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THE IMPACT OF URBANIZATION ON THE JAKARA STREAM CHANNEL MORPHOLOGY, KANO, NIGERIA

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ABSTRACT
This study examines the influence of urbanization on channel morphology in a watershed that drains Kano metropolis the largest urban centre in Northern Nigeria. Channel sites under different levels of urbanization in the Jakara catchment were sampled. Field surveys were conducted at transects in a total of six reaches of the Jakara channel, two each in fully urban, semi urban and rural sites. Measurements of channel, reach and Planform dimension parameters were used to assess the impact of urbanization. The results indicate high degree of variations in the channel dimension parameters considering that it is a 3rd order stream. However, all the parameters of full channel dimension show that the urban reach is larger than the semi-urban and rural reaches. The data also indicate that the width and depth increase in the downstream direction, as do cross-sectional area and wetted perimeter in the rural reach. The semi urban reach also shows a similar increase in these variables in a downstream direction. The urban reach however, shows a slightly different trend with mean depth, width and cross-sectional area not showing an increasing trend in the downstream direction.

Key words: Watershed; Channel full dimension; impervious surfaces. Stream reach; Stream Planform dimension

INTRDUCTION

The impact of urbanization on streams is well-documented and includes significant changes in basin hydrology, channel morphology, and physico-chemical water quality (Morisawa and Laflure, 1979; Nanson, 1981; Booth, 1991, 1990; Johnson, 2001; May *et al.,* 2002; Jeje and Ikeazota, 2002; Avolio, 2003; Brierley and Fryirs, 2005).

Several approaches have been used to assess the impact of urbanization on stream morphology. In one approach, urbanization is considered a single factor and streams or stream reaches with different levels of urbanization are sampled. Morphological variables at the sampling sites are analyzed in terms of that single factor to infer effects of urbanization (Kennan and Ayers, 2002; Roy *et al.,* 2003b; Walters *et al.,* 2003a). In another approach, Morphological variables are ordinated, correlated, or regressed against a variety of physical and environmental factors, often including the original measure of urbanization used to design the study. Significant environmental factors are then related back to urbanization using similar correlative methods. Some studies have focused on viewing a large amount of streams in a given area to attempt to understand how differing land uses effect stream morphology within a given region or area (Dunne and Leopold (1978).

Because urbanization is largely an irreversible process that changes earth surfaces, urbanizing channels are necessarily changed through the adjustment process, consequently, managing urban channels poses particular challenges because, most are undergoing adjustments at one stage or another. Understanding the evolution of urban rivers can help to determine "what is natural" in restoration efforts (Graf, 1996), because the pre-urban channel state often can no longer be sustained under the changed hydrological conditions. Thus, different management goals are probably appropriate for channels at varying stages of urban development (Booth *et al.,* 2002). In this context, identifying which channels are suitable for protection (least disturbed), rehabilitation (improving moderately degraded channels), or stewardship (maintaining the channel but improvement unlikely) could wisely guide restoration efforts (Booth *et al.,* 2004).

In Nigeria, in particular, studies of urbanization impacts on river systems have concentrated in the humid tropics of south west and south east notably by Ebisimiju,(1989ab), Odemerho,(1992),Jeje and Ikezeato, (2002).Despite the growing literature on the effect of urbanization on stream channel morphology, none of these investigations have examined areas in semi arid Northern Nigeria, which means there still remains a great shortage in quantitative data on the effects of urbanization on stream system in this area. This work assessed the impact of urbanization on the morphology of the Jakara channel, a small catchment (3rd order) with uniform local conditions through comparison of channel reaches under different levels of urban influence.

Study Area

The study is on the Jakara River catchment which is located between latitude 12^o 25 to 12^o 40 N and longitude 8^o 35 to 8^o 45E. The present climate of the study area is the tropical wet-end-dry type which is characterized by a wet season that lasts between June and September during which about 800mm of rain occur.

Temperature is high throughout the year however, climate changes have occurred ending about 10,000 years BC (Grove and Warren, 1968). During the arid phases desertic conditions are believed to have prevailed. On the other hand humid conditions wetter than the current tropical wet climate prevailed during the fluvial phases.

The study basin is located on the Basement Complex, and within the area where a wind drift material (a silty wind-blown deposit of the last arid phase) has concealed the pre-arid regolith and its associated ferruginous soils on the upland plain and old alluvial deposits on the river terraces. The silty surface cover impedes infiltration because initial splashes create puddles which block the tiny pores. However, the material on the channel beds is very sandy, porous and seasonally mobile.

According to the Kano chronicles human settlement in and around Kano city dates from the 7^{th} century. Urbanization along the Jakara channel is not uniform. The main concentration of urban surface is at the upper course where the catchment land area is almost all under impervious cover. The middle course is a transition area experiencing very rapid change from rural to urban with the impervious surfaces covering about 33%. The lower course is generally rural, with impervious areas covering less than 3% of the catchment.

MATERIALS AND MEHODS

The impact of urbanization on the Jakara channel was studied by comparing sections of the channel under varying intensities of urbanization.

