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A REMOTE SENSING-BASED APPROACH FOR HYDROGRAPHIC MAPPING OF COASTAL AREA OF EASTERN OBOLO LGA OF AKWA IBOM STATE OF NIGERIA

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Abstract
Remote sensing-based approach being the acquisition of data from a distance object without having physical contact with it, is a reliable method of acquiring hydrographic information of coastal areas. Hydrographic mapping involves mapping of water related environments. Eastern Obolo LGA of Akwa Ibom state of Nigeria being a coastal environment faces a lot of coastal hazards including coastal erosion, siltation and dumping of wastes along the coastal waters. Aiming at applying remote sensing based approach for hydrographic mapping of the study area, the objectives included acquiring/processing a medium resolution satellite imagery of the area, determining bathymetric data of its coastal waters by empirical modelling, classifying Landcover/Landuse (LULC) of the area and generating its hydrographic map. The methodology used involved acquiring/processing Landsat 8 OLI satellite imageries using ArcGIS Pro and ENVI 5.3. The results revealed that Eastern Obolo LGA has 242.58 km^2 land coverage, 56.25 km^2 forest and moderate size areas of cropland and open space. Bathymetry result shows shallow area of 4.48 km^2, moderate depth area of 58.09 km^2 and much expanse of deep and very deep area. Data validation with that gotten from SPDC gave a correlation coefficient of 0.69 suggesting moderately accurate data with good degree of confidence.

Keywords: Remote sensing, Hydrographic, Bathymetric, Mapping, Coastal area

Introduction

Hydrographic mapping simply refers to mapping of water bodies. It is mostly done through bathymetric mapping. Bathymetric mapping simply means the mapping of sea floor to determine the water depth from the water surface (Samaila-Ija *et al* 2014, Chukwu and Badejo 2015). It has to do with the application of sounding and other surveying methods, such as remote sensing (aerial photography and satellite mapping/imageries) to acquire the depth information of a water body. By extension, hydrographic mapping covers all surveys done in the coastal and deep sea waters (such as swamp, estuaries, wetlands, flood plains, ponds, shorelines, lakes, rivers, seas, oceans etc.) with the aim of determining or extracting topographic/depth, size (including stream length and width), coordinate, temporal changes through change detection, and other information, including seismic data during exploration for mineral deposits beneath the seabed.

According to Qihao (2013), remote sensing refers to the science and technology of acquiring information about the earth's surface (land and ocean) and atmosphere using sensors on-board airborne (aircraft and balloons) or space borne (satellites and space shuttles) platforms. With this technology, hydrographic information over large areas can be covered at short time intervals (Lillesand *et al* 2008).

Eastern Obolo LGA of Akwa Ibom state being a coastal area which is chosen for this study is a coastal hazard area. Coastal environment refers to those environments adjacent to the coastline extending some distances landward and seaward from the coastline (Udoudo *et al* 2018). Coastal zone is that area comprising coastal public property, the coastal protection zone, coastal

access land and coastal protected areas, the seashore, coastal waters and the exclusive economic zone and includes any aspect of the environment on, in, under above such areas (Rochette 2010). It is also defined as the interface between the land and water (Nelson 2012). Coastal areas are normally rich in biological species of plants and animals, both of micro and macro forms. However, the area is mostly vulnerable to coastal erosion and other coastal hazards (Lavalle *et al* 2011, Rochette 2010).

Eastern Obolo LGAs of Akwa Ibom state is rich in biological resources (Uso 2013). Such areas in most cases experience tides and floodings. Previous researches in the area only focused on the bathymetric data of the deeper off-shore locations involving several nautical miles from the coastline, where oil and other minerals are found.

