

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

H.I. Jimoh and K.A Iroye

Department of Geography, University of Ilorin, Nigeria

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, to increase in percentage paved area brought about by deforestation activities and poor environmental attitude of the people, hence, 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 1 calendar year. Rainfall data were collected in each basin using a standard rainguage of 20 cm orifice, while basin discharge was collected twice daily (8:00 am and 6:30 pm) 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.

Key words: Managing, runoff discharge, river catchment, Ilorin, Nigeria

INTRODUCTION

Problems associated with high runoff discharge have been a common occurrence in most parts of Ilorin for sometimes (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 includes, 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 are daily manifesting in water and water related problems being experienced in Nigeria (Faniran, 1991; Jimoh, 2000). As population density and land values rises

in urban centres, floods become a greater problem both economically and as 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 3 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 researches 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 Ayandike and Phil-Eze (1989); all focusing on less urbanized basins, using selected few basin physiographic variables perceived as being important, leaving out many other variables unstudied. This current research thus, seek to advance the frontiers of knowledge by focusing on urbanized basins and incorporating those variables earlier left out unstudied in previous researches. This is in 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 thus:

- Generate runoff data in the 4 basins in the urbanized catchments
- Examine the runoff regime in the selected basins
- Analyse water budget characteristics in the urbanized catchments
- Evaluate the relationship between runoff and basin parameters and suggest management techniques for curtailing the extreme hydro-climatic events of flood

The study area: Ilorin, the capital city of Kwara state Nigeria is the study area for this investigation. It lies between latitude 8°24'N and 8°36'N and between longitude 4°10' and 4°36'E (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 2 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 rock 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, 1981; 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 4 drainage basins being investigated in this study (Fig. 1). The basins range in size between 5.8 and 17.1 km². Two of the basins (Okun and Aluko) are located on the western part of River Asa, while the other 2 (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.

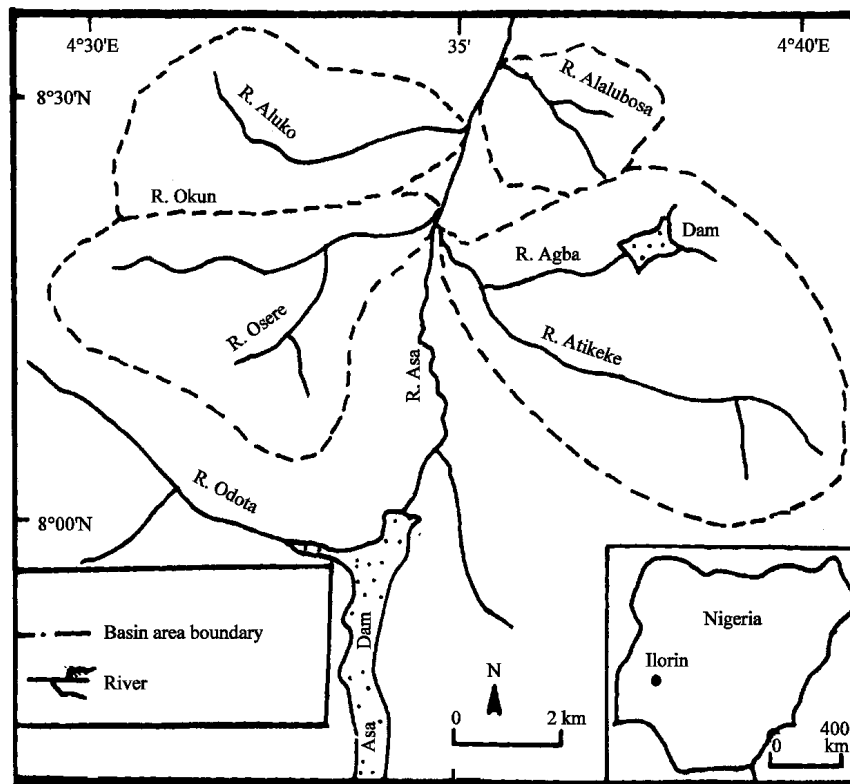


Fig. 1: Ilorin, showing the four drainage basins as the study area (Oyegun, 1983)

MATERIALS AND METHODS

Rainfall and basin discharge data were collected for a period of 1 calendar year (July 2005-June 2006). Rainfall data was collected with standard raingauge of 20 cm orifice in each of the basin while data on rate of river discharge was collected twice daily (8:00 am and 6:30 pm) 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 Thonhwaite and Marther (1955) formula using the temperature data obtained from the 2 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, streamlength 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 50 soil samples were also taken based on ratio analysis to a depth of 30 cm in the 4 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 26 independent variables of climate (rainfall and temperature), morphometric parameters (e.g., basin area, length, shape etc.), landuse and soil.

