Morphological Adjustment of a Tropical River to Urbanization

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Abstract

The work examined how stream channel morphological characteristics and hydraulic variables responses are significantly related to different parameters of urban land use practices in Orogodo River. A threefold research strategy was adopted. The first step involved demarcating the river long profile into ten (10) sites of 10km of the urbanized section as study area. This was done in order to obtain information on stream channel bank full cross sectional areas, basin morphometry and urban land use characteristics. Secondly, the chosen sites (10km) were detailed for measurement of stream hydraulic variables. Data on land use were obtained from systematic examination of topographic and land use maps of Agbor, 2009. Thirteen (13), urban land use and morphometric variables that are related to stream channel adjustment were factor analyzed. Three independent variables made up of amount of rain fall, volume of drainage discharge and infiltration capacity of the soil were statistically significant in explaining stream channel morphological characteristics. From the study, it is clear that prolonged engagement of urban land use to construction and creation of impervious surfaces will continue to cause stream channel to adjust to the changing run off and sediment yield such that over the years stream channel sizes are enlarged. It is therefore recommended that an integrated programme of basin land use and structural alternatives will include the development of green belts/lawns and other options that encourage high level of infiltration rather than the development of storm sewers. It is also recommended that, an approach of rain water harvesting should be encouraged within the river basin. If adopted by the inhabitants, it will reduce peak flow into river channel.

Keywords: Stream channel, Urbanization, Adjustment, Land use, Agbor

Introduction

Morphological adjustment of a river channel consequent upon land-use changes have now been investigated in a range of different environments, with the most emphasis on humid temperate areas. Since Wolman (1967) first illustrated how human activities causes changes runoff and sediment transport leading to adjustments in stream channel dimensions, it has also been discovered that river channels dimensions have resulted from construction of dams and rivers regulation, land-use changes, channelization, bridge effects and urbanization. Urbanization affects river channel by increasing run off so that channels tend to enlarge over time. Channels may initially aggrade during building activities due to increased sediment supply to urban streams channels (Wolman 1967; Wolman and Schick 1967). After urbanization is complete and sediment sources have been reduced, channel erosion and channel enlargement may become pronounced. Since such changes are some of the reason for channelization of urban streams (Brookes 1988; Brookes and Shields 1996), channel impacts often extends downstream of the urbanized area (Gregory and Downs 1992).

The urbanization of a river basin, amongst other things lead to the removal of vegetations and the establishment of other land uses like roads, buildings, houses, parking spaces among others. Also these uses considerable reduced groundwater recharge with the attendant increase in surface run off. Gregory and Walling (2007), affirm that the construction of houses and related engineering works tend to increase sediment generation and yield in a drainage basin.

Wolman (1967), identified three stages in the urbanization process of a drainage basin. These include: (i) an initial stable or equilibrium condition in which the landscape may be primarily agricultural (ii) a period of constructional activity during which bare land is exposed to erosion and (iii) a final stage consisting of new urban landscape dominated by streets, roof tops, sewers and paved surfaces.

In the Orogodo river basin, which is the study area, the urbanization process is in the second and third stages in which there is a massive constructional activity coupled with the development of new urban landscape dominated by streets, roof tops and impervious surfaces.

However, if the increase in the runoff and sediment generated from such impervious sites within the urban catchments are large enough, the river cannot make internal adjustment to maintain the previous equilibrium state. Instead, the additional discharge introduce imbalance into the stream channel system sufficient to initiate significant changes in both the channel capacity and hydraulic geometry until a new equilibrium state is re-established (Oyegun, 1994).

Several studies have been carried out in Orogodo river basin, but most of them have not specifically addressed the problem of urbanization as related to its channel dynamics. The aim of this study therefore, is to examine the effect of stream channel adjustment as induced by urbanization. This will be achieved by looking at the following objectives:

- To examine the effect of impervious surfaces in the urban landscape on flow characteristics in the basin;
- To examine the process involved in stream channel enlargement.
- To evaluate the implication of socio-economic development and basin management as it relates to the study area.

