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Managing High Runoff Discharge in the Urbanized Basins of Asa River Catchment Area of Ilorin, Nigeria

GESTION DE DECHARGE DES EAUX DE RUISSELLEMENT DANS LES BASSINS URBANISES DE LA RIVIERE ASA DANS LA REGION D'ILORIN, AU NIGERIA

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Abstract: Incidence of flood has been on the increase in Ilorin for sometime; and this exemplifies the problem operating in most urban centres in Nigeria. Increase in runoff production in an urbanized catchment is a function, among other factors of to increase in percentage paved area brought about by deforestation activities and poor environmental attitude of the people. This study examines the relationship between runoff discharge and basin characteristics in Ilorin. Data used were collected directly from the field over a period of one calendar year. Rainfall data were collected in each basin using a standard rainguage of 20cm orifice while basin discharge was collected twice daily (8.00am and 6.30pm) using fabricated staff gauge graduated in centimeter. Basin morphometric attributes were computed from topographic map while landuse map was prepared from satellite imagery. Soil samples were collected and analysed for particle size distribution. The result obtained indicates that basin size and landuse have profound influence on the explanation of discharge in the basins. The study thus, recommends a number of options to efficient basin management in the city.
Keywords: Managing; High runoff discharge; Urbanized basin; Asa river catchment; Ilorin; Nigeria

Résumé: La fréquence des inondations est en augmentation dans la région d'Ilorin depuis un certain temps; et cela illustre le problème de la gestion des eaux dans la plupart des centres urbains au Nigéria. L'augmentation des inondations dans les bassins urbainisés est due au pourcentage accru des zones pavées et d'autres facteurs comme les activités de déforestation et une sensibilisation faible de la population à l'environnement. Cette étude examine la relation entre la décharge des eaux de ruissellement et les caractéristiques du bassin à Ilorin. Les données utilisées ont été recueillies directement sur le terrain pendant une année civile. Les données pluviométriques ont été collectées

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dans chaque bassin en utilisant l’ombromètre d’un orifice standardisé de 20cm et la décharge des eaux de bassin ont été recueillies deux fois par jour (à 8h00 et à 18h30) à l'aide d’un jauge graduée en centimètres. Les attributs morphométriques de bassin ont été calculés à partir de la carte topographique et la carte de l’utilisation des terres a été prépareé à partir des images satellites. Des échantillons de sol ont été prélevés et analysés pour la distribution granulométrique. Le résultat obtenu indique que la taille du bassin et de l'utilisation des terres ont une influence profonde sur la décharge des eaux dans les bassins. L'étude recommande donc un certain nombre d'options pour une gestion efficace des bassins dans la ville.

Mots-clés: Gestion; décharge de ruissellement; bassin urbanisé; bassin de la rivière Asa; Ilorin; Nigéria

1. INTRODUCTION

Problems associated with high runoff discharge have been a common occurrence in most parts of Ilorin for sometime (Enendu, 1981; Olaniran, 1983; Jimoh, 2000). This extreme hydro-climate event exemplifies the problem currently operating in most urban centres, not only in Nigeria but also in most developing countries of the world (Harun, 1982; Faniran, 1991); hence the need for studies relating to river catchment analysis. Previous studies conducted in humid temperate regions of Europe and America have identified catchment variables controlling streamflow pattern. These variables include, parameters of climate (Pitlick, 1994), landscape morphometry (Gregory and Walling, 1973), measures of soil characteristics (Freeze, 1980) and vegetation cover (Ward and Robinson, 1990). The contributing effect of these variables to catchment streamflow pattern, however depends partly on the scale. As the size of a basin increases, the variability in climate and physiography increases; thus, requiring more variables in predicting accurately the basin runoff patterns (Pitlick, 1994).

The little attention being paid to runoff studies in Nigeria is daily manifesting in water and water related problems being experienced in country (Faniran, 1991; Jimoh, 2003). As population density and land values rise in urban centres, floods become a greater problem both economically and as a threat to safety due to increase in runoff production which is caused by deforestation activities, increase in percentage paved area, and blockage of waterways among others. Olaniran (1983) reported three floods event in Ilorin in just one decade, causing untold hardships and damages in the town. This problem till date has not abated, hence, the need for more attention in studies relating to basin management in the city. Most works in this field have been carried out in humid temperate regions of Europe and America where there are better asses to research materials. Studies earlier conducted in this field in Nigeria include those of Adejuwon et. al., (1983), Ogunkoya et. al., (1984) and Anyandike and Phil Eze (1989); all focusing on less urbarnized basins, using selected few basin physiographic variables perceived as being important, leaving out many other variables unstudied. This current work thus seeks to advance the frontiers of knowledge by focusing on urbanized basins and incorporating those variables earlier left out unstudied in previous works. This is in an attempt to detecting those factors, from the numerous catchment controlling variables in Ilorin with the aim of suggesting possible management techniques for curtailing its problems. The study thus, specifically attempts to fulfill the following objectives:

a. generate runoff data in the four basins in the urbanized catchments,

b. examine the runoff regime in the selected basins,

c. analyse water budget characteristics in the urbanized catchments, and

d. evaluate the relationship between runoff and basin parameters and suggest management techniques for curtailing the extreme hydro-climatic events of flood.

