Morphodynamics of river and coastal transport of sediments in mega delta basin, Niger Delta Nigeria

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Abstract. Niger delta is recognized as the third mega deltas in the history of mankind. Understanding the sediment dynamics and morphodynamics relationship between the morphology of the bedrocks to the hydrodynamic of its transport sediments is crucial for water bodies’ preservation, conservation, and sustainability. Sediments transportation in Niger delta involves a two-phase flow system in which one phase is considered to be fluid and the other phase is solid. The water bodies is seldom saturated with sediments occasioned by irregular solid waste dumps, erosions debris, and transported at ease without any form of management or control for many years now. Consequently, poor water resources, agriculture and fishery production are at extreme lost as sediment transport and deposition influences great magnitude of useful river dynamics. Therefore, the objective of this study is focused on whether sediment transport has an effect on the morphology of the channel in the Niger Delta basin. It is necessary to determine the relationship between these two key variables; Sediment yield and channel morphology. A correlation matrix was generated in MS Excel to determine the underlying relationship between the variables under study with a coefficient of determination of 11.23% and a positive correlation between suspended sediment yield, bed load and channel morphology of +0.345. The paper will be useful to research institutions, water resources agencies, government and environmental experts and engineers.

1. Introduction
Waterbodies such as rivers and lakes have since time immemorial been a major part of human settlement, due to availability of fresh water for crop cultivation and livestock rearing, and also as a means of transport and for their self-sustenance. These vital resources with time get polluted as population increases and sometimes reengineered in flood-prone areas. Technology and the invention of new machines have made it easier in recent times. It is therefore important to ascertain how these activities impact on sediment flow on morphology. Hickin [1], established the sediment continuity equation in an attempt to find a relationship between sediment flow and morphology. However, relating hydraulic variables in rivers to sediment transport has been quite unsuccessful for geomorphologists due to the variations in the flow of river bodies Ferguson and Ashworth, [2]. According to McLean and Church, [3], the channel morphology displayed is usually a result of sediment transport. It is therefore important to study this phenomenon with respect to the Niger Delta basin which has several waterbodies and has been prone to human activities such as fishing, oil exploitation and production as well as irregular dumpsites for municipal solid waste materials.

Morphodynamics is a term used to establish the relationship between the morphology of bedrocks to the hydrodynamic of transport of sediments. The transportation of sediments involves a two-phase flow system in which one phase is considered to be fluid and the other phase is solid. The fluid field is considered to be the river and the solid phase is the sediment grains. When sediments are moved by
flowing water, the individual grains are usually organized in morphological elements called bed forms. These bed forms vary in shapes and sizes. The most common modes of sediment transport in rivers are those of bed load and suspended load. In bed load, particles roll, slide, or saltate over each other, never rising too far above the bed. In suspended load, fluid turbulence comes into play, carrying the particles well up into the water column. In both cases, the driving force for sediment transport is the action of gravity on the fluid phase.

1.1 Geological and geomorphological settings

The Niger Delta Region is till date one of the most prolific oil-rich deltas in the world. It lies within Latitude 40N to 60N and longitude 50E to 80E records network of creeks, small islands and low lying swampy terrain which contains one of the highest concentrations of biodiversity and abundant flora and fauna, arable terrain that sustain a wide variety of crops of great economic value.

1.2 Hydrology of Niger Delta

To understand the morphodynamics of water bodies such as rivers in the Niger Delta basin requires an understanding of the properties of the water in the basin in relation to its movement to the land. This phenomenon is called hydrology. According to Abam [4-5] the hydrology of the Niger Delta basin has three predominant types of flow. These are; unidirectional, bidirectional tidal flow and mixed flow in the upper Niger Delta, coastal and estuaries, and the transitional zones respectively.

![Figure 1: Ecological areas and boundaries in the Niger Delta](image)

Dry flat country
Dry land with abundant swamp
Freshwater swamps
Mangrove swamps
beaches and bars

Source: From Abam [4]

The hydrography of the region is made up of a period of dry season period (December to April) and a wet season period with initially low levels of rainfall (and low water levels) which reaches a maximum by the month of September. Due to the low elevation of the interior back swamps, flooding usually occurs during this period. Water that is accumulated as a result of the flooding is difficult to discharge by gravity due to the low permeability of the soil and the gradient of the earth. The coastal areas on the other hand experience mixing of fresh water and sea water in varying proportions which migrates up and down the river and its estuary as Abam reported [5].
2. Sediment Transport
To understand how the waterbodies function in morphodynamics also require an understanding of the transport of sediments with respect to the properties of the waterbodies in the Niger Delta basin. Sediment transport according to Mmom & Chukwu-Okea, [6] is the set of processes that occur between the channel boundary and the flowing water. The methods of sediment transport depend on the size of the particle being transported as well as the direction of flow of the waterbody. Large particles will be rolled on the riverbed or the sea floor in what is called traction because they require more energy to be moved. Smaller particles, on the other hand, are lighter and do not require more energy to move and can thus be picked up but not carried in the body of the water for long so they are likely to move up and down in a bouncing motion which is called saltation. Very small particles are rather carried in the water body and are thus suspended in the water body, this is called suspension. Finally, the invisible particles which dissolve in the water are called solution. These can be transported relatively easier by the direction of flow or tidal movement in coastal areas.

