International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 25-11-2023, Accepted: 10-12-2023, Published: 26-12-2023
Volume 5, Issue 4, 2023, Page No. 27-36

Hydraulic parameter: An assessment of variation in flow velocity and wetted parameter of observed tributaries of Otamiri River in Rivers state, Nigeria

Nwaturuogu Christian C
Department of Geography & Environmental Studies, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Nigeria

Abstract
The study assesses the variation in flow velocity and wetted parameter of observed tributaries of Otamiri rivers in Rivers state, Nigeria. Quasi-experimental (field survey) research design was adopted for the study, as it involves observation on the morphometry parameters of the tributaries of Otamiri river. Primary data were collected through tape, ranging pole, float, and Stopwatch, while drainage maps and topographic map become secondary sources of data. The sample frame for this study is total length of all tributaries of Otamiri-river basin, in the study area. The total length of the tributary streams is 320 kilometers, the data were collected at interval 1 kilometre since total length is 320 kilometres, then 320 divide by 1, therefore the sample frame is 320 Sampling Station. Analysis of variance (ANOVA) was used in testing the various conjectural statements at 5% level of significance for acceptance or otherwise. Findings revealed that, there is variation in the flow-velocity of the observed tributaries of Otamiri river basin in the Southern Nigeria. Also, it was revealed that there is variation in the wetted perimeter of the observed tributaries of Otamiri river basin in the Southern Nigeria. From the findings, the study deduced that there exist geomorphic and morphometric variations both with the main trunk of the Otamiri river as well as the major tributaries. Thus, the study recommends that periodic studies should be carried out in order to monitor the geomorphic properties of the River dynamics.

Keywords: Hydraulic parameter, variation, flow velocity, wetted parameter, Rivers, tributaries

Introduction

Background to the Study

Rivers are one of the geomorphic agents that constitute an important focus of the attention in the surface water studies because of their dynamic nature and spatial linkage. Therefore hydraulic radius of major tributaries of a larger rivers exert profound influence on the downstream channel morphology (Dubey *et al*, 2017) [7]. The fundamental unit of virtually all watershed and fluvial investigation is the drainage basin. Each drainage basin is a Unit area whose runoff is channeled through a single outlet. In its simplest form, a drainage basin is controlled by the drainage divide which is an area that funnels all the runoff to the mouth of a stream. Drainage basins may be delineated on a topographic map by tracing their perimeter or drainage divides (Tejpai, 2013). A drainage divide is simply a line on either side of the river where water flows to different streams, or a line that separates two river basins. This line usually occurs as a crest ridge line of high land where rainwater on one side flows into one stream, and rainwater on the other side flows into a different stream (Thomas cited in Owamah *et al*, 2020 [23]; Bailey cited in Whipple, 2018) [28]. Locally, the most famous drainage divide is the continental divide; each drainage basin is entirely enclosed by a drainage divide (Hudson, cited in Gordon, 2016).

Drainage basins are commonly treated as physical entities. For instance flood control along a particular river invariably focuses on the drainage basin of that river alone. Drainage basins pattern are known as surface arrangement of rivers and streams that regulate themselves depending on the critical factors of geology and topography. Drainage basins have discrete landforms suitable for statistics, comparative, and analytical analysis. Innumerable means of numerical and descriptions have been proposed (Hassan, Seliman & Ghani, 20l4) [14].

Geomorphologists have used drainage basin morphometry to offer explanations in fluid analysis of streams (Federico & Spangnolo, 2004, cited in Susan, 2011). Morphometry is essentially quantitative, involving numerical variables whose values may be recovered from topographic maps. The importance of morphometry variables is their usefulness for comparisons and statistical analysis in relation to the drainage basins. Morphometric analysis is a quantitative measurement and mathematical analysis of land forms (Clark, 1996 cited in Kaur, 2016 [16]; Bailey's cited in Chang, 2018) [6]. Morphometric study of a basin provides valuable information about the drainage characteristics of a basin (Apama, 2015 [3]; Strahler, cited in Dubey, 2016). As Horton cited in Soni (2017) [26] described, morphometry analysis is an important indicator of landform structure and hydro-geologic processes. Conventionally river basin is the portion of land drained by a river and its tributaries. It encompasses the entire land surface dissected and drained by many streams and creeks that flow into ocean, (Gordon, 2016).

It is widely known that morphometric and statistical analyses are most widely used methods in this approach. Morphometric parameters are mainly classified into linear, areal and relief parameters. The quantitative analysis of morphometric parameters helps us to understand geologic structure that may control the river system in a watershed. Most studies on watershed morphometric analysis use the result to compare different watersheds by relating linear and areal morphometric parameters to stream orders.

Morphometric analysis is a quantitative measurement and mathematical analysis of land forms, it plays a significant role in understanding the geohydrological characteristics of a drainage basin in relation to the terrain features and flow patterns. (Clark cited in Kulkarni, (2013). Morphometric studies of basin provide valuable information about the drainage characteristics of a basin, in relation to the hydraulic parameters of channel depth, width, wetted perimeter and the flow velocity, Soni (2017) [26].

One of the basic impacts of some selected channel hydraulic parameters (width, depth, channel bed, channel slope, velocity and discharge) lies on the volume of water discharge, gradient of the channel bed of these various tributaries (rivers/stream) which is on the increase; the geomorphic effect of the hydraulic radius of these major tributaries are easily felt on the channel width, depth, volume of water discharge, flow velocity, wetted perimeter and bank-full properties of the larger river downstream reach. Secondly the morphometry variables, such as slope (gradient), sinuosity, cross-sectional and longitudinal channel form and flow pattern (Adebayo, 2017).

It is apparently noticed that the drainage basin occur at a variety of scales, in terms of comparison using morphometric variables, as these drainage basins have different lithological compositions, structures and characteristics, coupled with varying number of tributaries and other factors such as, climate, vegetation and land use and the general land elevation among others (Gizachew & Berhan, 2018) [11]. Fluvial processes are one of the most important geomorphic system operating on the earth surface, as river studies are multidisciplinary but the most prominent areas are hydrology and hydraulics. Hydrology treats the occurrence, distribution, movement, and properties of the waters of the earth and their relationship with the environment within each phase of the water cycle (USGA, 2012). Hydraulics applies engineering science to the practical problems of collecting, storing, measuring, transporting, controlling and using of water and other fluids (Saltcrfield cited in Sahu *et al*, 2017) [24]. One of the basic challenges confronting the drainage basin studies lies much on the dearth of data, relating to the hydraulic radius of major tributaries of rivers in question. Similarly, the inadequate literature on river studies in this part of the world has proved to be a barrier, poor interest and commitment also attributed to low interest on this area of research. Poor funding and its associated problems also cause a limitation on the people to carryout research on this area. Technology also stands as a factor limiting the extent to which people of this part of world pay attention to river basin studies (Moses & Bhole, 2015) [20].

