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Research Article

HYDROGRAPH TIME TO PEAK (T_P) AND BASIN PHYSIOGRAPHY IN THE UPPER KADUNA RIVER CATCHMENT, NIGERIA.

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ABSTRACT

Time to peak (T*p) is* an important variant in flood mitigation and designs of flood early warning signals (EWS). Flooding is a common hazard in Africa, but the disasters are easily forgotten immediately after their occurrences. Many flood studies in Nigeria are not hydrological in approach; hence, outcomes of such efforts could only render minimal hydrological solutions. This present study examines the impacts of basin environment on the hydrograph T*p* in the Upper Kaduna Catchment (UKC). In this study, T*p* was derived after Soil Conservation Service (SCS), United State Department of Agriculture (USDA) and Technical Centre for Agriculture and Rural Cooperation (ACP-EEC), while basin physiographic factors were extracted from maps. T*p* was calculated for the 20 sub basins of the UKC and 17 physiographic attributes of the basin were generated. The factor analytical method was used to reduce the variables to 8 orthogonal factors, which gave a cumulative explanation of 90.0%. The multiple regression analysis also showed that the 8 orthogonal factors explained 96.5% in the variance of the explanations of Tp in the UKC. Further, analysis by multiple stepwise regression analysis indicated that percentage area of the basin forested and percentage area of the basin underlain by quartzite dominated the explanation with 87.0% coefficient of determination. The result indicates redundancy in the ability of the basin variables explanations' of time to peak. It also shows that, although the geology of the UKC favours generation of overland flow, the impact of land use and morphometric factors altered runoff and have caused relatively longer T*p* with values ranging from 1.94 – 32.26 hours. The paper concludes that explanations of T*p* and basin flood characteristics should include a wider range of basin attributes.

***Key Words**: Time to peak (T_p), Physiography, Redundancy, Flood Prediction, Flood Early Warning*

INTRODUCTION

Time to Peak (T_p) is the time from the beginning of the rising limb to the occurrence of the peak discharge. It can also be defined as time in hour at which the peak runoff occurs. T_p is important in flood prediction, basin management, hydraulic designs and operation of river works and water release in reservoir operation. T_p is also relevant in the determination of the height of spillway, drainage works and central to water resources engineering. T*p* dictates flood waves, flood time and extent of flood damages. Therefore, examination of time to peak is crucial as it serves as a guide to flood warning and mitigation. Time to peak is affected by several factors some of which include: shape of the basin ((Horton, 1945; Strahler, 1964; Anderson, 1949; Anderson and Trobiz, 1949; Kent,1971;Viessman,1989), topography (Burt and Butcher,1985; Sherman, 1932, Taylor and Schwarz, 1952; Boyd, 1978, Betson, 1979; Berger and Entekhabi, 2001; Nyadawa and Mirangi, 2004)) geology (Ayoade,1988; Lacey and Grayson, 1998).), land use (Arena,1982, Cordery,1976) basin scale (Falvoden, 1963, Kinsel,1963; Ineson and Dowing 1964; Pilgrim, et .al. 1982), climatologic factors (Mimiouku,1984). It can also be affected by soil infiltration characteristics.

Time to peak is a key issue in flood prediction. Inability of man to accurately predict flood events has been a critical problem despite the fact that flooding has been on earth much longer than man. Brier (1998) gave account of the ancient El-Amana in Egypt and Hoyt and Langbein (1959) of various ancient encounters between flood and man dating back to 2,957 BC and 747 BC respectively. Flood account for 50% of water related disasters. Flood is the most common disaster in North Africa, the second most common in East, South and Central Africa, and the third most common in West Africa (AWDR, 2006). In the same vein, episodes of flood accounted for 26 percent of total disaster occurrences in Africa during 1971-2001 (Vordzorgbe, 2003). In ability to forecast flood accurately has led to various consequences particularly in the third world. In North Africa, the 2001 disastrous flood in northern Algeria resulted in about 800 deaths and economic loss of about $400 million. In East Africa, the El Niño-related flood in 1997/1998 destroyed infrastructure and property worth about $1.8 billion in Kenya. In Mozambique, the 2000 flood (worsened by two cyclones), reduced the annual economic growth rate from 10 percent to 4 percent, caused 800 deaths, affected almost 2 million people of which about 1 million needed food, displaced 329,000 people and destroyed agricultural production land, among other negative effects. The worst single episodes of flood in Africa occurred in East Africa: one event in 1997 killed 2,311 people in Somalia; another in 1999 affected 1.8 million people in the Sudan (AWDR, 2006; Urama and Ozor, 2010) In Nigeria, the impact of flood cannot be over flogged. The Ibadan flood of August 26th 2011 alone swept away 2,105 houses and killed about 100 people and destroyed property worth 100 million naira. (THE NATIONS, 2011, p.10), Flood has been reported in every parts of Nigeria, and more worrisome in recent times is the climate induced flood incidences in the Sudano-sahelian zone of Nigeria such as Sokoto, Maiduguri, Yobe, Kano, Bauchi, Kebbi, etc. However, despite the yearly problems of flooding, the problems tend to be forgotten after each flood and only to be remembered at the instance of another flood incidence. Reasons for this include: poor understanding of city planners about flood controls, disorganization in policies of government in flood management, problems of technological know how about flood management, ignorance of the public on flood management and poor efforts at flood prevention.

