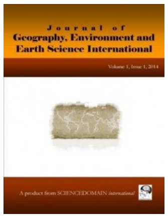

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Bathymetric Survey and Topography Changes Investigation of Part of Badagry Creek and Yewa River, Lagos State, Southwest Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author BOT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AGK managed the analyses and literature searches of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Bathymetry survey of Part of Badagry Creek and Yewa River was conducted with the aim of investigating the topography changes in depth between two epoch dataset by calculating the volume of sediment and dredged material between the two periods. Depth sounding at 100m interval, data grid of 100 m interval, constant vessel speed of 2.2 m/secs (8Km/hr) for data capture, data storage at interval of 30 Secs was ensured at both the creek and the river. Seabed topography changes of Part of Badagry Creek and Yewa River was investigated. The two dataset investigated was the data acquired in September 2008 and November 2015. Data acquisition was done using digital echo sounder SDE28, Handheld Real time Kinematic (RTK) Global Positioning System (GPS) in acquiring the spatial coordinates (x, y) and water depth (z). Six (6) wrecks (Shipping Boat) were determined along both the creek and the river. The initial processing was carried out with the use of HYPACK 2008 software for data sorting. ArcGIS 10.2.1 was used for data analysis as well as graphics design. The processed depths were presented in form of tables, map/plan and charts.

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The result showed that In 2008, the depth observed ranges from (-0.5 to 10.4) m while in 2015, the depth observed ranges from (-0.32 to 10.85) m which implies that some area have been cut. Also, the results of the volume of deposited sediments and dredged material are computed as 10.55 x 106 m3 and 7.24 x 106 m3. It showed from the result that volume of accreted sediment is greater than volume of the material dredged. Increase in volume of sediment deposited could be as a result of the adjoining river Yewa flowing into the larger river (tributaries) of the Badagry Creek. Therefore, further studies need to carry out in order to know the source of accreted mass through integrated coastal management plan.

Keywords: Bathymetric survey; topographic changes; depth sounding; wreck determination; volume determinations.

1. INTRODUCTION

The countless benefits offered humanity by the global oceans makes the study of water bodies a vital field of research to man [1,2]. Ranging from easing and ensuring safe navigation of vessels on waterways [1], simple reconnaissance (at project formulation) to payment for work carried out underwater, such as dredging or reclamation [3], mineral exploration [4] and other such benefits derivable from the water bodies, a concise study of the morphometric and/or physio-chemical properties of the water body is highly relevant. A common practice in such studies especially where water body's morphometry is of major concern is the bathymetric survey while morphometry represents the topographical expression of land by way of area, slope, shape, length, etc. and these parameters affect catchment stream flow pattern through their influence on concentration time [5,6].

A bathymetric survey is required whenever a detailed survey of the bed level is to be carried out. It is defined as the measurement of water depth e.g. lakes, oceans, dams, seas and rivers [7]. Bathymetry, according to Samaila-Ija et al. [8] is the measurement of the depths of water bodies from the water surface. It is the marine equivalent of topography and a major component of the overall hydrographic survey operation.

In bathymetric survey, charts are produced to support safety of surface or sub-surface navigations which usually shows seafloor relief or terrain as contour lines (depth contours), and such chart provides surface navigational information [1]. Bathymetric survey is just like carrying out topographic survey on land. The chart produced from bathymetric survey of underwater depicts the nature of the underwater bed. A three Dimensional (picture) of the bottom would meet this requirement, and this is exactly what is meant by High Definition Gridded Bathymetric (HDGB) [9]. It must be said that since inception, the major task of hydrography had been the capability to efficiently tie measured sea bed depths to the correct planimetric positions [3]. There are many instruments that have been designed to achieve better standard of hydrographic surveying. With such advance in class instruments, surveyors have the capability to perform better and straightforward data acquisition of observation in hydrographic surveying and at the same time achieve better accuracy in their observations [10]. For a bathymetric chart to be produced, tidal observation and reduction must be done in order to reduce sounding depth to chart datum [11].

Monitoring navigation channels for shipping, traffic safety, and mapping underwater sand bars, rocks, shoals, reefs, and other hazardous marine features relies on accurate and up-to-date seafloor topography (Bathymetry) information [12,13]. Bathymetry changes rapidly in response to storm surges, sea level rise, changes in river condition, and engineering activities such as dredging [14]. Bathymetry information is also important in navigation safety, water volume computation, pollution control, mineral and fish industries, underwater engineering construction, harbor and docks construction and maintenance [15]. Improvement are continually made to the types of data and analysis method used for estimating bathymetry across the global ocean as stated by Olusegun et al. [14].

The repeated emergence and submergence of coast have been instrumental in shaping the morphological expression of the continental shelves in general and shorelines in particular [16]. The coast is going on emerging by tectonic movement as proved by Thanikachalam and Ramachandran [17]. As dredging occurs a lot in the creek and river, the equilibrium depth of such creeks and rivers will be less than the optimum depth required for navigation as stated by Van Bentum [18]. This is very crucial for the mariners and the shippers that need up-to-date information about the creeks and rivers before embarking on any activities so as to avoid presence of wrecks and other dangerous marine features.

Physical loss and damage to the seabed has widespread effects on biodiversity, ecosystems, food web dynamics and marine habitats [19]. Thus, understanding seafloor morphology and its evolution is critical to scientific investigations of boundary layer processes. Hydrographic survey supports a variety of marine functions: port and harbour maintenance (dredging), coastal engineering (subsidence assessments and restoration projects), coastal management and offshore resources development [20].

Accurate estimation of dredged volume is a very important aspect of dredging. This is because volume computation is the only way to monitor the dredging process, thereby comparing the amount of materials planned to be dredged and the amount that was actually dredged [21].

The accuracy of a resultant volume is dependent on many random variables, such as the horizontal positioning accuracy, elevation (or depth) measurement accuracy, data density or personified footprint size relative to the overall area, terrain uniformity, and the volume computational method employed [22]. Therefore, this study investigates topography changes in the sea bed between two adjoining rivers (part of Badagry Creek and Yewa River) using two epoch data of 2008 and 2015 bathymetric dataset, so as to reveal the spatial/morphological changes that has occurred between the periods of the study.