2. THE STUDY AREA

Ilorin, the capital city of Kwara State Nigeria is the study area for this investigation. It lies between latitude $8^{0}24^{1}$N and $8^{0}36^{1}$ North and between longitude $4^{0}10^{1}$ and $4^{0}36^{1}$ East (Oyegun, 1983). The city has a humid tropical climate, which is characterised by wet and dry season. Rainy season in the city begins towards the end of March and ends in October with two peak periods in June and September. Temperature is uniformly high throughout the year and open air insolation can be very uncomfortable during the dry season (Oyegun, 1983)

Ilorin is underlain by Precambrian igneous metamorphic rocks of basement complex which are neither porous nor permeable except in places where they are deeply weathered or have zones of weakness. Substantial area of the town is also laid by sedimentary rock, which contains both primary and secondary laterites and alluvial deposits. The soil type has both sandy and clayey deposits lying on top of each other. While the sandy deposit is characterized by low water holding capacity, which encourages infiltration; the clayey deposit beneath results in water logging during rainy season; thus encouraging runoff generation in the city.

Urbanization process is fastly replacing the Guinea savannah vegetation in Ilorin with artificial (paved) surfaces with consequent effect on runoff generation, hence, frequent occurrence of flooding (Enendu, 1982; Olaniran, 1983), sediment yields (Jimoh, 1997) and erosion (Jimoh, 2000) in the city.

The city is drained mainly by consequent River Asa; and its tributary Rivers such as Aluko, Alalubosa, Okun, Osere, Agba and Atikeke form the four drainage basins being investigated in this study (Fig 1). The basins range in size between 5.8sqkm and 17.1sqkm. Two of the basins (Okun and Aluko) are located on the western part of River Asa, while the other two (Agba and Alalubosa) can be found on the eastern part of the river. Landuse pattern in the basins can be classified into built-up (paved) area, forest covered, farms and fallow area, area covered by grassland and bare surface area.

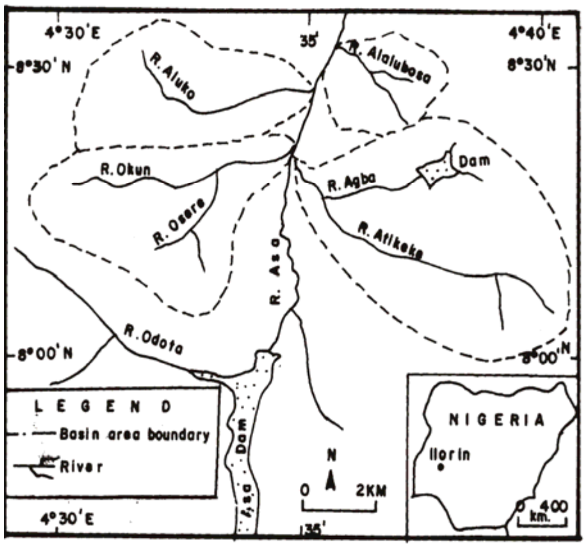

Fig. 1: Ilorin, showing the four drainage basins as the study area
Source: Oyegun (1986)

3. THE STUDY METHOD

Rainfall and basin discharge data were collected for a period of one calendar year (July 2005 – June 2006). Rainfall data were collected with standard raingauge of 20cm orifice in each of the basin while data on rate of river discharge were collected twice daily (8.00am and 6.30pm) at the outlet of each of the drainage basins using fabricated staff gauge graduated in centimeter. Streamflow discharge was subsequently calculated using velocity cross sectional area method; results of which were used in the calibration of rating equations for the studied basins. Values obtained from the daily rainfall and basin discharge were later used in deriving the weekly, monthly, seasonal and annual hydrological records for the studied basins. Runoff value was obtained as the ratio of basin discharge to basin area while percentage ratio of runoff value to rainfall amount in a basin gives the runoff coefficient for such a basin.

Monthly water budget positions in each of the studied basins were determined from evapotranspiration values calculated from the modified Thornthwaite (1948) formula using the temperature data obtained from the two weather stations in the city (Nigerian Meteorological Stations, Ilorin International Airport and Meteorological Station, Niger River Basin Development Authority, Ilorin). Basin morphometric attributes such as area, drainage density, streamlenght, etc were computed from Ilorin NW topographical map sheet 223 of scale 1:50,000 after the necessary corrections as explained by Morisawa (1957). Landuse/vegetation map of the study area was prepared from satellite imagery obtained from RECTAS, OAU, Ile-Ife using spectral signatures with other available maps serving as basemaps. A total of fifty (50) soil samples were also taken based on ratio analysis to a depth of 30cm in the four basins and analysed for particle size distribution.

Data obtained in the study were subjected to correlation and factor analysis to determine and explain the nature and magnitude of relationships between the parameters of basin runoff (dependable variables) and twenty six independent variables of climate (rainfall and temperature), morphometric parameters (e.g basin area, length, shape etc), landuse and soil.

4. REVIEW OF RELATED LITERATURE

4.1 Factors affecting catchment runoff

Results from past studies have revealed a number of variables controlling catchment runoff pattern. Some of the identified variables include parameters of climate, namely rainfall and temperature. Others are landscape (morphometric) factors of basin size, slope, length, shape, stream length, drainage density, etc, soil, vegetation characteristics and human factors. The contributing effects of these variables to volume of catchment runoff pattern however depend on the size of the drainage basin (Pitlick, 1994). As the size of drainage basin increases, the more numerous the runoff influencing parameters. This is because of variability in climate and physiography with increasing basin size.

