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(Research Article)

Modeling of some hydrodynamics characteristics of Orashi River in the Southern Region of Nigeria

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Abstract

The dynamic nature of rivers and its effect on the inhabitants and its surroundings is of fundamental concern to Hydro Scientists, Coastal Engineers, and Surveyors. These changes have remained unpredicted and hence the focus of this study. The aim of this study is to develop a geo-model of the dynamics of Orashi River in Ogba/ Egbema/ Ndoni Local Government Area of Rivers State. The objectives are to determine the river dynamics parameters, to develop a functional multiple regression model of Orashi River dynamics and to determine the percentage contributions of each of the independent variables. This study was carried out using classical survey methods such as river current measurement, river cross-sectional area determination, river water discharge rate determination, bathymetric operation, runoff water computation, water gauge reading and conventional ground surveying. A multiple regression analysis was carried out using data obtained in 2013, 2015 and 2017 used as the independent variables while the river level changes is used as the dependent variable. The result of this study show changes in the river current and river discharge. The data analysis show the contribution of the independent variable to the dynamics of Orashi River for 2013 to be 24.83%, 30.63%, 20.24%, 0.33% and 24.97% for river current, runoff peak discharge, rainfall intensity, temperature and humidity respectively. The analysis was also carried out in 2015 & 2017and different results were obtained. A functional model of the dynamics of the changes in Orashi River was developed for 2013, 2015 and 2017 which can be used in monitoring the changes in Orashi River.

Keywords: Hydrodynamics; Runoff water peak discharge; River Current; River water discharge; Meteorological Data; Multiple Regression Analysis.

1. Introduction

There have been recent changes observed in Orashi River mostly along the communities in Ogba/ Egbema/ Ndoni Local Government Area of Rivers State and its environment.

Orashi River as a tributary of River Niger is frequently changing due to the effect of meteorological factors and hydrodynamics. These changes have affected human activities along the stretch of that River and also distort the operation of multi-national companies operating in that area.

Meanwhile meteorological factors are primary controls influencing river hydrology and geomorphology as it impacts the precipitation timing and quantity which establishes the hydrologic character of a river system (Schumm, 2016 [14]).

Climate change is expected to impact on the hydrodynamics cycle due to increased temperatures (thereby leading to changes in snow and ice regimes) as well as shifts in the precipitation distribution (Arnell 2013 [1]). It also causes shifts in hydrological extremes leading to floods and droughts that can have devastating economic and social effects such as

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loss of land, crops, or livestock, an increase in diseases, or even death (Intergovernmental Panel on Climate Change, 2014 [7]).

The impacts of climate and hydrodynamic changes in our river system and its environment cover all spatial scales, from local environmental to global environmental (Lahmer, Pfützner and Becker, 2001 [12]; Coulthard, Lewin and Macklin, 2005 [4]). There is now substantial evidence indicating that over the most recent decades, the global hydrological cycle has already been responding to observed global warming (Bates, Kundzewicz, Wu and Palutikof, 2008 [3]), which includes increasing atmospheric water vapor content (humidity) and changing precipitation pattern.

Aside the negative effects on health, both floods and droughts impact the mortality of the exposed population, as substantiated already for floods in Asian countries (Jonkman, 2005 [11]).

Meanwhile river rise in Nigeria are fluvial (resulting from Rivers overtopping their natural and manmade defenses), coastal (affecting mainly the coastal areas) and pluvial (flash, arriving unannounced following a heavy storm) in nature and have been a major cause of concern for rural areas and cities within the country (Houston, Werritty, Bassett, Geddes, Hoolachan and McMillan, 2011[6], Bashir, Oludare, Johnson and Aloysius, 2012 [2], Douglas, Alam, Maghenda, Mcdonnell, Mclean and Campbell, 2008 [5]).

With the history of devastating rise and fall of the level of water of Orashi River mostly in 2012 and 2018 which has affected millions of human population and caused fiscal losses of property worth of billions of naira by multi nationals companies and individuals in the study area, Hence, it becomes imperative to identify the factors causing these seasonal changes in volume of water of Orashi River and changes in its geometry as it impact on the inhabitants and its environment. It is also important to explore more realistic approach in studying the dynamics of Orashi River in other to develop a more appropriate model for future monitoring of the dynamics of Orashi River.

Figure 1 Pictures of Flooded Study Area

Source: Authors Fieldwork, 2018.

1.1. Aim and Objectives

The aim of this research work is to develop a geo-model of the dynamics of Orashi River.

