Hydrographic Mapping of Coastal Area of Ibeno LGA of Akwa Ibom State of Nigeria using Remote Sensing Method

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Abstract: - One of the most accurate and reliable methods of carrying out a hydrographic mapping of a larger coastal area is by remote sensing technique because it gives a wider coverage than the ground surveying method. Remote sensing is the method of gathering an information of a remote object from a distance position when there is no physical contact with the object in question. Hydrographic mapping deals with mapping of water related environments. It includes bathymetric mapping for determination of water depth, mapping of the coast line for change detection and mapping of coastal waters for resource exploitation and for sitting of engineering structures. Ibeno LGA is one of the LGAs found in the coastal region of Akwa Ibom state of Nigeria. The area is highly vulnerable to coastal hazards like coastal erosion, deforestation of the swampy forest, flooding and biodiversity destruction. There are much the activities of crude oil exploration and exploitation within the area. The occupants also are seen building residential structures in the low-lying areas and in the flood plains within the creeks and water ways resulting in casualties during high flooding. The study aimed at applying a remote sensing-based approach for hydrographic mapping of the area. The objectives of the study were to; acquire and process a medium resolution satellite imagery of the study area, using empirical modelling of the processed images to determine the depth and topography of the seabed of the coastal waters of the area, determine the available water surface area and the Landuse/Landcover (LULC) pattern of the area by performing its LULC classification, and to generate a detailed hydrographic or a composite map of the area by integrating its bathymetric data and LULC pattern. The methodology adopted for the study involved acquisition and processing of satellite imagery (Landsat 8 OLI). The software used to acquire LULC classification and bathymetric analysis included ArcGIS Pro and ENVI 5.3. The result of the study revealed that in the area, Water bodies covered the largest area with an extent of 601.85 km^2, Forested areas covered 175.46 km^2, Croplands covered 6.844 km^2, Built-up areas covered 12.013 km^2, and Mangroves covered 0.283 km^2 while Open spaces covered an area of 3.39 km^2. The bathymetry result of the area showed that the shallow zone covered an area of 132.76 km^2 along the shoreline, with depth values ranging from 10.04 meters to 25.42 meters, the moderate zone covered an area of 146.02 km^2 along the shoreline, with depth values ranging from 25.42 meters to 40.79 meters, the deep zone covered an area of 136.79 km^2 along the shoreline, with depth values ranging from 40.79 meters to 56.17 meters, while the very deep zone covered an area of 139.04 km^2 along the shoreline, with depth values ranging from 56.17 meters to 71.54 meters. Data validation with that gotten from Shell Petroleum Development Company gave a correlation coefficient of 0.68, indicating a moderate positive correlation between the two datasets. It was then deduced that the bathymetric results of the processed imagery obtained using log ratio algorithm from Landsat 8 OLI are moderately accurate, meaning that it can be used with a good degree of confidence for decision-making processes. Some recommendations were made including the need for application of other remote sensing and GIS techniques for bathymetry of the area in order to acquire a result with a higher validation, accuracy and reliability.

Key Words: — ***Hydrography, Mapping, Remote Sensing, Coastal Environment.***

I. INTRODUCTION

The act of mapping of water bodies and its related environment is what is referred to as Hydrographic mapping, and this is

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always done through bathymetric surveying, which according to (Samaila-Ija 2014, Chukwu and Badejo, 2015) is seen as the mapping of sea floor to determine the water depth from the surface of the water. Remote sensing on the other hand is a means of gathering an information about a remote object without establishing a direct physical contact with that object of information. Remote sensing according to (Qihao 2013, Adjei-Darka 2017, Lillesand *et al* 2008), can simply be defined as the acquisition of an information about an object through remote means, and it involves using instruments called sensors, without getting into a direct physical contact with the object in which the information is needed.

Several techniques could be applied for hydrographic mapping of seabed for depth determination. Such technique ranges from the direct methods of sounding, with sounding poles and lead lines in shallow waters, to remote sensing methods (otherwise referred to as the indirect soundings techniques) in deeper waters including conventional echo sounding, swath sounding, aerial photography, satellite mapping and satellite altimetry techniques. The satellite remote sensing technique, when applied to the deep sea has the ability of giving a more holistic hydrographic information of the coast, the coastal waters and the seabed than the direct methods and the ordinary echo sounding technique (Ekpa and Ojinnaka, 2015).