Rainfall is the most important and most variable hydro-meteorological element affecting catchment runoff. It has a fundamental effect both on catchment response and catchment process (Hamlin, 1983). Catchment runoff is generated when rainfall intensity exceeds infiltration capacity of the soil (Horton, 1933). Thus, the longer the storm duration, the higher the rainfall amount and the larger the saturation zones over which runoff is generated. Runoff contributing area therefore expands and contracts with catchment storm size (Hewlett and Nutter, 1970; Whipkey and Kirkby, 1978)

Temperature, through the supply of energy for vaporization affects catchment runoff pattern either directly through evaporation process from open water bodies such as ponds, lakes, rivers, wet roads and even raindrops as they fall from cloud or indirectly through the process of transpiration from living plants, mainly by way of leaves. Evaporation process takes place continually while transpiration occurs at potential maximum rate until a stage of soil moisture deficiency is reached when the uptake of water no longer balances transpiration (Thonthwaite and Mather, 1955). The combined effect of these two processes (i.e. evaporation and transpiration) as they influence catchment water loss is termed evapotranspiration.

Land morphometry represents the topographic expression of land by way of area, slope, shape, length, etc. These parameters affect catchment streamflow pattern through their influence on concentration time (Gregory and Walling, 1973). The significance of these landscape parameters was pointed out by Morisawa (1962) when she expressed catchment streamflow pattern as a general function of geomorphology of a watershed. This assertion still stand valid; as various studies have also observed that, geomorphic characteristics of a river basin play a key role in controlling the basin hydrology (Adejuwon, et. Al, Ogunkoya, et.al 1983; Pitlick, 1994; Ifabiyi, 2004).

Soil is another characteristic which affects catchment runoff pattern. It is produced from inter-related factors of relief, climate, vegetation, parent organism and time (Olson, 1981). The influence of soil type on the component of hydrological cycle has long been a major theme in hydrological analysis of a drainage system, as it represents a reservoir that has to be filled before rainfall contributes to runoff (Roels, 1984). Soil through its physical characteristics of compaction, texture, temperature, antecedent moisture content and hydraulic conductivity affects infiltration capacity (Atoyebi, 1995), hence its effect on movement of rainwater as either surface or underground water.

Catchment streamflow pattern is also being significantly affected by vegetation cover. This is through its biological, thermal and physical effects (Jones, 1997). Vegetation reduces catchment runoff through its thick litter production (Ifabiyi, 2000) and through the effect of evapotranspiration resulting from canopy interception (Pilgrims, et. al, 1982) and plant stage of growth. While interception by plant canopies aid evapotranspiration process, thick litter production increases soil organic matter which promotes the activities of soil organisms, thus opening up soil pores resulting in high infiltration rates (Atoyebi, 1995), hence low runoff process. Afforestation thus results in low flows, while forest clear cut increases runoff volumes resulting in higher peak discharge due to reduction in concentration time caused by more overland flow.

The theoretical operation of hydrological cycle within a drainage basin is however being affected by urbanization process. This is mainly through the increase in amount of paved surfaces (Jones, 1977). Increase in urban development thus, results in corresponding increase in runoff volumes, reduction in lag time due to increase in velocity of overland flow and subsequent reduction in infiltration capacity of soil (Roels, 1984). However, factor affecting catchment runoff increases as the size of a catchment increases. This is due to variability in climate, physiography and even socio-economic characteristic of the population.

4.2 Data analysis and discussion of results.

4.2.1 Morphometric and physiographic parameters of the basins

Contained in Table 1 is the computed morphometric and physiographic characteristics of the studied basins.

Table 1: Morphometric and physiographic parameters of the studied basins

	Morphometric characteristics	Agba drainage basins	Alalubosa drainage basin	Aluko drainage basin	Okun drainage basin
1	Basin area (59km)	17.1	5.8	9.3	12.5
2	Basin length (km)	7	2.7	4.6	6.1
3	Basin slope (0)	0.35	0.51	0.44	0.34
4	Drainage density	0.66	0.47	0.41	0.57
5	Bifurcation ratio	2.0	2.0	1.0	3.0
6	Stream frequency	0.41	0.52	0.11	0.32
7	Mainstream length (km)	6.3	2.1	3.8	5.7
8	Basin shape	0.35	0.80	0.44	0.34
9	Elongation ratio	1.55	2.1	2.01	1.70
10	Circulatory ratio	0.74	0.95	0.56	0.60
11	Relief ratio	0.04	0.15	0.08	0.06
12	Leminiscate ratio	0.72	0.31	0.57	0.74
13	Mean elevation (meters)	3.06	300	293	300
14	Percentage area in ponds & lakes	2.98	0	0	0
15	Total stream length	11.3	2.7	3.8	7.1
	Landuse characteristics				
16	Percentage built-up area	66.5	84.5	97.8	67.2
17	Percentage forest area	11.3	1.7	-	10.4

To be continued

Continued

	Morphometric characteristics	Agba drainage basins	Alalubosa drainage basin	Aluko drainage basin	Okun drainage basin
18	Percentage farms and fallow area	8.2	3.5	-	2.4
19	Percentage grassland area	12.2	8.6	1.1	18.5
20	Percentage bare surface area	1.8	1.7	2.3	1.6
	Soil characteristics				
21	Percentage sand	86.0	85.4	79.9	85.5
22	Percentage silt	6.95	6.95	12.9	7.8
23	Percentage clay	6.95	7.65	7.5	6.75

Source: The Authors Field survey

Basin area ranges in size from 5.8 to 17.1sq.km, while total stream length ranges between 2.7 and 11.3km. Mean elevation ranges from 293 to 306meters. Built-up area ranges between 66.5 and 97.8% with a mean value of 79% while percentage area covered by forest ranges between 1.7 and 11.3sqkm with a mean value of 5.8sqkm.