In some parts of the world where rivers, and river drainage basins are studied, such as U.S.A, Canada including Western Europe, scholars like Morton (1947), Strahler (1964), Thronbury (1969), Leopold (1962), Huggett (2012), Leopold (1992), Selby (1995), Ashley (1998), Wende (2010) among others have carried out extensive studies on drainage basins at one point in time or the other. However in Africa very few scholars like Oyegun and Oku cited in Oku (2016) [21], Adebayo (2015) [1, 4], Ogunchi (2014), Okon and Ikebude (2015) among others have also carried out studies of drainage basin among others. Scholars tike Horton cited in Owamah *et al* (2020) [23] worked on river ordering, morphology of watershed; hydraulic geometry was studied by Leopold and Maddock cited in Whipple (2018) [28]; river meander by Stahler cited in Fashae (2017) [9]; quantitative geomorphology by Schum cited in Ibisate (2017) [15] and his evolution of drainage pattern and slope in badlands (Miller cited in Olutoyia and Adetoye, 2017) [22] and his quantitative, geomorphic study of drainage basin characteristics in the Clinch mountain area; Oyegun and Oku cited in Oku (2016) [21] worked on urbanization and stream processes. The paucity of literature still exists on some rivers in Africa most especially the hydraulic radius of major tributaries of Otamiri River in the southern Nigeria were not considered, necessary. Thus, most of the relationship of tributaries and the changing channel characteristics (Hydraulic parameters) have not been studied by many scholars. Hydraulic radius (R) is the quantity which is often used in measuring the efficiency of the cross-sectional form of a channel. In more technical term; Hydraulic radius is defined as the ratio, of the cross-sectional area (A) and the length of the wetted perimeter (Pw) in other words it is defined as the cross-sectional area (A) divided by the wetted perimeter.

i.e. $R = A/Pw$

One of the major outcomes of these studies was the extension of the knowledge of watershed and stream morphology, mostly in the area of progress towards formulation of comprehensive, analytical and quantitative prediction techniques. For instance, the theory of hydraulic geometry has been postulated based on the previous work done on river studies, at one point in time or the other by various reputable scholars of the contemporary era.

Secondly, one of the outcomes of the study, were morphometric properties of Bulkiina (Nafthanah) North-East Iraq from topographic maps. In his study, Thronbury cited in (Chang, 2018) [6] highlighted the importance of morphometric analysis, of the drainage basin. Norton cited in Owamah *et al* (2020) [23] adopted a modern approach of quantitative analysis of drainage basin morphology in their evaluations; evaluated quantities or parameters are drainage density, bifurcation ratio, stream frequency, form factors circularity ratio and elongation ratio using established mathematical equations of morphometric analysis that consist of three properties. (Strahler cited in Oku 2016) [21], namely morphological, terrain, and morphometric characteristics Morphological characteristics include the area of catchment; the boarders of the study area. Its length and width, circularity factor etc, morphometric, characteristics, include the stream order, number and frequency, drainage density and bifurcation ratio etc. the terrain characteristics include, the relief ratio, hypsometric integral and ruggedness value, etc.

Nevertheless, drainage basin and its patterns are known as surface arrangement of rivers and streams that regulate themselves depending on the synthetic factors and topography (Hassan, Seliman & Ghani cited in Gezahegn *et al*, 2018) [10], Rivers or watersheds are interconnected and interdependent, because of this interconnection and linkages between upstream and downstream ecosystems, drainage basins provide a useful unit for considering and managing most environmental systems (Basiwa and Chandrades, 2016). Drainage basins occur at a variety of scale, with smaller basins (known as sub-basins) included within the basins of larger streams or rivers; when seen from above, river systems often display a tree-like pattern, with many small streams feeding into fewer larger rivers and eventually into one very large river, which flows finally into the sea. A stream flowing into a large river is called a tributary to that river (Adebayo, 2016).

Based on this, drainage basins are described by a number of characteristics, which range from size, terrain, climate, elevation, aspect, soil, storage, vegetation and land-use and (the human influences. Several scholars of both local and

international repute have carried out studies on river systems, drainage basin morphometry, hydraulic characteristics, hydraulic geometry and so on. They include Horton (1934) cited in Guth (2017) [13] on river ordering, erosional development of streams and their drainage basin.
Strahler cited in Gizachew and Berhan (2018) [11] evaluated the study on quantitative geomorphology of drainage basins and their channel networks. Leopold and Miller (1956) cited in Oku (2016) [21] examine the ephemeral steams, hydraulic factors and their relation to the drainage network; Leopold and Maddock cited in Guth (2017) [13] observed the hydraulic geometry of stream channel and some physiographic implications. Miller cited in Soni (2017) [26] worked on, quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain, Virginia and Tennese Project. Dingman cited in Dubey (2017) [7], studied fluvial Hydraulic, Chopra (2016) on morphometric analysis of sub-watersheds in Gordaspordistric, Punjab using remote sensing and GIS technique.
Similarly, Dubey (2017) [7] carried out a study on morphometric analysis of the Ban as River basin Rajasthan India, using the GIS technique etc. Buswajit and Balai (2016) analyse hydraulic parameters and morphometric variables interactions in bedrock channel. The study, which Biswajit and Balai (2016) did, was within India subcontinent of Asia, concerning the lower-reach of River Bhataihor which is one of the major tributaries of River Subarnarekha, at Havindungri village showcasing the morphometric indices of relief, and the lithological composition of the underlying rocks.
At local level, mostly Africa and Nigeria in particular, Arohunsoro and Adebayo, (2015) [1, 4] studied morphometric parameters as a correlate of flooding in River Ajilosun in Ado-Ekiti, Nigeria. However, Oguchi (2014), studied the drainage density and relative relief in humid steep mountains with frequent slope failure. Girema and Bhole (2016) carried out a study on morphometric characteristics and relation of stream orders to hydraulic parameters of river Goro: an ephemeral river in Dive-dawa, Ethiopia. Okon and Ikebude (2015) came up with a study of hydraulic characteristics of Ikpa river in the south eastern Nigeria.
There are few researches on the hydraulic parameters of major tributaries in general and no study has been done on hydraulic radius of major tributaries of Otamiri river in Southern Nigeria in particular. Most of hydraulic parameters of the tributaries are situated in remote rural settings of Southern Nigeria which pass through thick forest-vegetation which is less habitable. Downstream water discharge, sediments transport, channel width, depth, velocity and slope roughness and wetted parameter etc, require the knowledge of hydraulic radius of major tributaries (rivers). This study will serve as a baseline for those who want to further investigate the influence of discharge in watershed morphometric parameters on the hydraulics and channel, processes of the main channel. Even if it has been studied, temporal variation in natural and anthropogenic inputs within the basin make the study vital to further explain its present status of the variables investigated.

