Characterization of the Nigerian Shoreline using Publicly-Available Satellite Imagery

Olumide Fadahunsi  
_Nigerian Navy Hydrographic Office_

Shachak Pe'eri  
_University of New Hampshire, Durham, shachak.peeri@unh.edu_

Andy Armstrong  
_University of New Hampshire, Durham_

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Making Use of Publicly Available Satellite Imagery

Current methods of shoreline mapping include aerial and high-resolution satellite imagery and ground-based surveying, all of which require considerable investment of human and material resources. Mapping and continuous updating of the shoreline for developing countries, such as Nigeria, is a challenge. Most of the information on the Nigerian shoreline is based on ‘surveys of opportunity’ performed by various government agencies over a wide time span. Additional surveys conducted by the multi-national oil and gas companies exploring in the region are typically not available for use by government agencies. In cases where the data are available, the variety in methods used for shoreline mapping can result in inconsistencies.

Shoreline Position and Character
The Nigerian shoreline lies in the West Coast of Africa (Figure 1) and is part of the Gulf of Guinea. The Nigerian shoreline is typically classified into one of the four major coastal groups: barrier island coast, mud coast, Niger Delta coast and the strand coast. The character of the shoreline can be used as an indicator for coastal management. In addition to the geological characterisation, the International Hydrographic Organization (IHO) provides a description of shoreline characteristics and the corresponding symbols and features used on a nautical chart. The shoreline position is marked on the chart at a selected vertical datum, typically a tidal datum. The shoreline character symbols and features vary between charting organisations, but can generally be divided into three main cartographic groups: natural, manmade and undefined.

In Nigeria, the current navigational charts are produced by the United Kingdom Hydrographic Office (UKHO) (Figure 1). Three Admiralty Charts at a scale of 1:350,000 cover the whole Nigerian coastline referenced to the Mean High Water Springs (MHWS).

Shoreline Mapping and Characterisation Procedure
The mapping and characterisation of shorelines using multi-spectral satellite imagery was performed in a GIS environment. Key steps in the procedure include: pre-processing, land/water separation (shoreline delineation), water subset analysis (man-made features and bathymetry) and land subset analysis (vegetation and exposed land). Landsat 7 imagery was used for mapping the position and character of the shoreline. The major consideration in selecting Landsat imagery was the availability of suitable multispectral datasets at no cost for many coastal areas around the world.

Free and publicly available data is the solution

and only a few key locations (e.g., Lagos and Escravos) are covered by charts at scales larger than 1:80,000. The horizontal datum of the UKHO Admiralty charts is WGS 84 (original realisation), and a Transverse Mercator map projection is used. The vertical datum to which soundings are referenced is the Lowest Astronomical Tide (LAT), while heights and the shoreline are referenced to the Mean High Water Springs (MHWS).

Three Nigerian sites were selected based on their coastal characteristics, national priority for mapping and availability in nautical charts and topographic maps. The Lagos study site is a barrier coast type shoreline

Olumide Fadahunsi, Nigerian Navy Hydrographic Office Lagos, Nigeria; CCOM/UNH, USA

Shachak Pe’eri, CCOM/UNH, USA

Andrew Armstrong, NOAA OCS/JHC, USA
with man-made features on both sides of the Lagos inlet. The Lagos study site has sparse vegetation, typically shrubs and short grass. Escravos and Pennington are located in a Niger Delta coast type shoreline: a densely vegetated area composed mainly of mangrove and tall shrubs. The vegetation in both sites does not extend to the low water line except within the channel where the water is usually calmer. Man-made features (moles and oil rigs) are also present in the Escravos study site.

To assess the suitability of the methods developed in this study, the procedure was first conducted using a calibration site located along the northeast coast of Massachusetts in the United States, between Merrimack River and Cape Ann. The criteria for selecting this site included the availability of remote sensing survey data that can be used as reference datasets. The site also contained shoreline characters similar to the Nigerian study sites, in addition to rocky outcrops.

Although the data for the calibration site is from a NOAA chart, the chart symbols are similar to those of the UKHO charts of the Nigerian sites. The procedure included a decision tree (Figure 2) that: a) classified the images into land and water (level 1), b) characterised the dry land into exposed, vegetated and man-made classes (level 2), c) calculated bathymetry for the submersed areas (level 2), and d) assigned an attribute to different segments along the shoreline character (level 3).