Study Area

The study area was carried out in the mid stream urbanized section of Orogodo river. The river is a short (about 50km in length) located in Delta State of Nigeria. It lies between latitude 5^{o} 10' and 6^{o} 20' and longitude 6^{o} 10' 6^{o} 26' East (Fig 1). The river is fed principally by ground seepage from aquifer in the thick rainforest zone of Mbiri and secondly by precipitation, municipal effluence and surface run off from riparian communities. It flows through Agbor main town, Owas-Ofie, Ekunma-Abavo, Oyoko and ends in a swamp between Obazagbon-Nugu and the oil rich town of Oben in Edo State.

The river basin is made up of the soil type known as ferrasols, which precisely is the red and brown soil in abundantly free iron oxides. The weathering profile consists mostly of red and yellow earth and loose, poorly sorted sand and in some places sandy with clay loam. It's nature makes for easy cultivation and also suffers from excessive internal drainage and intense leaching.

The study area is located in the humid tropical setting. The natural vegetation of moist tropical rainforest has been destroyed by shifting cultivation over much of the area. Today the landscape is mosaic of different stages of agricultural vegetation and deteriorated derived savanna community. The mean annual rainfall ranges from 1120mm in the north to 1490mm in the south. Over 60 percent of the rainstorm has maximum intensities greater than 25mm hr^{-1} (Lal, 1976) which means that majority of rain events cause actual soil loss in this area.

Due to population pressure on land, steeper slopes and marginal lands are increasingly being put into traditional cultivation. Also, the tendency towards reduced fallow to the point of continuous cultivation is common place. The environmental manifestation of these trends include augmented stream flow and sediment discharge.