Approaches to flood studies in Nigeria are sometimes not hydrological. For example, Olaniran (1983) was interested in rainfall which can induce floods, while Durotoye (2000) identified causes of flood in Bayelsa state Nigeria, Oriola (1997) in Ondo southwest Nigeria was interested in the impact of socio cultural activities on flood, Okoduwa (1999) adopted a digital elevation modelling of landscape, while Ologunorisa (2004) attempted a flood risk analysis of Niger delta.

This study will attempt a discussion of the relationships between hydrograph time relation and basin attributes with a view to predicting the response of basin attributes to flood generation within the northern Nigeria portion of Basement complex. It is hoped that the findings there-from will be useful for flood management in Nigeria.

The study area

The Upper Kaduna Catchment is located on latitude 9^{0} 00\` and 11$^{0}$ 30\`N and longitude 6^{0} 00\` and 8$^{0}$ 00\`E. politically it covers the present day Kaduna state and the south eastern part of plateau state around Assob. It has high rural population density and straddles 2 different climatic zones; it is endemic to effects of peak flows in rainy season and low flows in dry seasons.

The climate is controlled by the movement of the ITD; it has six months each of dry and wet seasons. Wet season starts in May and end in October while dry season is from November and end in April. Latitudinal pattern is noticed in rainfall. For example, within the Kahugu basin in the extreme north of UKC, lengths of rain days is 150 days and mean annual rainfall is 980mm, while to the south-east of the UKC in the in the Kogun sub basin length of rain days is 180days and mean annual rainfall is 1,500mm. This high rainfall is due to the orographic effect of the Jos plateau. Water deficit increases from 600m on the Kogun basin in the south east to 1,700 mm Kahugu to the north of the catchment.

Three vegetation types are discernable namely: guinea savanna, Sudan savannah and plateau grassland. Plains and dissected and hilly landscape dominate the relief. The geology comprises mainly of undifferentiated basement Complex covering about 91% of the basin while the south eastern tip is underlain by volcanic rock especially in the Assob and Kogun basins. Others are: porphyritic biotite, younger granite, undifferentiated granite, and quartzite. Zaria group of soil overlying with drift material covers 75% of the area while the Kagoro soil which are dark, fertile and porous and rich in organic content is found in the area around latitude 10^{0}N. It covers about 25% of the basin particularly the more humid south. The soil of the basin is largely ferruginous in origin with a compact B-horizon. Runoff is possibly generated through the saturated overland flow approach.

Major land use types include: forested, *fadama*, urbanized, rock outcrops and cultivated landscapes. Many water dependent industries such as petroleum refinery petrochemical plant, automobile assembly plant, fertilizer plant, textiles, bottling and brewery are found in the catchment. Large settlements such as Kaduna, Zaria, Kagoro, Kafanchan, Kachia, Saminaka, and Kwoi are found in the study area. All these will modify runoff in the basin.

MATERIALS AND METHODS

Data base

The data used in this study are mainly morphometric and physiographic data obtained from topographic map.

Morphometric data

Two morphometric parameters are required in this study, they are: basin scale and shape characteristics. Basin shapes were calculated using the circularity ratio, leminiscate ratio and form factor. These were extracted from 1:50,000 topographic map covering the study area. The maps were published by the northern Nigeria survey (Ebisemiju, 1976, Anyadike, and Phil-Eze,1989, Ogunkoya,1983). The data used in this study were extracted from sheets 100-103,123-126, 144-147 and 165-168 sheets of the Nigeria 1:50,000. Physiographic attributes of land use and geology such as the percentage areas under each geological and land use types were determined by graphical method and extracted from the 1:500,000 Geological and Land use Maps prepared for the Kaduna State Agricultural Development Project (KADP) by AERMAP of Florence, Italy, 1987.

Hydrograph time relation

The empirical relation used in this study has earlier been applied and adapted by Soil Conservation Service (SCS) and the United State Department of Agriculture; it has also been used to study irrigation potential in the Sahelian Zone of Northern Africa by the Technical Centre for Agriculture and Rural Cooperation (ACP-EEC) Taeur and Humburg, 1992). T_p is defined as equation 1.