Site and reach selection

Based upon the degree of urbanization, Jakara stream was divided into three sites with different levels of urbanization

a) An upper watershed dominated by urbanization (Fagge/Airport road/Nomansland)

b) A middle section that is under going urbanization exurban/semi urban (Gama kwari)

c) A lower watershed that is primarily rural (Dosara/Yadakunya)

The sites were selected after a field reconnaissance to establish that they conform to convention as demonstrated by Neller, (1988), May *et al*., (2002). Efforts were made to best represent the end members of the range. The percentage of impervious land was treated as an estimator of the percentage of land experiencing urbanization. Having determined the three sites along the Jakara channel, two reaches were selected from each of the three sites for detailed study.

The sample reaches were determined after a field reconnaissance to assess the overall character and the diversity of the channel morphology. Distortions especially points where a tributary or sewer joins the channel were avoided (Hynes 1975; Vannote *et al.,* 1980; Booth and Jackson,1997; Fitzpatrick *et al.,* 1998, Klauda *et al.,* 1998). The selected reaches were transacted to measure the morphological variables. The following channel morphological variables were measured in the profiles at each of the six selected reaches:

Channel full dimension parameters: Cross section; Width; Depth; Wetted perimeter; Land use Slope.

Channel Planform dimension parameters: Meander length; Meander width; Sinuosity; Number of threads (single or multiple)

Channel morphology was measured using tape, level rod and hand leveler to acquire detailed bankful cross-sectional data. Impervious area was estimated from air photographs, land use maps, roadmaps, layout plans and land Landsat imagery and road map of Kano metropolis. The percent area made impervious for each site was calculated by summing the area of homes, streets and other structures and multiplied by average size of the development as determined by map inspection. These were groundtruthed by fieldwork.

RESULTS AND DISCUSSION

Urbanisation in the Jakara Catchment

A detailed study of land cover along the Jakara catchment was conducted using black and white air photographs taken in 1961 and 1981. These were used together with land use maps, road maps and layout plans to determine the extent of urban land use from 1961 to 2006 along the catchment. The results indicted that up to 1961, the amount of urban structures on the Jakara catchment is minimal and this was a period of low urbanization with less than 5% urbanization of the watershed. In addition, urban structures were not impervious (houses were made of up mud and most of the roads were laterite covered) and well outside the channel. A substantial part of the catchment is used for agriculture and grazing only. The amount of urban development within the Jakara watershed increased substantially from 1987, the period of high urbanization. When expressed as percentage of the total catchment area, the amount of urbanized land increased from 4% in 1961 to 27.95% in 1987. Figs. 1, 2 and 3, were produced with data from Landsat imagery interpretation followed by intensive field verification which show land use changes along the Jakara catchment for the years 1987, 1995 and 2006.