Coastal environments are fragile environments, and due to their undulating topography, coupled with numerous industrial and engineering activities, high rate of coastal erosion and other coastal hazards are noticed than on the inter land. According to Uso (2013) gradual changes in the shoreline take place yearly. Despite the research efforts done so far in the area, coastal problems such as coastal erosion, sedimentation, siltation and floodings are seen to persist. This study aimed at applying a remote sensing based approach for hydrographic mapping of the study area, while the objectives were to acquire and process medium resolution optical remotely sensed images of the area, determine the bathymetric data of its coastal waters using empirical modelling of the processed images, carry out a LULC classification of the area and to generate a detailed hydrographic map of the area.

The use of remote sensing for hydrographic mapping to acquire hydrographic data for safe navigation, resource utilization and management of Eastern Obolo LGA necessitates this study because it is a stepping stone to protecting and managing the area.

The Study Area

Eastern Obolo is one of the coastal Local Government Areas (LGAs) of Akwa Ibom state of Nigeria bordering the Atlantic Ocean. It lies nearly horizontal to the Atlantic coastline. It is located along the coastline between Imo River and Qua Iboe River. In the North, it is bounded by Mkpat Enin and Ikot Abasi LGAs. In the East, it is bounded by Onna and Ibeno LGAs. The North-West has Ikot Abasi LGA and bounds with the Atlantic Ocean in the Southern part. Eastern Obolo is between Latitude 4° 27’ and 4° 34’ North and between Longitude 7° 32’ and 7° 48’ East (See Figures. 1 and 2). Eastern Oblolo has a lot of creeks and inland water ways. Thus there is a network of streams draining the area.



Figure 1: Map of Nigeria showing Akwa Ibom State

The people of Eastern Obolo in particular are the typical people of Akwa Ibom state having a mixture of Andoni and Iko cultural heritage and language, and have a very strong cultural affinity existing among them. It has a total landmass of approximately 117,008 square kilometers with a very long estimated shoreline distance of about 184 km long Uso (2013). The official language is the Obolo language which is also spoken in the Andoni LGA of Rivers State of Nigeria. Their population of the area is dominated by the people that are mostly farmers and fishermen. Most of the modern industries are dominated by the foreigners.

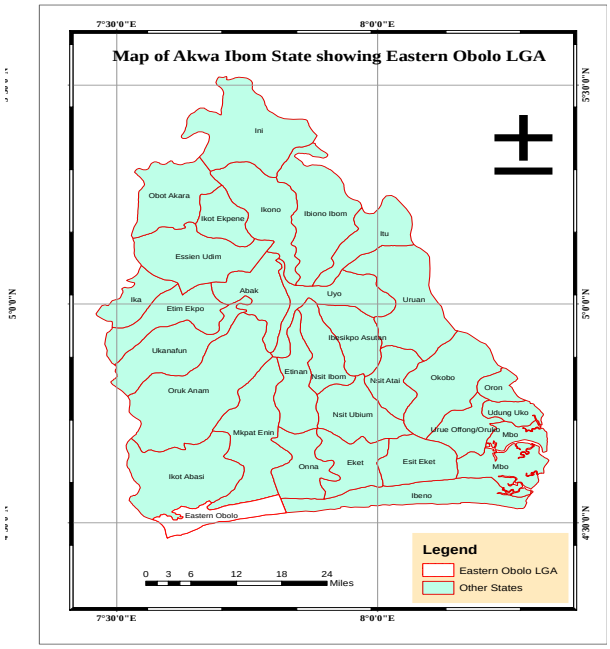


Figure 2: Map of Akwa Ibom showing Eastern Obolo LGA

Methodology

The methodology applied for this research involved the application of remote sensing based technique for hydrographic mapping of the coastal area of Eastern Obolo LGA of Akwa Ibom state. This approach proves more accurate because according to Ekpa and Ojinnaka (2015), the applications of conventional technique of bathymetry such as echo sounders or swath sounding systems are inadequate for mapping waters with very shallow depth due to sensor fouling or prohibitive cost in attempt for full sea floor coverage. And with this technology, hydrographic information over large areas can be covered at short time intervals (Lillesand *et al* 2008). Therefore, it can be deduced 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. The remote sensing based approach was necessary for this study because it gives a wider and holistic view of the survey area and is cheaper, faster, more accurate and more reliable result than surface and ground based methods.