Review of related literature

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 vis 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 affect 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 occur at potential maximum rate until a stage of soil moisture deficiency is reached when the uptake of water no longer balance transpiration (Thonhwaite and Marther, 1955). The combine effect of these 2 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 (1967), 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.*, 1983; Ogunkoya *et al.*, 1984; Pitlick, 1994; Ifabiyi, 2004).

Soil is another characteristic, which affect 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 being a major theme in hydrological analysis of a drainage system, as it represent 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 affect infiltration capacity (Atoyebi, 1995), hence its affect 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 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 majorly 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.

RESULTS AND DISCUSSION

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

Basin area ranges in size from 5.8-17.1 km², while total stream length ranges between 2.7 and 11.3 km. Mean elevation ranges between 293-306 m. 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 11.3 km² with a mean value of 5.8 km².

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 336.8 mm in Agba and 492.6 mm in Aluko drainage basins. These values represents between 87.3 and 99% of the total runoff generated in the 2 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 2 basins. While Agba drainage basin has a percentage built-up area of 66.5% with >31% of its remaining land area occupied by different vegetation types; Aluko drainage basin is paved up to 97.8% with <2% of its remaining land area covered by only grassland. Thus, while >31% land area in Agba encouraged infiltration

Table 1: Morphometric and physiographic parameters of the studies basins

Morphometric characteristics	Agba drainage basins	Alalubosa drainage basin	Aluko drainage basin	Okun drainage basin
Basin area (59 km)	17.10	5.80	9.30	12.50
Basin length (km)	7.00	2.70	4.60	6.10
Basin slope (0)	0.35	0.51	0.44	0.34
Drainage density	0.66	0.47	0.41	0.57
Bifurcation ratio	2.00	2.00	1.00	3.00
Stream frequency	0.41	0.52	0.11	0.32
Mainstream length (km)	6.30	2.10	3.80	5.70
Basin shape	0.35	0.80	0.44	0.34
Elongation ratio	1.55	2.10	2.01	1.70
Circulatory ratio	0.74	0.95	0.56	0.60
Relief ratio	0.04	0.15	0.08	0.06
Leminiscate ratio	0.72	0.31	0.57	0.74
Mean elevation (m)	3.06	300.00	293.00	300.00
Percentage area in ponds and lakes	2.98	0.00	0.00	0.00
Total stream length	11.30	2.70	3.80	7.10
Landuse characteristics				
Percentage built-up area	66.50	84.50	97.80	67.20
Percentage forest area	11.30	1.70	-	10.40
Percentage farms and fallow area	8.20	3.50	-	2.40
Percentage grassland area	12.20	8.60	1.10	18.50
Percentage bare surface area	1.80	1.70	2.30	1.60
Soil characteristics				
Percentage sand	86.00	85.40	79.90	85.50
Percentage silt	6.95	6.95	12.90	7.80
Percentage clay	6.95	7.65	7.50	6.75