Statement of the Problem

Hydraulic radius of the major tributaries has been a major determinant of efficiency of the cross-section of the down-stream channel width, depth, the volume of discharge and flow velocity, the extent of wetted perimeter of the main stream (Laurent, Stephan & Tom, 2016).
Nevertheless, Gordon (2015) [12] evaluated the flow characteristic and hydraulics, properties of the drainage basin. However, Schumm cited in Sahu *et al* (2017) [24] analysed fluvial processes with a historical perspective in Northern Carolina USA and established the relationship between the amount of discharge and the channel perimeter.
Similarly, Laurent, Stephan and Tom (2016) studied the flow patterns in an open channel confluence with increasingly dominant tributary inflow, in Belgium and observed the relationship between the pattern of open flow and tributary discharge. Archunsoro and Adebayo (2015) [1, 4] stated in their study in Ado-Ekiti, Nigeria, that morphometric parameters are correlates of flooding in Ajilosun, and found out that morphometric parameters of river channel may exercise strong influence and control on the pattern and characteristics of river channel depth, width flow-velocity and wetted perimeter.
Moreover, Okon and Ikebude (2016) observed the hydraulic characteristics of Ikpa River in South-Eastern Nigeria, pointed out how the hydraulic parameters, including channel width, depth and flow velocity, influenced the hydraulic characteristics of Ikpa River, at a station hydraulic geometry. This study was conducted at Ibiono Ibom in Akwa-Ibom. Nigeria. They used a survey -research method as a methodological tool, where field observations with the help of GPS survey instrument were used. Kevin and John cited in Chopra (2018), Gardiner and Jackson cited in Farhan *et al* (2017) [8], worked on discharge and other hydraulic measurements for characterizing the hydraulic of lower Congo River. Local bedrock controls were seen to have large effects on the flow in the river. They made use of differential global position system (DGPS) as a tool for field observation at a station, the search adopted field-observation method.
Leopold and John cited in Oku (2016) [21] used descriptive statistics as their statistical tool to analyzed their finding. While Laurent. Stephen, and Tom (2015) adopted large-eddy simulations as a tool for investigation. They used experimental research method to analyse their work Vijuya cited in Gizachew and Berhan (2018) [11] made used of field-survey research method where GPS was to generate data. Adebayo & Ardunsoro (2015) [1, 4] made use of descriptive research method. Schumn cited in Guth (2017) [13] made use of both field -survey and descriptive statistics in analyzing his data. One major point of difference lies on the followings: their works were mainly based on Eastern Europe, USA. Asia Whilst few were carried in Africa, besides, they overlook the importance of tributaries (rivers), and their influences on larger drainage basin. Hydraulic radius of major tributaries to larger watershed has not been given attention in Southern Nigeria, particular the Otamiri river-basin. More scholars have overlooked the contribution of smaller river-basins to the wetted perimeter of larger drainage basins. They also paid less attention to hydraulic geometry of tributary streams to the river channel etc. Hence, a significant geomorphic gap exists in the local geomorphic literature on the input of tributary streams to the geomorphic development of the downstream channel. Similarly processes are dynamic and a continuous study of such processes will fast track an understanding of development over time and the process of model building in geomorphology.

Aim and Objectives

This study analyses of the hydraulic radius of major tributaries of Otamiri River in the Southern Nigeria.

In order to realize this aim, the study has the following specific objectives to:

1. State the variation on the observed flow velocity of the tributaries of Otamiri River.
2. Determine the variation of wetted perimeter on observed tributaries of Otamiri River.

Research Hypotheses

The following hypotheses are formulated to guide the study;

1. There is a variation in the flow-velocity of observed tributaries of the Otamiri River.
2. There is a significant variation in the wetted perimeter of the observed tributaries of the Otamiri River.

The Study Area

The study area is the Otamiri River (drainage basin) and its tributaries in the southern Nigeria, with its source at Egbu-Owerri, just about 500 meters from Egbu cathedral and about 20 (twenty) kilometers from Owerri metropolis, and which covers a distance of about three hundred and fifty (350) kilometers from its source at Egbu to its mouth in Opobo Estury down to Atlantic Ocean.

Secondly, this aspect of the study centres on the geographical setting of the study area "Otamiri river and its major tributaries in the southern Nigeria" with the aim of highlighting the hydraulic radius of the major tributaries and the interplay of hydraulic parameters of depth, width, flow velocity and cross- section of the down reach of Otamiri River.

Location of the Study Area

Otamiri watershed (river basin) and its major tributaries in the southern Nigeria, happens to be located in about four degree, thirty minutes, North, fifteen degrees ten minutes North of equator ($4^0 30^1$ - $15^0 10^1$N) and about fifteen degree fifty minutes to six degree fifty minutes East of greenwich meridian (5°50'E - 6°50'E). It is one of the major river basins in the southern Nigeria that empty into the in Atlantic Ocean (fig. 1). It is the fourth largest watershed (drainage basin), in the area. It has four major tributaries joining at one point or the other.

These four tributaries are Nworie river at Nekede, Okatankwo joining Uramiriukwa, at Emeabiam, Uramiriukwa joining Otamiri river very close to Orwu in Etche, Ogeochie joined Otamiri river at Opiro, closed to Nihi Etche and Otamiri river other tributaries joined Otamiri river at Opoku, before crossing Bori- Uyo bridge, at East-West road, after which Otamiri river flows into the Atlantic Ocean through Opopo estuary (Fig. *2*)

Thirdly Otamiri river basin or watershed cuts across four states within the Southern Nigeria, the states are, Imo, Rivers, Abia and Akwa-Ibom States

Geology/Topography

Otamiri river basin crisis-crosses these four states in the southern Nigeria, with its major tributaries emanating from different points, of fairly different geological and topography backgrounds, depicting a unique spatial pattern of landscapes, both local rolling topography backgrounds, and low lying areas, under ten to twenty metres (I0m-20m) above sea level, (Ofune cited in Fashae, 2017) [9]. The geological composition of Otamiri watershed, shows alternating sequence of sands stones and clay-shale into young sedimentary rock of southern Nigeria, within Niger-Delta region, though as the river passed through some parts of these states, the presence of sand-stone, muddy-clay formation mostly at the source areas, but as the Otamiri enters the coastal environment of Niger Delta, presence of young sedimentary, deltaic soil with much alluvial soil formation is noticeable due to the coastal region environment.