Ibeno LGA is a coastal zone or area of Akwa Ibom state, and a coastal area is defined to be the land area adjacent to the sea, and the very interface between the land and the sea (Nelson 2012, Rochette 2010). These areas are rich in biological species of plants and animals and are also vulnerable to coastal erosions, floods and other hazards of the coastline (Rochette 2010, Lavalle *et al* 2011). Coastal area is highly vulnerable to coastal hazards like coastal erosion, oil spillage, deforestation of the swampy forest, flooding and biodiversity destruction (Udoudo *et at* 2018, Uso 2013, Henry *et al* 2013). There are much of the activities of oil companies including crude oil exploration and exploitation. However, such areas area is seen by Nelson (2012) as being very important zones because majority of the world's population inhabit such zones. Mapping of coastal area is thus very paramount as it facilitates its safety, sustainability and proper management of her numerous resources (Uso 2013, Lavalle *et al* 2011). Despite its numerous advantages, the zones are also seen to be very fragile environments which need to be properly protected and conserved (Udoudo *et al* 2018). That prompt a lot of managerial efforts by governments and developers in the area.

However, despite the numerous efforts put by researchers, developers and government in the area, there is still a level of persistency of the environmental hazards and challenges. Thus, the use of remote sensing techniques to carry out a hydrographic survey in the area will present a kind of a holistic approach to viewing and studying the area, and will also proffer a better approach to solving those noticeable coastal hazards such as coastal erosions, flooding, biodiversity destruction and oil spill. This goes in line with Ekpa and Ojinnaka (2015), that the use of echo sounder and ordinary surface remote sensing for hydrographic mapping of coastal areas and coastal waters is not adequate, as it has lots of limitations including non-application to shallow waters. This study therefore aimed at combining the LULC classification data obtained from the satellite imagery with the hydrographic and bathymetric data of the same place to produce a composite map of the area to help in its proper understanding of the area, resource utilization and management.

II. The Study Area

Ibeno LGA, which is the study area is one of the coastal LGAs of Akwa Ibom state of Nigeria. Akwa Ibom state is one of the states found in the South-South region of Nigeria (Figure 1). The LGA thus is located at the mouth of the Atlantic Ocean as a coastal state, and lies slightly horizontal along the coastline of Nigeria to Atlantic Ocean.

Ukpenekang is the headquarters of Ibeno LGA while the LGA itself is that LGA in Akwa Ibom state with the largest area of the Atlantic coastline. Thus, the LGA is in the Mangrove swamp forest zone of the Niger Delta region within Nigeria.

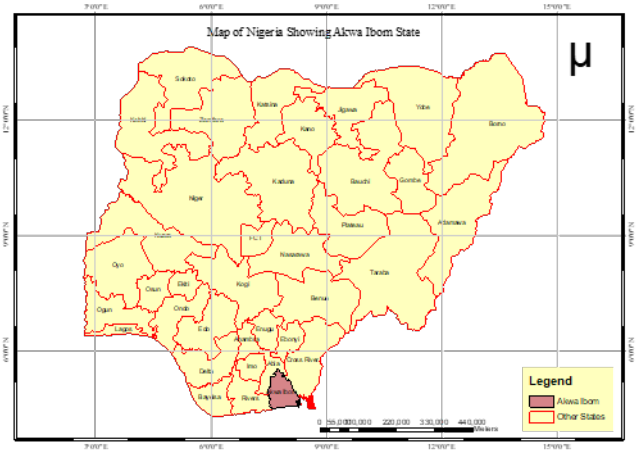

Fig.1. Map of Nigeria showing Akwa Ibom State

Ibeno LGA (Figure 2) is adjacent coastal LGA of Akwa Ibom state to Eastern Obolo LGA. The latitude is between 4° 32' and 4° 37' North and Longitude 7° 48' and 8° 19' East. In the West

Ibeno LGA shares boundary with Eastern Obolo Local Government Area, while to the east, it shares boundery with Mbo LGA. The North is bounded by three LGAs, including Onna, Esit Eket and Eket. Lastly, in the South, it is bounded by the Atlantic Ocean. Ibeno Local Government Area is located at the South end of Akwa Ibom State, occupying a vast coastal area of over.