2. THE STUDY AREA

The study location is a section of Badagry Creek and Yewa River (Fig. 1). Badagry creeks is located in Badagry, Lagos State, Nigeria. It lies within geographic longitude 2°42′00" E and 3°42′ 00" E and geographic latitude 6°22′00" N and 6° 42′00" N. It covers approximately a total distance of 177 km [23] while part of the creek study covers a total distance of 43.88 km in length and 1.14 km in segment. River Queme and Nakoue lagoon are the major sources of water into the Creek. Combination of these two water bodies form the Badagry creek which joins part of the continuous lagoon known as Osa lagoon that stretches from Porto-Novo to Lagos and finally opens into the Atlantic Ocean via Lagos harbour in three channels [24]. Yewa River is an

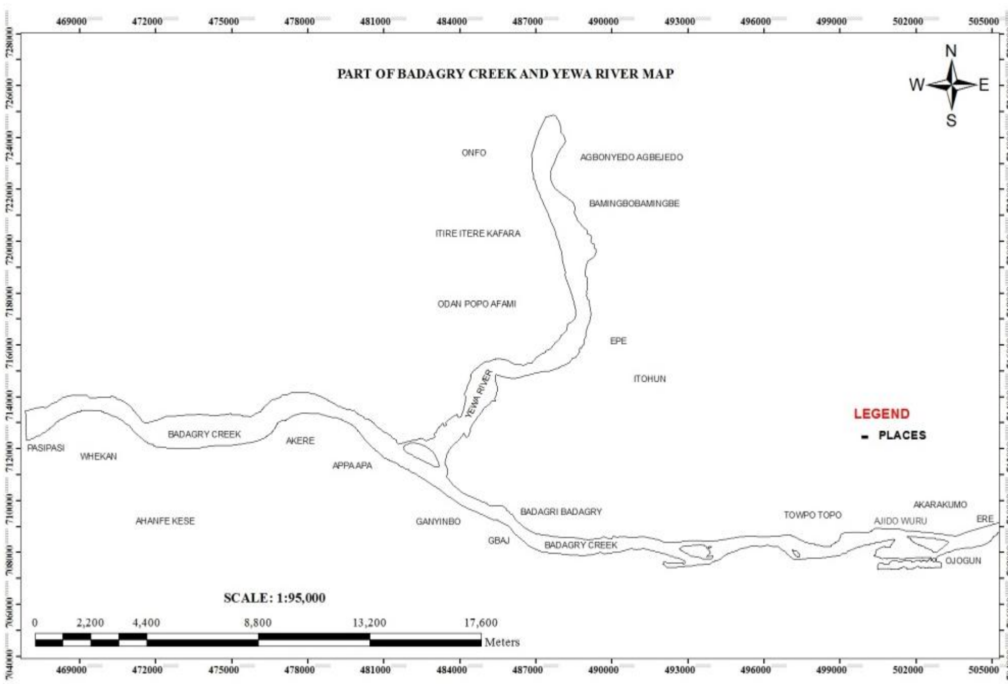


FIG. I. MAP OF THE STUDY AREA

Fig. 1. Map of the Study

adjoining stream flowing into Badagry Creek in Lagos, Nigeria. It is located at an altitude of 36 meters above sea level with a population of about 174,52. Yewa River is a trans-boundary river crossing Benin Republic and Nigeria and it lies approximately within geographic longitude 2° 42′00" E and 3°00′00" E of the Greenwich meridian and geographic latitude 6°15′00" N and 6°45′00" N of the equator. It covers a total distance of 16.90 km in length and 0.09 km in segment.

3. MATERIALS AND METHODS

3.1 Bathymetric Instruments Used for the Study

The equipment used for this bathymetric operation is as follows:

i. SDE28 Digital Echo Sounder and its accessories
ii. Transducer (Component of Echo Sounder)
iii. Garmin 78s (Handheld) GPS
iv. Service Boat with 4hp engine
v. Life Jacket

3.2 Methods of Data Acquisition

The collection of data for this study cuts across various methods of surveying. In line with the aim and objectives of the study, the following methods were employed to acquire all the necessary data needed.

a) Sounding.
b) Wreck determination across the Creek and River.
c) Use of tidal prediction Table for depth correction.

3.2.1 Sounding operation (Depth sounding)

The data acquisition was done by setting up the Echo sounder on the vessel connected to the transducer and setting data storage interval at 30 Secs and the observations carried out in strips. The vessel speed was kept constant while vessel heading was also maintained throughout each observation strip and the instrument automatically stores the XYZ values of every point.

3.2.2 Setting data acquisition timing

Sounding interval of 100 m was used; the vessel speed was kept constant at 2.2 m /secs (8 Km/hr) during the data capture. The Echo Sounder was then set to capture data every 31 secs. As such the data grid of 100m interval was ensured.

3.2.3 Setting the parameters in the echo map

The echo Map parameters were set as follows:

Coordinate System: WGS 1984 UTM Zone 31N

Units - Meters
Projection - Traverse Mercator
Ellipsoid - Clarke 1880 (Minna)

3.2.4 Sounding preview

In order not to miss any point during sounding, having left the site only to discover that one or two or several other points were not sounded, check was done on the raw data files in the main window of the echo sounder so as to see if there are any such point(s) or other problems. All this was ascertain before leaving the site.

3.2.5 Detailing / wrecks positioning

Surface wrecks within the creek and Yewa River were mapped using a hand-held GPS. As such the positions of all surface wreckages were determined (see Fig. 3). Three fishing boat were found each along the Creek and River (see Fig. 3) which was not found in 2008 bathymetric survey. During the sounding, no underground wrecks were found. The coordinates (x, y, z) of wreck position were determined with handheld GPS (Table 1). The four (4) coordinates observed each for the submerged wrecks denotes the two bottoms and the two edge of the boat.

3.3 Extracting Depth Information for Corresponding Points in Data 2008

The “griddata” command statement in MATLAB was used for extracting depth of corresponding points as taken during the 2015 bathymetry survey from the 2008 bathymetry data (see Table 3). Using the 2008 data as a base data frame, the “griddata” command interpolates for the value at same corresponding points as taken in the 2015 observation using the nearest neighbor search algorithm.

3.4 Water Channel Erosion/Accretion Rate Assessment

Understanding the mechanisms and rates of bank erosion, accretion and lateral channel migration has fundamental significance, as well as results of this researches which are applicable in the field of water and soil resources management, hydro-technical works, and in different aspects of the environmental protection [25,26]. Riverbank erosion has important implications for short and long term channel adjustment, development of meanders, sediment dynamics of the river catchment, riparian land loss and downstream sedimentation problems [27]. Detecting the rate of spatial change in sea bed topography at the part of Badagry creek and Yewa River was done after depths at corresponding points have been determined. The methodology involved in the change detection approach is as shown in Fig. 2. The rate of seabed change for Bathymetry data 2008 and 2015 were plotted using ArcGIS and Microsoft excel software. The resulting graphs showed variation in depth for both years. Algebraic addition of the stream path graph of both years thus resulted in the residual graph for the study area.