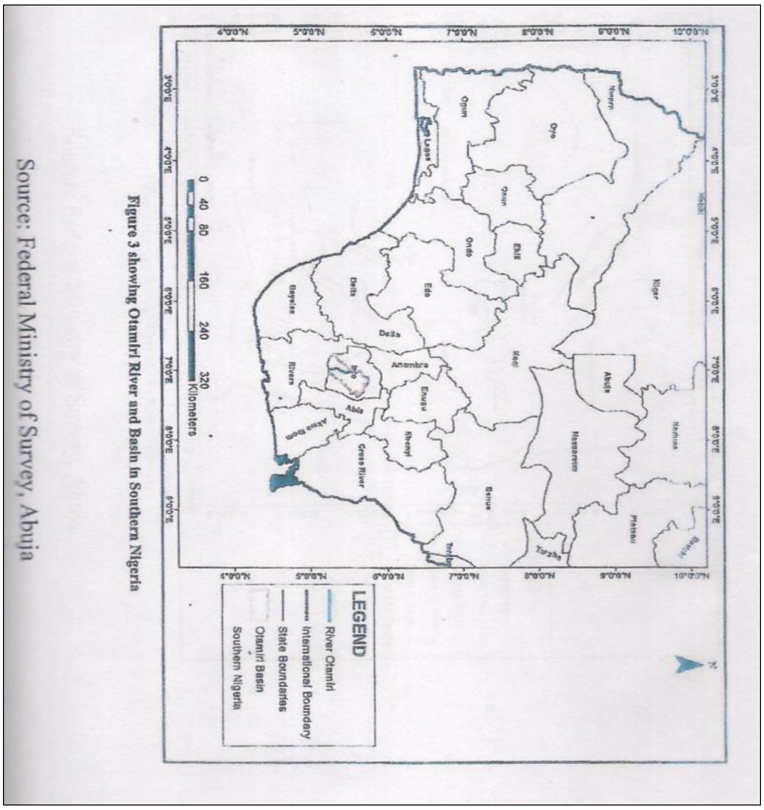

Figure 3 showing Otamiri River and Basin in Southern Nigeria

Source: Federal Ministry of Survey, Abuja

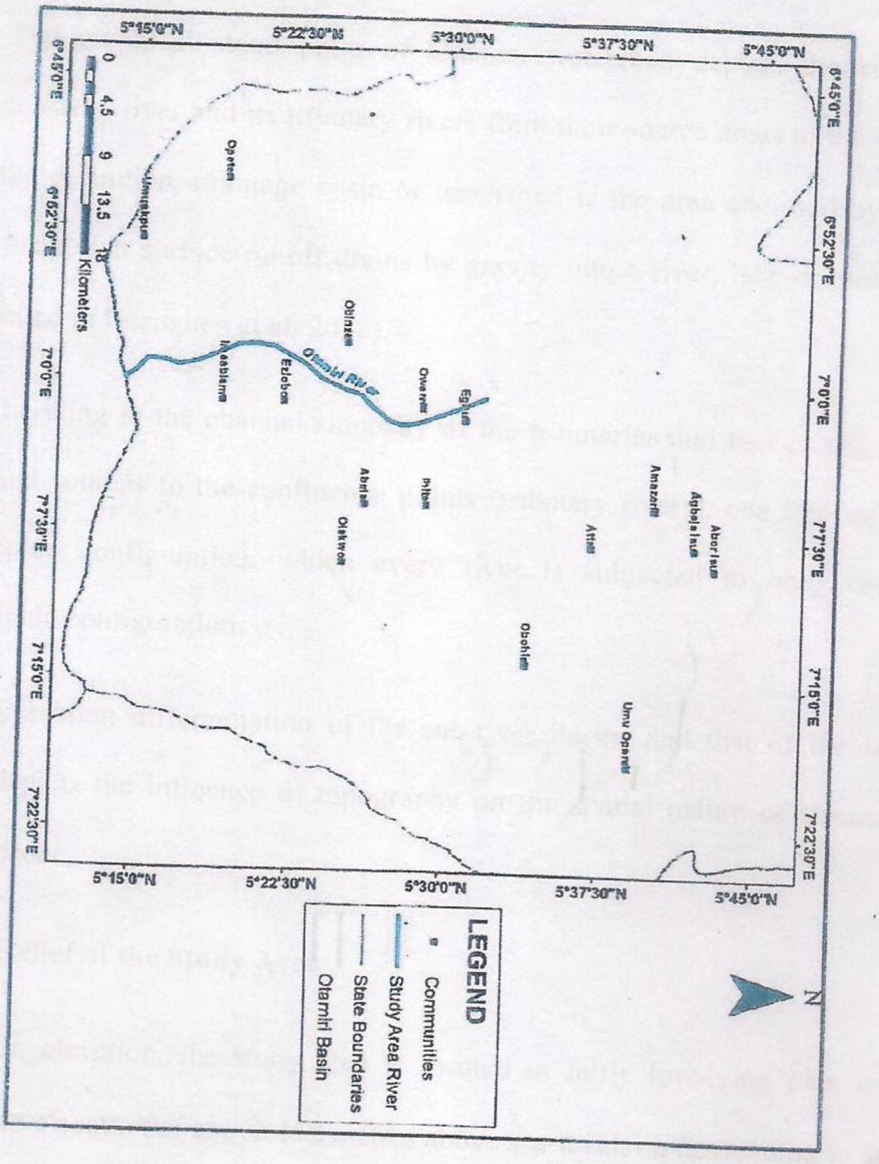

Figure 5 showing Study Area Map showing Otamiri River

Source: Federal Ministry of Survey, Abuja

Topographical stand point of Otamiri watershed depicts the sinuosity of the drainage basin, river and its tributary rivers from their source areas to the entrance to sea. From the definition, drainage basin or watershed is the area enclosed by a topographic divide such, that surface runoff drains by gravity into a river, lake or other water bodies (WSC cited in Gezaghen *et al*, 2018).

Looking at the channel sinuosity of the tributaries and that of Otamiri from their individual sources to the confluence points (tributary rivers), one noticed the impact of topographic configuration, which every river is subjected to obey the principle of topographic configuration.

Elevation differentiation of the sub-river basins and that of the larger drainage basin, depicts the influence of topography on the spatial nature of stream network and stream order.