**Comparison Results**

The satellite shoreline position results for the US calibration site showed a good agreement with the MHW shoreline depicted on NOAA charts. NOAA archive tidal stage information indicated that the Landsat image was acquired at a high stage of tide. Next, a qualitative cartographic comparison over the Nigerian study area was conducted. In Lagos Channel, visual agreement in shoreline position was observed between the satellite-derived shoreline and the charted MHWS shoreline. In the Escravos study site, cartographic comparison also shows good agreement between the charted shoreline and the satellite-derived shoreline along most of the coast. It is important to note that MHWS and LAT shorelines in the Escravos study site are almost coincident over their entire length. This can be attributed to the relatively steep beach slope in the area and the 1:60,000 scale of the chart used in the comparison. In the Pennington study area, only a single MHWS shoreline is depicted on
the chart because of the chart scale
(1: 350,000). The Landsat shoreline
agreed well with the charted shoreline.

A thematic comparison was also made
between the Landsat-derived shoreline
and other sources. High-resolution
satellite imagery (IKONOS) was used
to validate that the separation of
vegetated areas from exposed areas
was successful using Landsat over
the US calibration site and Escravos. The Landsat imagery provided more
details on the shoreline character
than the available charts and maps
(Figure 3). It was possible to separate
the vegetation and exposed shoreline
into more classes, however, the symbols
on the charts were not detailed enough
to validate the results. In addition, a
submerged mole was identified using
satellite derived bathymetry and validated using the reference (Figure 4).

Based on consideration of the
nominal georeferencing accuracy and
resolution of the Landsat 7 imagery,
the lack of tide information, and the
method of shoreline extraction, the
estimated positional uncertainty of
the shoreline in all three Nigerian sites
(Lagos and Pennington) is ~150-200 m
at 95% confidence level. Cloud cover in
some of sites limited the comparison
areas. Ground truth is required to
evaluate the results and determine the
threshold between various land covers
and vegetation types.

Characteristics of the
shoreline are an indicator for
coastal management

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the vegetation and exposed shoreline
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on the charts were not detailed enough
to validate the results. In addition, a
submerged mole was identified using
satellite derived bathymetry and validated using the reference (Figure 4).

Conclusions
The characteristics of a shoreline
are indicative of potential changes
that can occur in the position of
that shoreline, as well as coastal
development. Unfortunately, many
developing countries are not able to
map their shorelines on a frequent

basis due to limited resources. This
procedure offers a solution to this
challenge using free and publicly
available data. Although, the shoreline
characterisation procedure was
developed based on datasets from
study sites along Nigerian coastline,
the procedure is suitable for mapping
coastal areas in other developing
regions. Investigation of more study
sites with ground truth data as a
controlled reference will provide
a more robust procedure that can include various land covers and
vegetation types.

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Further Reading
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The Authors
Cdr. Olumide Fadahunsi is a hydrographer
with the Nigerian Navy Hydrographic Office.
He earned a BSc from the Nigerian Defence
Academy (1996) and an MSc from CCOM, UNH
(2012). He has served in a variety of naval
and hydrographic positions, including the
implementation of the International Ship and
Port Facility Code in Nigeria.

Shachak Pe’eri is a research assistant
professor at the Center of Coastal and Ocean
Mapping (CCOM), University of New Hampshire
(UNH). His research focus is in airborne remote
sensing with a focus on experimental and
theoretical studies of airborne Lidar bathymetry,
topographic Lidar, and terrestrial laser scanning
and hyperspectral remote sensing.

Andrew Armstrong is the NOAA co-director
of the NOAA/University of New Hampshire
Joint Hydrographic Center. Along with his UNH
counterpart, he manages the research, mapping
and educational programmes of the centre.

Figure 3: Lagos study site: (a) historical map, (b)
UKHO chart, (c) Landsat 7 image, and (d) thematic
map of the coastal characters.

Figure 4: Indirect
mapping of a
submerged mole in
the Escravos site:
(left) UKHO Chart,
(centre) satellite-
derived bathymetry
from Landsat
imagery, (right)
Ikonos reference
imagery.