Potentials of Morphometric Parameters in The Assessment of Groundwater and Conservation Strategies in The Niger Delta: Niger South, Ha5

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Abstract

The study on the potentials of morphometric parameters in the assessment of groundwater and conservation strategies in the Niger Delta was successfully done. The ArcGIS 10.1 software was used for calculation, delineation, and morphometric analysis of the catchment from Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM). The morphometric attributes and runoff relationship was explored for the determination of linear, aerial, and relief aspects of the drainage networks. The DEM derived information revealed a drainage density of 0.3 which indicates low stream frequencies and sparse drainage network. Low drainage density is a favourable terrain for infiltration and groundwater recharge. The infiltration number of 2.97 is moderate and shows potential for active infiltration. A drainage texture 3.3 indicates a coarse texture. This attribute has positive correlation with the drainage density in promoting groundwater recharge. The elongation ratio of 0.65 suggests that the basin belongs to the elongated types and implies a longer duration of the overland flow which offers an advantage to groundwater recharge. The length of overland flow 1.7 indicates a less structural disturbance, and less runoff conditions are good factors for water percolation into the soil. The Constant of channel maintenance (C) 3.3 means an average of 3.3km^2 surface area is needed for the creation of one linear km of stream. This implies the soil is porous with a potential land subsidence, erosion, river bank failure and possibility of intrusion of foreign material into the underground water. The relief ratio (Rh) value of 1.29 shows HA5 has a gentle slope. This is a factor to slow runoff, thus, favouring groundwater recharge. The natural and anthropological impacts ranging from saltwater intrusion and effluent-related contamination from oil spillage, gas flaring, municipal, industries and agriculture will aggravate the contemporary water conditions in the basin and more pressure on the available freshwater. Therefore, concerted efforts are required for proper conservation of the ecosystem and pollution load reduction to engender improved freshwater availability in the basin.

INTRODUCTION

Safe drinking water is a necessity for an improved standard of living and is a fundamental goal for sustainable water resources management under water supply sanitation and hygiene (Hutton, 2016 as seen in Odagiri, 2020). Generally, water resources are facing myriads of challenges from quality to quantity (Amir, et al (2020). Groundwater is regarded as a source of high-quality freshwater, used not only for domestic purposes but to also support industrial and agricultural activities. Groundwater accounts for one-third of all freshwater withdrawals, supplying about 36% domestic, 42% agricultural, and 27% industrial water use activities worldwide. The ease of access to meet the required water demand with little substantial infrastructure promotes the widespread development of groundwater use (Carrard, 2022).

Presently, the Catchment is the economic hub of the country due to crude oil exploration. This has attracted petrochemical industries into the area resulting in rural-urban migration thereby responsible to a rise in the urban population in the area. The surge in population has placed a tremendous pressure on the available water resources in the area (George, 2018).

Oil spillage, flooding and gas-flaring have caused significant degradation of groundwater quality in the area (Alfred, Ekpenyong, 2020), thereby instigating federal government of Nigeria to wades in for remediation of the soil, surface, and groundwater resources. Flooding events are recorded every year in the catchment, specifically Delta, Bayelsa and Rivers states, and cause disasters which are attributed to climate change (Ibrahim et al., 2020). Floods are a threat to groundwater quality and quantity. It has, therefore, become necessary to under the catchment geomorphological parameters to order understand groundwater potentials with the prospects for conservation strategies that will engenders ecosystem preservation and sustainable groundwater exploration in the area.

Study Area

Niger Delta is located between the longitude 6ºE and latitude 8º36'N North West, longitude7°37.8'E and latitude7º37.2'N northeast, longitude5°26.4'E and latitude5º6'N southwest, longitude7°0.6'E and latitude4º25.8'N southeast with approximately 33 million people in the region (>265 people per km^2), making it one of the most densely populated regions in Africa and the world (Okwu-Delunzu et al., 2021). Niger Delta hydrographical region is the Hydrological area 5 (HA5) in Nigeria. States in the hydrological area include Delta, Rivers, Bayelsa, parts of Edo, Anambra, and Kogi States. Vegetation in the project area can be classified into four types. Namely: The Guinea Savannah, Tropical Rainforest, Fresh water Swamp and the Salt water Swamp.

The climate of the Niger South Catchment is characterized by a long rainy season from March- April through October-November. The precipitation increases from the north of the catchment (with an average of 1,500 mm around Lokoja) to the coastal area of the Niger Delta where mean annual rainfall averages around 4,000 mm, making it one of the wettest areas in Africa.