Table 1. Coordinates x, y, z opf wreck position along the creek and the river

Coordinates of wrecks along Yewa River		
Wreck	Easting	Northing
1st Wreck	488474.62	719747.59
	488188.93	719747.59
	487952.37	719747.59
	488011.51	719925.01
	488602.90	715489.60
2nd Wreck	488307.21	715489.60
	488070.65	715489.60
	488129.79	715667.02
	483812.66	712710.08
3rd Wreck	483516.96	712710.08
	483280.41	712710.08
	483339.55	712946.63
Coordinates of wrecks along Badagry Creek		
	500134.96	708392.95
1st Wreck	499839.27	708392.95
	499602.71	708452.95
	499661.85	708629.50
	504333.82	708511.22
2nd Wreck	503978.98	708511.22
	503801.57	708511.22
	503860.71	708688.64
	505161.76	708747.78
3rd Wreck	504866.07	708747.78
	504629.51	708747.78
	504688. 65	708925.20

3.5 Data Processing

The data which was saved in the memory card in coordinate format (Easting, Northing and Depth) in the data storage of the Echo Sounder and was save in Microsoft excel for editing. Sample of the results are as presented in Table 1. The observed sounding readings were then reduced to the sounding datum (sounding values) by applying formula below;

$$\text{Value} = S.R - (Sounding\ Value_{Sounding\ Datum} - Predicted\ tidal\ reading_{tide\ table}) \quad (1)$$

Where;

S.R = Observed Sounding Reading

Thereafter, the sounding values are reduced to actual depth (chart datum) using the general formulae below;

$$\text{Chart Datum (Mean Water Level)} = Reduced\ Level_{sounding\ Datum} + Sounding\ Value \quad (2)$$

$$\text{Depth n} = Depth_n = Mean\ Water\ Level - Sounding\ Value \quad (3)$$

Where;

n = All other subsequent observations apart from the first reading.

In the determination of mass volume for this study, the data was first stored in grid raster format in an arrays structure in square cells. Since the depth difference has been determined between the two epoch dataset 2008 and 2015 (Table 2), then the volumes for dredged mass (area cut) and volume of mass accretion (area fill) on the topography are determined. It was calculated from the Table of content of the raster map dataset in ArcGIS 10.2.1 by selecting open the attribute Table from the raster and select the attribute Table and choose volume >0 for dredged volume which is positive and volume <0 for accreted volume which is negative (see Fig. 8a and b).

From the attribute table, the volume row was right click (yellow colour as a query for the volume determination (Fig. 8a and b), then select the statistic of the raster cut fill to show the volume of accreted portion and was calculated as 10.55 x 10^6 m^3 (negative) which showed area that have been filled (material added/area fill) and that of dredged materials was calculated as 7.24 x 10^6 m^3 (positive) which also showed area that been cut (material removed/area cut).

In order to show the areas where spatial changes occurred, then this is done using the Arc Toolbox menu by selecting from the 3D Analyst, the raster surface and select the before raster (i.e. 2008 raster) and after raster (i.e. 2015 raster). Then the clip volumes from the raster image showed the net gain/dredged portion, unchanged portion and accretion area created.

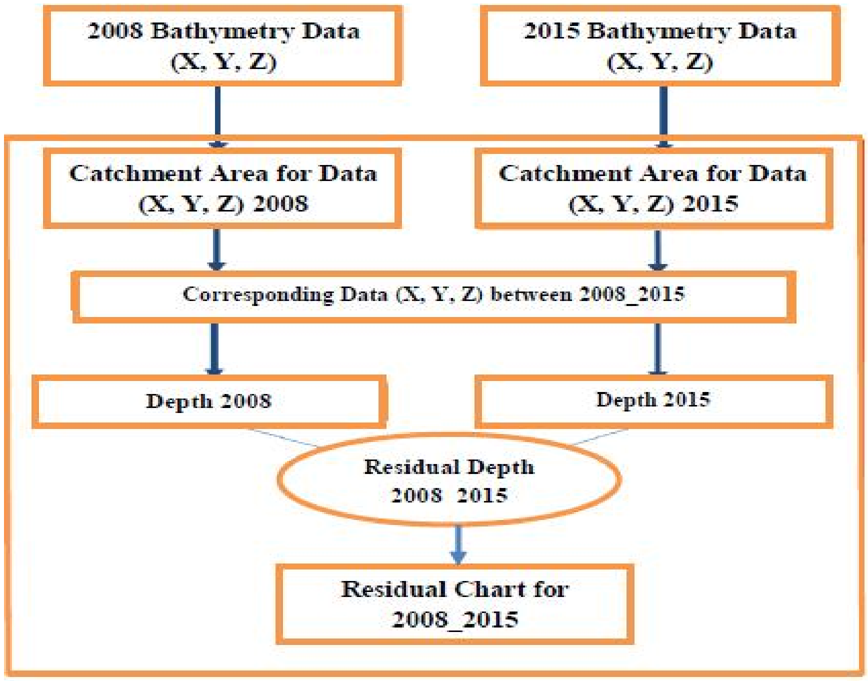
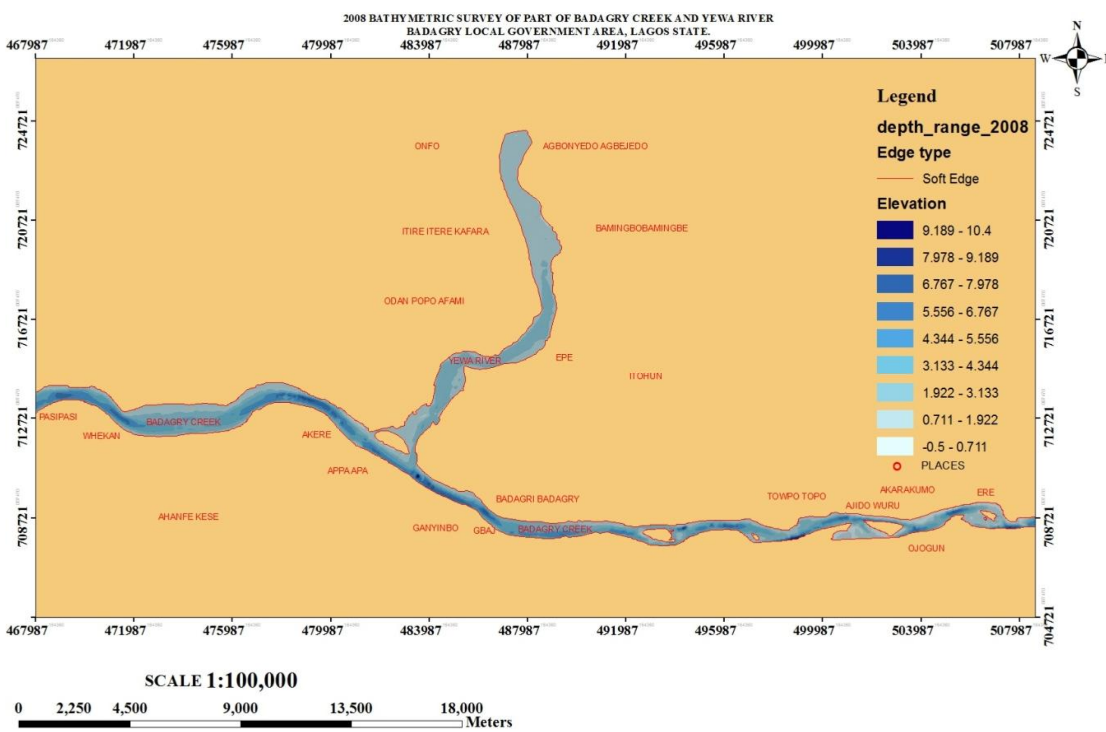