The objectives of this study are to:

- Determine the Hydro River dynamics parameters of Orashi River.
- Develop a functional multiple regression model of the Orashi River dynamics.
- Determine the percentage contributions of each of the independent variables.

1.2. Study Area

This study is located in Ogba/Egbema/Ndoni local Government area of Rivers state with headquarter at Omoku Town and form part of the oil mining lease 58 (OML58) where Agip Oil Company (NAOC) and Total E&P have some of their facilities.

The study area is located on latitude 633902mN – 572127mN and longitude 219601mE – 255551mE, in the WGS84 UTM Zone 32N with a population size of 283,294 according to 2006 census and a land mass of 1,621 square kilometers.

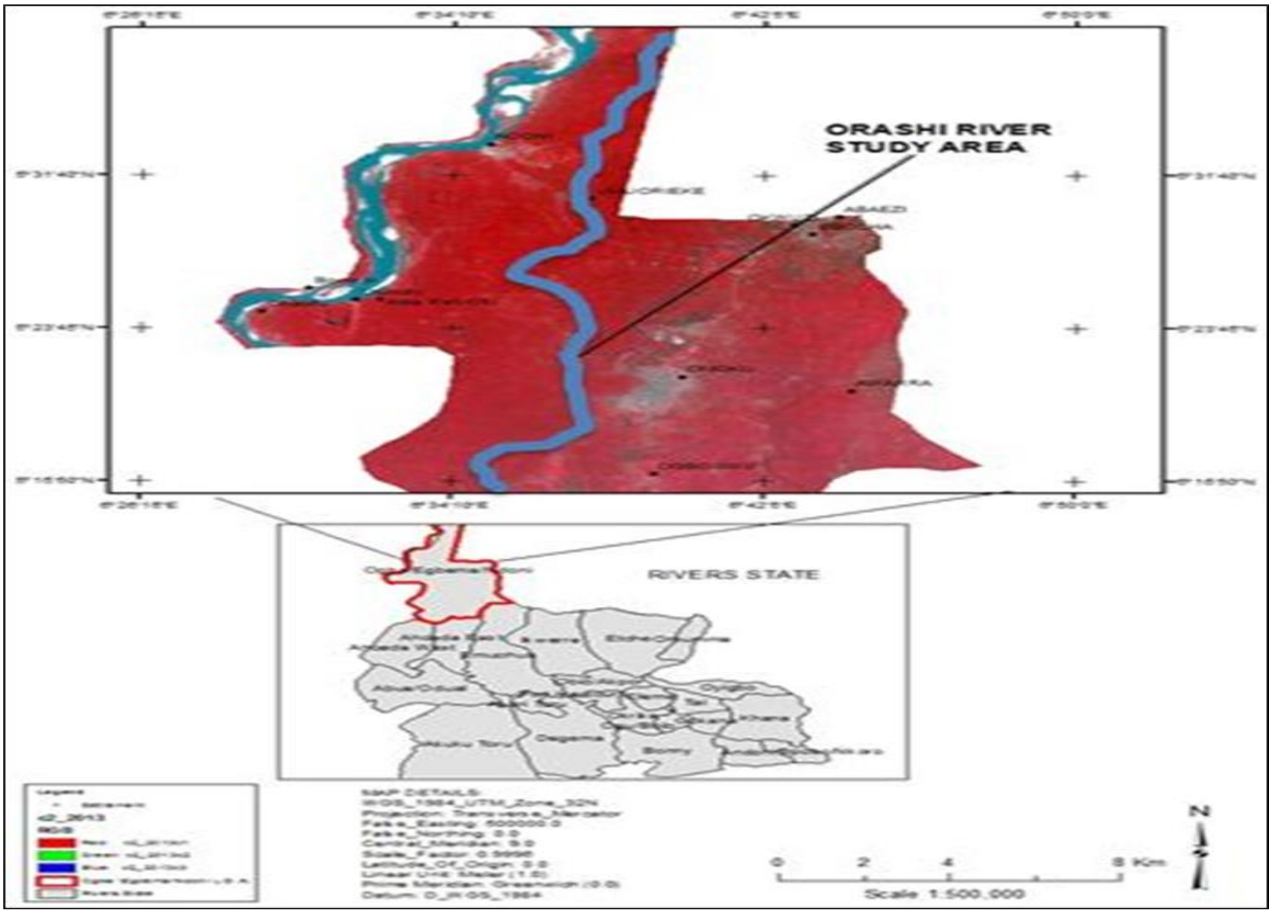

Figure 2 Map of the Study Area Showing Orashi River**.**

Source: Authors Fieldwork, 2019.