4.2.2 Runoff regimes

Runoff discharge in the studied basins reflects closely the rainfall pattern with periods of peak maximum discharge coinciding with periods of heavy rainfalls. (Fig.2). Total rainy season runoff values in the basins ranges between 336.8mm in Agba and 492.6mm in Aluko drainage basins. These values represents between 87.3 and 99% of the total runoff generated in the two basins for the study period. Thus, while Agba drainage basin can be said to have generated the least total percentage runoff in rainy season, Aluko drainage basin, which is the most, urbanized generated the highest total percentage runoff. This finding reflect the amount of paved surfaces in the two basins. While Agba drainage basin has a percentage built-up area of 66.5% with more than 31% of its remaining land area occupied by different vegetation types; Aluko drainage basin is paved up to 97.8% with less than 2% of its remaining land area covered by only grassland. Thus, while more than 31% land area in Agba encouraged infiltration process, Aluko drainage basin which is virtually empty of vegetation and with comparatively higher steep slope (Table 1) have very short time to peak, time of concentration, travel time and lag time. Thus, Aluko drainage basin discharges almost all its water immediately after each rainfall event as the basin surface area which is almost completely paved up disallows infiltration during rainy season by encouraging quickflows. The same scenario operates in the two remaining basins with Alalubosa drainage basin with percentage paved area of 84.5 and Okun with percentage paved area of 67.2 generating 94.6 and 85.8% as rainy season percentage runoff amounts respectively. Dry season percentage runoff amount however ranges between 1.1mm in Aluko and 14.3mm in Okun. The higher dry season percentage runoff amounts in Agba and Okun basins are being sustained by groundwater seepage in the two basins, as infiltration process which took place during the rainy season encouraged by different vegetation types aids in sustaining dry season runoff discharge in the two basins, though not at a very high value because of level of urban development which is more than 65%.

The weekly discharge regime in the studied basin (Fig. 3) presents a clearer picture of river discharge patterns in the study area. Streams in the studied basins exhibit quick response to rainfall events, particularly during the rainy season; thus, maximum discharges were generally high in all the basins. This is due to amount to paved surface encouraged by high density of artificial drainage channels that have smooth bed and banks. This allows quick dissipation of rainfall intercepted out of the basin in a very short time following each rainfall event, hence, the very low mean and minimum discharge. This observation supports earlier findings of Hall (1984) and Roels (1984) which linked increase in runoff volumes to the degree of urban development. Rainfall events observed in the 7th week in Alalubosa and Agba and in the 31st and 32nd weeks in Aggba basin did not reflect in the shape of discharge hydrographs. Reason for this may not be unconnected with the antecedent weather conditions in the basins.

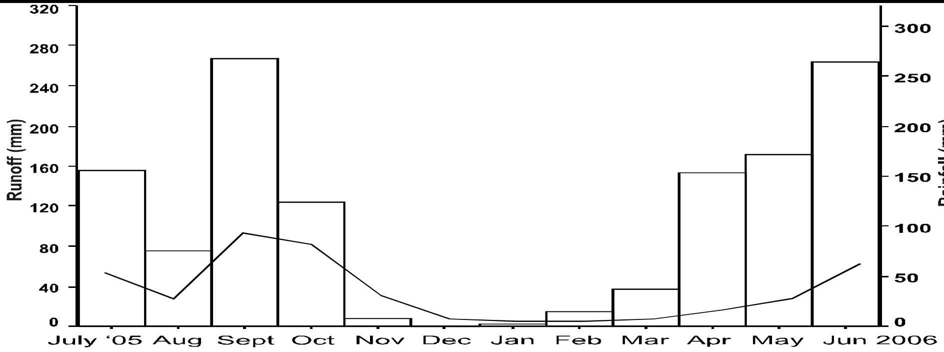

Fig. 2a Monthly rainfall-runoff regime in Agba basin
Source: Author担 fieldwork (2006)

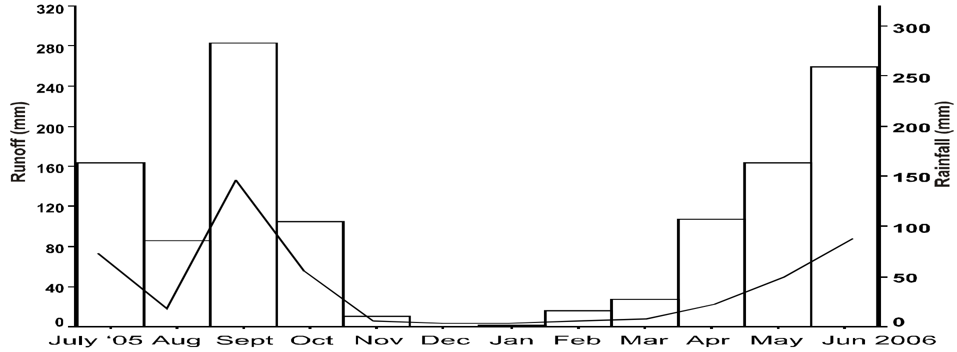

Fig. 2b Monthly rainfall-runoff regime in Alalubosa basin
Source: Author's fieldwork (2006)

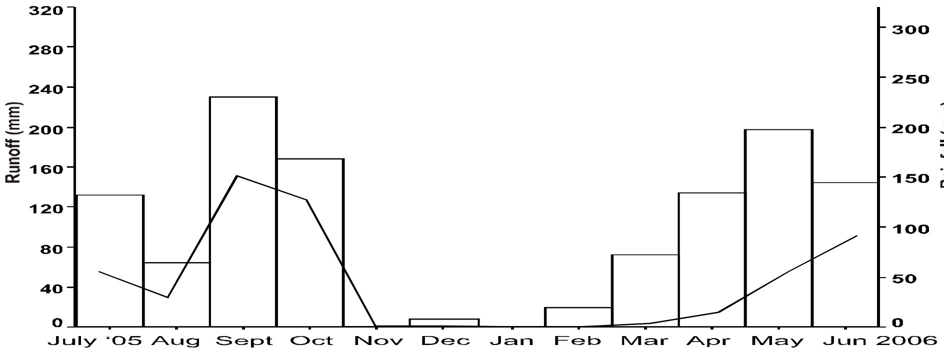

Fig. 2c Monthly rainfall-runoff regime in Aluko basin
Source: Author担 fieldwork (2006)