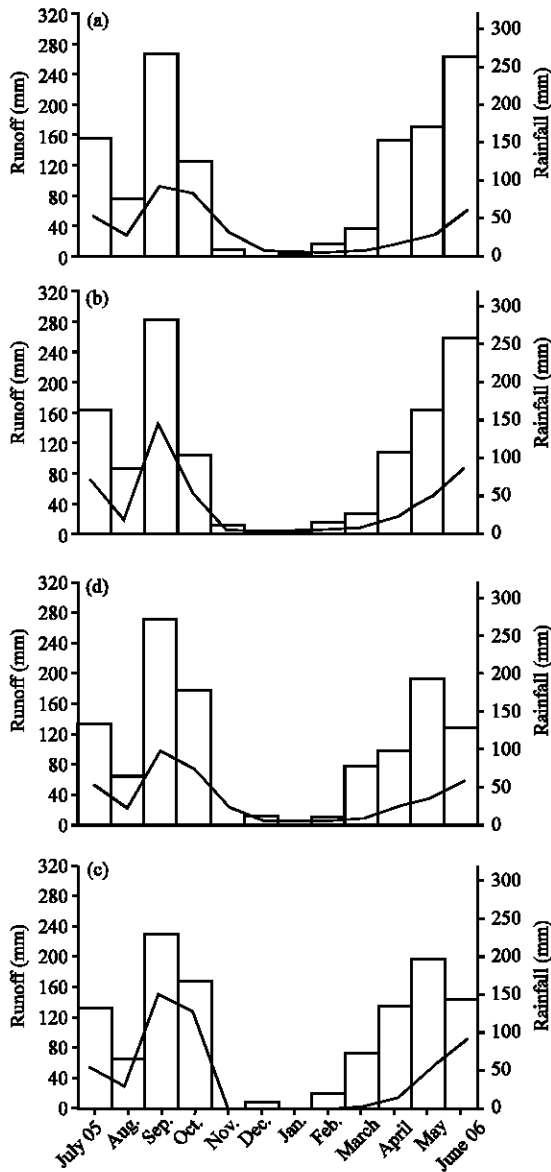


Fig. 2: a) Monthly rainfall-runoff regime in Agba basin. b) Monthly rainfall-runoff regime in Alalubosa basin. c) Monthly rainfall-runoff regime in Aluko basin. d) Monthly rainfall-runoff regime in Okun basin

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 disallow infiltration during rainy season by encouraging quickflows. The same scenario operates in the 2 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 1.1 mm in Aluko and 14.3 mm in Okun. The higher dry season percentage runoff amounts in Agba and Okun basins is 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 2 basins, though not at a very high value because of level of urban development, which is >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 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.

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).