Fig. 2. Workflow diagram for assessment of river bed topographical changes



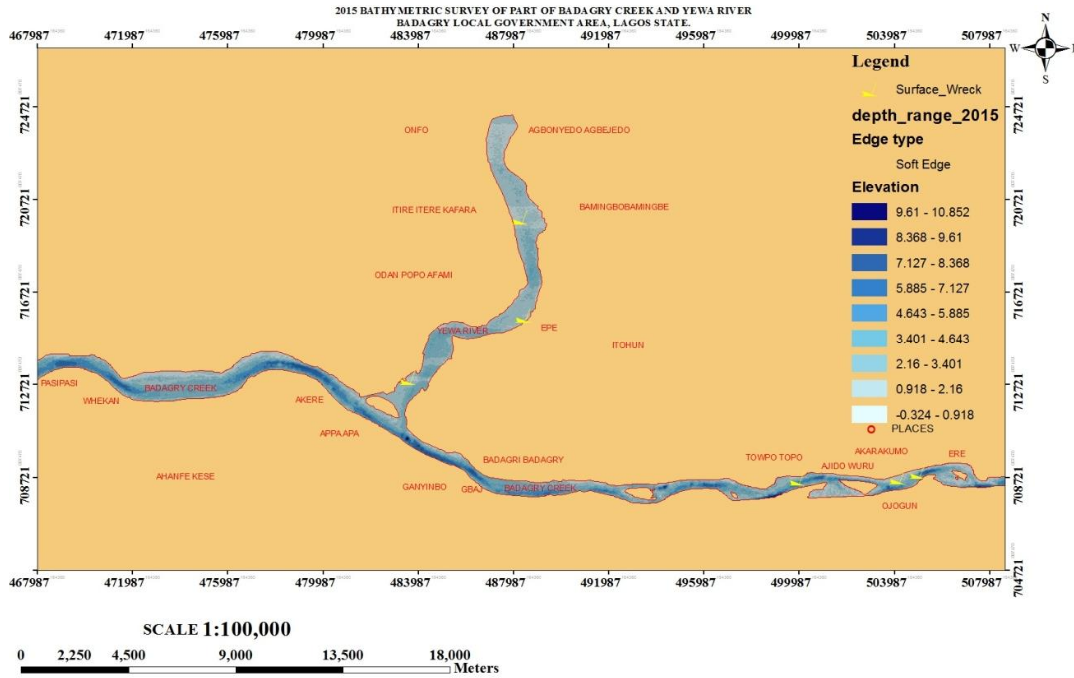


Fig. 3. Spot values of part of Badagry Creek and Yewa River sea-floor obtained for 2008 and 2015 dataset

4. RESULTS AND DISCUSSION

The results of the analyses of 2008 and 2015 are presented in this section. Fig. 3 is a processed bathymetric dataset for 2008 and 2015 survey as observed with the echo sounder plotted with ArcGIS 10.2.1 software. In 2008, the depth observed ranges from -0.5 to 10.4 m with area of low depth ranges from -0.5 to 0.71 m and area of high depth of 9.19 to 10.4 m while in 2015, the depth observed ranges from -0.32 to 10.85m with area of low depth of -0.32 to 0.92 m and area of high depth of 9.61 to 10.85m (see profile graph in Fig. 4). Fig. 4 showed the profile graph of depth variation along the seabed. Fig. 5 showed depth variation between 2008 and 2015 and their depth residuals overtime. Fig. 6 described the spatial changes that occurred between 2008 and 2015. To detect depth change over time on the creek and river topography. A graphical plot of change in sea bed topography has also been shown in Fig. 7. Fig. 8a is the volume of sediment deposited with its query while Fig. 8b is the volume dredged volume with their query. Table 2 show the processed bathymetric data for dataset 2008 and 2015. Table 3 shows depth residual data from 2008 and 2015 survey.

From the Table 2, negative depth difference denotes sounded depth increase which implies that mining/dredging (material added/area filled) operation has occurred in those areas whereas; positive depth difference denotes presence of sediments (material removed/area cut).

Fig. 4 showed that from the profile graph (a & b), at 20,000 m (20 km) in 2008, the depth was 2.0 m while in 2015, the depth was 2.5 m which implies that dredging has taken place after 2008 observation leading to increase in depth in 2015. At 40,000 m (40 km) in 2008, the depth was 2.15 m while in 2015, the depth was 1.90m which denotes sediment deposit in 2008. From profile graph (c & d), it showed that at 2500 m (2.5 km) in 2008, the depth was 2.4 m while in 2015, the depth was 2.2.8 m which means that dredging has taken place after the 2008 observation. At 15500m (15.5 km), the depth was 1.40m while in 2015, the depth was 1.26m which denotes sediment deposit in the area (area fill). Profile graph (e & f) showed that at 4000 m (4 km) in 2008, the depth was 1.01 m while in 2015, the depth was 4.90m which indicates that dredging has taking place after 2008 observation. At 15000 m (15 km) in 2008, the depth was 3.80 m while in 2015 the depth was 2.90 m which indicates sediment deposit has taken place after the 2008 observation.