2. Materials and Methods

This research methodology was based on the principle of classical survey method in its data acquisition and multiple regression analysis in its data analysis.

2.1. Data Acquisition

The data acquisition was based on both primary and secondary data and its methodologies were adopted in the following headings;

2.1.1. Control Establishment and Instrument Check

For the purpose of this study, a Total station (TRC 703) instrument was used, and was subjected to proper calibration and certify before it was use and the automatic level (Pentax 125) instrument used was also calibrated, certify through a two peg test. A traverse was run in loops as a quality control by starting and closing back on the same known station. The survey was based on "SAT12-019 and SAT12-019A" reference controls pillars located at Obagi community by Total E&P Nigeria limited. Heights were transferred to the two control pillars and other subsidiary benchmarks established at the Shore of IDU River starting from SAT12-019 (With known elevation) and closed back on the same station.

2.1.2. Water Gauge Fabrication and Installation

A metal bracket to fit in the water gauge (Staff) was well fabricated and a well graduated 5 meters water gauge was firmly installed and fitted to the bridge pier in the River to avoid disturbance from river users and accessible by boat only.

The gauge was mounted in a position were readings can be clearly taken using a binocular. There was a water gauge design in the wall of the pier to use when the water level rise above the staff and it was graduated up to 12.50 meters.

After the installation of the gauge, Heights and coordinates were transferred to the gauge and the base of the pier, referencing IDU1 and 2.

Figure 3 Water Gauge Fabrication

Source: Authors Fieldwork, 2019.

2.1.3. River Current (U) Measurement

The current of the river was determined by a repeated observation for five times with respect to three positions which include bank1, center and bank2 using float method and the average time taken and all encumbrances taken care of and the current which is also the velocity (U) of the river was computed using appropriate velocity equation.

$$U = KV \qquad 1.1$$

Where:

U is the average velocity (m/s)

k is the velocity correction factor (0.85).

V is the velocity of the River (m/s).

This was done in the eight section of the river along the stretch of the Orashi River and the Average of the eight section was computed using the formula below;

$$\nabla = \frac{U_1 + U_2 + U_3 + U_4 + U_5 + U_6 + U_7 + U_8}{8} \qquad 1.1a$$

Where

V is the average velocity for the eight sections (m).

U_1 to U_8 are the average velocity of the eight sections computed along the river stretch (m).

2.1.4. Cross-Sectional Area (A) Computations

The cross-sectional area was computed by measuring the depth of the river at equal interval of 10m along the width of the eight sections as discuss above and multiply each depth by the interval and adds them together. This was achieved using trapezoidal rule of continuity equation and this procedure was adopted for the two seasons of this research and for the three epochs.

2.1.5. Discharge Rate (Q) Determination

The discharge rate is based on a simplified form of continuity equation which implies that any incompressible fluid, such as liquid water, the discharge (Q) is equal to the product of the streams cross-sectional area (A) and its mean velocity (U). Haven't known the depth of some part of the cross-section of the river and the velocity of the river, the Discharge (Q) will be determined using relevant equations. This was also done in all the eight sections and in two seasons, three epochs as the Current using equation 3.3 above.

2.1.6. Bathymetric Operations

The depth data for the three epochs (2013, 2015 and 2017) used for this research was obtain by the bathymetric work done in 20 meters interval along a reasonable section of the river length and 10 meters along the width of the River using single beam echo sounder (Odom MK III) after a thorough bar check.

2.1.7. Runoff Water Computation

The estimated runoff water yield was computed using the rational formula in equation 3.5 above.

2.1.8. Water Level Observation

The water level observation was carried out two times a week to monitor the rise and fall of volume of water of part of Orashi River to ascertain the changing pattern of the water of Orashi River. This process was continued for 2013, 2015 and 2017 and all the appropriate readings taken.

2.1.9. Shoreline Changes

The position of the shoreline was observed and coordinated in 2013, properly marked with iron peg and also rechecked in 2017 to determine the changes. This was done in eight places refers to as section in this research along the stretch of the river.

2.2. Method of Data Analysis

2.2.1. Multiple Regression Analysis

The data for this research work will be analyze using multiple regression analysis to ascertain the factors or variables that are contributing most to the rise and fall of Orashi River mostly along Ogba/ Egbema/ Ndoni Local Government Area of Rivers State axis.