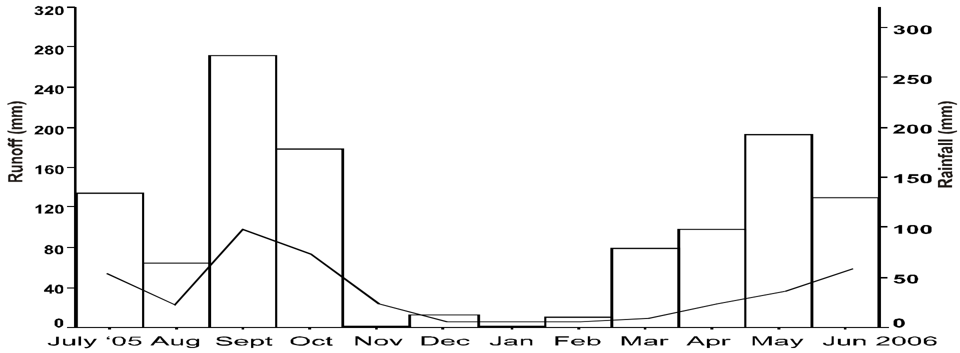

Fig. 2d Monthly rainfall-runoff regime in Okun basin
Source: Author担 fieldwork (2006)

4.2.3 Water budget position and runoff discharge

The antecedent soil moisture condition exercised great control on the hydrological process in the studied basins. This fact can be buttressed with the water budget graph plotted for the basins (Fig 4). All the studied basins had water deficits in their soils between the months of November and April. Significant water surplus was however observed between the months of May and July in all the basins before another deficit situation in August which can be attributed to August break in rainfall. The implication of this is that, the water surplus depicted by water budget graph between May and July is first utilized in recharging the high deficit in groundwater reserve between the months of November and April; while the little deficit in August is easily overcome by the September surplus, hence, the high runoff discharge in the city in September, which most times leads to flood incidence (Enendu, 1981; Olaniran, 1983).

4.2.4 Relationships between runoff discharge and basin parameters

The relationship between runoff discharge and basin parameters (Table 2) revealed a variety of interesting relationships, which can be understood in the multivariate nature of hydrological study. Total basin discharge is positively correlated with basin area (r = 0.97), basin length (r = 0.99), mainstream length (r = 0.97), leminiscate ratio (r = 0.94) and total stream length (r = 0.91), while total runoff is positively correlated with percentage built-up area (r = 0.93). Dry season runoff is also positively correlated with percentage built-up area (r = 0.98), while dry season discharge is positively correlated with basin area (r = 0.87), basin length (r = 0.86), drainage density (r = 0.96), total stream length (r = 0.91), mainstream length (r = 0.89) and percentage forest area (r = 0.99) and negatively correlated with percentage built up area (r = -0.96) and elongation ratio (r = -0.96). Rainy season runoff is negatively correlated with elevation (r = -0.92) and percentage forest area (r = -0.95).

To remove the disturbance caused by collinearity and interdependency among the parameters, factor analysis was applied. This statistical technique aids in determining the underlying structure of interrelationship among the variables. Table 2 shows that three factors are important in the explanation of basin runoff discharge after varimax rotation; their eigenvalues, percentages of variance and cumulative percentages are as presented on the table.

Component I which explained 54.3 percent of total variance, has significant loading (i.e. greater than ± 0.80) on basin area, basin length, basin shape, mainstream length, elongation ratio, relief ratio, leminiscate ratio and total stream length. This component describes the general trends resulting from increasing basin area i.e basin with large area have long length, long stream length, high leminiscate ratio, low elongation and relief ratio. These can thus be regarded as measures of basin size.

Component II has high loading on bifurcation ratio, percentage sand, silt, built-up area, grassland and bare surface area. The component explains 27.8 percent of the total variance and it suggests that basins, which are not built-up, are covered by grassland and have high percentage sand and little silt contents in their soils. The underlying dimension thus suggests landuse.

Component III explains 18 percent of total variance and has high loading in percentage area in lake, percentage clay, percentage area in farm and fallow, total rainfall, maximum weekly rainfall and evapotranspiration. It suggests that basins with high maximum weekly rainfall had high total rainfall, high potential evapotranspiration and are covered by farms and fallow area. It is thus indicative of basin climate.

The above result thus shows that basin size has a profound influence on the explanation of discharge pattern in the studied basins. This agrees with previous studies which have identified basin size as the most important catchment parameter controlling streamflow discharge (Anyandike and Phil Eze, 1989; Pitlick, 1994; Ifabiyi, 2004). This is because, the larger the basin, the greater the volume of rainfall it intercepts and the higher the peak discharge. Not only this, basin area is also highly correlated with other catchment characteristics which influence discharge such as basin length and stream length.

