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Seasonal shoreline behaviours along the arcuate Niger Delta coast: Complex interaction between fluvial and marine processes

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ABSTRACT

Deltaic coasts are dynamic geomorphic systems where continuous changes occur on diverse spatial and temporal scales, and these changes constitute an important aspect of their evolution. Based on three-year satellite-derived shoreline data coupled with re-analyzed wave data and hydro-meteorological data, a comprehensive analysis of the dominant processes governing the seasonal shoreline changes along the oil-rich arcuate section of the Niger Delta, in the Nigerian Shelf of the North Atlantic Ocean has been undertaken. Shoreline analysis results show that the delta coast is characterized by predominant summer erosion and maximum winter accretion. Between 2010 and 2012, erosion dominated over accretion and a total of 9.1 km^2 deltaic land was lost to coastline erosion at an annual average erosion rate of 4.55 ± 1.21 km^2/yr. A greater understanding of the dominant factors responsible for the change is presented. Shoreline change interactions with cross-shore sediment exchange processes are prominent at seasonal timescale (Summer $R^2 = -0.85$ and Winter $R^2 = 0.7$), and interannual timescale ($R^2 = -0.93$) with longshore sediment transport processes. Correlation analysis reveals a gradual degeneration of relationship between the suspended sediment flux and coastal hydrodynamics beginning from 2010 to 2012 (cross-shore transport, R=0.68, 0.36 and 0.2 for 2010, 2011 and 2012, respectively; longshore transport R=0.63, 0.44 and 0.2 for 2010, 2011 and 2012, respectively). The study concludes that the effect of fluvial sediment reduction to the delta coast due to capital dredging of the Lower Niger River channels between 2009 and 2012, and periodic fluctuations in the nearshore hydrodynamics processes caused the observed annual shoreline erosion that eventually forced the deltaic coastline toward a state of landward migration during the study period.

1. Introduction

Deltaic coasts are complex geomorphic systems where continuous changes occur at diverse spatial and temporal scales. These changes constitute an important aspect of the deltaic coasts evolution. For instance, coastline changes has been reported in some deltaic coasts, e.g. Ebro Delta (Marino, 1992), Nile Delta (Fanos, 1995), Axios Delta (Poulos et al., 1996), Danube Delta (Giosan et al., 1999), Changjiang Delta (Chen and Zong, 1998), Yellow Delta (Li et al., 2004; Liu et al., 2014), etc. Studies have also shown that, in the short term, changing coastlines are related to oscillations in wave energy and associated processes. However, in the long term, coastline changes have been linked to relative fluctuations of sea level and river sediment discharge (Crowell et al., 1993), while on an intermediate time scale, complex and interrelated factors caused by both natural and anthropogenic processes are responsible for coastline changes (Del Río et al., 2013). Recently, Musa et al. (2014) evaluated the vulnerability of the Niger Delta coast to sea level rise using Geographic Information Systems (GIS). They reported that 42.6% of the Niger Delta is highly vulnerable to sea level rise, such areas as characterized by low slopes, low topography, high mean wave heights, and unconfined aquifers. Thus, there is a need for timely and continuous shoreline change information, in terms of retreat and progradation, as it is important for the coastal environment monitoring and protection, sustainable coastal development and coastal resources management, especially in a delta coast like the Niger Delta which is one of the largest, most important and strategic deltas in the world for its abundant natural resources but lack publications on coastal processes (Kuenzer et al., 2014).

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Recent studies have established a strong shoreline change for the Niger Delta coast. Adegoke et al. (2010) investigated the Niger Delta coastline change between 1986 and 2003 using optical and thermal bands of Landsat TM/ETM+ images. 46,535 km was reported as the total area of coastline changes, with erosion (27.65 km^2, 59.43%) exceeding accretion (18.88 km^2, 40.57%). Obowu and Abam (2014) employed optical satellite imagery and SRTM digital elevation model to detect coastline change from 1972 to 2008. They reported that for most of the coastline sections there have been periods of erosion and accretion over the 36 years of their study and very few sections show consistent erosion or accretion over the years. They stated that natural fluvial, marine factors and human activities played a major role in this development. Kuenzer et al. (2014) examined the delta coastline dynamics and reported the erosion and accretion processes. They reported that between 1986 and 2003, annual accretion rates were higher than erosion rates (average annual accretion rate of 2.6 km^2/yr and the average erosion rate of 0.8 km^2/yr). Between 2003 and 2013, annual accretion rates decreased and erosion rates increased in all coastal states, except for Akwa Ibom, with high erosion rates in Bayelsa (the present study area), where net erosion rate of 3.8 km^2/yr was recorded. Dada et al. (2015) investigated the evolutionary trend of Niger Delta shoreline in the last 100 years and found that it is characterized by long-term erosion and short-term accretion. They concluded that rainfall and river discharge played key roles in the evolutionary trends of the Niger Delta shoreline change during the last 100 years.