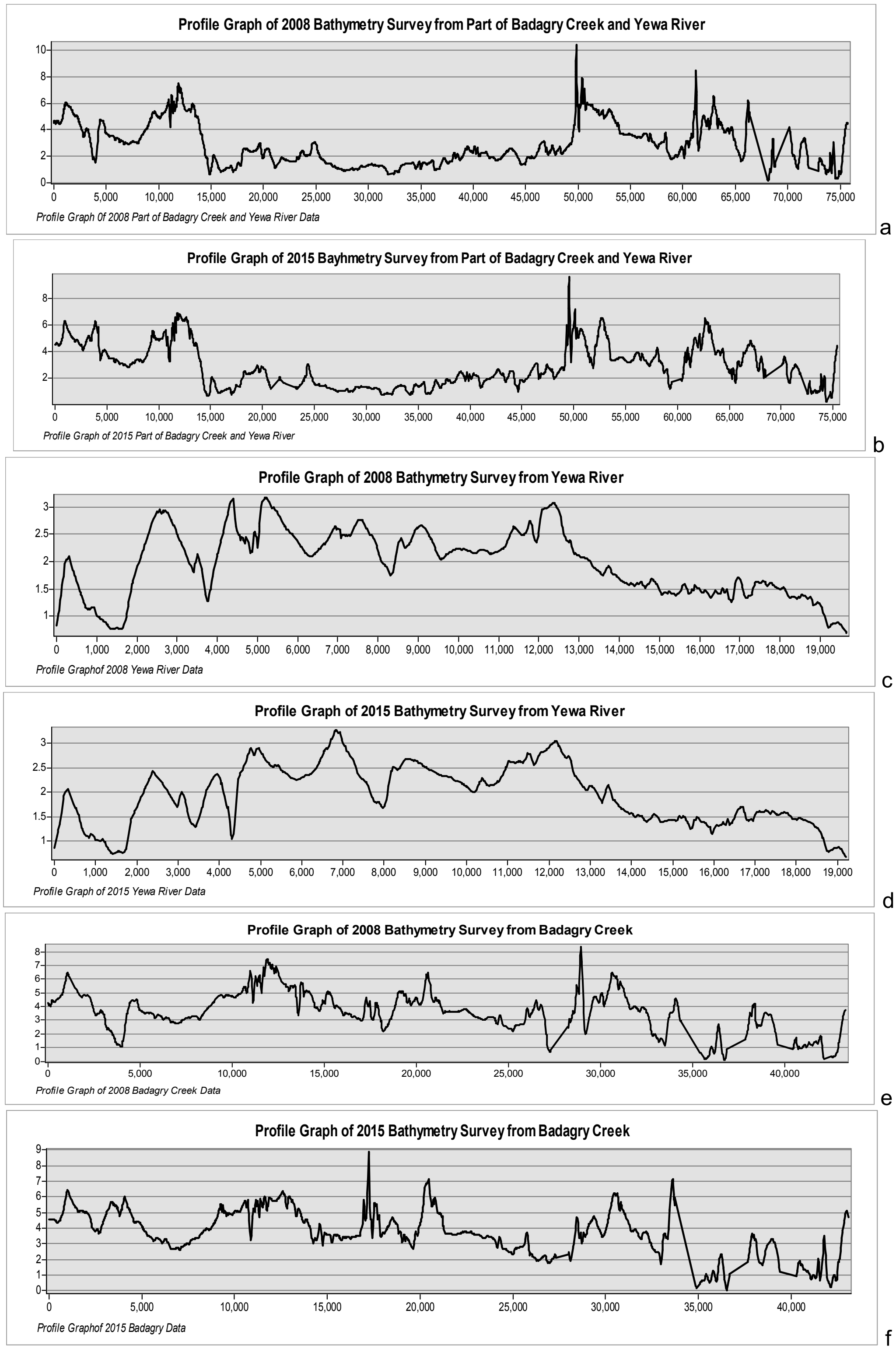


Fig. 4. Sea-bed profile graph from 2008 and 2015 Bathymetry data from Badagry Creek and Yewa River

Table 2. Sample of the processed dataset for 2008 and 2015

2008 bathymetric data for Badagry Creek			2015 bathymetric data for Badagry Creek			Depth Diff. (2008/15)
Easting	Northing	Depth	Easting	Northing	Depth	
483252.77	711334.73	2.01	501410.26	708870.86	0.02	1.99
483302.43	711340.52	2.27	501515.37	501515.37	0.08	2.19
483352.09	711346.31	2.46	501565.04	708838.57	-0.32	2.78
483401.76	711352.10	2.61	503962.92	708564.41	0.01	2.60
483197.31	711378.60	1.63	503957.13	708614.07	0.71	0.92
483246.98	711384.39	1.91	501769.48	708812.06	-0.08	1.99
483296.64	711390.18	2.17	501819.14	708817.85	0.32	1.86
483346.30	711395.97	2.35	501868.81	708823.65	0.35	2.00
483395.97	711401.76	2.51	501076.64	708278.24	0.30	2.21
483191.52	711428.26	1.53	501719.82	708806.27	0.19	1.34
483241.19	711434.05	1.81	504231.95	708847.47	0.41	1.40
483290.85	711439.85	2.07	504281.61	708853.26	0.86	1.21
483340.51	711445.64	2.26	504331.28	708859.05	0.60	1.66
483390.18	711451.43	2.44	504380.94	708864.84	0.81	1.63
483185.73	711477.93	1.43	501360.59	708865.07	0.85	0.58
483235.40	711483.72	1.71	504424.81	708920.29	0.70	1.01
483285.06	711489.51	1.97	504474.48	708926.08	0.85	1.13
483334.72	711495.30	2.16	504524.14	708931.87	0.87	1.29
483384.39	711501.09	2.34	504573.80	708937.66	0.01	2.33
483130.28	711521.80	1.15	504623.47	708943.45	0.52	0.63
483179.94	711527.59	1.35	504717.00	709004.70	0.68	0.67
483229.61	711533.38	1.61	504766.67	709010.49	0.16	1.45
483279.27	711539.17	1.87	504816.33	709016.28	0.77	1.12
483328.93	711544.96	2.06	504865.99	709022.07	0.02	2.04
483378.60	711550.75	2.24	504915.66	709027.86	0.66	1.58