The data used for the study included Landsat 8 OLI 2017 satellite imagery which was extracted or downloaded from www.earthexplorer.usgs.gov website. The shapefiles of the administrative boundaries of the area were gotten from the hard copy maps from the Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, and then digitized to convert them into soft copy maps for easy processing. Other data requirements included the sample points coordinates from GPS, bathymetric data (2022) extracted from Shell petroleum Development Company (SPDC) and the non-spatial data collected through oral interviews. The software for processing and analysis included; ArcGIS Pro for band combination, image classification and accuracy assessment. ENVI 5.3 was used to display, process, enhance the data, as well as water depth extraction models and band ratios. Also, Microsoft suite (Microsoft Excel and Word) was used for performing statistical analysis and also the task of editing and production of text report.

In the study, the downloaded image was added as data to the ArcGIS and the area of interest was clipped out for classification and processing. The type of image classification engaged for the satellite image was a supervised image classification. Other step that followed included, Image pre-processing, which was done to correct the imageries of atmospheric errors based on the algorithm developed by Stumpf and Pennock (1991) for several remote sensors, including Coastal Zone Colour Scanner, Advanced Very High-Resolution Radiometer, and Landsat Thematic Mapper.

For the bathymetric depth, a model developed by Stumpf *et al* (2003) was used to determine the depth of water bodies from remote sensing data, and this was used to estimate the bathymetric depth of the seabed for the coastal waters of the Eastern Obolo LGA.

The Image Subset which refers to the process of selecting and extracting a specific portion or subset of an image was also done. The level one classification scheme by Anderson *et al* (1976) was adopted, which categorizes LULC into; Built-up area, Cropland, Open space, Forested area, Mangrove and Water body. Finally, the integration of bathymetric results with land use/land cover data was done to provide valuable information about the spatial distribution of physical and biological features of aquatic ecosystems. This helped to align and resample the two datasets so that they have the same spatial resolution and coordinate system.

Results and Discussion

The results of the landuse/landcover and bathymetric mapping using remote sensing-based approach which this study employed has given a detailed landuse/landcover classification and the bathymetric details of the coastal waters in the study area, which covers some distances landward (the swampy region and the near continents) and some distances seawards (the nearshore zone).

Hydrographic mapping of the coastal area is broad as it stands, but this approach is only limited to image classification and bathymetric depth extraction by acquiring, processing, analysing and interpreting of the satellite imageries.

Landcover refers to the natural environmental features that covers the surface of the Earth, including natural vegetation, water bodies, and man-made structures. Landuse on the other hand describes the different uses by which human put the land to, including; agriculture, residential, industrial, institutional, recreational, or educational purposes.

Based on the classification results (see Figures 3 and 4), Eastern Obolo has a total water surface area of 242.58 square kilometers, which is the largest landcover class in the area. This suggests that Eastern Obolo is dominated by aquatic ecosystems, which could be due to the presence of the Atlantic Ocean or numerous rivers, creeks and streams draining the region. The area is located in the coastal region of Nigeria, where the Atlantic Ocean borders the area to the south. Additionally, numerous rivers and streams flow through the area, such as Imo River, Ekombi River, and Ibeno River. The water bodies in the area are important for fishing, transportation, recreation, and tourism.