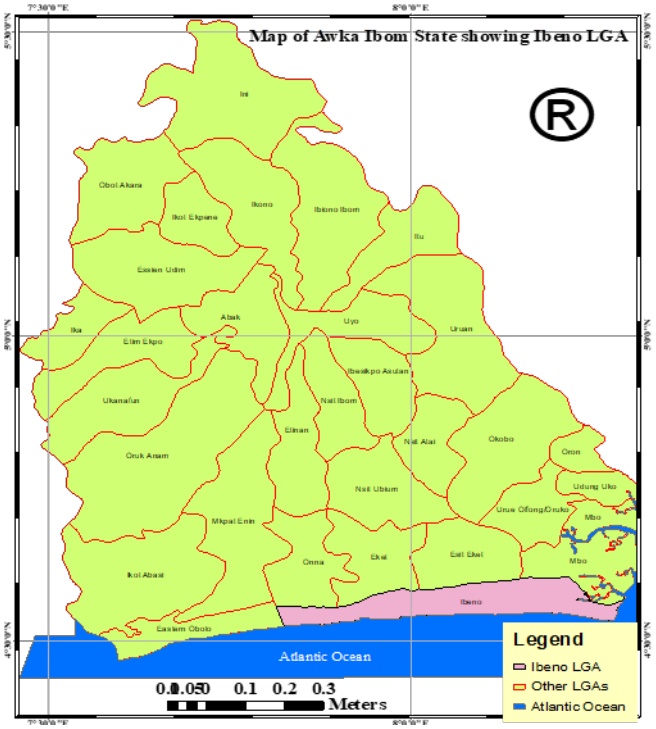

Fig.2. Map of Akwa Ibom showing Ibeno LGA

The Ibeno people speak Ibeno language as their official language, which is a mix up other languages including Ibibio (form Akwa Ibom state), Andoni, Ijaw and Opobo (from River state) and Efik language (from Cross River state). This also shows that their origin is a contribution of their language. The dominating oil company in the LGA is Exxon Mobil though there are few others operating in a minor scale. The culture of Ibeno is a typical culture of that of Oron nation, and thus resembles that of Eastern Obolo LGA of the same state.

III. Materials And Method

The methodology applied in this study involved the application of a remote sensing approach to carry out a hydrographic mapping of the area. Landsat 8 OLI 2017 (Landsat 8 Land Operational Imager 2017) satellite imagery downloaded from www.earthexplorer.usgs.gov was used. Other data source included the shapefiles of the administrative boundaries of the Ibeno LGA, sample points coordinates taken with GPS, bathymetric data (2022) which was gotten from Shell petroleum Development Company (SPDC) data. Non-spatial data were also collected through oral interviews. For processing and analysis of data, the following software were used; ArcGIS Pro for band combination, image classification and accuracy assessment, ENVI 5.3 for displaying, processing, enhancing of the data and for extraction of water depth using models and band ratios. Microsoft office tool including MS-word and Microsoft Excel was used for statistical analysis, editing and production of text.

Pre-processing of the downloaded image was done in order to do atmospheric error corrections, and this was done by using an algorithm in order to extract the depth of water bodies through bathymetry. Determination of the depth of water bodies from the acquired remote sensing data was done with a model developed by Stumpf *et al* (2003). This was used in extraction and estimation of the bathymetric depth of the seabed in the area. After that, Image Subset (for selecting and extracting a specific portion or subset of an image) was done. By adopting the level one classification scheme by Anderson *et al* (1976), the LULC was categorizes into five categories including; Built-up area, Cropland, Open space, Forested area, Mangrove and Water body. The categorized LULC was then integrated with the bathymetric results and the needed composite hydrographic and environmental information was extracted.

IV. Results and Discussion

The natural features that cover the surface of the earth such as water bodies, vegetation covers, desert, bare land and many others are referred to as the land cover. On the other hand, land use refers to diverse uses to which man put the land covers into. Such includes agricultural, industrial, residential, recreational, institutional, and many others uses.

Forested areas covered an area of 175.46 square kilometers in the area. These forests could be natural or cultivated, and provide numerous ecosystem services, such as erosion control, carbon sequestration, national parks, tourism, wildlife habitation, and timbers and non-timbers forest products. They can also be a source of medicinal plants. However, deforestation and forest degradation by human activities can have severe environmental and social impacts, including soil erosion, increase in temperature, loss of biodiversity, and displacement of indigenous communities.