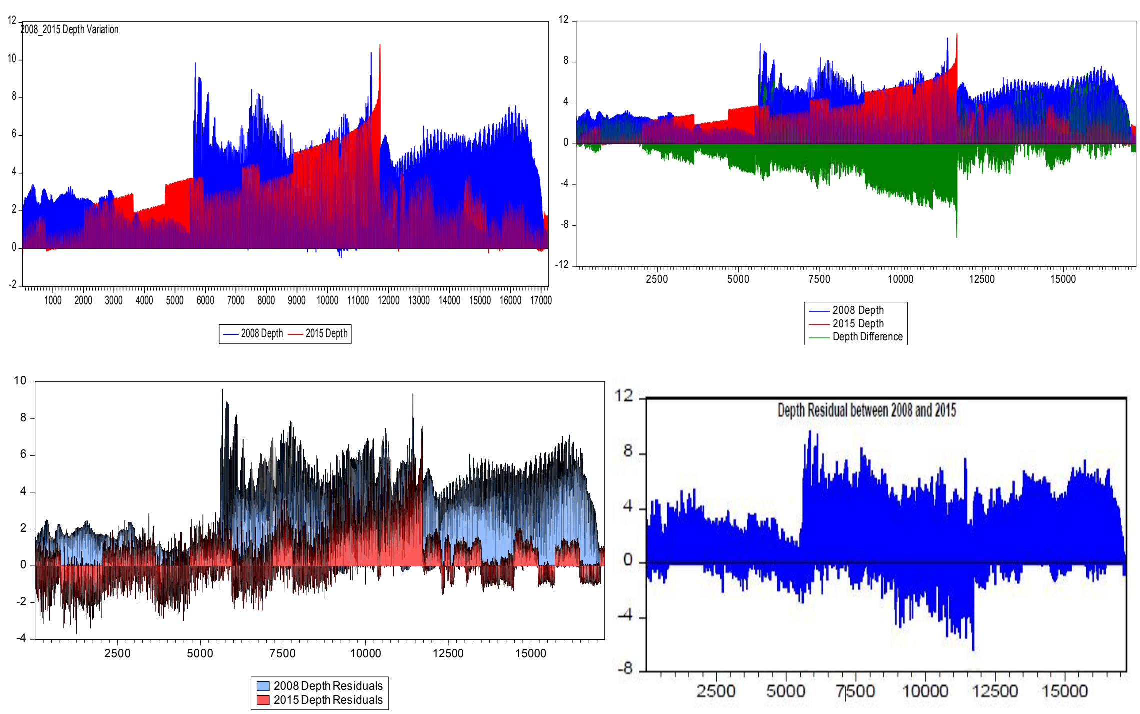


Fig. 5. Variation in 2008 and 2015 depth, depth difference and their depth residuals

Table 3. Residual values between 2008 and 2015 depth across Badagry Creek and Yewa River

Easting(m)	Northing(m)	Depth 2008	Depth 2015	Res.(2008/15)	Easting(m)	Northing(m)	Depth 2008	Depth 2015	Res (2008/15)
483892.7	710265	-2.61	-3.36	0.75	487968.6	716135.1	-2.11	-1.95	-0.16
483477.7	710543.9	-2.61	-3.36	0.75	488334.6	716475.9	-2.54	-1.864	-0.68
483062.8	710822.8	-2.01	-2.85	0.84	488700.5	716816.6	-2.51	-2.096	-0.41
482647.8	711101.7	-1.63	-1.94	0.31	488879.3	716983	-2.65	-1.811	-0.84
482232.8	711380.7	-0.93	-1.13	0.2	488810	717086.9	-2.77	-3.658	0.89
481817.9	711659.6	-1.61	-1.68	0.07	488675.7	717568.5	-3.03	-3.48	0.45
481402.9	711938.5	-0.77	-1.52	0.75	488545.4	718051.2	-1.78	-2.097	0.32
480987.9	712217.5	-0.77	-1.52	0.75	488410.6	718532.7	-1.40	-2.07	0.67
480573	712496.4	-0.77	-1.52	0.75	488275.8	719014.2	-1.45	-2.436	0.99
482992.4	711996.4	-0.75	-1.17	0.42	488141	719495.7	-1.16	-0.697	-0.46
483296.8	712393.1	-1.26	-1.35	0.09	488006.2	719977.2	-1.01	-0.727	-0.28
483601.2	712789.7	-0.73	-0.79	0.06	487871.4	720458.7	-0.98	-1.289	0.31
483905.6	713186.4	-1.34	-1.65	0.31	487736.6	720940.1	-1.13	-1.669	0.54
484210	713583	-1.78	-1.114	-0.67	487601.8	721421.6	-1.20	-2.147	0.95
484514.4	713979.7	-2.32	-3.065	0.75	487390.2	722177.3	-1.47	-2.267	0.80
484818.8	714376.3	-2.34	-2.982	0.64	487182.5	722696.8	-1.56	-1.5	-0.06
485123.2	714773	-2.59	-3.179	0.59	487332.1	723173.8	-1.42	-0.70	-0.72
485277.9	714974.5	-3.22	-3.426	0.21	487481.8	723650.9	-1.30	-0.59	-0.71
486870.8	715113	-2.61	-2.852	0.24	487631.5	724128	-0.86	-1.49	0.63
487236.8	715453.7	-2.57	-1.616	-0.95	487736.5	724462.9	-0.68	-1.28	0.60
487602.7	715794.4	-1.9	-1.837	-0.06					