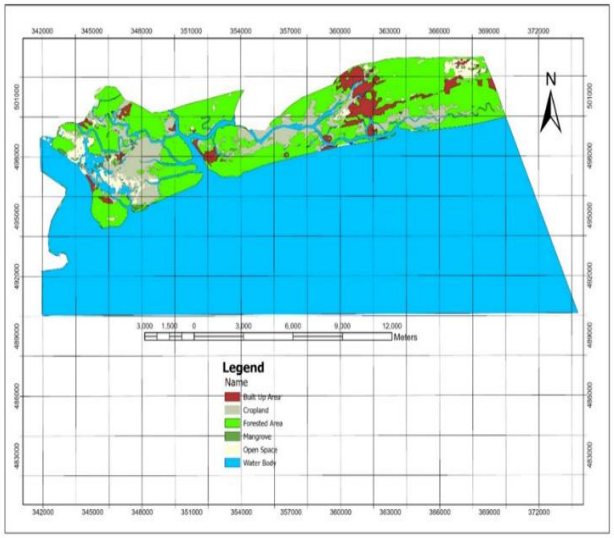


Figure 3: Landcover and landuse distribution of Eastern Obolo LGA

The second-largest landcover class in Eastern Obolo is the forested area, which covers an area of 56.25 square kilometers. The forests in the area are composed of both natural and planted forests. The natural forests are important for biodiversity conservation and climate regulation. The planted forests are used for timber production, which is a significant economic activity in the area. The forests in Eastern Obolo are also important for forest products including bush meat and traditional medicine as many plants in the area have medicinal properties. This implies that the area has a significant amount of forest resources, which could be valuable for timber production or conservation purposes.

Croplands cover an area of 17.75 square kilometers, indicating that agriculture is practiced in the area. The crops grown in the area include pineapples, cassava, maize,

yam, plantain, vegetables and tree crops. The agricultural practices in the area are subsistence farming and small-scale commercial farming. The soils in the area are fertile (though some are waterlogged), and the climate is favourable for agriculture. The swampy waters are used for rice production.

Built-up areas cover an area of 7.44 square kilometers, indicating that human settlements are present and expanding in the area, and this could include urban centers, villages, and other human-made structures.

Mangrove, covering an area of 0.976 square kilometers, indicates the presence of mangrove forests. These coastal forests are adapted to saltwater environments and provide numerous ecosystem services, such as shoreline stabilization, carbon sequestration, and habitat for fish and other aquatic species. However, mangroves are threatened by a range of human activities, including coastal development, logging, and shrimp farming.

Lastly, the Open Space landcover class covers an area of 5.43 square kilometers, indicating the presence of open fields and grasslands, which could be used for livestock grazing or other purposes and recreational activities. These areas could include grasslands, parks, and other undeveloped lands. Open spaces 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 area is dominated by water bodies, followed by forested areas, croplands, built-up areas, mangroves, and open spaces. The landcover and landuse patterns of Eastern Obolo 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, this is illustrated in figures 3 and 4.

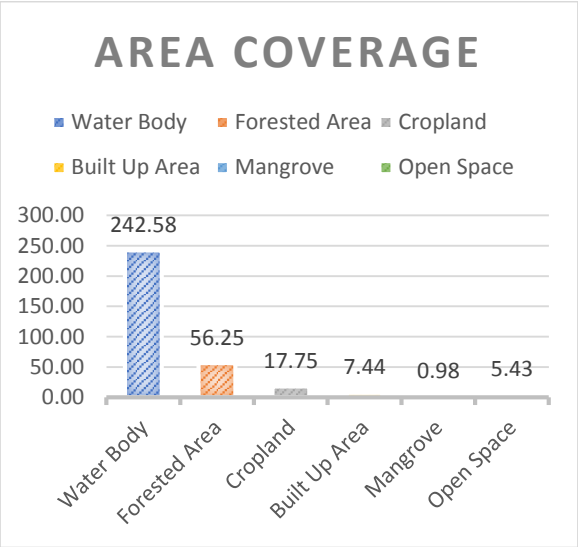


Figure 4: Landcover and landuse percentage coverage of Eastern Obolo LGA

The Bathymetric Analysis of Eastern Obolo LGA shoreline as shown in Fig. 5, shows that the area is located along the Atlantic Ocean coastline of Nigeria, and the bathymetry of its shoreline provides information on the water depth variations along the coastline. The bathymetry of its shoreline was also divided or classified into four depth zones: The Shallow, Moderate, Deep, and the Very Deep zones (see Figure 5).