All these studies highlight the fact that the delta coastline is the dynamic between erosion and accretion processes. However, comparatively, less emphasis has been placed on the character and importance of waves and littoral transport processes on the formation, change, and stability of the Niger Delta coastline. The only

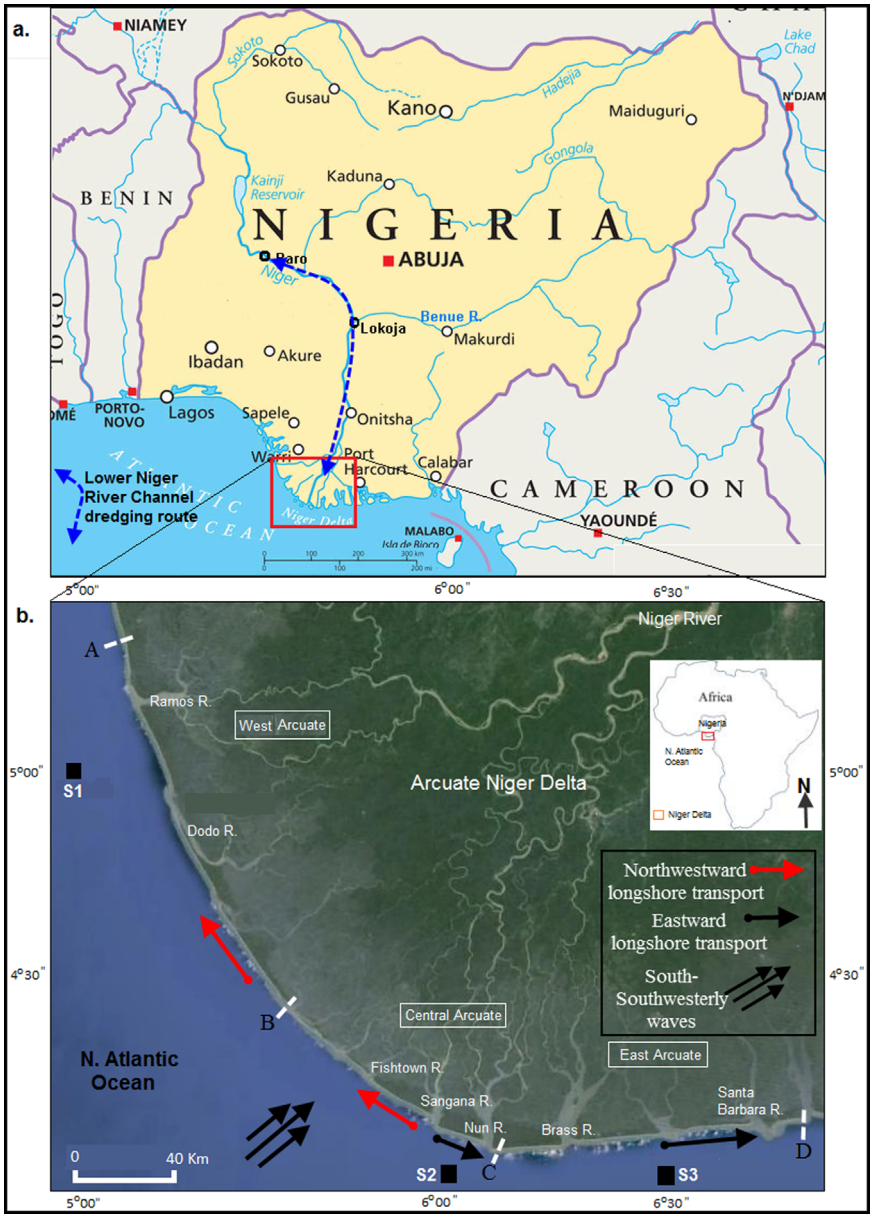

Fig. 1. (a) Map of Nigeria showing lower Niger dredging project route from Baro to Warri from 2009 to 2012 (modified from Africaguide.com) (b) Map of the arcuate Niger Delta showing rivers/tidal inlets. Inset: map of Africa showing Nigeria and Niger Delta (modified from Google Earth). Points A, B, C, D indicate the study area. Point A to B (Sector 1) is the west arcuate delta and is from the west of Ramos River mouth to the west of Pennington River mouth. Point B to C (Sector 2) is the central arcuate delta and is between the east of Pennington River mouth and the west of Nun River mouth. Point C to D (Sector 3) is the central arcuate delta and is from the east of Nun River mouth to the east Santa Barbara River mouth.