The factors under investigation in contributing to changes in the level of Orashi River are, River Current (U), Runoff Water (Q), Rainfall Intensity (I), Temperature (T), and Humidity (H).

These factors will be referred to as independent variables in this research work.

The linearity equation to be adopted for this research work is given is in equation 3.10.

2.2.2. Model Fittings

In order to fit this model, the regression coefficient k, m1, m2, m3, m4 and m5 will be estimated using statistical method and Statistical Package for Social Sciences Software (SPSS).

SPSS is a software design for complex statistical data analysis; it is used by researchers for processing and analyzing data. It offers four programs that assist researchers with their complex data analysis; the programs are statistical program, modeler program, text analytics and visualization designer.

2.2.3. Coefficient of Determination

This will be used to judge the goodness of fit of the model and it is given as;

$$R^2 = \frac{SSR}{\Sigma Y^2} \qquad ...3.12$$

Where:

R^2 is the coefficient of determination.

SSR is the sum of square due to regression.

ΣY^2 is the sum square of the product of Y, where Y is the dependent variable.

While SSR is given as;

$$SSR = m_1 \Sigma x_1 Y + m_2 \Sigma x_2 Y + m_3 \Sigma x_3 Y + m_4 \Sigma x_4 Y + m_5 \Sigma x_5 Y \qquad ...3.13$$

Where $m_1 \Sigma x_1 Y, m_2 \Sigma x_2 Y, m_3 \Sigma x_3 Y, m_4 \Sigma x_4 Y, m_5 \Sigma x_5 Y$ are the sums of the product of m Y.

The Degree of Freedom (F) will be used to show the level of significance between the dependent and the independent variables.

The degree of freedom F is given as;

$$F = \frac{SSR/k}{SSE/(n-k-1} \qquad ...3.14$$

Where:

SSE is the sum of square due to residual.

n is the total number of the observations.

k is the number of independent variables.

3. Results and Discussions

3.1. Control Data

The data of both vertical and horizontal controls used in this research work and the controls established in Orashi River shore at Idu axis of the river is listed in table 3.1;

Table 1 Control Stations

PILLAR	NORTHING (m)	EASTING (m)	ELEVATION (m)
SAT 12-019	460921.036	137974.274	12.808
SAT 12-019A	460951.063	138019.910	13.106
SAT 12-019B	460854.364	138006.477	12.795

Source: Author 2019

3.2. River Current Data (V)

Table 2 River Current 2013, 2015 & 2017 for Dry and Wet Season**.**

	2013 (Dry & Wet)		**2015 (Dry & Wet)**		**2017 (Dry & Wet)**	
Stations	(V) m/s	(V) m/s	(V) m/s	(V) m/s	(V) m/s	(V) m/s
Sectn.-1	0.42	0.61	0.42	0.62	0.42	0.73
Secti.-2	0.39	0.73	0.42	0.73	0.43	0.76
Sectn.-3	0.39	0.69	0.41	0.72	0.42	0.75
Sectn.-4	0.42	0.72	0.41	0.71	0.4	0.74
Sectn.-5	0.39	0.73	0.41	0.71	0.39	0.73
Sectn.-6	0.39	0.73	0.41	0.73	0.4	0.73
Sectn.-7	0.4	0.72	0.4	0.74	0.41	0.74
Sectn.-8	0.44	0.71	0.4	0.73	0.39	0.72
Average	0.41	0.70	0.41	0.71	0.41	0.74

Source: Author 2019

3.3. The Cross-Sectional Area (A) and Discharge Rate (Q).

The cross-sectional area and the Discharge rate of the River as computed using equation 3.2 and 3.3, it is presented in table 3.3(a-c) for the different sections and different seasons of 2013, 2015 and 2017 respectively.

Table 3 Cross-Sectional Area and Discharge Rate for 2013.

Stations	**(A)m²;Dry**	**(A)m²;Wet**	**(Q)m³/s;Dry**	**(Q)m³/s;Wet**
Sectn.-1	617.70	1166.88	263.89	711.75
Sectn.-2	737.63	2194.80	287.68	1602.20
Sectn.-3	742.04	1628.29	287.68	1123.52
Sectn.-4	603.81	1656.53	253.60	1192.70
Sectn.-5	107.20	1316.20	41.81	960.83
Sectn.-6	552.58	1331.28	215.51	865.33
Sectn.-7	703.73	1304.70	281.49	939.38
Sectn.-8	620.67	1305.32	273.07	926.78

Source: Author, 2019

Table 4 Cross-Sectional Area and Discharge Rate for 2015.