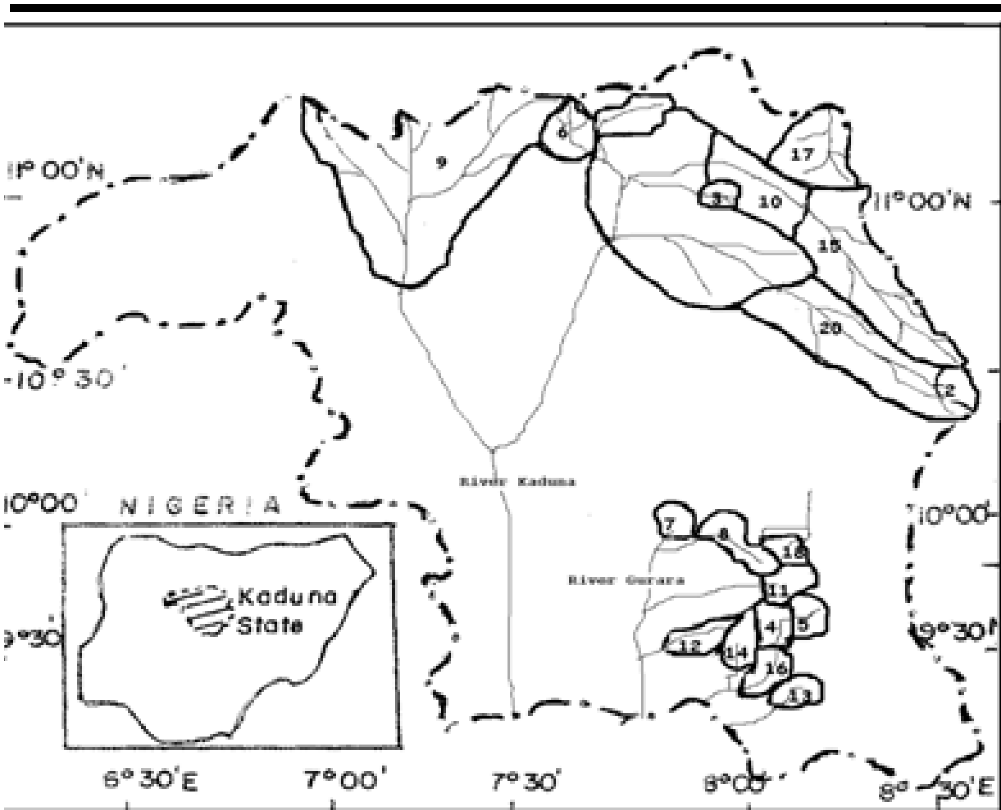
T_p=a. A^b………………………………………………….. (eq1)

a=0.872(an empirical constant)
A=basin size
b=0.4(an empirical constant

Statistical Method

Correlation analysis was used to examine the types of associations existing among the thirty basin variables. Factor Analysis was adopted to overcome the problem of multicollinearity; hence, it was adopted to rewrite the 30 basins parameters to orthogonal factors.

The multiple regression method was used to establish a relationship between total runoff and the factor scores of the eight orthogonal factors derived from the result of factor analyses to predict runoff response to total runoff. In addition to the above, the linear regression model was also used to order the individual contributions of the 8 orthogonal factors to total runoff using the result of the stepwise multiple regression as input.



Labels for respective Sub-basins in UKC	
1.Galma At Gubunchi	11.Chalwe At Zango Kataf
2. Karami At Saminaka	12. Gurara At Gatan
3. Jamana At Soba	13. Assob At Assob
4. Kogun At Kagoro	14. Dorogoin At Dorogoin
5. Kogun At Ungwan Rimi	15.Galama At Kuzuntu
6. Shika At Kano Road	16. Kogun At Jagindi
7. Shaho At Kachia	17. Kahugu At Ikara
8. Kachia At Kachia	18.Kwassau At Zonkwa
9. Tubo At Kaduna Road	19.Kudan at Hunkuyi
10. Galma At Gubunchi	20.Karami at Kauru