Next in the area is the Croplands which covered an area of 6.844 square kilometers, indicating that agriculture is practiced in the

area. Agriculture is a crucial industrial and economic activity in many rural areas of Nigeria, and provides food, employment, and income for the local people and communities. However, unsustainable agricultural practices can lead to soil degradation, siltation of water ways, water depletion, and other environmental challenges.

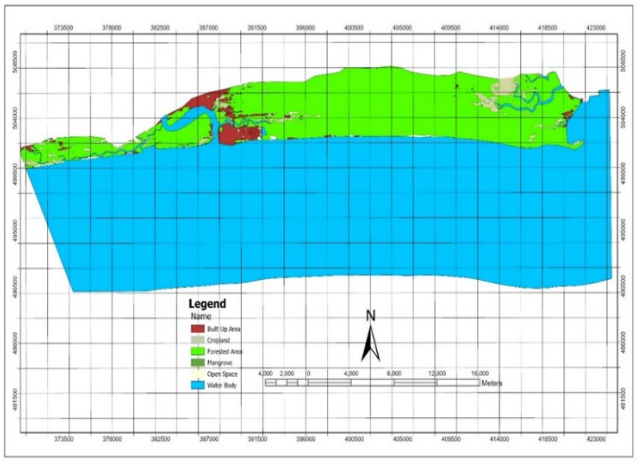

Fig.3. Landcover and Landuse Distribution of Ibeno LGA

The LULC carried out in the study also showed that Water bodies covered the largest area with an extent of 601.85 square kilometers. These water bodies could include part of the Atlantic Ocean, rivers, creeks and streams in the area. Water bodies are very essential for a numerous reason, including providing habitat for aquatic species (both the fauna and the flora), supporting fisheries, irrigation and supplying water for human domestic uses.

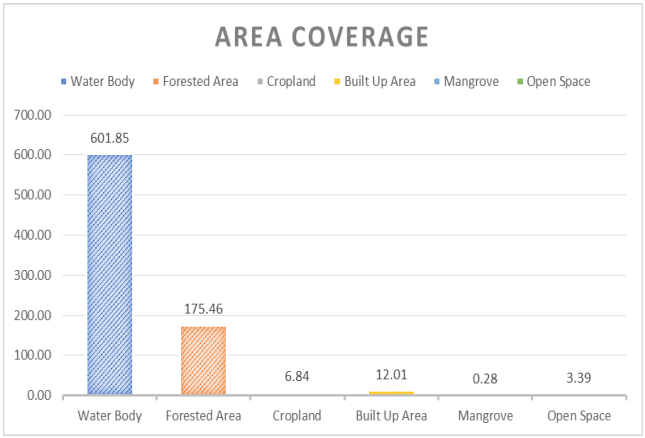

Fig.4. Landcover and Landuse Coverage of Ibeno LGA

Built-up areas covered an area of 12.013 square kilometers in the area. These areas include urban centers, residential areas, villages, and other human-made structures. Built-up areas which are typically associated with high human population density and economic activity, and do have significant environmental impacts, such as increased energy consumption, water, soil and air pollution, and waste generation.

Mangroves covered an area of 0.283 square kilometers in Ibeno LGA. These coastal forests are adapted to saltwater environments and provide numerous ecosystem services, such as shoreline stabilization, carbon sequestration, and habitat for amphibians, fish, crabs and other aquatic species. However, mangroves in the area are threatened by a range of human activities, including, urbanization, coastal development, logging activities, and shrimp farming.

Open spaces covered an area of 3.39 square kilometers in Ibeno LGA. These areas include grasslands, recreation centers, parks, and other undeveloped lands. They provide important ecosystem services, such as carbon sequestration, biodiversity conservation, and recreational opportunities. They also contribute to the overall aesthetic value of an area.

In summary, the landcover and landuse patterns of Ibeno LGA reflect the interaction between natural and human-made environments. Understanding these patterns is crucial for sustainable resource management, conservation planning, and urban development in the area. Based on the provided landcover and landuse distribution, Ibeno LGA is dominated by water bodies, followed by forested areas, built-up areas, croplands, open spaces, and a relatively small area of mangroves. This information can be useful for various applications, including resource management, urban planning and conservation planning, this is illustrated in figures 3 and 4.