Literature revietheoretical framework

Systems Theory

The hydraulic radius of major tributaries of a river, derived its system in terms of open system: an open system is not isolated from its environment, but exchanges materials or energies with it. In this, a system may also contain subsystems, that is, smaller systems within it, these are said to be its components. As stated above, that, hydraulic radius derives its system in terms of simple action (non-feedback) systems Michael cited in Sahu *et al* (2017) [24] observed that simple action system is one in which the chain of cause and effect runs all in one direction, on given instance of rainfall effects on the rate of soil erosion, but soil erosion has no effects on rainfall just like this statement to hydraulic radius of major tributaries of a river (Otamiri river) has similar example, hydraulic radius of major tributaries of a main stream (river) affect the rate of wetted parameter, which is the measure of efficiency of the main river and the increasing volume of water downstream, but the wetted perimeter, efficiency and the volume of water downstream have no effect on the hydraulic radius of major tributaries of rivers (streams).

He further stated that systems can be classified according to the way in which they involved man, Schultze cited in Oku (2016b) [21] used the term cascading system in describing the effect of hydraulic radius of major tributaries of river (contribution of stream to main river) in hydraulic, channel characteristics changes of the main river, which is one of the effects of hydraulic radius of major tributaries of a river as per the volume of water discharged and the efficiency of main river.

Besides, hydraulic radius as a measure of efficiency is not exempted, as this cascading which is the part of system theory. States that hydraulic radius to the measure of efficiency in an open flow channel of tributaries (rivers) to the main river, the efficiency of the main river is considered as series of cascading system. It is clear from the above discussion that although a number of theories of at-a-site and downstream hydraulic geometry have been developed, it is not clear how these theories compare; Comparison of these theories using the same data is lacking and should be pursued. Furthermore, it is also not clear which theory should be applied where and under that condition? Some of the theories require more data than others. The survey of literature made in this study suggests that there is plenty of data available for different rivers in different countries but efforts to achieve these data and organize them into a data base have not been reported. Despite all the work done and new theories developed during the past half a century, the classic work of Leopold and Maddock as cited in Fashae (2017) [9] still remains the benchmark contribution. This then raises a question if real progress has indeed been achieved in the area of hydraulic geometry. Another area that needs greater attention is the watershed geometry and evaluation of channel networks. The work on hydraulic geometry of channels serves as an excellent starting point to more on to the development of a theory of drainage basin geometry and channel network evaluation.

This will permit integration of channel hydraulics and drainage basin hydrology and geomorphology.

- Importance of watershed or catchment to downstream water discharge.
- Importance of channel pattern to hydraulic radius.

The effects of stream/river size of the tributary river to the downstream hydraulic variables.

Variation in Channel Velocity

Mackin (1963) has noted that in individual channels there are just as many such segments with a downstream decrease in velocity as there are with a downstream increase in velocity. Carlson cited in Mohd *et al* (2017) [19] found in the Susquehanna River in the United States that the number of streams with a downstream velocity increase was balanced by an equal number of streams with either a constant velocity or a downstream decrease in velocity; The most common relationship on long segments of rivers is a nearly constant velocity; however, in many smaller streams the velocity may increase or decrease downstream because of geological influences present at the mean annual discharge. Large rivers, such as the Mississippi, accommodate a downriver increase in discharge principally through increase in depth, whereas smaller rivers generally accommodate the downriver increase in discharge principally through increase in width. Leopold cited in Whipple (2018) has shown that large scale floods which move large quantities of sediment have nearly constant downstream velocity.

Drainage Basin Wetted Perimeter

Susan, cited in Soni (2017) [26] put it that wetted perimeter is term use to denote the line of contact between water and the river bed. In a cross-sectional area of river channel, Knighton cited in Ali and Bashir (2018) [2] viewed the term wetted perimeter, as the perimeter of cross-sectional area that is "wet", he also emphasized that the wetted perimeter is commonly used in field of engineering, hydrology and geomorphology etc. as the surface of the channel bottom and sides in direct contact with the aqueous body.

In line with the above statement Susan cited in Soni (2017) [26], Aroshunsoro, and Adebayo and Archunsoro (2015) [1, 4] stated that the concept of wetted perimeter refers to the section of a river channel which constant contact with water. Pierre (2014) stated that the river channel width can often be approximated by the wetted perimeter. In an open channel flow drainage basin wetted parameter is viewed as the surface of the channel bottom and "sides' in direct with the aqueous body, and when a channel is much wider than it is deep, the wetted perimeter approximates the channel width.

According to Munson, Yong and Okiishi (2017) wetted in upper course, the channel is narrow and rough there is large wetted perimeter due to lots of boulders and rocks etc, wetted perimeter, to them, the wetted perimeter is the total length of the bed and the banks of the river in contact with water in any given cross-section when there is a large wetted perimeter in relation to the amount of discharge in the rivers, there is more friction which reduces the velocity of the river. The river is less efficient. Strahler and Strahler cited in Oku (2016) [21] in their study of stream channel geometry viewed wetted perimeter as the length of line of contact between the water and the channel as measured from the cross-sect ion.

Sparks cited in Fashae (2017) [9] put it that wetted perimeter, is the term associated with geomorphology, civil engineering, environmental engineering and hydrology, it means the surface of channel bottom and sides in direct contact with the aqueous body; he further stressed that the friction losses usually increase with an increasing wetted perimeter, resulting in a decreases in heat. He stated that in practical experiment one is able to measure the wetted perimeter with a measuring tape weighted down to the river bed to get a more accurate measurement. Accordingly, he stated that when a channel is much wider than it is deep, the wetted perimeter approximates the channel width.

Strahler and Strahler cited in Oku (2016) [21] state that wetted perimeter is the length of line of contact between the water and the channel as measured from the cross- section. Wetted perimeter (p) denotes the actual length of line of contact between the water and the channel, as measured from the cross-section. Strahler and Strahler cited in Oku (2016) [21].

In open channel flow, the term wetted perimeter denotes the surface of the channel bottom and sides in direct contact with the aqueous body. The wetted perimeter is not necessarily large upstream; in fact it is usually much lower than downstream because upstream channels are relatively small. What is important is the hydraulic radius, which represents the ratio of bed and banks to cross-sectional water flow (discharge) and which tends to get larger further downstream. The wetted perimeter is the total length of bed and banks in contact with the water in any given cross-section. Wetted perimeter is measured with a tape, ranging - pole and hand-held global position system (G.P.S) (Kevine *et al* cited in Soni (2017) [26].

In the upper course the channel is usually narrow and rough; there is a large wetted perimeter due to the presence of boulders/rocks etc. as the total length of the bed and banks of the river that is constantly in contact with water, which is referred to as wetted perimeter, when large area is constantly in contact with water (wetted perimeter) in relation to the amount of water discharge in the river, there is more friction which reduces the velocity of the river, the river is less efficient. At the middle and lower course the channel becomes larger and smoother (less rough), this makes the river more efficient. At point in the river, the wetted perimeter is proportionately smaller than the amount of discharge in the channel. Eventually there is less friction to reduce velocity. The river is more efficient; Harlan, (2016) in line with the above statement Susan, cited in Yunus *et al* (2018) [29], Aroshunsoro, and Adebayo and Archunsoro cited in Merritt (2018) [18] stated that the concept of wetted perimeter refers to the section of a river channel with constant contact with water. Pierre cited in Soni (2017) [26] stated that the river channel width can often be approximated by the wetted perimeter.