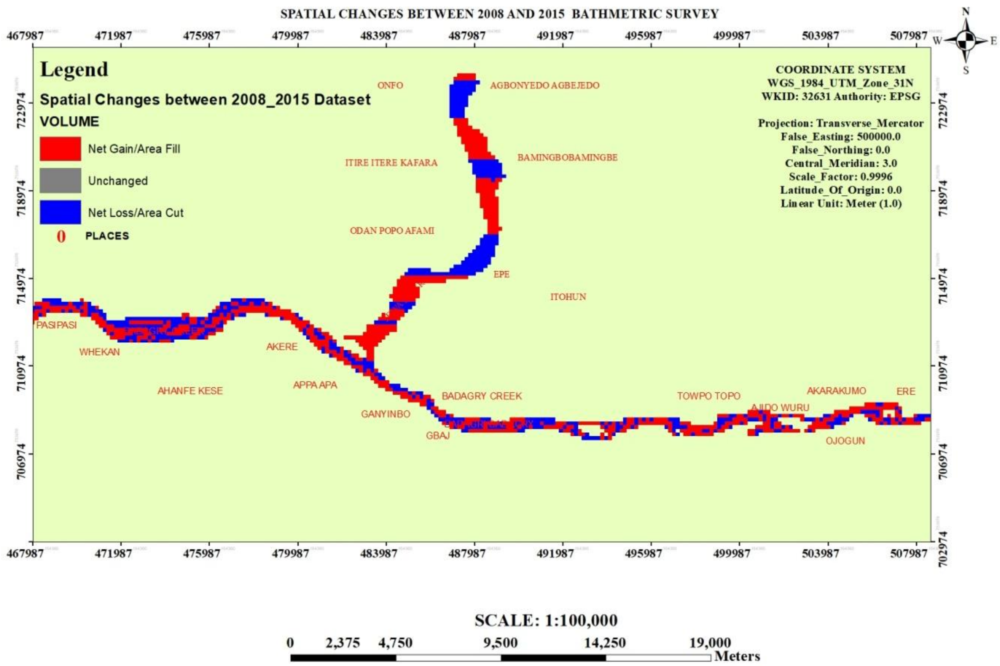


Fig. 6. Spatial changes between 2008 and 2015

It showed from Table 3 that equal depth exists in forty-one (41) points between Badagry Creek and Yewa River.

4.1 Mass Volumes Determination

Volume can be determined from a triangular irregular network (TIN) model using spatially referenced depth-point measurements obtained from hydroacoustic surveys [28,29]. Spatially referenced hydroacoustic instruments have become common means to collect depth data for waterbody volume estimates [30,31,29].

The total volume computed from this study for the accretion and as well as dredged material was 17.79 x 10^6 m^3. From the volumes computed from the image raster, it showed that sediment of the deposited volume is higher than the mass of the material dredged from the creek and the River.

4.1.1 Volumes conversion to metric ton

Volumes were respectively converted into metric tons after the volume of accreted area was determined as 10.55 x 10^6 m^3 and that of dredged materials as 7.24 x 10^6 m^3 (Fig. 8a and b). The volume determined are now converted to weight and computed as thus;

Density of the wet sand (D) = Sediment Mass/ Volume of accreted material.

Given the density for wet sand as 1922 kg/cu.m
For the accretion Sediment Mass in (Kg) = density of wet sand × Volume accreted.

Therefore, Net Gain/Sediment Mass (kg) = 1922 kg/cu.m × 10.55 x 10^6 cu.m = 20.27 x 10^9 kg.

For the dredged materials.

Given the density for wet sand is 1922 kg/cu.m, then.

Density of wet sand = sediment Mass/Volume of dredged material.

Therefore, dredged mass (kg) = Density of wet sand × Volume dredged**=** 7.24 x 10^6 m^3 × 1922 kg/cu.m = 13.92 x 10^9 kg

The number of tons was also determined for both sediment material and Dredged material. Since 1 metric ton is 1000kg.

Mass (tons) for both dredged material and sediment materials are computed as;

Sediment Mass (Metric tons) = (1922kg × 7.24 x 10^6) / 1000 = 13.92 x 10^6 Metric tons

For Dredged mass (kg), since 1 metric ton is 1000 kg.

Then for the dredged mass (Metric Ton) = Dredged mass (kg)/1000kg = (139.18 x 10^9 /1000) kg = 139.18 x 10^6 metric tons.

From Fig. 6, areas in red colour are net gain/sediment portion (area filled) while deep blue colour shows net loss (area cut) and grey colour showed area where no changes exists which is similar to the study by Akwaowo and Imo [32].