Figure 1: The Upper Kaduna Catchment

RESULTS AND DISCUSSION

The sub basins of the study area are generally large basins ranging from 3rd to 6th order basins. According to Table 1 and Fig 2, T_p ranges from 1.94hrs in Dorogoin at Kwoi to 32.3hrs in Galma the largest sub basin in the Upper Kaduna Catchment. In the 3rd order category, Kudan at Hunkuyi has the highest T_p (6.43hrs), while Dorogoin at Kwoi recorded the least. In the order 5 category, Galma at Gubunchi has the highest (21.6hrs), while in Assob at Assob T_p is 6.79 hours it is the shortest of the 5th order basins. In the order 6 basins, Galma at Ribako has the longest of 32.3hours. Gurara at Gatan has only 10.5 hours before peak. This position clearly suggests that certain underlying factors are relevant to the pattern exhibited in Table 1. In the same vein, the physiographic characteristics show that all the sub basins are heavily cultivated; there is no sub basin with less than 70% cultivation in the UKC. This has resulted to delaying time to peak, because surface roughness will reduce velocity and force T_p to be longer. This is expected in view of the high rural population in the UKC (Mortimore, 1972). Only 4 sub basins (namely: Shika at Kano road, Kwassau at Zonkwa, Gurara at Gatan and Assob at Assob) have less than 50% of undifferentiated Basement Complex. All others are mainly underlain by undifferentiated Basement Complex. This shows the dominance of crystalline rocks in the geology of UKC. Hence, it is expected that overland flow will be high in almost every part of this catchment. It is expected that runoff generation via Horton's (1933) infiltration hypothesis will dominate the hydrograph.

Basin variables and hydrograph time to peak.

The results in Table 2 show that the 17 basin variables were reduced to only six with 88.5% explanation in the variance. The result of factor analysis is presented Table 2.

i. ***Component 1**:* this component offered 16.1% explanation to the variance. It has high loadings on all the shape attributes of the basins. The factor defining variable is leminiscate ratio, which is an **index of basin elongation**. This show that majority of the basins are elongated. This explains the relatively longer time to peak in many parts of the UKC.

ii. ***Component II**:* contributed 14.3% explanation, and it is strongly loaded on % volcanic rocks, % undifferentiated Basement Complex rocks and drainage density. This component is an **index of drainage pattern.** The drainage pattern in the UKC is dendritic in nature. This is expected in view of the underlying Basement Complex. This implies that the basin is well drained. The factor defining variable is % area underlain by undifferentiated Basement Complex.

iii. ***Component III**:* contributed 12.4 % to the variance and it is strongly loaded on percentage area underlain by porphyritic biotite and % area covered with *fadama*. This is tagged basin fadama. This is an **index of basin wetness**. *Fadama* a local name for wetland is known to be an area of intense cultivation, particularly where market gardening and dry season farming are been practiced. Within the wetland area, wetland vegetation and ploughs (heaps) from cultivation create surface roughness that delays runoff. This tends to lengthen time to peak.

iv. ***Component IV**:* this component is strongly loaded on 2 variables which are % area covered by forest and the basin order. This clearly points to the prominence of vegetation in flood management. Forest cover has been found to affect interception, rainfall drop impacts, evapotranspiration, increase infiltration, and also creates surface runoff that delays overland flow. A number of gallery forests are found in the Galma basin. This play significant role in time to peak in the Galma sub basin. This is an **index of basin vegetation**. The factor defining variable is the percentage of the basin forested.

v. ***Component V**:* this component is strong on 3 land use attributes of the basin. These are: percentages of the basin cultivated, urbanized, and that on rock outcrops. More than 70% of the 20 sub basins in UKC are cultivated; this is in view of the high rural population in the UKC. Cultivation is known to cause surface roughness and slower time to peak. Urbanization in Zaria on the Galma basin, and some urbanized areas south of Latitude 10^{o} such as Kwoi, and Kafanchan are built area have effects on runoff. Urbanization will increase overland flow and this explains high flow in areas outside cities. The faster Tp in Kogun basins are partly due to urbanization. This factor is an **index of basin land use**. The factor defining variable is percentage of the basin urbanized.