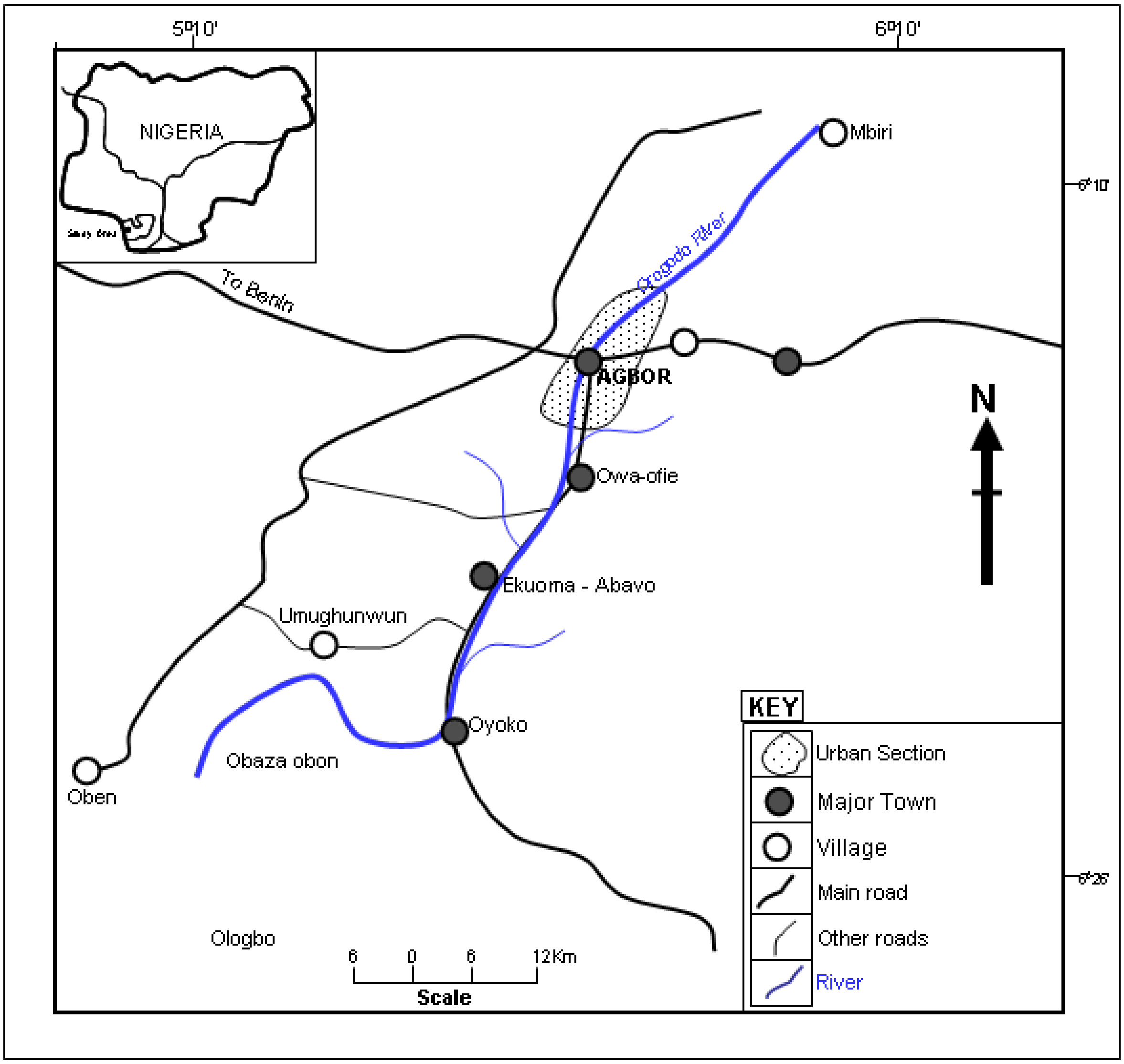


FIG. 1: MAP OF STUDY AREA

Materials and Methods

In order to investigate the morphological characteristics of river Orogodo, at the urbanized section threefold research strategy was adopted. The first step involved the selection of ten sites (10) along the river profile with a distance of five kilometer (5km) apart since the entire distance of the long profile is 50km. However, investigation was carried out within the span of 10km which is the urbanized section of the river. This was done in order to obtain information on stream channel bank full cross sectional area, basin morphometry and urban land use characteristics. The sites were detailed for measurement of stream hydraulic variables of width, depth, velocity and discharge.

In order to measure each station for channel morphology at bank full stage, the cross sectional length was divided into segments of one metre (1m) each. Secondly, two carefully surveyed poles were placed on the bank top of each section and a tagged measured cable was stretched across the stream such that it is level with the bank top surface. The bank full depth at each tagged segment is the vertical distance between the bed surface and the cable at the bank top. A horizontal-axis-Ott-type current meter mounted on a wading rod was used in the field measurement of velocity for each segment at the mid-segment of the stream. The time for each velocity measurement was 60 seconds. This measurement was carried out from the month of July – October, 2012 during which runoff and sediment discharge is at its peak level.

In order to obtain data on the total amount of rainfall, a non-recording rain gauge was planted on the ground within the basin and the amount of rainfall collected for each rainfall day, and total for each month spanning from January – December for two years (2010-2012).

Infiltration rate or capacity was determined using a double ring infiltrometer. The outer ring according to Winter (1974) was meant to act as a buffer against the inner ring and to prevent lateral water seepage. The inner is smaller and longer than the outer one. Two infiltrometers were placed on both impervious and non-impervious surface area. At the end of each rainfall episodes, the amount of water that went into each infiltrometer was recorded. Each test lasted for 60 minutes (1hr). This was done for each month spanning from January to December, (2010-2012).

In order to generate data on amount of discharge for each station, velocity/area discharge estimation necessitated the survey of the water prism geometry which was used in at-a-station hydraulic geometry and analysis of downstream trend in flow characteristics. An improvised gauging was constructed along the river profile at each segment. Current meter was used to measure depth at 0.6m. Discharge was derived using the formula below:

$$q_1 = \left[\frac{di_1 + di_2}{2} \right]$$

Where di_1 and di_2 are marginal depths and marginal velocities are means in the verticals measured by current water at 0.6 x depth.

Measurement was carried out on selected days from the months of March – November 2010 – 2012 and observed for interval of 1hr (60 seconds). Data on other morphometric variables such as basin area of each of the station, relief ratio, were measured from a topographic map of Agbor (Edition 2) produced and published by Federal Surveys, Nigeria, 1995 on a scale of 1:50,000.