Based on the bathymetric information extracted from Landsat 8 OLI using the log ratio algorithm, the bathymetry of Ibeno LGA shoreline was divided into four depth zones: Shallow, Moderate, Deep, and Very Deep.

The shallow zone covered an area of 132.76 square kilometers along the shoreline, with depth values ranging from 10.04 meters to 25.42 meters. This zone is likely to be influenced by near shore processes such as wave action, tides, and currents. The shallow depth values in this zone suggest that it may be suitable for various coastal activities, such as fishing, boating, and swimming.

The moderate zone covered an area of 146.02 square kilometers along the shoreline, with depth values ranging from 25.42 meters to 40.79 meters. This zone is likely to be influenced by both near shore and offshore processes, such as wave refraction, sediment transport, and ocean currents. The moderate depth values in this zone suggest that it may be suitable for offshore

activities, such as oil and gas exploration and marine transportation.

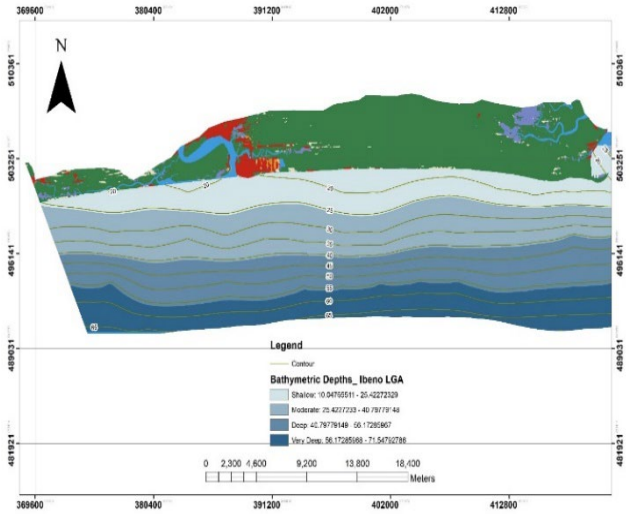

Fig.5. Ibeno LGA Bathymetric Mapping

Table.1. Ibeno LGA Shoreline Depth Range and Coverage

S/N	Class	Depth Range	Depth Coverage (km^2)	Percentage
1	Shallow	10.04m - 25.42m	132.76	24.06
2	Moderate	25.42m - 40.79m	146.02	26.47
3	Deep	40.79m - 56.17m	136.79	24.79
4	Very Deep	56.17m - 71.54m	136.04	24.66

The deep zone covered an area of 136.79 square kilometers along the shoreline, with depth values ranging from 40.79 meters to 56.17 meters. This zone is likely to be influenced mainly by offshore processes, such as ocean currents and bathymetric features. The deep depth values in this zone suggest that it may be suitable for deep-sea activities, such as submarine exploration and mining.

The very deep zone covered an area of 139.04 square kilometers along the shoreline, with depth values ranging from 56.17 meters to 71.54 meters. This zone is likely to be influenced by bathymetric features, such as underwater canyons and ridges. The very deep depth values in this zone suggest that it may be suitable for deep-sea research and exploration.

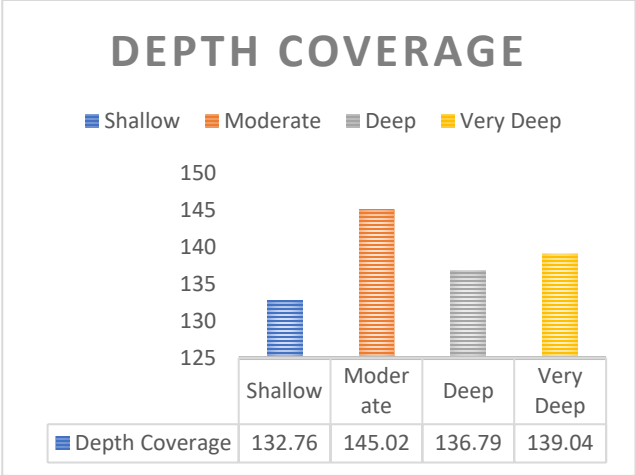

Fig.6. Ibeno LGA Bathymetric Depth Coverage

Overall, the bathymetry of Ibeno LGA shoreline provides important information for various coastal and oceanographic applications, such as coastal management, marine resource exploration, and oceanographic research.