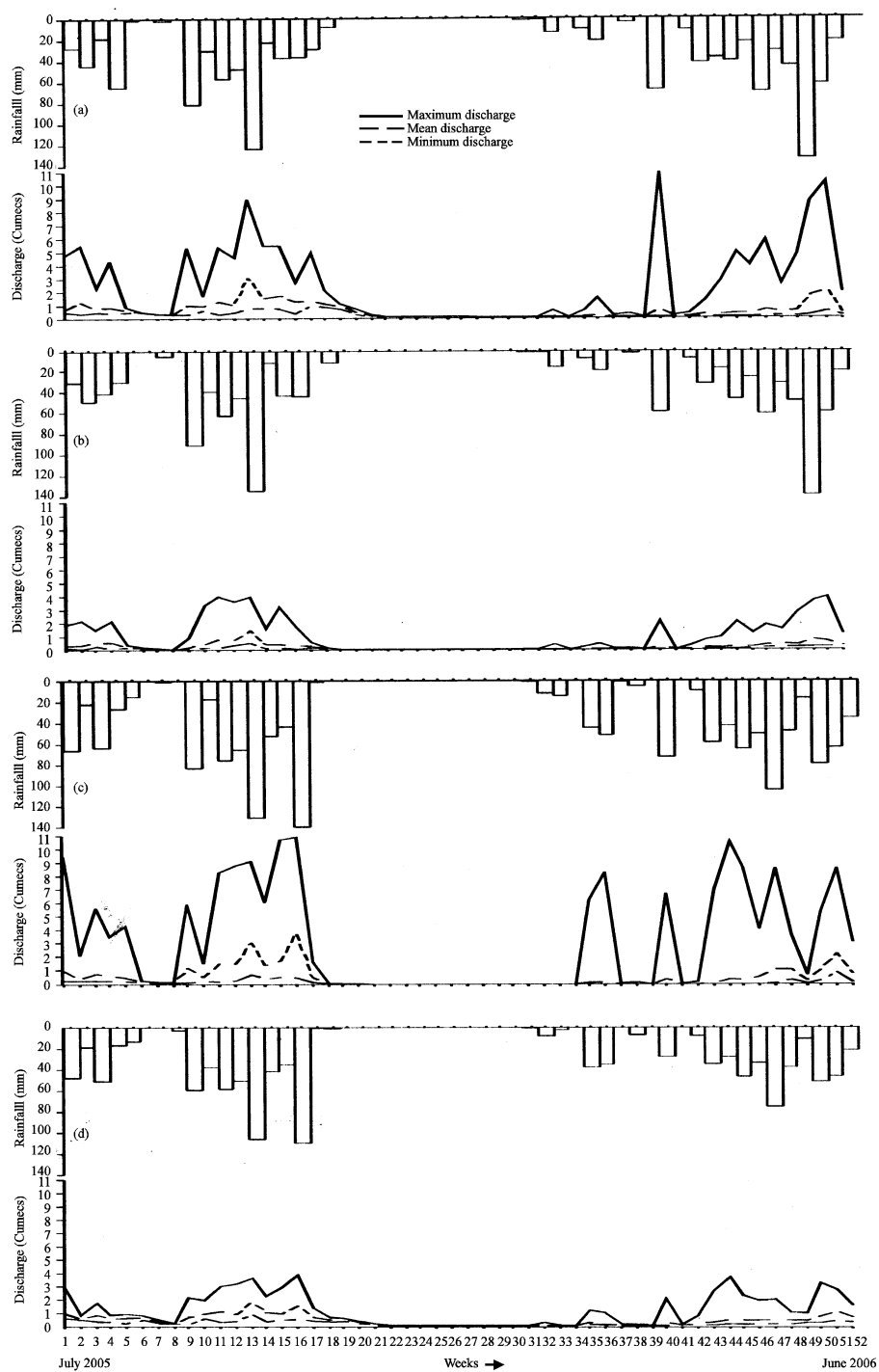


Fig. 3: a) Weekly rainfall and discharge regime an Agba basin. b) Weekly rainfall and discharge regime an Alalubosa basin. c) Weekly rainfall and discharge regime an Aluko basin. d) Weekly rainfall and discharge regime an Okun basin

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 terms of multivariate nature of hydrological study. Total basin discharge is positively correlated with basin area ($r = 0.97$), basin length ($r = 0.99$), mainstream length ($r = 0.97$), lemniscate ratio ($r = 0.94$) and total stream

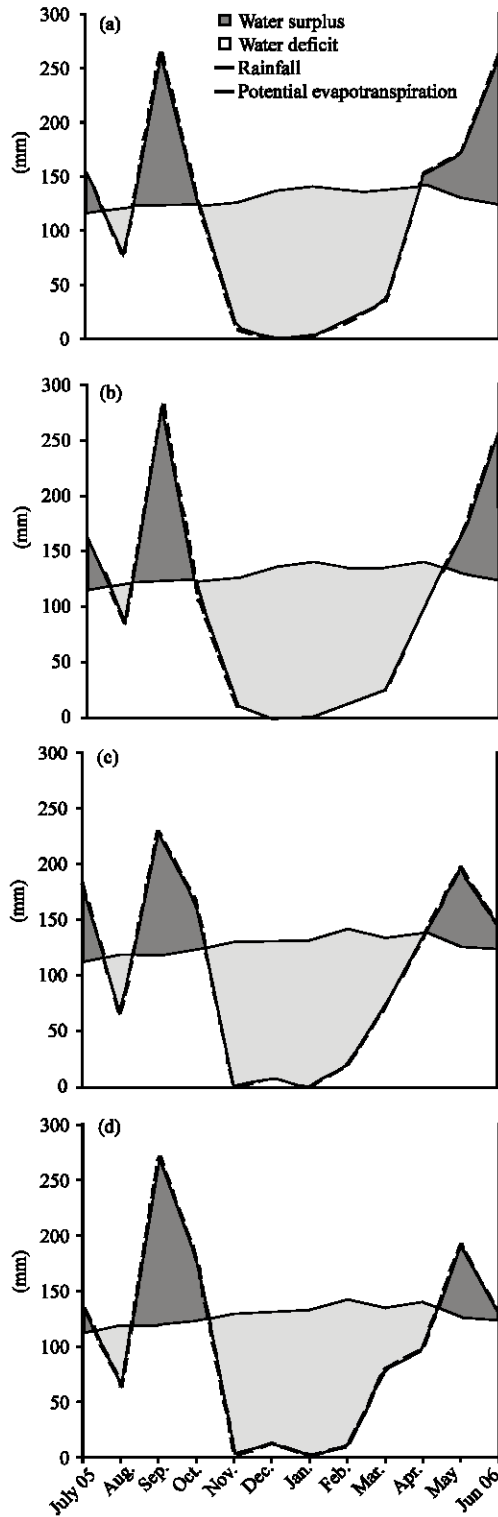


Fig. 4: a) Water budget graph for Agba basin. b) Water budget graph for Alalubosa basin. c) Water budget graph for Aluko basin. d) Water budget graph for Okun basin

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 3 factors are important in the explanation of basin runoff discharge after varimax rotation; their eigenvalues, percentages of variance and cumulative percentages.