Data on land use was obtained through systematic examination of landuse maps from Ministry of Lands and Surveys, 2009 which was modified to reflect the landuse maps for the study.

In order to determine if a relationship exists between index of channel size and urban land use variables, the multiple regression analysis was explored. This was done using the step wise method. The dependent variables consists of both morphometric and landuse factors which include: basin area, relief ratio, channel bankfull-cross sectional area, average basin overland flow, overland flow inhibition factor, interaction variable, paved roads/streets, commercial buildings, paved residential houses, industrial estate, cultivable land, undeveloped land and wooded land. While the independent variables are: amount of rainfall, volume of drainage discharge and infiltration capacity of the soil.

Morphometric variables

Y_1 = basin area; Y_2 = relief ratio; Y_3 = channel bankfull cross-section area; Y_4 = average basin overland flow; Y_5 = overland flow inhibition factor; Y_6 = interaction variable

Basin land use variables:

Y_7 = roads/streets; Y_8 = commercial buildings; Y_9 = residential houses; Y_{10} = industrial estate; Y_{11} = cultivable land; Y_{12} = undeveloped land; Y_{13} = wooded land

Independent variables:

X_1 = amount of rainfall; X_2 = volume of drainage discharge; X_3 = infiltration capacity of the soil

Correlation matrixes of the dependent and independent variables were carried using stepwise multiple regressions. This method has the quality of selecting independent variables that statistically explain the greatest variables in independent variables. This is a search procedure with a prime focus on identifying the independent variable (s) that actually possesses strong relationship with the dependent variables. The stepwise multiple regressions involves among other procedure, adding one variable at a time to the regression equation.

The product-moment correlation matrix showing the inter-correlated variables was subjected to factor analysis in order to eliminate the problem of collinearity. The final variables in the regression model were selected from the rotated factor loadings matrix.

Result and Discussion

A survey of the basin revealed that sixty percent (60%) of the area is under impervious surfaces such as paved roads/streets, commercial buildings, residential houses, and industrial estates while the remaining forty percent (40%) of the area lay under non-impervious surface such as cultivable land, undeveloped land and wooded land. It was found that stream basin in the impervious areas displayed larger stream bankfull cross-sectional areas as compared to those under the non-impervious cover (See Table 1). For example, the impervious surface area had a mean value of 6.11km^2 while the non-pervious was 1.17km^2.

Table 1: Stream Channel Size Variation in Relation to Land Use

Basin surface land use	Average bankfull stream cross-sectional area (m^2)	Mean values
Impervious surfaces		
Roads/street surfaces	7.32	
Houses (residential) surfaces	9.52	
Commercial building surfaces	2.23	6.11m^2
Industrial estates	5.36	
Pervious surfaces		
Cultivable land	2.44	
Undeveloped land	1.15	1.17m^2
Wooded land	1.10	

Source: Fieldwork, 2012

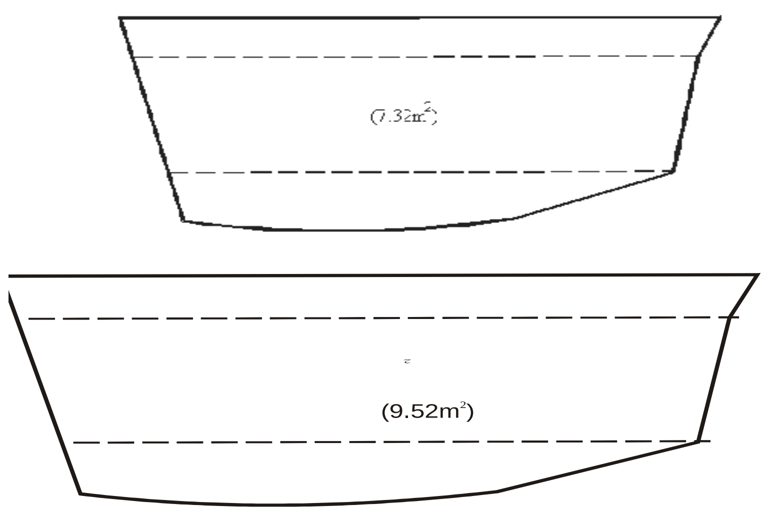
River channel tend to vary within each land use category depending on whether impervious or previous. Hammer (1972) and Dune and Leopold (1987) showed that channel size is best expressed as a function of watershed size.