The variations in water depth along the coastline can have various implications for the ecological, economic, and social aspects of the area, and the bathymetric data can be used to inform sustainable development and resource management strategies (figures 5 and 6 and table 1).

Using data gotten from Shell Petroleum Development Company, the validation of bathymetric data obtained from Landsat 8 OLI was carried out for regression analysis, with the aim to evaluate the accuracy of the bathymetric results obtained from Landsat 8 OLI by comparing it with that from SPDC. The validation process involved the use of log ratio algorithm to obtain bathymetric data from Landsat 8 OLI. The essence of the regression analysis was to compare the results derived from the Landsat8 OLI data with the data collected by Shell Petroleum Development Company (SPDC). Being done to assess the closeness of the two datasets and was actualized by calculating the correlation coefficient which is a statistical measure to determine the strength of the relationship between two variables. The value obtained from the analysis was 0.68 correlation coefficient, and this was an indication of a good positive correlation between the two sets of data. This shows that the bathymetric results obtained from Landsat 8 OLI through the use of log ratio algorithm has a positive linear relationship with that of the bathymetric data collected from Shell Petroleum Development Company (SPDC). The result obtained showed that the values gotten are reliable, and this is

a good indication that it can be used for decision making with a good degree of confidence.

The composite result which combined the landus/landcover data with the bathymetric data obtained from the Ibeno LGA was produced and this is seen as presented in a composite map in figure 7 map below.

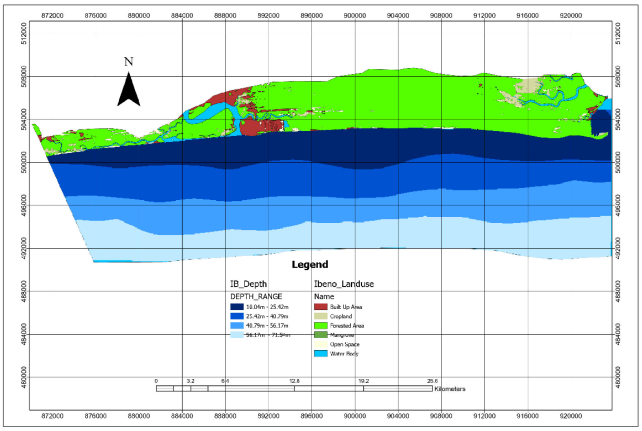

Fig.7. Composite Hydrographic map of bathymetric and LULC classification of Ibeno LGA

V. CONCLUSION

In conclusion, Ibeno LGA is a coastal area of Akwa Ibom state and thus, faces numerous humans induced coastal hazards. The image classification of the area shows that it has a total Water body covering the largest area with an extent of 601.85 square kilometers. Forested areas covered an area of 175.46 square kilometers. Built-up areas on the other hand covered an area of 12.013 square kilometers in the area. The Mangroves Forest covered an area of 0.283 square kilometers while Open spaces covered an area of 3.39 square kilometers.

For the bathymetry, the area was categorized into four depth zones including the; Shallow, Moderate, Deep, and Very Deep zones, which helped in the bathymetric analysis. This analysis for depth determination carried out in the area through the use of remote sensing and GIS technique shows that in the area, the shallow zone covered an area of 132.76 square kilometers, ranging from 10.04 meters to 25.42 meters. The moderate zone covered an area of 146.02 square kilometers, ranging from 25.42 meters to 40.79 meters. The deep zone covered an area of 136.79 square kilometers, ranging from 40.79 meters to 56.17 meters, while the very deep zone covered an area of 139.04 square kilometers, ranging from 56.17 meters to 71.54 meters.

In recommendation, since the validation of the data derived from the bathymetric mapping with that form SPDC gave a correlation coefficient of 0.68, there is a need for more efforts in applying other remote sensing and GIS techniques for bathymetry in the area in order to improve the accuracy of the result for more reliability. There should also be more research efforts to tackle the conservation of Mangrove in the area so as to help in the conservation of the biodiversity in the area. Sustainable Land Use is also recommended in the area. Thus, the coastal resources of the area should be exploited in such a way that it meets the needs of the present time without compromising the needs of the future. Disaster Risk Reduction should also be set up to help in reducing or totally eliminating casualties in case of emergency of coastal flood, Tsunami and other coastal hazards.

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