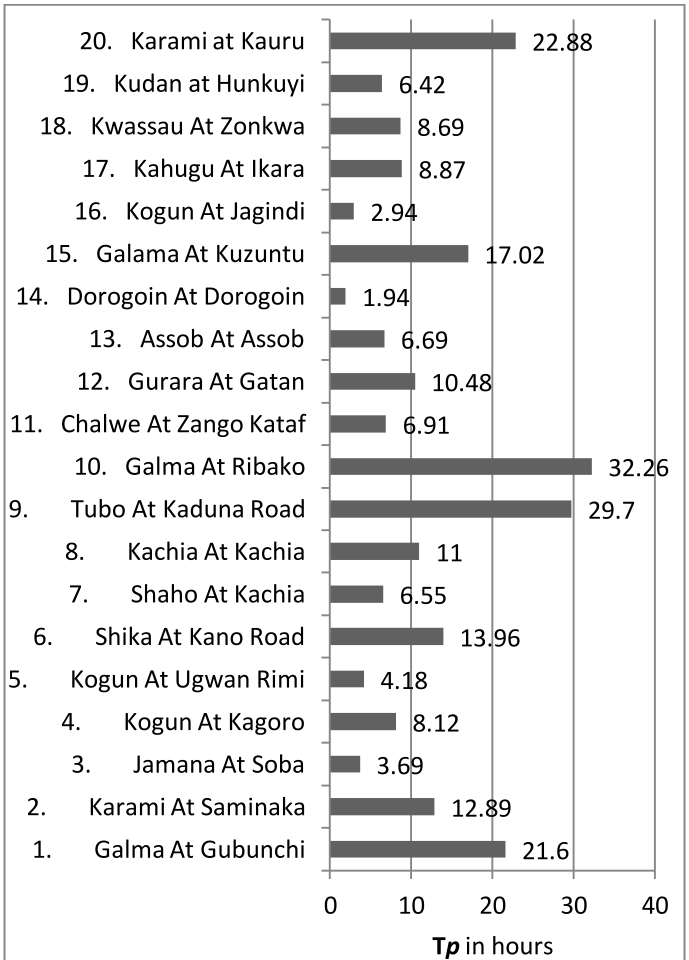


Figure 2: Pattern of T*p* in hours over the UKC

vi. ***Component VI**:* this component loaded highly only on relief ratio and percentage of the basin on undifferentiated granite. The UKC have many of its sub basins lying on relatively rolling terrain with the exception of a few sub basins in the south eastern part; south of latitude 10^o with high relief ratio and shorter time to peak. This offered 8.34%. It is an **index of basin relief**. Generally areas underlain by granite are rugged in terrain and they form the major watershed or headwaters of rivers, such as Galma at Shaho, Chalwe, Galma, etc, within the UKC. The factor defining variable is relief ratio.

vii. ***Component VII**:* this component loaded on percentages of the basin on quartzite and undifferentiated granite. It contributes as much as 8.28%. It is tagged index of basin geology. Quartzite is a metamorphic rock with high porosity. Porosity is significant to time to peak because it changes the pattern of runoff generation from overland flow to groundwater generation. This will delay T_p. About 5 basins (Shaho, Kogun, Chalwe, Galma, etc) are underlined by undifferentiated granite. This will unlike quartzite will encourage overland flow and shorten T_p particularly along these basins. This factor is an index **of basin geology**. The factor defining variable is percentage quartzite.

viii. ***Component VIII**:* this component offered 7.17% explanations. It loaded highly on percentages of savanna scrubland and that underlain by younger granite. The areas of savanna scrubland are the few remnants of uncultivated remote areas that are almost inaccessible within UKC; these portions are mainly found in Galma at Ribako and Shaho at Kachia. On the other hand, the areas underlain by younger granite are rock massifs that are also inaccessible in Assob and Shaho sub basins, which forms the ring complex areas from which the headwaters of river Kaduna and many other rivers are springing out. A common feature of these 2 variables is limited human interference. This is tagged **index of limited human access**. A feature of these landscapes is delayed flow through surface roughness caused by dense and natural vegetation and hilly landscapes. This will therefore reduce T_p. The factor defining variable is percentage of the basin covered by savanna.

Presentation of results

The results presented above shows how interactions of basin land use and geology can alter Tp. The wide dominance of Basement Complex geology implies that Tp will be short in many sub basins, but the effects of land use and basin morphometry ameliorated the situations and relatively prolonged T_p in many parts of UKC. Indeed, Ramachandra and Delleur, (1974) call for a need to extend studies of response pattern of T_p beyond the factor of morphometric variables.

Of all the factors affecting T_p basin morphometry and indeed basin shape plays significant role. Basin shape has been found to be an important offender. The result reported in this study showed that basin shape have important relationship with time to peak. For example, lemniscate ratio remains dominant; its dominance is relatively manifested in the long time to peak experienced basin wide in UKC. Leminiscate ratio has the highest explanation (Table 2). Also, basin geology plays an important role in the determination of time to peak. Basin geology determines the soil type, the topography and the basin geomorphologic variables such as drainage area, pond areas, slope, channel length, drainage density, relief ratio, etc. The UKC is predominantly underlain by undifferentiated Basement Complex (about 90% of the basin). This would have accounted for T_p which is faster compared to the sizes of the basins. In many parts of the study area, T_p are longer than 1hour. This suggests low incidences of flash floods. Crystalline rocks are expected to have lower infiltration compared to sedimentary formation.