Figures 2(a) indicates average bankfull stream cross-sectional area that drains areas made up of impervious surfaces such as paved roads/streets, while figure 2(b) shows stream cross-sectional areas that passes through areas made up of impervious surfaces of residential compounds.

Fig 2: Stream Channel Cross-Sections Representing Areas Draining Impervious Basin Sections (A) Roads and (B) (Residential Houses). Dashed Lines Indicate Water Levels Within Which Hydraulic Variables Were Measured

(a)

(b)

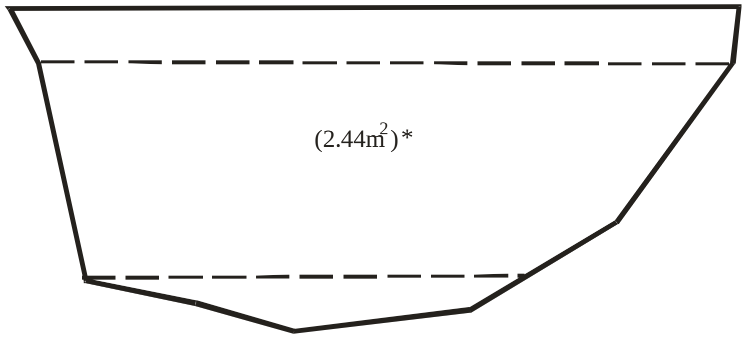


Source: Field work, 2012.

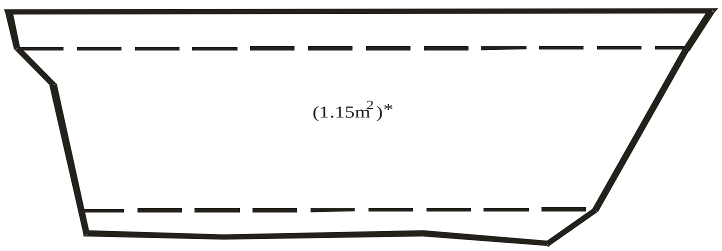
Figures 3(a) indicates average bank full stream cross-sectional area that drains areas made up of pervious surfaces such as cultivated land area, while figure 3(b) shows stream cross-sectional areas that passes through areas made up of pervious surfaces made up of undeveloped lands.

Figures 3: Stream Channel Cross-Sections Representing Areas Draining Non-Pervious Basin Sections (A) Cultivated and (B) (Undeveloped Land). Dashed Lines Indicate Water Levels within Which Hydraulic Variables Were Measured Values of Cross-Sectional Area

(a)



(b)



Source: Field work, 2012.

From Figures 2 and 3, it can be deduced that stream channel size is consistently larger for basins draining areas subjected to long period of construction (such as roads/streets, rooftops, commercial building surfaces) than those under uncultivable and unused land surfaces. This is due to the increase in storm stream flow resulting from such urban land use construction. The stream adjusts to this increased discharge by first increasing its velocity to attain sufficient flow competence. This initiates channel scourge and size adjustment, while under cultivated and undeveloped land, the stream velocity is lower. It appears to stabilize at a velocity that is just sufficient to maintain the new stable channel configuration. Further adjustments continue until a new equilibrium relation is achieved among hydraulic variables. However, the stream adjustment is in a state of flux, since the basin studied is frequently put to different land uses.

Table 2: Key to Thirteen Variables used in Factor Analysis

S/N	**Description of Variables**	**Symbols**
1.	Basin area	BA
2.	Relief ratio	Rh
3.	Channel bankful cross-section area	CBCA
4.	Average basin overland flow	ABOF
5.	Overland flow inhibition factor	OFF
6.	Interaction variable	INTER
7.	Roads/street surfaces	RD
8.	Commercial building surfaces	CBS
9.	Residential houses surfaces	RHS
10.	Industrial Estate	IE
11.	Cultivable land	CL
12.	Undeveloped land	UDL
13.	Wooded land	WDL

Source: Fieldwork, (2012)

Thirteen variables of impervious and non-impervious land use surfaces and morphometric attributes in the study area was subjected to factor analysis as shown in Table 2 and Appendix I-III.