Component I which explained 54.3% 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, lemniscate 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 lemniscate 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% 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% 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 result thus, shows that basin size have a profound influence on the explanation of discharge pattern in the studied basins. This agrees with previous studies, which has identified basin size as the most important catchment parameter controlling streamflow discharge (Ayandike and Phil-Eze, 1989; Pitlick, 1994; Ifabiyi, 2004). This is because, the larger the basin, the greater the volume of rainfall it intercept and the higher the peak discharge. Not only this, basin area is also

Table 2: Patterns of loadings and percentage explanation of factors

Variables	Component		
	1	2	3
Basin area (P1)	0.91	0.15	0.39
Basin length (P2)	0.98	0.12	0.17
Basin shape (P3)	-0.99	0.13	0.11
Drainage density (P4)	0.65	0.60	0.46
Bifurcation ratio (P5)	0.27	0.92	-0.29
Stream frequency (P6)	-0.39	0.79	0.45
Main stream length (P7)	0.97	0.20	0.13
Basin slope (P8)	-0.68	-0.14	-0.72
Elongation ratio (P9)	-0.89	-0.37	-0.29
Circulatory ratio (P10)	-0.72	0.48	0.51
Relief ratio (P11)	-0.99	0.08	-0.10
Lemniscate ratio (P12)	0.99	0.06	-0.08
Total stream length (P13)	0.82	0.29	0.49
Percentage area in lake and ponds (P14)	0.52	0.12	0.84
Mean elevation (P15)	0.32	0.63	0.71
Percentage sand (S1)	-0.04	0.85	0.53
Percentage silt (S2)	0.05	-0.93	-0.37
Percentage clay (S3)	-0.10	0.36	-0.93
Percentage built-up area (L1)	-0.57	-0.80	-0.20
Percentage forest area (L2)	0.75	0.63	0.19
Percentage farms and fallow area (L3)	0.30	0.49	0.82
Percentage grassland area (L4)	0.43	0.89	-0.16
Percentage bare surface area (L5)	0.00	-0.99	0.01
Total rainfall (C1)	0.04	0.29	0.96
Maximum weekly rainfall (C2)	0.22	-0.12	0.97
Evapotranspiration (C3)	-0.36	0.38	0.85
Eigenvalue	14.11	7.22	4.67
Percentage variance explained	54.28	27.76	17.96
Cumulative percentage	54.28	82.04	100.00

highly correlated with other catchment characteristics, which influence discharge such as basin length and stream length.

Basin landuse affect catchment response as it does not only changes 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 2 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 $>25.4 \text{ mm day}^{-1}$ occurring in a month about 3 or more times during periods of soil moisture surplus, while Ogunkoya *et al.* (1984) 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 $>82\%$ of the total variance and covariance of the original 26 variables. Thus, variance between the 26 variables can be

attributed to 2 major factors of size and landuse, while the 3rd 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 26 parameters examined is mainly due to 2 underlying common dimensions, which account for $>82\%$ of the total explained variance.

Planning implications for efficient basin management:

This study has further demonstrated the roles played by climate, landscape and landuse due 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 represent the 1st step in solving flood problems in the city. The following options are thus, suggested.

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), Aynadike and Phil-Eze (1989) and Ogunkoya *et al.* (1984) have highlighted the roles play by different vegetation cover on runoff process.

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 ecological valuable.

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

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.

Improvement in farming techniques: Farming practices can be improved upon by adoption of new techniques directed at either increasing infiltration rates or increase 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.

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 an urban centre like Ilorin, causing untold hardships, misery and sometimes loss of lives too. As human population within a settlement rise, 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 were however, put forward towards curtailing this extreme climatic event in the city.