The soils of the Niger South Catchment fall into three zones- (a) interior zone of laterite soils (parts of Kogi State), (b) zone of alluvial soils (parts of Kogi, Edo, Delta, Anambra, Bayelsa, and Rivers States, and (c) southern belt of forest soils (parts of Edo, Delta, Anambra, Bayelsa, and Rivers States). The soils are all fluviatile origin, except for the Coastal Barrier Islands that consist of marine sand overlain with an organic surface layer.

For many communities in the Niger South Catchment, erosion and the associated flooding constitute serious environmental hazards.

Land uses and salt water intrusion impact on groundwater.

The groundwater from shallow coastal aquifers in the Niger Delta is under intense stress resulting from both natural and anthropogenic impacts ranging from saltwater intrusion, effluent-related contamination and pollution to oil spillage, gas flaring, municipal, industries and agriculture.

The salt water intrusion into the aquifers has let to so many boreholes abandoned while the development of potable water for the communities is also hampered thereby increasing pressure on freshwater demand. These issues call for stringent conservation measures for sustainable ecosystem management and water pollution load reduction to improve freshwater availability in the basin.

MATERIAL AND METHODS

The study on assessment of groundwater potentials and conservation strategies in the Niger Delta was conducted engaging Geographical Information System (GIS). The remotely sensed data was geometrically rectified, and the digitization of dendritic drainage pattern was conducted in Arc GIS 10.1 software. Consequently, information on morphometric parameters were derived as by-products of the Digital Elevation Model (DEM).

Literature Review

Ajibade et al., 2010 (as seen in Shekar, 2022) conducted a morphometric analysis of Ogunpa and Ogbere drainage basin located on the basement complex rock in the Southern part of Nigeria. The inferences from the analysis showed the larger basin have the most important morphometric parameters controlling catchment runoff pattern due to the greater volume of rainfall it intercepts and the higher peak discharge with low flood risks due to the basin size.

Tesfaye, 2015 (as seen in Colby, 2019) published an Analysis conducted on a Watershed Attributes for Water Resources Management Using GIS: The study was to examine the characteristics of the micro-watershed and to understand the water resource potential of the area.

Atrayee, 2014 (as seen in Bogale, 2021) made research on, “Governs the Dynamics of a Drainage Basin: Analysis and Implications”, at the Himalayan provinces of India. The result of the analysis provided knowledge and database for decision making for strategic planning and delineation of prioritised hazard management zones and assessment of groundwater potential of the region for effective water harvesting sites.

Collection of Data/information

Assessment of data was based on the use of remote sensing and GIS technique.

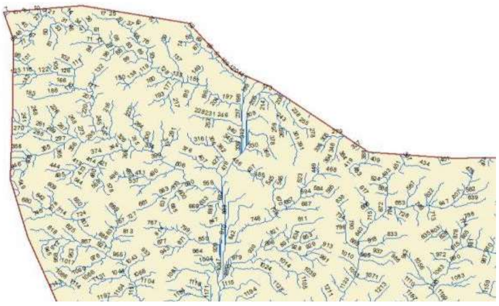


Figure 1: A cross section of the digital map of Niger Delta showing the ordering systems.

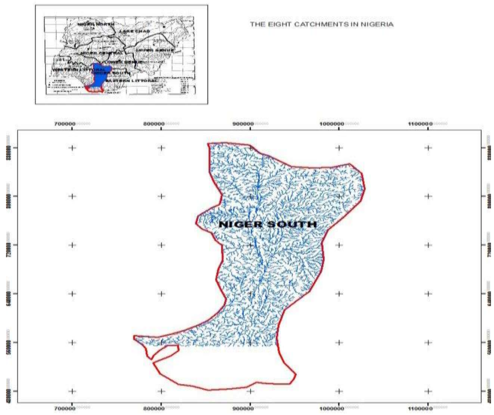


Figure 2: Digital Map of Niger Delta showing all the streams.

Data Analysis

The derived data from the DEM are as provided in Table 1.

Table 1: Aerial Aspects of the Study Area

Morphometric Parameters	Symbol/Formula	Result
Area (km^2)	A	496.8
Basin Length (km)	L_b	387.2
Axial width (km)	W_b	125.2
Slope (S)	$S = \Delta E/L$	1.29
Drainage density (km/km^2)	$Dd = \Sigma Lu/A$	0.3
Infiltration number	DdxFs	2.97
Elongation ratio	$Re = 2R/L_b$	0.07
Constant channel maintenance (C)	1/Dd	3.3
Drainage frequency	$Fs = \Sigma Nu/A$	9.9
Overland flow L_O	1/2Dd	1.7
Drainage Texture	$Dt = \Sigma Nu/P$	3.3

RESULTS

Linear Aspects

The results of the study indicated that the pattern classification of the Niger Delta is a dendritic type, which is characterized by homogeneous subsurface strata.