The salient aspect of the factor analysis results are shown in Appendix I to III. The correlation among the 13 variables in the analysis is shown in Appendix I. Since one of the goals of factor analysis is to obtain "factors" that help to explain these correlations, the variables must be related to each other for a factor model to be appropriate.

The next important stage is the extraction of factors and factor loadings on the variables. Since all variables and factors are usually expressed in standardized form and since there are 13 variables used in this study and each is standardized to have a variance of 1, the total variance here is 13. Thus, only factors that account for variances greater than one (the eigen-values is greater than 1) were extracted. Factors with a variance less than one are no better than a single variable since each variable has a variance of one. The extracted factors, their eigen-values and the percentage of total variance accounted for by each factor are shown in Appendix III. The five factors extracted accounted for almost 86 percent of the total variance in the original 13 variables.

The factor loadings are co-efficient which indicate the extent of the relationship between a variable and a factor. Thus, factors with high coefficient for a variable are closely related to the variable.

A further step from the above is the interpretation of the factors as representing a group of variables. For this purpose, only factors with loadings greater than 0.5 was considered for interpretation and labeling. Thus, residential houses, roads, commercial buildings, interaction variable and overland flow factor which generates storm discharge has been named surface runoff factor. For similar considerations, factors two, three, four and five have been variously named as channel elevation, slope form, vegetal surface and areas in plantation.

Next, factors scores on each of the five factors were computed. The factor scores represent the new values of the new variables (the factors) on the original observations. They serve as input into the next stage of the analysis- the step-wise multiple regression analysis.

In attempting explanations of the level of river channel adjustment, three independent or explanatory variables were utilized in a step-wise multiple regression analysis. The three independent variables are the amount of rainfall X_1; volume of drainage discharge (water and sediment-X_2) and infiltration capacity of the soil X_3.

The three independent variables were regressed against each of the five factors extracted from the factor analysis- these factors constitute the dependent variables that induce channel adjustment of the river in the study area. The results of the regression analysis are shown in Appendix V. As with step-wise regression, the independent variable that explains the greatest amount of variance in the dependent variable is entered first in the regression. Next, the partial correlations between each dependent variable and all other independent variables are computed and the independent variables with the highest partial correlation among all others are then entered at the second step, and so on. This procedure continues until all the specified independent variables are included (as in Appendix V).

Thus from Appendix V, about 23 percent of the variance in a level of river channel adjustment is collectively accounted for by all the three independent or explanatory variables of which, infiltration capacity of the soil explains 18.5 percent of the variance that was first entered.

The amount of rainfall (X_1) with a higher partial correlation than the volume of drainage discharge (X_2) was next entered. The amount of rainfall factor together with the factor of infiltration capacity of the soil collectively explains about 21 percent of the variance in stream channel adjustment of river Orogodo. Thus, the volume of drainage discharge account for only 1.8 of the variance in this dependent variable.

For the dependent variable (V4 that is factor) only two of the three independent variables were entered in the stepwise regression. This two independent variables – amount of rainfall and infiltration capacity of the soil- together account for about 45 percent of the total variance of this dependent variable in the river basin. The third independent variable amount of rainfall-is of no importance in the explanation of the variance in the dependent variable V4 and was therefore not entered in the regression.

Summary of Findings

The following sequence of statement summarizes the findings of this study;

- The long run environmental effects of the creation of impervious surface induced by urbanization consequently lead to increased volume of surface runoff and soil erosion.
- The surface runoff and sediment loss reach the stream to increase stream flow discharge, peak flow, and sediment load. These in turn introduce imbalances into the stream channel system sufficient to initiate channel adjustments and enlargement of activities.