REFERENCES

- Adejuwon, J.O., L.K. Jeje and O.O. Ogunkoya, 1983. Hydrological response patterns of some 2nd order streams on the Basement complex of Southwestern Nigeria. *Hydrol. Sci. J.*, 28 (3): 377-391.
- Akintola, R.A., 1966. Flood problems in Ibadan, western Nigeria. *Nigerian Geogr. J.*, 9 (2): 101-113.
- Atoyebi, J.O., 1995. Infiltration in urbanized basins in Ilorin, Kwara State. Unpublished Ph.D. Thesis Geography Department, University of Ilorin, pp: 239.
- Ayandike, R.N.G. and R.C. Phil-Eze, 1989. Runoff response to basin parameters in Southeastern Nigeria. *Geogr. Ann.*, 71A (1 and 2): 75-84.
- Enendu, S.N., 1981. Flood problems in Ilorin. Unpublished B.Sc. dissertation, University of Ilorin, Ilorin, pp: 68.
- Faniran, A., 1991. Water resources development in Nigeria. University of Ibadan, pp: 95.
- Freeze, R.A., 1980. A stochastic-conceptual analysis of rainfall-runoff processes on a hill slope. *Water Resour. Res.*, 16: 391-408.
- Gregory, K.J. and D.E. Walling, 1973. Drainage Basin Form and Process: A Geomorphological Approach. Edward Arnold, London, pp: 456.
- Hall, M.J., 1984. Urban hydrology. Elsevier Applied Science, Barking, UK, pp: 299.
- Hamlin, M.J., 1983. The significance of rainfall in the study of hydrological processes at basin scale. *J. Hydrol.*, 65: 73-94.
- Harun, R., 1982. Urban flood problems in Benin city, Nigeria: Natural or Man-made? *Malaysian J. Trop. Geogr.*, 6: 8-14.
- Hewlett, J.D. and W.L. Nutter, 1970. The varying source area of streamflow from upland basins. Proceedings of the symposium on interdisciplinary Aspect of watershed management, Montana State University, Bozeman, American Society of Civil Engineers, pp: 65-83.
- Horton, R.E., 1933. The role of infiltration in the hydrological cycle. *Trans. Am. Geophys. Union*, 14: 446-460.
- Ifabiyi, I.P., 2000. Variability of infiltration rates in Samaru, Nigeria. *Geo-Stud. Forum*, 1(1 and 2): 87-95.
- Ifabiyi, I.P., 2004. The response of runoff and its components to basin parameters in the upper Kaduna catchment of Nigeria. Unpublished Ph.D. Thesis, University of Ilorin, pp: 328.
- Jimoh, H.I., 1997. Individual rainfall events and sediment generation on different surfaces in Ilorin, Nigeria. Unpublished Ph.D. Thesis University of Ilorin, Ilorin.
- Jimoh, H.I., 2000. Effects of river erosion on houses: A case study of Asa river catchment in Ilorin, Kwara State, Nigeria. *Ilorin J. Business Soc. Sci. University of Ilorin, Nigeria*, 7 (1): 17-23.
- Jones, J.A.A., 1997. Global Hydrology, processes, resources and environmental Management. Longman, pp: 399.
- Maidment, D.R., 1992. Handbook of Hydrology. McGraw Hill, Inc. New York.
- Morisawa, M.E., 1957. Measurement of drainage basin outline form. *J. Geol.*, 66: 86-88.
- Morisawa, M.E., 1967. Relation of discharge and stream length in Eastern United States. *Proc. Int. Hyd. Symp.* Fort Collins, Colorado, pp: 173-176.
- Ogunkoya, O.O., J.O. Adejuwon and L.K. Jeje, 1984. Runoff response to basin parameters in Southwestern Nigeria. *J. Hydrol.*, 72: 67-84.

- Olaniran, J.O., 1983. Flood generating Mechanism in Ilorin, Nigeria. *Geo-J.*, 7 (3): 271-277.
- Olson, G.W., 1981. Soil and the environment: A guide to soil survey and their Applications. Chapman and Half, London.
- Oyegun, R.O., 1983. Water resources in Kwara State. Matanmi and Sons Printing and Publishing Co. Ltd. Ilorin, pp: 113.
- Pitlick, J., 1994. Relations between peakflows, precipitation and physiography for 5 mountainous regions in the Western USA. *J. Hydrol.*, 158: 219-240.
- Roels, J.M., 1984. Surface runoff and sediment yield in the Ardche Rangeland. *Earth Surface Processes and Landforms*, 9: 371-381.
- Thonthwaite, C.W. and J.R. Marther, 1955. The water balance. Centerton, NJ, Laboratory for Climatology Publications in Climatology, 8: 1-86.
- Ward, R.C. and M. Robinson, 1990. Principles of Hydrology. 3rd Edn. McGraw Hill, London, pp: 365.
- Whipkey, R.Z. and M.J. Kirkby, 1978. Flow Within the Soil. In: Kirkby, M.J. (Ed.). Hillslope Hydrology. Chichester, Wiley, pp: 121-44.