Geomorphic implications of tributaries to the river basin

Stream network or river system often displays a tree-like pattern with many streams/rivers and converges into one very large river. A stream flowing into larger river is called tributary river/stream to the larger river, Chitale cited in Guth (2017) [13]. The smaller river basins which make-up the larger river basin, are the major tributaries of such river and formed the sub-basin to such larger river basin.

In river/stream order analysis, the first step in drainage basin analysis is order designation, following a system only slightly modified from Horton cited in Birsan *et al* (2017) [5], which pictured the channel network map includes all the intermittent and permanent flow lines located in a clearly define valleys, the smallest finger-tip tributaries are designated order 1, where two-finger-trip streams join, a channel segment order 2, is formed, where two of order 2 join, a segment of order 3, is formed; and so forth. The trunk stream through which all discharged of water and sediment passes is therefore the stream of highest order.

Geomorphic Implications of Flow Velocity in Hydraulic Radius

The concept flow velocity has to do with the stimulating discharges hydrographs and the residence time of water in the hydrological system. Flow velocity in rivers has a major impact on residence time of water and thus on high and low water as well as on water quality. For global scale hydrological modelling only very limited information is available for simulating flow- velocity. Based on the Manning and Stickler equation, a simple algorithm to model temporally and spatially variable flow velocity was developed with objective of improving flow routing in the global hydrological model of water GAP. If a single or a limited number of catchments are modelled, complex flow velocity equations can be parameterized with observed catchment specific values. Thus, this may not be possible at large scales: hence, for global approach, a simplified methodology is needed.

Flow - velocity is always calculated based on measured discharge and compared to measured velocity. In state-of-the-art global hydrological models either no lateral routing and thus no river flow velocity is used (Amell cited in Merritt, 2018) [18], Yates cited in Yunus *et al*., 20I8) [29] or just simple approaches like constant river flow Doll, Kaspar and Lehner cited in Ali and Bashir (2018) [2]. Simple functions of discharge (Vordsmary & Jaspar cited in Chang, 2018) [6] or of topography Hagermann and Dumenil cited in Kenth and UI Hassan (2017) [17] are applied to simulate flow velocity or retention time in rivers respectively.

The concept of flow velocity as it relates to hydraulic parameters, denotes the rate at which water discharge flows within water course, along the channel, it is a combined product of bankfull discharge, gradient (slope), to evacuate debris and sediments from the river source to its confluence point (mouth) etc; it also refers to the rate of flow of water in a particular stream segment, it is measured with the instrument called current-meter; the river energy which denotes the ability of water to move in volume, it is affected by the following factors, - mass - of water, the height of river above sea level and the gradient of the channel.

One of the geomorphic implications of flow velocity is determining the flow pattern in downstream reach of the larger basin, channel, and confluences of open channels of tributaries are important elements in hydraulic networks of rivers and man-made channels. The associated flow velocity patterns of these various tributaries govern the transport of solutes and sediments in the network and influence the water level of the downstream reach of the larger basin channel (Laurent, Stephen and Tom, 2017). It is obvious, that one of features that appear in an open channel confluence can be conceptualized to depict what normally happens, at a point where two incoming flows meet, a stagnation zone develops, that is a zone of reduced flow velocity. From the stagnation zone, a mixing layer departs which delineates the merging streams. At downstream junction corner, the tributary flow may detach, causing the formation of a separation zone. Next to the separation zone, is the merging flows passing through a narrowed cross-section are concentrated leading to increased velocities downstream.

Simulating river flow velocity on global scale one of the geomorphic implications of flow velocity is observable on its major impacts on residence time of water and thus on high and low water as well as on water quantity (Doii cited in Fashae, 2017) [9].

This simple function of discharge applied to simulate flow velocity or retention in rivers respectively. In this work, a simple algorithm to model flow velocity based on a limited number of parameters is presented. The approach allows simulating spatially and temporally variables river flow velocities based on parameters derived from globally available data and discharge time series that might be provided by measurement or by spatially distributed hydrological models. It was tested against independent flow velocity measurements at several river cross-sections. The long-term objectives of these efforts if is to improve flow routing in the water gap global hydrology model, (WGHM, Poll cited in Tundean. 2017).

The Manning strickler formula or equation to calculate river flow velocity is considered to meet this demand.

$$v = n^{-1} R^{2/3} S^{1/2} \text{(m/s)}$$

v = is the flow velocity (m/s)
n = is the river bed roughness (-)
R = is the hydraulic radius (m)
S = is the river slope (m/m)

The hydraulic radius ® of a specific river cross-section is temporally variable due to river stage dynamics. It depends on the shape of the river bed profile and the actual water level.

Research methodlogy

Kpolovie as stated in Selvan *et al* (2017) noted that research design depicts the entire procedure for successfully carrying out the enquiry in order to arrive at new knowledge which is meticulously and logically planned. He went further to state that, it is a very crucial and central phase that maps out in unmistakable terms everything that will be done to ensure that all the hypotheses or research questions formulated in the first step are objectively tested to answer the questions posed and achieve the purpose of the study. Based on this, the study entails a field- survey (field-observation) of the hydraulic variables of channel width, depth, and flow discharge in the study area. Quasi-experimental (field survey) research design was adopted for the study because the study itself is a field-based, involving observation on these morphometry parameters of the tributaries of Otamiri river, as they influence its channel width, depth, flow velocity and discharge, mainly toward the downstream reach.

The nature of data used in this study is non-discrete (continuous) data, as they relate to hydraulic parameters of tributaries of Otamiri river in the southern Nigeria. The sources of data for this study, are primary and secondary sources. The primary source of data includes the field observations such as, channel, width, depth and flow velocity which were collected by using tape, ranging pole, float, and Stopwatch. The secondary source of data includes all the data obtained from the drainage maps and topographic map. Satellite imagery of the drainage basins of the Southern Nigeria, the Nigeria Inland Waterways (N1W) from Federal Secretariat Port Harcourt. Providing the necessary (information (data) on these rivers and their tributaries. However, the sample frame for this study is total length of all tributaries of Otamiri-river basin, in the study area. The total length of the tributary streams is 320 kilometers, the data were collected at interval 1 kilometre since total length is 320 kilometres, then 320 divide by 1, therefore the sample frame is 320 Sampling Station. The study used analysis of variance (ANOVA) to test the various conjectural statements at 5% level of significance for acceptance or otherwise of the stated hypothesis of the study. The reasons for using analysis of variance (ANOVA) is that the data involves variation.