In the same vein, percentage area underlain by quartzite has been found to be relevant to Tp, this is because quartzite encourages infiltration, and this will extend the time to peak. The 11% quartzite in Tubo sub basin has contributed to delaying runoff despite the relatively rugged terrain the T_p is 29.7 hours. Relief ratio is an index of basin ruggedness and it is an indication that time to peak will be longer. The impact of relief ratio is discernable in Kogun at Jagindi where despite the higher basin order of 5, the T_p is 2.94hours. This value is the lowest of all 5th order basins. This is also the case in Kachia at Kachia, which despite being a 4th order, has longer time to peak (11hours), greater in value than some 5th order basins such as Kwassau (8.68hours), Chalwe (6.91hours).

The impacts of wetlands on runoff generation cannot be over flogged. The *fadama* wetland is intensively cultivated particularly during the dry season for dry season faming; in the wet season it forms runoff-source- areas (Ward, 1990) of runoff and easily generates runoff and faster time to peak. Rivers Galma and Tubo have been known to have large percentage of their basins covered by *fadama*. Rivers Kudan and Galma are known to have extensive *fadama* which are about 30% and 9.3% respectively. Indeed, the rolling topography along these basins has given rise to water spreading. Indeed, this explains the relatively long time to peak in Kudan despite the fact that it is a 3rd order basin T_p is 6.42 hours which is greater than the value of Kogun at Ugwan Rimi, a 5th order basin with 4.18hours time to peak.

The nature of the surface and more importantly the use to which land is put is an important factor. Bare surfaces will generate faster T_p. The UKC is heavily cultivated; indeed, three is no part of the UKC with less than 70% cultivation. This will increase the surface roughness and consequently flow of runoff will be hindered. This has encouraged high Tp in UKC. It also accounts for the low incidence of flood in the catchment. The 3.13% forest in Galma at Ribako has further contributed to delay runoff in the sub basin with T_p of 32hours. Urbanization has also affected flow in Kogun at Jagindi, Kogun at Ugwan Rimi and

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Table 1: Hydrograph Time to Peak (T_p) and Basin Characteristics in the Upper Kaduna Catchment (UKC).

	Geological Variables (%)						Landsue Variables (%)						Basin Shape			Basin Relief			Sub Basins
T_p	vol	yg	ug	pb	qzt	ubc	cut	sav	for	urb	roc	fad	cr	fa	k	ord	rh km/km^2	dd	
3.69	0	0	0	0	0	100	100	0	0	0	0	0	0.47	0.37	0.68	3	0.0003	0.67	1.Jamana at Soba
6.42	0	0	0	26	0	74	70	0	0	0	0	30	0.9	0.71	0.35	3	0.0023	0.5	2. Kudan at Hunkuyi
12.89	0	0	0	0	0	100	100	0	0	0	0	0	0.96	0.76	0.33	5	0.025	0.87	3. Karami at Saminaka
13.96	0	56	0	0	0	44	100	0	0	0	0	0	0.82	0.64	0.38	5	0.0003	0.77	4. Shika at Zaria Road
21.6	0	0	24	0	0	76	87	0	0	0	26	0	0.12	0.21	1.91	5	0.006	0.46	5. Galma at Gubunchi
17.02	0	0	46	0	0	54	95	0	0	0	4.54	0	0.82	0.41	0.62	5	0.18	0.46	6. Galma at Kuzuntu
8.87	0	0	0	0	0	100	100	0	0	0	0	0	0.43	0.33	0.74	5	0.01	0.76	7. Kahugu at Ikara
32.26	0	0	9	17.6	0	73	83	1.21	3.13	1.21	1.21	9.3	1.2	0.93	0.27	6	0.0057	0.54	8. Galma at Ribako
29.7	0	0	35	11.8	11.76	54	87	0	0	0	2.65	0	1.35	1.06	0.23	6	0.001	0.71	9. Tubo at Lagos Road
22.88	0	0	0	0	0	74	90	0	0	0	10	0	0.45	0.35	0.71	6	0.0096	0.75	10. Karami at Kauru
1.94	0	0	0	0	0	100	94	0	0	0	3.92	0	0.5	0.39	0.64	3	0.01	1	11. Dorogoin at Kwoi
6.55	0	0	33.3	0	0	67	92	7.14	0	0	0	0	0.86	0.66	0.38	5	0.005	1	12. Shaho at Kachia
8.12	12	0	33	0	0	71	90	0	0	0	0	0	0.78	0.43	0.74	5	0.0093	1.31	13. Kogun at Kagoro
11	0	0	0	0	0	100	100	0	0	0	0	0	0.23	0.2	1.41	4	0.001	1.12	14. Kachia at Kachia
8.69	54	0	0	0	0	46	100	0	0	0	0	0	0.42	0.33	0.77	5	0.0038	1.27	15. Kwassau at Zonkwa
6.91	0	0	11	0	0	89	100	0	0	0	0	0	0.81	0.64	0.01	5	0.0008	1.62	16. Chalwe at Zango Kataf
10.48	100	0	0	0	0	0	100	0	0	0	0	0	0.27	0.22	1.13	5	0.0053	2	17. Gurara at Gatan
4.18	12	0	18	0	0	71	68	0	0	2.7	29.7	0	0.82	0.64	0.38	5	0.0095	1.61	18. Kogun at Ugwan Rimi
6.69	45	51	0	0	0	0	50	0	0	0	50	0	0.8	0.61	0.41	5	0.053	2.8	19. Assob at Assob
2.94	29	0	0	0	0	73	73	0	0	2.22	24.4	0	0.49	0.39	0.64	5	0.0152	1.09	20. Kogun at Jagindi
SN 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	