Stations	**(A)m²;Dry**	**(A)m²;Wet**	**(Q)m³/s;Dry**	**(Q)m³/s;Wet**
Sectn.-1	625.85	1494.66	262.86	926.69
Sectn.-2	778.56	2740.76	778.56	2000.75
Sectn.-3	661.41	1954.41	661.41	1407.17
Sectn.-4	512.86	1733.85	512.86	1231.03
Sectn.-5	625.62	1586.97	625.62	1126.75
Sectn.-6	490.40	1546.87	490.40	1129.22

Sectn.-7	646.06	1547.21	258.42	1144.94
Sectn.-8	715.39	1644.50	286.16	1200.49

Source: Author 2019

Table 3 Cross-Sectional Area and Discharge Rate for 2017.

Stations	(A)m^2;Dry	(A)m^2;Wet	(Q)m^3/s;Dry	(Q)m^3/s;Wet
Sectn.-1	671.72	1617.95	282.12	1181.10
Sectn.-2	624.39	2796.23	268.49	2125.13
Sectn.-3	833.64	1897.06	333.46	1422.80
Sectn.-4	762.30	2064.52	304.92	1527.74
Sectn.-5	631.63	1919.09	246.34	1400.94
Sectn.-6	625.77	2184.30	250.31	1594.54
Sectn.-7	685.41	1785.61	281.02	1321.35
Sectn.-8	620.74	2050.48	242.09	1476.34

Source: Author 2019

3.4. Runoff Water Peak Discharge

The area of the catchments and the average runoff water peak discharge (Q_p) of the various catchments along the River was computed for 2013, 2015 and 2017 using equation 3.5 and are presented in table 3.4;

Table 6 Runoff water Peak Discharge of Orashi River For 2013, 2015, 2017

2013 Q_p (m^3/s)	2015 Q_p (m^3/s)	2017 Q_p (m^3/s)	Month
752.75	57.90	173.71	January
752.75	3763.77	0.000	February
2258.26	2084.54	4284.90	March
4053.29	2547.78	4458.62	April
4863.94	2779.39	3937.48	May
8917.24	8917.24	8975.14	June
5153.47	5153.47	9727.89	July
2084.54	2084.54	6774.78	August
3474.24	3474.24	7411.73	September
5674.60	5153.47	3416.34	October
2779.39	926.46	810.65	November
2084.54	0.000	0.000	December

Source: Author, 2019

3.5. Average Water Level Readings

The average water level obtained in the weekly observation of the water gauge installed at Idu axis of Orashi River for 2013, 2015 and 2017 are presented in table 3.5.

Table 7 Water Gauge Readings of Orashi River**.**

Months	2013(m)	2015 (m)	2017 (m)
January	3.072	3.165	3.216
February	3.170	3.193	3.216
March	3.282	3.211	3.257
April	3.348	3.220	3.365
May	3.405	3.382	3.448
June	3.479	3.725	3.805
July	3.659	3.635	4.199
August	4.304	4.025	5.571
September	4.847	5.406	7.738
October	5.951	8.709	9.264
November	5.263	4.414	4.312
December	3.954	3.227	3.388

Source: Author, 2019

3.6. Meteorological Data of the study Area.

The average meteorological data of the study area for 2013, 2015 and 2017 as received from Nimet are presented in table 3.6.

Table 8 Average Meteorological Data for 2013 (Source: NIMET).

Rainfall (mm)			Temperature (deg. C)			Humidity (%)			Month
2013	2015	2017	2013	2015	2017	2013	2015	2017	
1.30	0.10	0.30	33.60	33.80	32.70	74.00	77.00	78.81	January
1.30	6.50	0.00	33.50	35.80	33.70	74.00	80.00	74.01	February
3.90	3.60	7.40	33.10	32.70	32.50	75.00	81.00	85.10	March
7.00	4.40	7.70	33.00	32.60	32.90	77.00	81.00	83.00	April
8.40	4.80	6.80	31.90	31.50	32.00	81.00	83.00	84.60	May
15.40	15.40	15.50	29.70	30.20	29.30	84.00	87.00	86.60	June
8.90	8.90	16.80	28.80	29.10	28.60	86.00	86.00	87.00	July
3.60	3.60	11.70	29.10	28.70	28.50	87.00	88.00	90.10	August
6.00	6.00	12.80	29.50	29.80	29.80	87.00	88.00	87.10	September
9.80	8.90	5.90	30.70	30.60	30.70	82.00	86.00	85.20	October
4.80	1.60	1.40	32.40	31.80	32.40	77.00	83.00	84.00	November
3.60	0.00	0.00	33.90	32.90	33.90	64.00	72.00	85.00	December

Source: Author, 2019

3.7. Independent Variables Data (Current, Runoff Water, Rainfall, Temperature, Humidity).

The data use as the independent variables in this research work are presented in table 3.7.