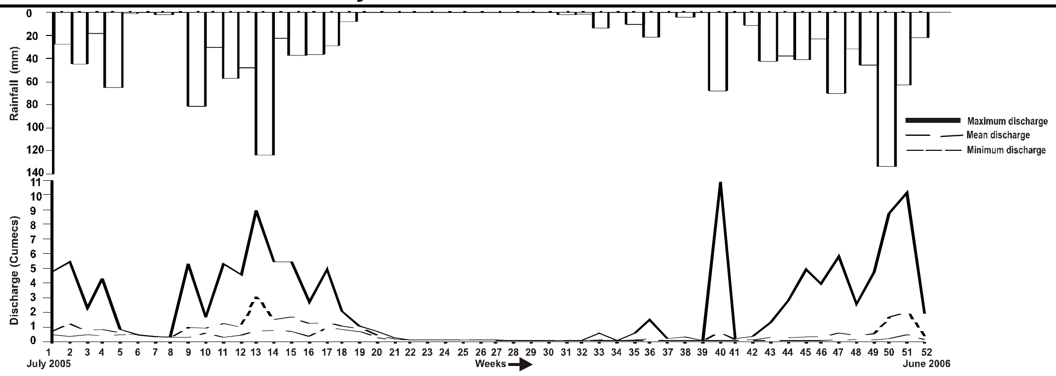

Fig. 3a Weekly rainfall and discharge regime in Agba basin
Source: Author's fieldwork (2006)

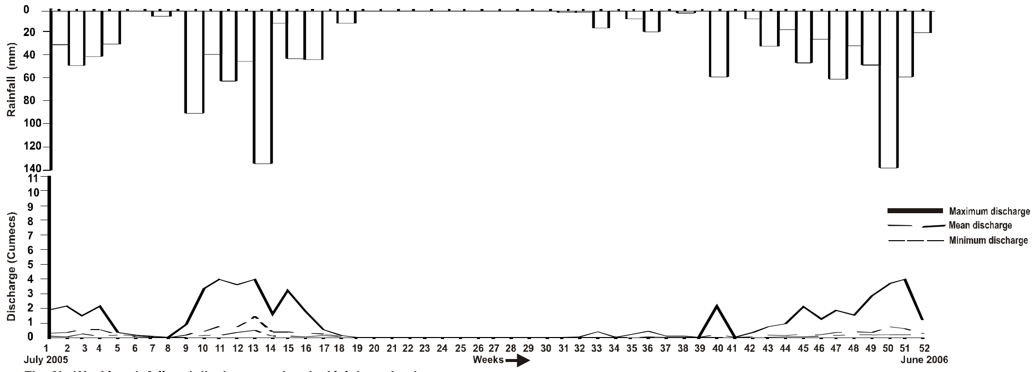

Fig. 3b Weekly rainfall and discharge regime in Alalubosa basin
Source: Author's fieldwork (2006)

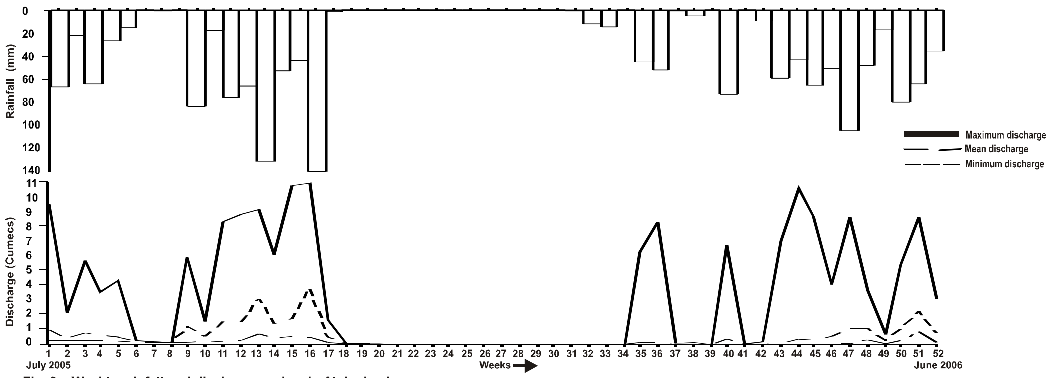

Fig. 3c Weekly rainfall and discharge regime in Aluko basin
Source: Author's fieldwork (2006)

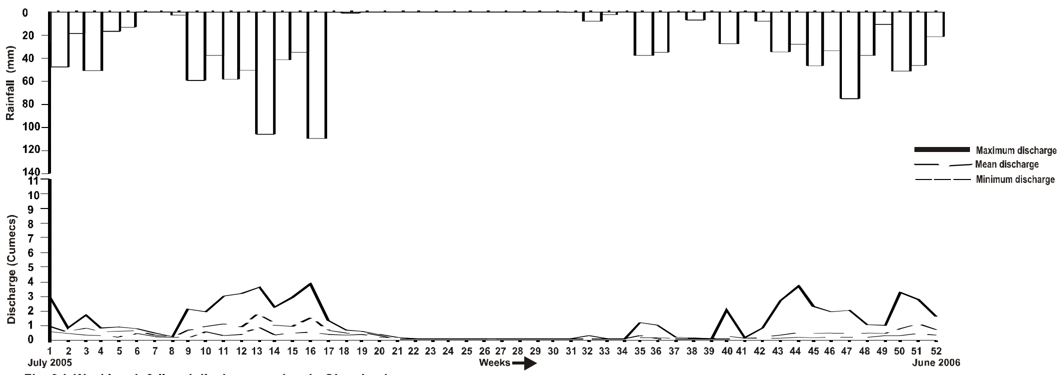

Fig. 3d Weekly rainfall and discharge regime in Okun basin
Source: Author's fieldwork (2006)