Results and discussion

Presentation of Data

Summary Table of Measured Numbers

Summary of Channel Parameters of Each Sampling Station

S/no.	Coordinates	Wetted Perimeter (m	Flow Velocity (/permin)
1.	4º 59’ 38” N, 7º 03’ 25” E	320.60	4.9
2.	4º 59’ 30” N, 7º 03’ 27” E	317.10	5.00
3.	4º 59’ 29” N, 7º 03’ 31” E	230.10	3.5
4.	4º 59’ 18” N, 7º 03’ 35” E	345.30	3.4
5.	4º 59’ 6” N, 7º 03’ 00” E	345.30	3.1
6.	4º 58’ 5” N, 7º 04’ 00” E	309.70	2.6
7.	4º 58’ 49” N, 7º 4’ 7” E	229.35	2.04
8.	4º 58’ 44” N, 7º 04’ 21” E	235.15	2.4
9.	4º 58’ 36” N, 7º 04’ 36” E	350.20	2.5
10.	4º 58’ 5” N, 7º 05’ 00” E	340.65	2.49
11.	4º 58’ 01” N, 7º 05’ 6” E	350.30	3.1
12.	4º 57’ 12” N, 7º 05’ 21 E	350.30	3.1
13.	4º 57’ 45” N, 7º 05’ 28” E	325.51	6.10
14.	4º 57’ 38” N, 7º 05’ 35” E	340.50	10.20
15.	4º 57’ 31” N, 7º 05’ 45” E	305.67	10.70
16.	4º 57’ 23” N, 7º 05’ 55” E	298.70	11.10
17.	4º 57’ 13” N, 7º 05’ 10” E	300.0	13.05
18.	4º 57’ 06” N, 06’ 00” E	302.70	12.35
19.	4º 56’ 53” N, 7º 06’ 05” E	310.35	12.80
20.	4º 56’ 48” N, 7º 06’ 13” E	302.90	11.60
21.	4º 56’ 41” N, 7º 06’ 19” E	298.50	2.0
22.	4º 56’ 36” N, 7º 06’ 25” E	297.90	2.6
23.	4º 56’ 30” N, 7º 06’ 31” E	301.70	3.00
24.	4º 56’ 24” N, 7º 06’ 39” E	230.30	3.3
25.	4º 56’ 17” N, 7º 06’ 45” E	220.30	2.8
26.	4º 56’ 10” N, 7º 06’ 55” E	220.30	3.00
27.	4º 55’ 58” N, 7º 07’ 08” E	250.30	3.2
28.	4º 55’ 59” N, 7º 07’ 18” E	126.10	6.4
29.	4º 55’ 44” N, 7º 07’ 30” E	205.35	6.6
30.	4º 55’ 28” N, 7º 07’ 42” E	280.70	6.7
31.	04º 55’ 28” N, 07º 07’ 50” E	320.60	7.10
32.	04º 55’ 28” N, 07º 07’ 50” E	330.50	6.30
	Total	9,060.68	178.43

Discussion of Findings

Research question one: state the variation in the flow velocity of the tributaries of Otamiri river. Hypothesis two states that there is no significant variation in the flow velocity of observed tributaries of Otamiri river. The findings of this study revealed that the objective determine the variation in the flow-velocity of observed tributaries of Otamiri river in the southern Nigeria, from Table 4.3.4, ANOVA summary relating to the research hypothesis above, depicted the calculated F-ratio of 16.7506 which is greater than F-critical which is 0.0000 at 0.5 significance level. Based on this, the findings revealed that, there is variation in the flow-velocity of the observed tributaries of Otamiri river basin in the Southern Nigeria.

Mackin cited in Chopra *et al* (2018) also noted that there is variation in flow velocity among individual channels at different point. Also Carlson cited in Gutama *et al* (2917) also made similar observation in Susquehanna river in the United States of America, according to him the number of streams with downstream velocity increase was balanced by an equal number of streams with downstream decrease in flow velocity.

From the observations Mackin cited in Dubey *et al* (2017) [7] and Carlson cited in Sahu *et al* (2017) [24] which agrees with the finding of hypothesis two which revealed that there is variation in flow velocity of the observed tributaries of Otamiri river basin.

Research question two: states the variation in the wetted perimeter of the observed tributaries of Otamiri river. Hypothesis three, stated that there is no variation in the wetted perimeter of observed tributaries of Otamiri river. The findings of the study revealed that there is variation in the wetted perimeter of the observed tributaries of Otamiri river basin in the Southern Nigeria.

Aroshunsoro and Adebayo (2016) stated that the concept of wetted perimeter refers to the section of river channel which is contact with water, which varies among different river basins as well as stream length. Yong and Okishi cited in Soni (2017) [26], stated that wetted perimeter in the upper course is narrower and wider in the downstream reach, as it is in line with the findings of hypothesis which revealed that there is variation in wetter perimeter of the observed tributaries of Otamiri river basin.

Summary, conclusion and recommendation

Summary

The result revealed that there is significant variation in the flow velocity of the observed tributaries of Otamiri River basin. These variations in the flow velocity emanated from water discharged by these tributaries at different points of their convergence to the main stream channel of Otamiri River, for instance the flow velocity of Nworie river at the highest point was 3.35 metres per minutes. The second segment or tributary to Otamiri river being Oeramiriukwa was 3.90 meters per minutes. The third segment of the Otamiri river basin is the Okitankwo river was 5.10 meters per-minutes and the fourth segments being ogechie river was 5.05 metres per minutes, this is due to the broad nature the channel at that point. Another points of consideration lies much on the gradient of the Otamiri channel which is product of topographic composition of the channel coupled with the Lithological composition of the bedrock along the main channel of Otamiri river basin.

There is significant variation in the wetted perimeter of the observed tributaries of Otamiri river; As the various tributaries of Otamiri river basin emanated from different points with different lithological back ground and area coverage, the wetted perimeters differ the first tributary of Otamiri river being Nworie river at point of the highest is 301.60 metres at station eight, that second tributary being Oeramiriukwu is 299.60 metres, the third segment being Okitankwu river is 310.20 meters and the fourth segment being Ogechie river has 250.50 metres: These variations in wetted perimeters of the various tributaries of Otamiri river, depicted the extent to which lines of contact with water differs among these tributaries of Otamiri river basin.

Conclusion

From the finding of the study, the researcher concluded that the Otamiri river basin is one of the river basins in Nigeria. From the study geomorphic and morphometric variations exist both with the main trunk of the Otamiri river as well as the major tributaries.