Table 9 Independent Variables for 2013.

V.m/s			Q.(m^3/s)			Rainfall (mm)			Temp. (deg. C)			Hum. (%)		
2013	2015	2017	2013	2015	2017	2013	2015	2017	2013	2015	2017	2013	2015	2017
0.41	0.41	0.41	752.75	57.90	173.71	1.30	0.10	0.30	33.60	32.70	33.80	74.00	77.00	78.81
0.41	0.41	0.41	752.75	3763.77	0.000	1.30	6.50	0.00	33.50	33.70	35.80	74.00	80.00	74.01
0.41	0.41	0.41	2258.26	2084.54	4284.90	3.90	3.60	7.40	33.10	32.50	32.70	75.00	81.00	85.10
0.41	0.41	0.41	4053.29	2547.78	4458.62	7.00	4.40	7.70	33.00	32.90	32.60	77.00	81.00	83.00
0.70	0.71	0.74	4863.94	2779.39	3937.48	8.40	4.80	6.80	31.90	32.00	31.50	81.00	83.00	84.60
0.70	0.71	0.74	8917.24	8917.24	8975.14	15.40	15.40	15.50	29.70	29.30	30.20	84.00	87.00	86.60
0.70	0.71	0.74	5153.47	5153.47	9727.89	8.90	8.90	16.80	28.80	28.60	29.10	86.00	86.00	87.00
0.70	0.71	0.74	2084.54	2084.54	6774.78	3.60	3.60	11.70	29.10	28.50	28.70	87.00	88.00	90.10
0.70	0.71	0.74	3474.24	3474.24	7411.73	6.00	6.00	12.80	29.50	29.80	29.80	87.00	88.00	87.10
0.70	0.71	0.74	5674.60	5153.47	3416.34	9.80	8.90	5.90	30.70	30.70	30.60	82.00	86.00	85.20
0.41	0.41	0.41	2779.39	926.46	810.65	4.80	1.60	1.40	32.40	32.40	31.80	77.00	83.00	84.00
0.41	0.41	0.41	2084.54	0.000	0.000	3.60	0.00	0.00	33.90	33.90	32.90	64.00	72.00	85.00

Source: Author 2019

3.8. Dependent Variables

The dependent variables which are the average water level obtained in the weekly observation of the water gauge for 2013, 2015 and 2017 are presented in table 4.9 below.

Table 10 Dependent Variables (Orashi River Changes).

Months	2013(m)	2015 (m)	2017 (m)
January	3.072	3.165	3.216
February	3.170	3.193	3.216
March	3.282	3.211	3.257
April	3.348	3.220	3.365
May	3.405	3.382	3.448
June	3.479	3.725	3.805
July	3.659	3.635	4.199
August	4.304	4.025	5.571

September	4.847	5.406	7.738
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December	3.954	3.227	3.388

Source: Author, 2019

3.9. Data Analysis

3.9.1. Multiple Regression Analysis

Multiple regression analysis (MRA) was used in the analysis of the dependent variable which is the daily readings obtained from the water gauge installed at Idu axis of Orashi River and the independent variables which include the current of the River, Runoff Water Peak Discharge, Rainfall Intensity, Temperature and Humidity of the study area for 2013, 2015 and 2017.

The data were converted to their various standard units and analyzed statistically for the three epochs. The data were further analyzed simultaneously to obtain the regression coefficient M_1, M_2, M_3, and M_4 using statistical package for social sciences (SPSS) software as illustrated below;

$M_1\Sigma X_1^2 \;\; M_2\Sigma X_1X_2 \;\; M_3\Sigma X_1X_3 \;\; M_4\Sigma X_1X_4 \;\; M_5\Sigma X_1X_5 = \Sigma X_1Y$ ... (a)

$M_1\Sigma X_2X_1 \;\; M_2\Sigma X_2^2 \;\; M_3\Sigma X_2X_3 \;\; M_4\Sigma X_2X_4 \;\; M_5\Sigma X_2X_5 = \Sigma X_2Y$ ... (b)