- Over the years, stream basin areas put under construction by man for different land use purposes have developed larger stream channel bankfull cross-sectional areas than those under either fallow or forest, due to augmented discharges and associated stream channel erosional activities.
- The study also revealed that five specific factors influence the amount of discharge (water and sediment) to the river channel in Orogodo river basin, namely; runoff, vegetal surface, slope form, channel elevation and areas of economic trees (silviculture).
- Channel enlargement appears to be directly related to increased flood magnitudes, but channel enlargement does not keep pace with increasing flood magnitudes in a one to one manner. This suggests that increased flood flows are partially accommodated by increased over bank flow or increase in peak flow velocities, which may represent an intermediate step in the long term equilibrium adjustment of a stream to changing hydrologic regime.
- A geomorphic threshold appears to be operative in the relationship of urban land, development areas versus channel enlargement ratio such that above a certain degree of constructional activities, a radical increase in the effects on flood magnitudes and channel enlargement results.

The result of adjustment displayed by both impervious in the Orogodo river channel, are in line with the findings of the work carried out by Odemerho, 1984 in South Western Nigeria (Humid Tropics), which had values of 6.45m^2 in areas draining impervious basin sections of roads and 10.52m^2 of residential houses. On the other hand, values of 3.46m^2 was obtained for areas draining non-impervious sections of cultivated areas and 1.25m^2 of undeveloped lands.

Conclusion and Recommendations

Studies in urbanized watershed in reference to the stream channel in River Orogodo has demonstrated to be consistently larger for basin under impervious land surfaces due to the effect of urbanization and increase run off. The stream adjust to this increase storm flow by first increasing its velocity and later enlarging its channel to accommodate the discharge, and eventually decreasing over bank flow. These changes which are in a state of flux will continue until a new equilibrium state is reached. But should changes continue in the basin, the equilibrium state becomes unattainable unless urbanization process ceases.

Therefore, changes in stream flow regime and channel morphology associated with impervious land use as a result of urban development are of considerable consequences in basin management. Such problems includes:-

- Decreased channel conveyance due to increasing deposition of sediments;
- More frequent and severe flash flooding;
- Increased channel erosion;
- Reduced water quality as result of increased period of low flows, and
- Reductions in aesthetic and recreational value of streams

It is therefore suggested that an integrated basin land use method such as residential and commercial housing building codes be improved upon with emphasis on the roofing pattern and the surrounding surface in order to channel rain water into pipes that run into lawns and bare surfaces made which are made more pervious. Also, the approach should involve the construction of underground water drains that should be channeled into reservoirs, treated and sent into taps for house hold consumption. This will help to reduce the amount of peak flow during severe storm conditions into urban river channels. Moreover, farming practices along the cultivated land use areas should involve modern farming techniques that will reduce the state of imperviousness.

The positive relationship between land use and increase in the amount of discharge in the study area calls for government attention for the need to create a stabilization scheme in the river Orogodo, in order to contain excess runoff.

The development of green belts/lawns and other options that will encourage infiltration rate in the area will be more successful than the development of drains. This can be done by cultivating lawns on bare surfaces in residential compounds, commercial housing areas as well as pedestrian walk ways. The inhabitants of the area should be encouraged to carryout rain water harvesting. Rain water harvesting refers to the collection of rain water and its storage for domestic use. If this is done, it will help to reduce peak flow from the impervious surfaces to the river channel in every rainfall episode.

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Appendix I: Correlation Matrix of Land use and Morphometric Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	0.082	1.000												
3	-.082	-1.000	1.000											
4	0.676	0.246	-2.246	1.00										
5	-0.148	-0.176	0.176	0.053	1.000									
6	0.553	0.146	-0.146	0.435	0.696	1.000								
7	-0.296	0.022	-0.022	0.028	0.538	-0.747	1.000							
8	-0.533	0.089	-0.089	-0.326	0.403	-0.800	0.794	1.000						
9	-0.432	0.107	-0.107	-0.156	0.481	-0.781	0.791	0.946	1.000					
10	-0.260	0.157	-1.57	-0.057	0.216	-0.285	0.268	0.333	0.181	0.340	1.000			
11	-0.204	0.148	-0.148	-0.202	0.118	-0.433	0.236	0.217	0.335	0.623	0.713	1.000		
12	0.605	-0.337	0.337	0.389	0.027	0.482	-0399	-0.583	-0.489	-0.337	-0136	-0.307	1.000	
13	0.077	0.052	-0.052	0.027	-0.023	0.017	-0.093	0.073	-0.117	0.076	-0.054	0.116	0.002	1.000