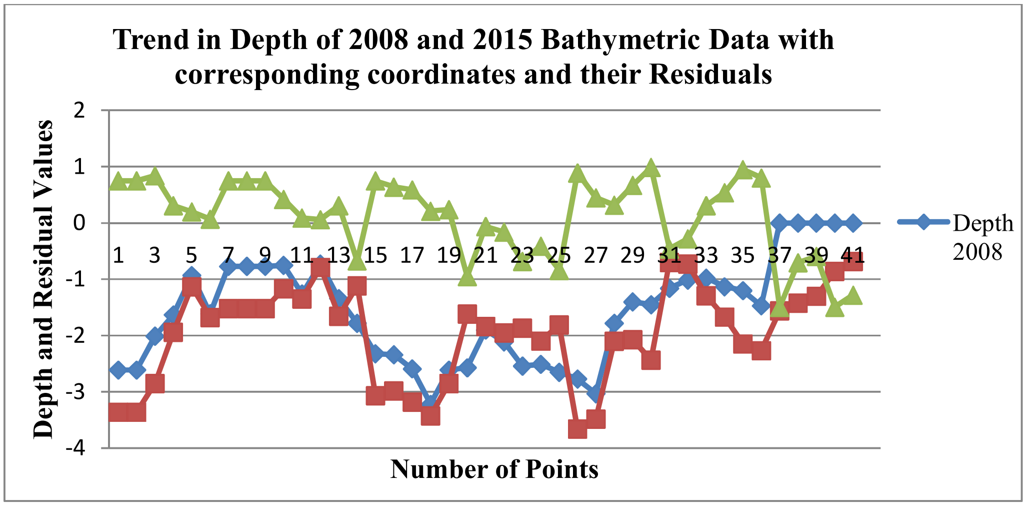


Fig. 7. Profile lines along which sea-bed topographical analysis was carried out

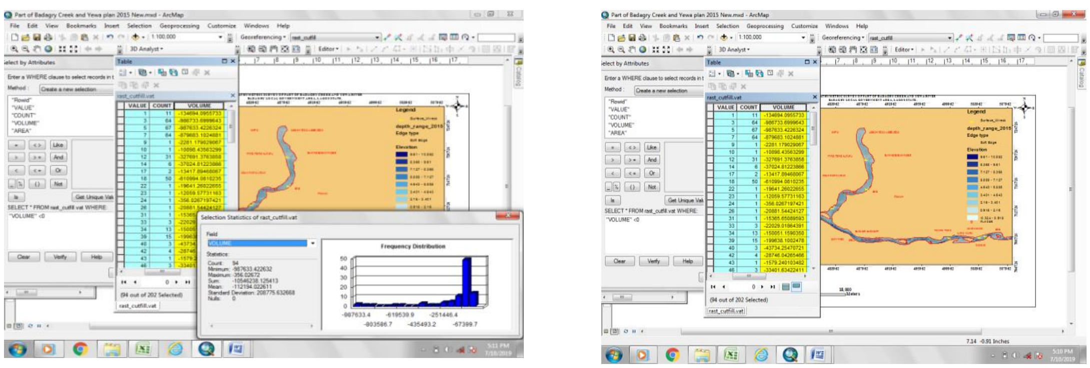


Fig. 8a. Volume of deposited sediments with statistical window and its query

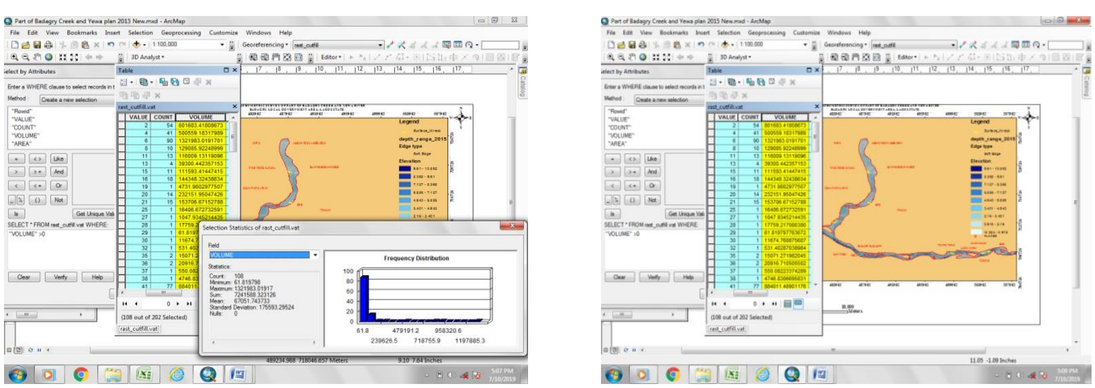


Fig. 8b. Volume of dredged material with the statistical window and its query

4.2 Discussion of Results

From Fig. 3, the deepest points within the Badagry creek and Yewa River occur in the southern area (base) of the water body contrary to expectations of a deeper inner seaward region. This pattern is suspected to have taking place as a result of dredging activities going on around the southern shoreline of the Badagry creek and the river. This is further proved by the seabed variation pattern drawn in Figs. 4, 5 and 7. The inadequate nature of the profile graph shows an uneven sea bed topography which likely could have resulted from erosion and aggravated by dredging activities (see Figs. 4, 5 and 7) since the study area have continue witnessing rapid changes in terms of development and infrastructural developments which led to deposition and erosion in the creek and river and resulted in downstream delivery of sediments [33]. From Fig. 6, it showed that spatial changes exist in both the Creek and the River. The results also showed that area fill is greater than the area cut in Yewa River while in Badagry Creek, it showed almost equal area fill and area cut.

Fig. 7, profile line shows the significant amount of erosion and soil loss in the sea bed. This shows the deeper values of depth in the 2015 bathymetry data as compared to the 2008 bathymetry data (Table 3) and therefore negative residuals. However, traces of sedimentation are also noticed in some areas of the creek and the river (Tables 3). Significant decrease in sedimentation from the headwater areas in the study area resulted in degradation of the creek and river channel while equivalent increase in sediments led to general aggradations. The mixed dynamics (erosion and accretion) observed in the creek and the river is not unexpected as the pattern of sea-bed topography variation complies with the natural behaviour of water bodies in their lower course. As the water travels from the high sea towards the Badagry creek and the river, it reaches a low lying plain (as evidenced by the bathymetry results in figure 4 in its final course and begins to a winding course (meander). Meanders are systems that are constantly changing, following a sinusoidal pattern, and playing an important role in the modelling and shaping of the landscape around them. These beautiful patterns have been the object of study of many researchers in diverse areas in the last 50 years [34–38]. Two main processes in meander migration are bank erosion and bank accretion [34,35,39]. On one hand, bank erosion is unpredictable, fast, and has very well-known negative effects on the environment and society [34]. On the other hand, bank accretion is a slow process and is commonly related with vegetation and sediments deposited at the bank-toe [34].

This meandering therefore has led to the erosion noticed around the curved surface i.e., the concave bank and as a result deposition at the convex bank of the meander. This thus requires that the officials of Nigerian Inland waterways Authority (NIWA) in conjunction with the Navy make conscious efforts to properly monitor the activities within the Badagry creek before this presently on-going concurrent erosion and deposition degenerates into the formation of an oxbow lake in the area. It can be deduced from this study that 3.30 x 10^6 m^3 of sand are dredged (Area cut) from the Creek and the River between 2008 and 2015 which is similar to result obtained by Badejo and Fidelis [40]. From the mass volume estimated; it showed that more than average of the above metric tons of sand has been dredged or deposited to some part of Creek and the River; and this showed that some portion of the accreted area have been dredged and there is no means of determining the quantity in mass sediments that has been dredged and later on leading to accretion. However, the source of this sediment deposits along the Creek and River topography requires investigation on the entire part of the land adjoining or near the seabed, and this estimated accretion volume is in confirmation with the study conducted by Abiose [41]. From the results of the study, mass sediment in the study area may likely caused by waste disposal into the Creek and the river by the resident in the neighboring communities, submerged wreckages such as shipping boats as determined in the course of the study, tidal current and erosion moving upstream and downstream into the Creek and the adjoining river Yewa, jetty construction along the waterways etc.

5. CONCLUSIONS

This study has investigated the topography changes of part of Badagry Creek and Yewa River and the cause of such changes. Geographic Information System (GIS) has proved to be the best tool available in monitoring any spatial-related changes on any part of the world. Moreover, spatial changes were detected to have taken place in the study area within the two epoch time of 2008 and 2015. The result from the findings of this study showed that gradual changes occurred between 2008 and 2015 bathymetric observation which was in two forms; that is the areas of sediment deposits/accreted portion/area fill and areas of material dredged/ area cut. The volume of accretion as well as the dredged volume of sand within the area was computed, and they are respectively 10.55 x 10^6 m^3 and 7.24 x 10^6 m^3 similar to the result of [33,40]. The result from the findings also showed that mass sediment (20.27 x 10^9 kg) is greater than mass dredged (13.92 x 10^9 kg) similar to the result of [30,37]. Moreover, it showed that in Yewa River, area fill is more than the area cut and in part of Badagry Creek; almost equal portion has been cut and fill (Fig. 7). Further study is required on the other part of Badagry Creek in order to determine the source of mass deposit into the Creek. The need for a wholesome embrace of an integrated Coastal Management, where the activities of the dredgers are to be monitored especially along Badagry creek. So also, the needs to carry out research into the source of accreted mass through integrated coastal management plan along the creek and the river. Lastly, wreck along the navigation route should be removed for easy navigation on water.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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