$M_1\Sigma X_3X_1 \;\; M_2\Sigma X_3X_2 \;\; M_3\Sigma X_3^2 \;\; M_4\Sigma X_3X_4 \;\; M_5\Sigma X_3X_5 = \Sigma X_3Y$ ... (c)

$M_1\Sigma X_4X_1 \;\; M_2\Sigma X_4X_2 \;\; M_3\Sigma X_4X_3 \;\; M_4\Sigma X_4^2 \;\; M_5\Sigma X_4X_5 = \Sigma X_4Y$ ... (d)

$M_1\Sigma X_5X_1 \;\; M_2\Sigma X_5X_2 \;\; M_3\Sigma X_5X_3 \;\; M_4\Sigma X_5X_4 \;\; M_5\Sigma X_5^2 = \Sigma X_4Y$ ... (e)

Where M_1, M_2, M_3, M_4 and M_5 are the regression coefficients of the independent variables, ΣX_1X_2, ΣX_1X_3, ΣX_1X_4 and ΣX_1X_5 are the sum of the multiple of the independent variables.

While the estimate of the intercept K was obtain as follows;

$$K = \overline{Y} - M_1\overline{X}_1 - M_2\overline{X}_2 - M_3\overline{X}_3 - M_4\overline{X}_4 - M_5\overline{X}_5$$

Finally, the model $H = K+M_1X_1+M_2X_2+M_3X_3+M_4X_4+M_5X_5$ for 2013 as defined in equation 3.7.0 above is given as follows;

$$H = -68.86 + 2.628X_1 - 0.004X_2 + 2245.57X_3 + 0.223X_4 + 0.048X_5$$

Where H is the changes in water level, -68.86 is the intercept or constant of the independent variables while 2.628, -0.004, 2245.57, and 0.048 are the regression coefficients of the independent variables.

3.10. Test of the Model for 2013

The model test will be done collectively and independently as followed;

Collective test:

$$3.98 = -68.86 + 2.628(0.56) - 0.004(3537.88) + 2245.57(0.0062) + 0.223(304.75) + 0.048(79)$$

$$3.98 = -68.86 + 1.47 - 14.28 + 13.92 + 67.96 + 3.79$$

$$3.98 = 4.00$$

Independent test of the variables to ascertain the most contributing factor to the rise and fall of the River was done and the following results were obtained; 67.39, 83.14, 54.93, 0.90, 65.07 for River Current, Runoff Water, Rainfall Intensity, Temperature and Humidity.

The percentage of contribution of the independent variables to the rise and fall of the volume of water of Orashi River was computed and the following results were obtained; 24.83%, 30.63%, 20.24%, 0.33%, 24.93% for River Current, Runoff Water, Rainfall Intensity, Temperature and Humidity. The coefficient of determination R^2 is 0.67 = 67% while the degree of freedom F is 2.42.

Consequently, 2015 result analyses are presented below following the steps in 2013 above; the functional model for 2015 is given as below;

$$H = -188.75 + 5.719X_1 - 0.00003293X_2 - 6.558X_3 + 0.567X_4 + 0.207X_4.$$

Independent test of the variables to ascertain the most contributing factor to the rise and fall of the River was done and the following results were obtained; 185.55, 188.85, 188.78, 16.06, 171.64for River Current, Runoff Water, Rainfall Intensity, Temperature and Humidity.

The percentage of contribution of the independent variables to the rise and fall of the volume of water of Orashi River for 2015 was computed and the following results were obtained; 24.71%, 25.15%, 25.14%, 2.14%, 22.86% for River Current, Runoff Water, Rainfall Intensity, Temperature and Humidity. The coefficient of determination R^2 is 0.68 = 68% while the degree of freedom F is 2.78.

Furthermore, 2017 result analyses are presented below following the steps in 2013 above; the functional model for 2017 is given as below;

$$H= 390.29 + 4.752X_1 + 0.0003X_2 - 435.106X_3 - 1.190X_4 - 0.284X_5$$

Independent test of the variables to ascertain the most contributing factor to the rise and fall of the River was done and the following results were obtained; 393.05, 391.54, 387.16, 27.60, 366.37 for River Current, Runoff Water, Rainfall Intensity, Temperature and Humidity.

The percentage of contribution of the independent variables to the rise and fall of the volume of water of Orashi River for 2017 was computed and the following results were obtained; 25.10%, 25.01%, 24.73%, 1.76%, 23.40% for River Current, Runoff Water, Rainfall Intensity, Temperature and Humidity. The coefficient of determination R^2 is 0.76 = 76% while the degree of freedom F is 3.83.