The shallow zone covers an area of 4.48 square kilometers along the shoreline, with depth values ranging from 9.23 meters to 22.12 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 covers an area of 58.09 square kilometers along the shoreline, with depth values ranging from 22.12 meters to 39.29 meters. This zone is likely to be influenced by both nearshore 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.

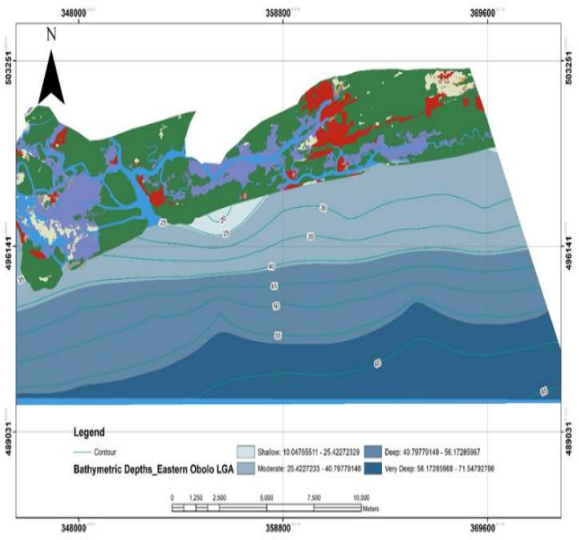


Figure 5: Eastern Obolo LGA bathymetric mapping

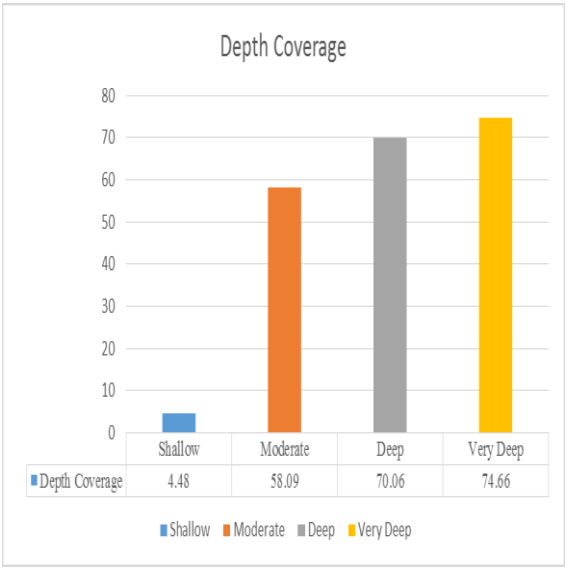


Figure 6: Eastern Obolo LGA bathymetric depth coverage

The deep zone covers an area of 70.06 square kilometres along the shoreline, with depth values ranging from 39.29 meters to 52.23 meters (Fig. 6). 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 covers an area of 74.66 square kilometers along the shoreline, with depth values ranging from 52.23 meters to 69.22 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.

Overall, the bathymetry of Eastern Obolo 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, this is illustrated in figures 5 and 6.