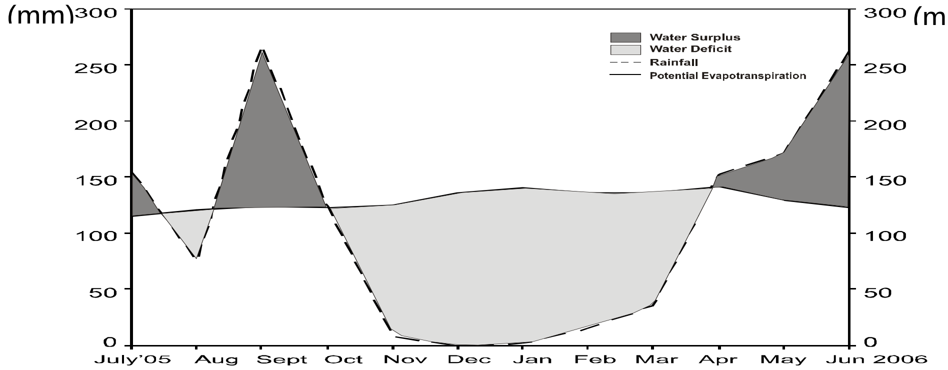

Fig. 4a Water budget graph for Agba Basin
Source: Author祖fieldwork (2006)

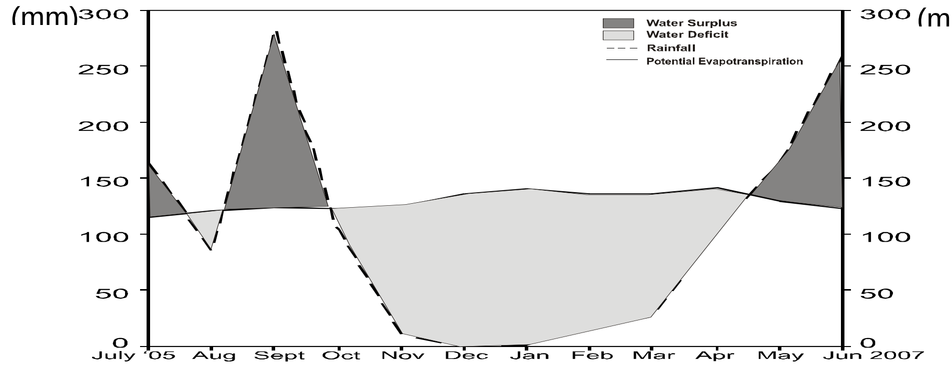

Fig. 4b Water budget graph for Alalubosa Basin
Source: Author祖fieldwork (2006)

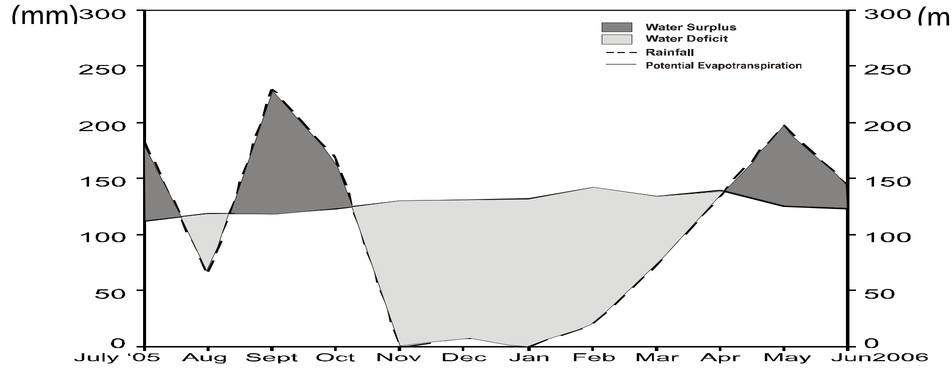

Fig. 4c Water budget graph for Aluko Basin
Source: Author祖fieldwork (2006)

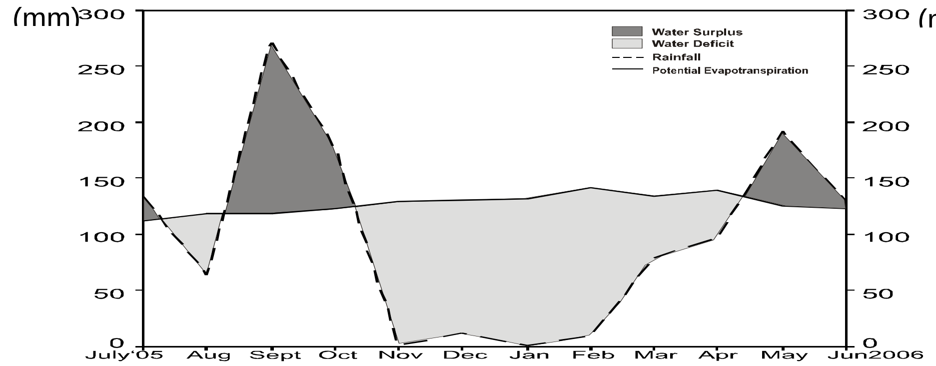

Fig.4d Water budget graph for Okun Basin
Source: Author祖fieldwork (2006)