These variations could be a function of temporal variation in the input factors as well as process modifications along the river channel and its basin area.

From the study the anthropogenic dependence on river for survival over time account for such noticeable modification both the main channel and the tributaries.

Recommendations

Based on the findings of the study, the following recommendations are made by the researcher.

1. Periodic studies should be carried out in order to monitor the geomorphic properties of the River dynamics.
2. Further studies should be carried out in other related areas of fluvial studies of Otamiri river basin, so as to find out other vital potentials of Otamiri river basin in the Southern Nigeria, for instance land use, land cover along Otamiri downstream reach should be investigated.

Contributions to Knowledge

The study has unraveled the current status of the Otamiri river basin and its major tributaries of Nworie, Oeramiriukwa, Ogechie and the Okatankwo. This has provided the necessary tool for geomorphic understanding and planning in managing its vast water resources.

This study unraveled the current status of the wetted perimeter and flow velocity which will guide the present planning and development opportunities along the river channel.

This study unraveled the current potentials available in both the major tributaries of Otamiri river as well as the downstream reach landscape of Otamiri river, such as finest gravel material which is a raw material for glass industries.

It also unraveled the current water discharge of the major tributaries of Otamiri river basin as capable of supporting regional water supply in the South-South region.

It unravels the spatial pattern of Otamiri river basin in southern Nigeria so as to provide the understanding of river ordering.

It offers a practical solution to environmental challenges mostly at downstream reach, proper and adequate periodic channelization of river course as to reduce or prevent flood occurrences.

References

1. Adebayo WO. Mophometric Parameters as Correlates of Flooding in Rivers Ajilosun in Ado-Ekiti, Ekiti State Nigeria. International Journal of Africa and Asian Study, 2015.
2. Ali and Bashir M. Soil-erosion risk and flood behaviour assessment of Sukhang catchment, Kashmir basin: using GIS and remote sensing. *Journal of Remote sensing and GIS*,2018:1:230. Google scholar
3. Apama. Cited in Sahu (2016) Morphometric analysis of Kanhur river basin in India. National Journal of India, 2015.

4. Adebayo WO, Archunsoro SJ. Morphometric, parameters as a correlate of flooding in rivers. Ajilosun in Ado-Ekiti Nigeria, 2015.
5. Birsan MV, Zaharia V, Chendes. Seasonal trends in Romania stream flow in hydrological process,2017:28:4496 -4505, Willey online library, Wed science, Google scholar.
6. Chang HH. River morphology and river channel changes: Transactions of Tianjin University,2018:14:254-262. https//doi.org/10.1007/sll220q-008-0045.3
7. Dubey SK, Sharma D, Mundetia. Morphometric analysis of the Banas river basin using the geographical information system. Bajasthan, India. *Hydrology*,2017:3(5):47-57.
8. Farhan A, Aubar A, Al-Shaikh N. Prioritization of semi-arid agricultural watershed using morphometric and principal component analysis, remote sensing and GIS technique, the Zerga river watershed; *Agricultural Sciences*,2017:8:113-148.
9. Fashae OA. Riparian vegetation and river channel morphology in the alluvial section of river Ogun. Department of Geography, University of Ibadan, 2017.
10. Gezahegn W, Autemeh T, Reddu RU. Spatial modeling of soil erosion risk and its implications for conservation planning: The case of the Gobele watershed, East Hararghe Zone Ethiopia, 2018.
11. Gizachew K, Berhan G. Hydro-georhorphological characterization of Phidhessa river basin, Ethiopa. *International Soil and Water Conservation Research*,2018:6:175-185.
12. Gordon A. The effect of bed-roughness on depth-discharge relations in alluvial channel. *Journal of Geography and Earth science international*,2015:3(1):1-11.
13. Guth PI. Drainage basin Morphometry: A global snapshot from the shittle radar topography mission: *Hydrology and Earth System Sciences*,2017:15:2091-2099.
14. Hassan MA, Seliman AA, Ghanai AA. Morphometric Properties of Bulkana North-East Iraq from Topographic maps. *An International Journal of Current Engineering and Technology*, 2014.
15. Ibisate A, Ollero A, Diaz E. Influence of catchment processes on fluvial morphology and river habitats limnetica,2017:30:169-182.
16. Kaur cited in Reddy. Morphometric analysis in basaltic terrain of central India using GIS Techniqued: A case study applied water sciences, 2016.
17. Kenth TA, Ul Hassan E. Morphometric analysis and prioritization of watersheds for soil and water resource management in water catchment using geospatial tools: International Journal of Geology, Earth and Environmental Sciences,2017:*2*:30-41.
18. Merritt DM. Downstream hydraulic geometry and channel adjustment during flood along an ephemeral stream arid regional drainage: *Geomorphology*,2018:52:165-180.
19. Mohd L, Haroon S, Bhar FA. Morphometric analysis of Shalinganga sub catchment Kashmir valley, India using Geographic Information System. International Journal of Engineering Trends and Technology,2017:4:10-21.
20. Moses G, Bhole V. Morphometric Characteristics and the relation of stream orders to Hydraulic parameters of River Goro, An Ephemeral River in Dire-dawa Ethiopia, Universal Journal of Geosciences,2015:3(1):13- 27.
21. Oku HB. The Niger Delta environment in local geography, Nissi Publishers, 2016.
22. Olutoyia A, Adetoye. Downstream morphologic characteristics of the alluvial section of lower river, Ogun, Nigeria, 2017.
23. Owamah H, Alfamu Oyebisi S, Emenike P, Otuaro E, Gopikumar. Groundwater quality monitoring and perception issue in popular Niger Delta University town in Nigeria. *Groundwater for Sustainable Development, 2020*.
24. Sahu N, Reddy O, Kuma N. Morphometric analysis in basaltic terra." of central India using CIS techniques: A case study. *Applied Water Science,* 2017, 30-1007.
25. Selvian MT, Ahmed S, Rashid SM. Analysis of the geomorphometics parameters in high altitude glaciarised terrain using SRTM DEM data in central Himalaya, India, *ARPN Journal of Science and Technology*,2017:1(1):22–27.
26. Soni S. Assessment of morphometric characteristics of Chakaror watershed in maahya Pradesh India using geospatial techniques. *Applied Water Science*,2017:*7*:2089-2102.
27. U.S.A. (2012). "'GN1S, FACT (http//geonames usgs gov/domestic/fegs.htm). United States Geological Survey.
28. Whipple K. Alluvial channels and their landforms in surface process and landscape evolution, 2018.
29. Yunus, *et al*. Morphometric analysis of drainage basins in the Western Arabia Peninsula using multivariate statistics. *International Journal of Geosciences,* 2018, 527-539.