Galma at Ribako; these sub basins will have delayed runoff. Basin relief will control the slope and the velocity of runoff. With the exception of Assob, Kogun, Shaho, Chalwe, Kwassau, Shika, Gurara basins with high relief, all other basins have gentle terrain. Hence, one expects a shorter time to peak in these basins with higher relief. The high percentage explanation explained (90%) above is however expected in view of the importance of the 8 factors discussed above to T_p in the Upper Kaduna Area.

Table 2: Factor Loadings, Eigen values and Contributions of Time to Peak and Basin Variables In The UKC

Basin Variables			**Component**							
			1	2	3	4	5	6	7	8
Hydrograph to Peak	1	Time To Peak	.058	-.103	.116	.874*	-.154	.160	.327	-.134
Geological variables	2	% Volcanic Rock	-.319	.869*	-.030	-.018	.043	-.197	-.006	.070
	3	% Younger Granite	.415	.444	-.173	-.027	-.002	.162	-.315	-.700*
	4	% Undiff. Granite	.105	-.125	-.105	.147	.024	.700*	.700*	.444
	5	% Porphyritic Biotite	.289	-.091	.905*	.225	.020	-.085	.161	-.006
	6	% Quartzite	.311	.007	.022	.171	-.081	-.023	.893*	-.093
	7	% Undiff. Basement complex	-.060	-.931*	-.029	-.153	-.053	-.234	-.068	.078
Land use Variables	8	% Cultivated Land	-.230	-.301	-.330	.074	-.793*	-.167	-.008	.152
	9	% Savanna Area	.268	.046	-.062	.005	-.099	.098	-.150	.790*
	10	% Forested Land	.197	-.107	.315	.769*	.121	-.140	-.301	.140
	11	% Urbanized	.052	-.121	-.042	.136	.846*	-.207	-.058	.176
	12	% Rock Outcrop	-.044	.323	-.149	-.061	.795*	.224	-.037	-.296
	13	% Fadama	.138	-.074	.958*	-.081	.016	-.041	-.094	-.016
Basin shape	14	Circularity Ratio	.872*	-.059	.218	.243	.062	.150	.239	.104
	1									

Variables	5	Form Factor	.867*	-.062	.245	.268	.101	-.031	.263	.056
	16	Lemniscates Ratio	* -.915	.017	-.071	.053	-.053	.064	.025	-.095
Relief attributes	17	Basin Order	.174	.222	-.367	.747*	.133	.089	.243	.091
	18	Relief Ratio	-.018	.021	-.054	.023	.029	.888*	-.093	-.036
	19	Drainage Density	.099	.758*	-.285	-.263	.298	-.140	-.102	-.054
		Factor defining variable	Lemniscate ratio	Undifferentiated basement Complex	%fadama	% forested	% urbanized	Relief ratio	% quartzite	% savanna
Factor description			**Index of Basin Shape**	**Index of Drainage Pattern**	**Index of Basin Wetness**	**Index of Basin Vegetation**	**Index of Basin Land Use**	**Index of Basin Relief**	**Index of Basin Geology**	**Index of Limited Human Access**
A. Total Eigen Value			**3.05**	**2.71**	**2.36**	**2.28**	**2.16**	**1.59**	**1.57**	**1/36**
B. % Variance Explained			**16.1**	**14.3**	**12.4**	**12.0**	**11.4**	**8.4**	**8.30**	**7.20**
C. % Cumulative Variance Explained			**16.1**	**30.3**	**42.8**	**54.7**	**66.1**	**74.5**	**83.0**	**90.0**

*.*Variables > 0.70; selected as variable defining purposes.**

Predicting to time to peak

The multiple regression analysis (Table 3) shows that all the 8 factors offered 96.5% explanation to the variance in the equation. All these factors are strong predictors of basin time to peak.