Table 2: Patterns of loadings and percentage explanation of factors

		Component		
	Variables	1	2	3
1	Basin area (P1)	.91	.15	.39
2	Basin length (P2)	.98	.12	.17
3	Basin shape (P3)	-.99	.13	.11
4	Drainage density (P4)	.65	.60	.46
5	Bifurcation ratio (P5)	.27	.92	-.29
6	Stream frequency (P6)	-.39	.79	.45
7	Main stream length (P7)	.97	.20	.13
8	Basin slope (P8)	-.68	-.14	-.72
9	Elongation ratio (P9)	-.89	-.37	-.29
10	Circulatory ratio (P10)	-.72	.48	.51
11	Relief ratio (P11)	-.99	.08	-.10
12	Leminiscate ratio (P12)	.99	.06	-.08
13	Total stream length (P13)	.82	.29	.49
14	Percentage area in lake and ponds (P14)	.52	.12	.84
15	Mean elevation (P15)	.32	.63	.71
16	Percentage sand (S1)	-.04	.85	.53
17	Percentage silt (S2)	.05	-.93	-.37
18	Percentage clay (S3)	-.10	.36	-.93
19	Percentage built-up area (L1)	-.57	-.80	-.20
20	Percentage forest area (L2)	.75	.63	.19
21	Percentage farms and fallow area (L3)	.30	.49	.82
22	Percentage grassland area (L4)	.43	.89	-.16
23	Percentage bare surface area (L5)	.00	-.99	.01
24	Total rainfall (C1)	.04	.29	.96
25	Maximum weekly rainfall (C2)	.22	-.12	.97
26	Evapotranspiration (C3)	-.36	.38	.85
	Eigenvalue	14.11	7.22	4.67
	Percentage variance explained	54.28	27.76	17.96
	Cumulative percentage	54.28	82.04	100.00

Source: Calculations from the author's Field survey.

Basin landuse affects catchment response as it does not only change the nature of cover, but also reorganizes the drainage network. Landuse factor is thus an important factor controlling catchment flood generation through its effects on infiltration rate and surface storage (Ifabiyi, 2004)

Climate plays an important role in determining streamflow variability though the relationship between the two is rather complex. Increase in rainfall amount is associated with increase in volumes of runoff, hence, the longer the storm duration, the higher the rainfall amount and the larger the saturation zone over which runoff is generated. Thus, Olaniran (1983) linked series of flood events in Ilorin to heavy rains greater than 25.4mm/day occurring in a month about three or more times during periods of soil moisture surplus, while Ogunkoya, et. al. (1983) linked increase in maximum weekly rainfall with total runoff and dry season runoff in southwestern Nigeria. However, increase in temperature tends to increase evapotranspiration leading to decrease in streamflow.

Components I and II together account for more than 82% of the total variance and covariance of the original twenty six variables. Thus, variance between the twenty six variables can be attributed to two major factors of size and landuse, while the third factor may be regarded as minor term as it accounts for just a small percentage of the total variance. Thus, factor analysis has shown that, the interrelatedness of the twenty six parameters examined is mainly due to two underlying common dimensions, which account for more than 82% of the total explained variance.

4.3 Planning implications for efficient basin management

This study has further demonstrated the roles played by climate, landscape and landuse due to urbanization process in aggravating problems relating to high river runoff discharge in Ilorin. However, there are a number of options to efficient basin management in the city. The success of these options however depends on the understanding of the combined roles played by all the catchment runoff controlling variables identified, as this action represents the first step in solving flood problems in the city. The following options are thus suggested:

a) Afforestation programme: This will not only aid in promoting infiltration process during rainy season but will also help in conserving water supply for dry season usage. Ifabiyi, 2000, 2004; Atoyebi, 1995; Anynadike and Phil Eze, 1989; Ogunkota, et. al.1984; have highlighted the roles play by different vegetation cover on runoff process.

b) Floodplain zoning: This is the recreation of floodplain wildscapes, where both ecological process and flooding will operate with as little human intergenence as possible. This management option will help in restoring floodplain’s hydrological function to delay flow and attenuate flood wave. The technique is not only cost effective, but also ecologically valuable.

c) Engineering construction: This entails the construction of storage reservoirs (microdams) along the main river channels and flood detention structures on the tributaries.

d) Controlled urban development: This is process of zoning the land area for future development. Buildings already erected on floodplains under this option can be pulled down and stream channels enlarged and deepened as recommended by Akintola, (1966). Paved parking lots can also be replaced with porous surfaces and rooftops redesigned to pond water.

e) Improvement in farming techniques: Farming practices can be improved upon by the adoption of new techniques directed at either increasing infiltration rates or increasing basin surface storage (Ifabiyi, 2004). This can be through the cultivation of crops such as groundnut with high root density and cowpea with high litter production. Adoption of new farming methods such as contour furrowing, level and graded terracing will also help in increasing surface storage, thus curtailing problem of high runoff discharge. Maidment (1992) reported a number of hydrology effect brought about by agricultural land change.

f) Improvement in hydro-meteorological facilities: This will develop process of basin management from the less logical approach of “traditional methods” to more scientific methods of atmospheric options, e.g cloud seeding.

Adoption of the highlighted management techniques will not only assist in solving the persistent flood problem in the city, but will also aid in general development of the study area though domestic water supply, Irrigation, industrial, fishing and recreational development.

CONCLUSION

Flood incidence has been increasing over the past few decades in Nigeria, most especially in urban centres like Ilorin, causing untold hardships, misery and sometimes loss of lives too. As human population within a settlement rises, more land is cleared of its available natural vegetation and replaced with impervious fronts leading to low infiltration-runoff ratio. The situation is further worsened by rise in value of urban land due to population increase. This forces people to erect buildings on floodplains; hence increment in both the magnitude and frequency of flood in response to high storm water runoff and channel constriction. The landuse factor due to urbanization process alongside the combined roles played by landscape and climatic parameters on runoff generation process in Ilorin have been thoroughly examined in this study; all demonstrating man’s inability to manage well his environment. Different management techniques are however put forward towards curtailing this extreme climatic event in the city.

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