo Seaside, Awoye waterside, Ori Oke Haramah, Alagbon, Obo waterside, Ebigham, Idiogba, Obe Nla, Alagbon Zion, Ugbonla, Ilowo Otumara, Abalala Seaside, Oroto, Awoye, Eruna, Idogun, Yaye, Igbogi, Lekki, Mokunwaje, Ibila, Masa, Otoropo, Italowo, Ehin Osa and several others. Interestingly, about 80% of the highly vulnerable communities are located around degraded ecosystems including permanently inundated lands and areas where active devegetation is occurring. This observation tends to support the hypothesis of increasing connection between creeping environmental change process and vulnerability to disasters especially at local levels.

3.3 Implications for disaster management in Nigeria

The priorities of the Hyogo Framework for Action 2005-2015 place much responsibility on nations to build resilience and develop disaster management strategies through legislation, mobilization, education, knowledge, training, infrastructures, among others, at regional, local and community levels. Specifically, it encourages nations to ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation, identify, assess and monitor disaster risks and enhance early warning, use knowledge, innovation and education to build a culture of safety and resilience at all levels, reduce the underlying risk factors, and strengthen disaster preparedness for effective response at all levels.

Nigeria is still far from achieving these priorities. Disaster preparedness and risk reduction as the first and most critical step in disaster management is still not in place. Lack of geospatial data for planning disaster preparedness and mitigation efforts has increased the severity of localized disaster and the vulnerability of population. NEMA needs to invest in geospatial data generation, integration, analysis and scenario modeling to manage disasters. Disaster education and reach-out which is important to disaster awareness should be stepped up to reach the local population especially in the coastal and riparian communities and other vulnerable places. The agency also needs to step up collaboration with other stakeholders, especially the Nigerian National Space Research and Development Agency (NASRDA) to strengthen its geospatial data gathering, processing and use capabilities, at least, until a Nigerian Geospatial Data Infrastructure (NGDI) is fully implemented. The launch of the NigeriaSat-2 with 2.5m resolution should now place Nigeria at an advantageous position to develop robust spatial databases for disaster preparedness and institute robust disaster management that meets global best practices.

4. Conclusion and Recommendations

The strong link between global environmental change and disaster has made disaster preparedness efforts imperative as a means for managing disasters. Natural resources degradation has serious implication for the vulnerability of communities especially in rural coastal areas. Sound environmental management has the tendency to increase rural livelihoods and reduce vulnerability. Active land ecosystems degradation with lack of spatial data to access the extent and determine the hazardousness of places and vulnerability of communities is in itself a recipe for disaster. Disaster preparedness needs to be taken as the critical basis for disaster management. It should be provided with a sound local basis through mobilization of local populations for the business of disaster management. Investment in early warning and disaster preparedness infrastructure (especially geospatial infrastructure) in Nigeria is a key to disaster risk reduction and timely response to future emergencies.

The results from this study confirm the connection between environmental change process and disaster vulnerability in poor rural communities of the mud beach coast. Therefore, sustainable environment and natural resource management is imperative for disaster management in the mud beach coast. There is the need for an urgent degraded ecosystem restoration and remediation programme. The national agency responsible for disaster management needs to invest in spatial data gathering, integration and processing to generate disaster-relevant geographic information critical for disaster risk reduction and emergency response at local levels. There is the need to inform, educate and sensitize the local communities on their levels of vulnerabilities to environmental change risks and disaster. This increased awareness can stimulate community cooperation and participation in local disaster management programmes. Disaster preparedness efforts including information, education and construction of resistance infrastructures including bulwarks and refuge platforms in strategic areas close to human habitations, as well as developing early warning systems should be urgently considered. Spatial re-organization and land-use planning approaches including provision of alternative livelihoods should be considered to reduce the number of people living in highly vulnerable areas. Micro-insurance scheme to encourage the local population (especially those in high risk areas) sign up for life and natural assets (such as farmland and fishing areas) is desirable. Disaster management organizations need to make disaster risk reduction a priority with strong local mobilization and community-centered risk reduction approaches. Lessons from Nigeria's experiences with disaster in the past few years suggest that the strategy of waiting for disaster to occur before responding is ineffective and dangerous for the society. We need to become more proactive and prepared by reducing the vulnerability of populations to disasters.

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