4. Discussions

The result of this research is discussed based on the objectives of the research as followed;

In 2013, 2015, 2017 dry season, the average cross-sectional area (A) are 585.67m², 632.21m², 681.95m² while the average cross-sectional (A) for wet season are 1488.00m², 1781.15m², 2039.41m². The average discharge (Q) of the river for 2013, 2015, and 2017 for dry season are 238.09m³/s, 484.54m³/s, 276.09m³/s while for wet season is 1040.31m³/s, 1270.88m³/s, 1506.24m³/s. From the above analysis, it is pertinent to note that the Orashi River experience increase in both cross-sectional and the discharge rate in wet season than in dry season.

The average current (V) of the River for 2013, 2015 and 2017 dry season is computed as 0.41m/s, 0.41m/s and 0.41m/s while for wet season, it is computed as 0.70m/s, 0.71m/s and 0.74m/s respectively. From the analysis above, it is observed that there is always an increase of the current of Orashi River during wet season.

Table 4.6, show the peak runoff water discharge (Q) for each catchment along the Orashi River for every month of the year. The results show the lowest runoff water discharge to Orashi River from the catchments in January and December for 2013, 2015 and 2017 respectively while the highest runoff water discharge to the river occurs in June, April and July for 2013, 2015 and 2017 respectively.

From the multiple regression analysis, it shows that the highest contributor the rise in volume of water of the Orashi River in the study area for 2013, 2015 and 2017 is the Runoff water peak discharge (Q_p) and River Current while the major contributor to the fall in volume of water of the river is the temperature (T) of the study area.

The coefficient of determination R^2 for the 2013, 2015 and 2017 are 67%, 68%, and 76% indicating that the independent variables contributes above 67% of the rise and fall of volume of water of Orashi River. It also means that the model is good to be used for further prediction of the dynamics of that River.

Subsequently, the computed degree of freedom (F) for 2013, 2015 and 2017 are approximately 2.42, 2.79 and 3.83 respectively which are greater than or equal to the tabular degree of freedom (F) with $f_1 = 5$ and $f_2 = 12$, this shows the significance of the estimated multiple regression analysis for 2013, 2015 and 2017. Thus, the combined effects of the independent variables contributed significantly to the variation in the dependent variables.

5. Conclusion

The study thus far has shown the dynamic state of part of Orashi River, the river has been found to be undergoing a seasonal changes occasioned by hydrodynamics and meteorological factors.

This study has shown a seasonal increase in the current (V) of the river which represent the flow of water from other sources in this research. The study shows an increase in current of the river of about 0.74m/s against its normal flow of 0.41m/s. This study has also shown an increase in the cross-sectional area (A) of the river during wet season. The cross-sectional area of the river ranges from 620.74m^2 during dry season and 2796.23m^2 for wet season. This change in the cross-sectional area of the river occasioned by the increase in volume of water of Orashi River also causes changes in the discharge rate (Q) of Orashi River. This study shows a seasonal change in the discharge rate of the river as 242.69m^3/s for dry season and 1527.74m^3/s for wet season.

This study has developed a model with minimum design error which the stakeholders or people living around and within the stretch of the river will use in monitoring the seasonal changes of the river. Three models were design for three epochs (2013, 2015 and 2017) to ascertain and compare the changes in those years. The 2017 model has shown to be the best fit for monitoring the changes in Orashi River based on its attributes. The application of the 2017 model result will serve as a time warner for those that are seasonally affected by the changes in the dynamics of Orashi River. It will also help in monitoring the increase in volume of water of that river and subsequently predict the amount of changes in terms of rise and fall in volume of water that will be expected in that river in a particular time, day, week or month.

This research has shown Runoff water peak discharge (Q_p) from the various catchments along the Orashi River and River Current (V) as the major contributor to the rise in volume of water of the river while the Temperature (T) of the study area is seen major contributor to the fall in volume of water of Orashi River. This study has further displayed the capabilities of Multiple Regression Analysis (MRA) in the studies of the dynamics of rivers. It can be concluded that the application of multiple regression analysis for monitoring river changes offers a technical guide and solution in the study of river dynamics. This research recommend among other things the dredging of Orashi River to enable it retain more volume of water, the use of the water gauge by the stakeholders around the gauge station and the use of the 2017 model in monitoring and predicting the seasonal changes in the dynamics of Orashi River.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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