The above agrees with the work of Ramachandra and Delleur, (1974) that causes of T*p* should be sought not only in morphometric factors. This paper has demonstrated that T*p* is a function of morphometric, geological and land use factors. The stepwise regression model was later used to identify the most important variables that best explain T*p*. The result is presented in Table 3. The result showed that only 2 variables are most important to T_p. These are percentage area by forest with 76.3% explanation and percentage of the basin underlain quartzite with 10.7% contributions to the variance.

Table 3: Multiple Regression Analysis between Tp and Basin Physiography in the Upper Kaduna Catchment.

Model		Un-standardized Coefficients		Standardized Coefficients	T	Sig.	% Explanation
		B	Std. Error	Beta	B	Std. Error	
(Constant)		11.839	.477		24.844	.000	96.5
	Lemniscate ratio (k)	.500	.489	.058	1.022	.329	
	%Undifferentiated Basement Complex (%ubc)	-.893	.489	-.103	-1.826	.095	
3	% Fadama (%fad)	1.010	.489	.116	2.066	.063	
4	% Forest (%for)	7.583	.489	.874	15.510	.000	
5	% Urbanized (%urb)	-1.340	.489	-.154	-2.741	.019	
6	Relief ratio (Rh)	1.393	.489	.160	2.849	.016	
7	% Quartzite (%qzt)	2.835	.489	.327	5.798	.000	
8	%Savannah Scrubland (%sav)	-1.160	.489	-.134	-2.373	.037	

Y=11.839+0.500k-.893%ubc+1.010%fad+7.583for+%-.340urb+1.393%urb+2.835%qzt-1.160%sav………………………………………... (eq. 2)
(R^2=96.5; SE=0.489)

Table 3: Stepwise Regression Analysis of Orthogonal Factors and T_p

Model		Un-standardized Coefficients		Standardized Coefficients	T	Sig.	% Explanation	
		B	Std. Error	Beta	B	Std. Error		
(Constant)		11.839	.739		16.015	.000	**% Variance**	**% cumulative Variance**
1	% forest	7.583	.758	.874	9.998	.000	.763	.763
2	%qzt	2.835	.758	.327	3.738	.002	10.7	.870

Y=11.839+7.583%for +2.835%qtz…………………………… (eq. 3)
R^2=87.0%; SE=0.002

These 2 variables have high amount of explanation of the variance. The result also shows that redundancies exist in the hydrological variables. For example, the 17 basin variables (Table 1) were reduced to only 8 (Table 2) orthogonal factors; meaning that the other 9 variables accounted for about 10% in the explanation in the variance of the T_p in UKC. Redundancy was also noticed in the regression equation (Table 3) as only 2 factors accounted (percentage area of the basin forested and percentage area of the basin underlain by quartzite) for 87.0 % explanation, while, other 6 factor defining variables (Table 3) account for 9.5% explanation in the variance.

Summary, conclusion and implication for flood management

An important approach to flood mitigation is the development of early warning signals (EWS) and efficient flood forecasting methods to guide policy makers and riparian communities. Indeed, flood prediction and early warning methodologies depend on the hydrograph time relations such as T_p. It is an important variable in flood management. Flood is an annual event in Africa. It is perhaps becoming more frequent and more disastrous in Nigeria, with its recent prominence in the hydrology of sub humid parts of Nigeria.

Indeed, the largely Basement Complex geology in UKC suffice that T_p will be short in view of he high overland flow contribution to the hydrograph, however, land use and geological factors have distorted this fact as T_p are generally long, with some basins having about 32hours of T_p.

T_p in 20 sub basins are generally long; ranging from 2 to 32 hours; suggesting low incidences of flood, particularly flash floods. High redundancy exists in the data as the 17 basin variables were reduced to 8 orthogonal factors (4 land use factors, 2 relief factors and 2 geological variables), which provided 90.0 % explanation. These groups of factors offered 85.5% explanation to the regression equation. The stepwise regression analysis also showed that only 2 factors (percentage area covered by forest and percentage area underlain by quartzite) explained 87.0 % of the variance in the stepwise multiple regression equation.

The result of the study agrees with the conclusion of Ramachandra and Delleur, (1974) that morphometric variables are not the only factors controlling flood characteristics. Hence, this present study shows that T_p is controlled by 3 groups of basin variables namely: relief, land use and geological attributes of the basin. The results showed that T_p seems long in many sub basins; this explains the low incidences of flood in the Upper Kaduna Catchment.

The orthogonal factors selected in this study (lemniscate ratio, undifferentiated Basement Complex, *fadama*, forest, urbanized, relief ratio, quartzite, savannah scrubland), could form input variables into a multipurpose flood and watershed management models in the UKC. Such efforts will assist in resolving problems of basin management in this large sub humid catchment of Nigeria.

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