Source: Author, 2012

Appendix II: Factor Loading on Landuse and Morphometric Variables

Variables	Symbols of Variables	Factor I	Factor II	Factor III	Factor IV	Factor V	Communality
1	BA	-0.281	0.820	0.053	-0.170	0.099	0.792
2	Rh	-0.016	0.073	0.972	0.084	0.019	0.958
3	CBCA	0.016	-0.073	0.972	-0.084	-0.019	0.958
4	ABOF	0.004	0.888	0.250	-0.029	-0.037	0.853
5	OFF	0.738	0.231	-0.286	0.164	0.007	0.707
6	INTER	-0.826	0.369	0.162	-0.259	-0.040	0.914
7	RDS	0.891	-0.026	0.075	0.101	-0.106	2.822
8	CBS	0.864	-0.411	0.156	-0.055	-0.011	0.943
9	RHS	0.896	-0.239	0.153	0.122	-0.044	0.900
10	IE	0.096	0.031	0.093	0.905	-0.163	0.864
11	CL	0.160	-0.187	0.107	0.886	0.157	0.881
12	UDL	-0.336	0.677	-0.456	-0.081	-0.019	0.786
13	WDL	-0.055	0.040	0.035	0.034	0.968	0.944
Variance Explained		37.7%	17.2%	12.1%	11.2%	7.4%	

Total explained: 85.6%
Source: Field work, 2012

Appendix III: Factors, Eigen-Values and Percent of Variance

Factors	Eigen-value	Percent of Variance	Cumulative Percent
1	5.28447	37.7	37.7
2	2.40349	17.2	54.9
3	1.69999	12.1	67.1
4	1.56331	11.2	78.2
5	1.03343	7.4	85.6

Source: Field work, 2012

Appendix IV: Factors Loadings Against Variables and Names of Factors

Variables	Variable Symbols	Variable Names	Factor I	Factor II	Factor III	Factor IV	Factor V
			Surface runoff	Channel elevation	Slope Form	Vegetal surface(gr ass land)	Areas in plantation
V9	RHS	Residential houses surfaces	0.89596				
V7	RDS	Roads/street surfaces	0.89139				
V8	CBS	Commercial building surfaces	0.86404				
V6	INTER	Interaction variable	-0.82631				
V5	OFF	Overland flow factor	0.73800				
V4	ABOF	Average basin overland flow		0.88806			
V1	BA	Basin area		0.81973			
V12	UDLS	Undeveloped land surfaces		0.67725			
V2	Rh	Relief ratio			0.97229		
V3	CBCA	Channel bankful cross-section area			-0.97229		
V10	IE	Industrial Estate				0.90470	
V11	CLS	Cultivable land surfaces				0.88582	
V13	WDL	Wooded land					0.96827

Source: Field work, 2012.

Appendix V: Stepwise Regression with V1 – V5 as Dependent Variables and XI – X3 Independent Variables

Dependent Variable	Step No	Independent Variables Entered	Multiple R	R^2	R^2 Change
V1	1	X_3	0.43059	0.18540	0.18540
	2	X_1	0.46301	0.21437	0.02897
	3	X_2	0.48207	0.23239	0.01802
V2	1	X_3	0.36558	0.13365	0.13365
	2	X_2	0.33286	0.11079	0.03518
V3	1	X_3	0.31420	0.09872	0.09872
	2	X_2	0.33286	0.11079	0.01207
	3	X_1	0.33818	0.11436	0.00357
V4	1	X_1	0.55616	0.30932	0.30932
	2	X_3	0.66859	0.44702	0.13771
V5	1	X_3	0.55472	0.30771	0.30771
	2	X_2	0.55956	0.31311	0.00540
	3	X_1	0.56363	0.31768	0.00457

Source: Field work, 2012.