Bifurcation ratio values of the Niger Delta ranging between 2.17 and 2.15 characterize a basin which has experienced minimum structural disturbances, Strahler (1964) as cited in Tasfaye (2015).

Areal Aspects

The low drainage density of 0.3 indicates low stream frequencies and sparse drainage network. Low drainage density results from permeable subsurface material, vegetation cover and low relief resulting in good infiltration capacity thereby favouring groundwater recharge. A drainage texture 3.3 indicates a coarse texture and offers more time for the infiltration of overland flow Tasfaye, 2015 (as seen in Colby, 2019).

The infiltration number of the watershed 2.97 is moderate and shows potential for active infiltration.

The calculated elongation ratio of 0.65 suggests that the basin belongs to the elongated type of shape basin and low relief. The 0.65 value obtained for Niger Delta indicates that the study area is of moderate relief category.

The length of overland flow 1.7 indicates a less structural disturbance, less runoff conditions and having moderate overland flow.

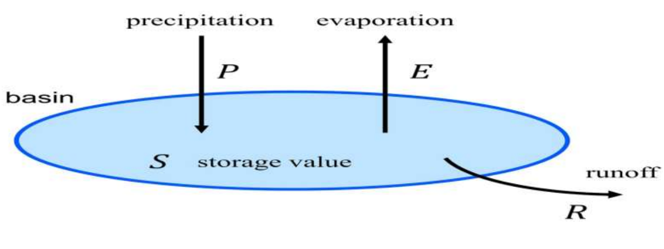
The Constant of channel maintenance (C) is the inverse of drainage density. The value is indicative of the area needed to maintain 1km length of stream. The value of (C) 3.3 means on an average 3.3km^2 surface area is needed in the watershed for the creation of one linear km of stream channel Waikar, 2014 (as seen in Colby, 2019). This implies the catchment is high permeable and viable for groundwater recharge, porous, and having the tendency for erosion, river bank failure and possibility intrusion of foreign material into the underground water thereby making the water source unsecured.

Relief Aspects

The relief ratio (Rh) value of 1.29 shows that the major portion of the HA5 is having a gentle slope. The slope measures the overall steepness of the area, and it is an indicator that the overland flow resident time duration would more and allow for optimum groundwater recharge.

Groundwater Conservation

Groundwater conservation implies a scope of measures aimed to prevent and remedy the damage of water clogging and depletion, maintain such quality and quantity of groundwater that would allow using it for national economy’s needs. The concept of conservation is better with the understanding of the water budget. A water budget is a hydrological tool used to quantify the flow of water in and out a system as shown in



Source: Wikipedia (2010)

Figure 3: Water budget

Water balance equation: $\boldsymbol{P = R + ET + \Delta S}$

Conservation Strategies

Groundwater conservation strategies includes policies, action plans to **Groundwater conservation strategies includes:**

i. compliance with water legislation and other regulatory documents in the area of water use and protection.

ii. accomplishment of measures aimed to prevent and eliminate leakage of wastewater and pollutants from the land surface to groundwater horizons.

iii. enhancement of waste water purification level and non-admission of untreated (raw) waste water disposal into streams, water bodies, and subsurface water-bearing horizons.

iv. Codes operationalization on groundwater explorations: Strict conformance with the requirements for the procedure of groundwater exploration, designing, construction, and operation of groundwater intakes.

v. systematic control over groundwater and environment condition, in water intake sites and in areas of large industrial and agricultural facilities.

sustainably manage the natural resource, to protect the hydrosphere, in order to meet the current and future human demand (avoiding water scarcity).

vi. conduction of other water-protection activities for conservation of groundwater.

CONCLUSION

The good climate of the Niger Delta and the forest nature of the environment endowed a good water budget for the basin. The terrain also has favourable environmental factors for underground water recharge. However, the natural and anthropological impacts ranging from saltwater intrusion and effluent-related contamination from the petroleum exploratory activities, municipal, industries and agriculture will worsen the already deteriorated water conditions in the basin. This will increase high demand on the diminished freshwater resources in the area. The optimum harnessing of the groundwater resources could only be achieved by environmental remediation through sustainable ecosystem management and pollution control to improve freshwater availability in the catchment.

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