The above transport processes can be categorized into the bed-material and wash load. These are all dependent on the size of the particles but rather gives perspective to the origin of the sediments in transport. The bed-material load are the sediments in transport whose sizes can be found mainly in the bed, whereas the part of the sediment in transport which occurs as a result of the erodible bed and the flow of the waterbody is referred to as the wash load. Mmom & Chukwu-Okeah, [7].

2.1 Sediment Transport in Niger Delta
The transport of sediments to the Niger Delta basin according to Mmom & Chukwu Okeah, derive from seven out of the eight hydrological provinces.

![Figure 2 hydrological areas and boundaries in the Niger Delta](source: From Abam [4])

Most of the sediments are formed as a result of erosion and transported by means of solution load, bed load (saltation) and suspended load. Dams along with the flow areas gradually become silted with some of these sediments which are most often entrapped leading to floods in the long-run, if not desilted. It is, therefore, necessary to ascertain whether sediment transport has an effect on the morphology of the channel in the Niger Delta basin.

3. Methods of Estimation and Materials used
Table 1. Review of Morphometric Parameter Calculation Methods

| Parameters                                                      | Reference                  |
|----------------------------------------------------------------|-----------------------------|
| Compactness Coefficient (CC), Form Factor (FF)                  | Suresh, [8]                |
| Fitness Ratio (FR), Wandering Ratio (WR), Hypsometric Curves    | Seth et al., [9]            |
| Circularity Ratio (CR), Elongation Ratio (ER), Stream Density (SD) | Reddy, [10]               |
| Bifurcation Ratio (BR)                                          | Chow et al., [11]          |
| Watershed Eccentricity (WE), Sinuosity Index (SI), Infiltration Number (IN) | Pareta & Pareta, [12] |
| Measurement of bed Load transport                               | Chang et al., [13]         |

The table 1 reveals as tabled various scholars who have proposed methods that could be used to calculate some parameters in respect to morphometric dimensions. However, we concentrated on the formula closely related to our peculiarity. Therefore, samples for the study were taken from the Niger South, the Benue sections of the basin. The channel measures about 725.2 m, which was divided into thirty at an interval of 38.4m this served as the sample points for the study. To determine the sediment load transport the Bedload sampler handheld BLSH was employed for sampling. The formula used was proposed by Chang et al [14].

\[ g_b = \frac{w_i}{(T, X h_p)} X b \]

Where,
- \( g_b \) = transport in kg/s,
- \( w_i \) = weight of bed load sample in kg.
- \( T \) = sampling time in seconds,
- \( h_p \) = width of sampler nozzle in meter
- \( b \) = section width of the stream in meter.

To determine the channel morphology (which in this case is the shape of the channel). The area of the channel was estimated using the cross-sectional area formula by Cuencea [15].

\[ \text{Area} = \text{width} \times \text{depth} \]

4. Result and discussion
The objective of this study is to ascertain whether sediment transport has an effect on the morphology of the channel in the Niger Delta basin. It is thus necessary to determine the relationship between these two key variables; Sediment yield and channel morphology. In order to achieve this, we used a correlation matrix to generate in MS Excel a determination of the underlying relationship between the variables.

|                  | Suspended Sediment Yield | Bed load sediment yield | Channel Morphology |
|------------------|--------------------------|------------------------|--------------------|
| Suspended Sediment Yield | 1.000                  | 1.000                  | 0.345              |
| Bed load sediment yield   | ✗                      | 1.000                  | 0.345              |
| Channel Morphology     | ✗                       | ✗                      | 1.000              |
In the correlation matrix above as shown in table 2, the existence of a linear relationship between suspended load sediment yield and the dependent variable of channel morphology, with a coefficient of determination of 11.23%. This represents the variation in channel morphology as explained by the suspended load in the study area. There is also a positive correlation between suspended sediment yield, bed load and channel morphology of +0.345. However, this correlation is not statistically significant.

5. Conclusion
The result of the study has revealed that there could be other factors besides the transport of sediments from one point to the other that determines the morphology of the basin. Therefore we cannot assume that the transport of sediments alone contributes to the morphological dynamics of the Niger Delta basin.

The study has also proven that sediment transport; bed load yield and suspended load has no effect on the channel morphology of the study area due to the statistical insignificant relationship that exists between the variables.

The study recommends that further studies should be conducted to identify the other factors that contribute to the morphodynamics of the Niger Delta basin.

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