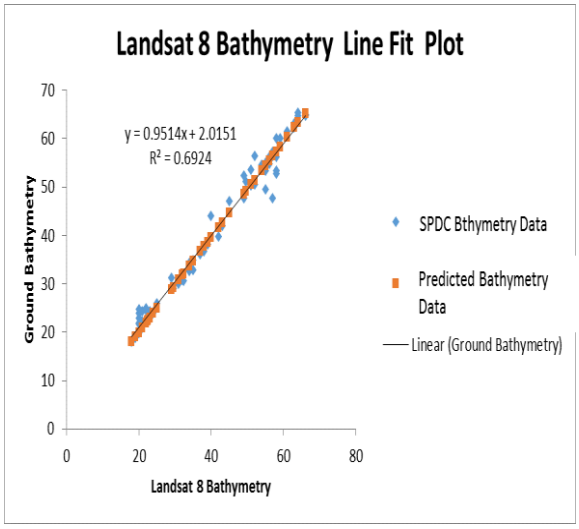


Figure 7: Validation of landsat 8 based bathymetry results

The validation of bathymetric data obtained from Landsat 8 OLI was carried out using data gotten from Shell Petroleum Development Company (SPDC). The aim of this validation process was to evaluate the accuracy of the bathymetric results obtained from Landsat 8 OLI. The validation process involved the use of the log ratio algorithm to

obtain bathymetric data from Landsat 8 OLI, and regression analysis was employed to compare the results with the data collected by SPDC.

The regression analysis aimed to assess the closeness of the two datasets by calculating the correlation coefficient, which is a statistical measure used to determine the strength of the relationship between two variables. The correlation coefficient value of 0.69 was obtained from the analysis, which indicates a moderate positive correlation between the two datasets. This value of 0.69 suggests that the bathymetric results obtained from Landsat 8 OLI using the log ratio algorithm have a moderately positive linear relationship with the bathymetric data collected from Shell Petroleum Development Company (see figure 7).

It is essential to validate bathymetric data, especially when using remote sensing techniques, as the accuracy of the data can be affected by several factors such as atmospheric conditions, sensor calibration, and environmental conditions. The validation process helps to ensure that the bathymetric data obtained from remote sensing techniques are accurate and reliable.

Overall, the correlation coefficient value of 0.69 obtained from the validation process indicates that the bathymetric results obtained from Landsat 8 OLI using log ratio algorithm are moderately accurate and can be used with a degree of confidence in further analysis and decision-making processes.

Conclusion and Recommendations

In conclusion, Eastern Obolo LGA had a total water body coverage of 242.58 km² as the most dominant land cover. The implication of this is that the coastal waters need to be utilized sustainably to avoid coastal hazards. Forested area was the most prominent land use pattern in the area. This implies that the area has much of its area not urbanized yet. Thus, much efforts should be made to conserve it as the forest here harbours many biological species or biodiversity. Such ecosystem should not be allowed to be degraded. For bathymetry, Eastern Obolo has the shallow, moderate, deep, and very deep zones covering areas of 4.48 km^2, 58.09 km^2, 70.06 km^2, and 74.66 km^2, respectively. This shows that the shallow region is very small as compared to the other zones. It should also be protected against coastal construction and engineering activities that will be inimical to the preservation of the near shore ecosystem and stability. The deeper zones can generate marine resources to the area in commercial quantities.

Based on the results and analysis obtained, the following recommendations were made;

1. Conservation of Mangrove: The results on mangrove cover in Eastern Obolo LGA highlight the need for wetland conservation efforts in area.

2. Sustainable Land Use: The results on land use and land cover in the area (with forested area: 56.25km^2; cropland: 17.75km^2; built-up area: 7.44km^2; mangrove: 0.98 km^2; and open space: 5.43km^2) can be used to promote sustainable land use practices that support biodiversity conservation, soil conservation, and climate change mitigation.

3. Bathymetric Mapping: The validation of bathymetric data collected from Landsat 8 OLI using log ratio algorithm with data collected from Shell Petroleum Development Company gave a correlation coefficient of 0.69. There is therefore a need for more detailed bathymetric mapping in the area to improve the accuracy and precision of the data. More data can then be collected using other remote sensing techniques or through surface and field measurements to improve the resolution of the bathymetric data.

4. Disaster Risk Reduction: The information on bathymetry can be used for disaster risk reduction planning to predict and monitor the effects of sea level rise, storm surges, and tsunamis and other coastal hazards. The data on the distribution of shallow, moderate,

deep, and very deep areas in the area can be used to establish early warning systems and contingency plans for emergency peradventure there is an event of natural disasters.

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