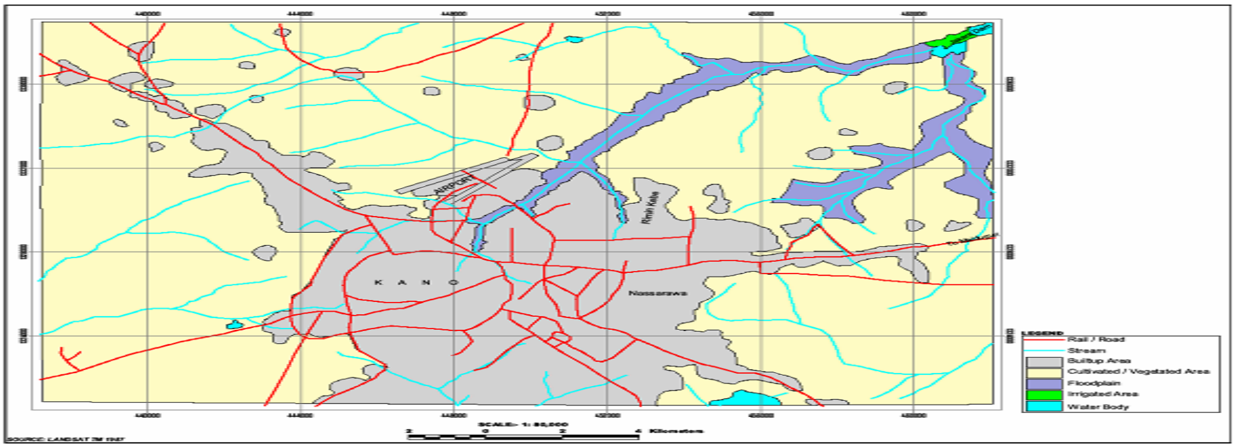

Figure1: Land use along the Jakara catchment Kano metropolis, 1987

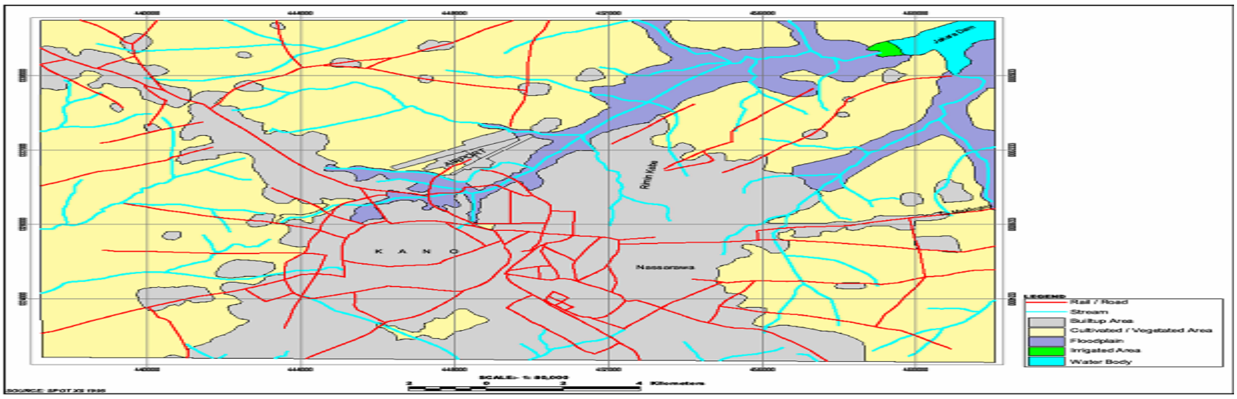

Figure 2: Land use along the Jakara catchment Kano metropolis, 1995

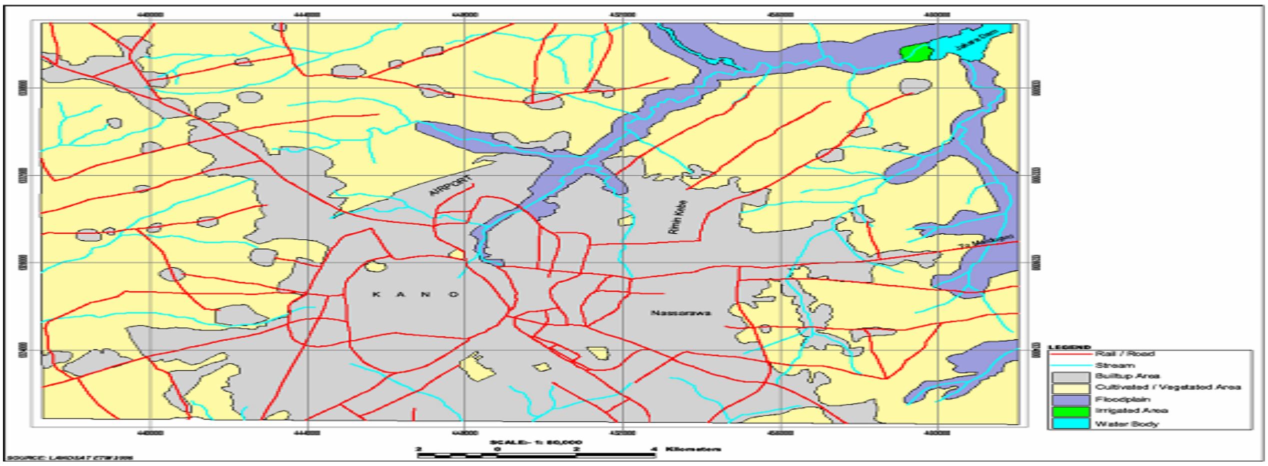

Figure 3: Land use along the Jakara catchment Kano metropolis, 2006

The observed land use distribution and changes is shown in Table 1. Analysis of the data indicates that the imperious surface cover for the entire Jakara steam as a whole was 38.67% in 2006 from 28% in 1987.

The main concentration of urban/impervious surface is at the upper course where the catchment is 100% under impervious cover. The middle course is a transition area experiencing very rapid change from rural to urban with the impervious surfaces covering about 13%. The lower course is generally rural, with impervious areas covering only about 3% of the catchment.

Result indicates that of all the land use classes, remarkable changes were in the reduction in vegetation /cultivation area and significantly of more interest to this study increase in built up areas reflecting the increased conversion of agricultural land to impervious surfaces. In 1987, 28% of the watershed is built up, by 2006 the built up area has increased to 38.67% .In contrast, cultivation/vegetation was about 68% in 1987 but has dropped substantially to 52% of the catchment area in 2006.

Table1: Land use distribution along the Jakara catchment for 1987,1995, and 2006.

KANO 87			
DESC	**AREA (Sq.m)**		**LENGTH**
WATER BODY	1709652.719	ROAD	171206.993
IRRIGATION	503903.813	RIVER	201257.41
FLOODPLAIN	23813891		
CULTIVATION/VEGETATION	299309792.5		
BUILTUP	126233129.2		
TOTAL	451570369.3		
KANO 95			
DESC	AREA (Sq.m)		LENGTH
WATER BODY	3764007.75	ROAD	258340.269
IRRIGATION	471841.875	RIVER	212476.138
FLOODPLAIN	39895747		
CULTIVATION/VEGETATION	238066334.1		
BUILTUP	169372438.6		
TOTAL	451570369.3		
KANO 06			
DESC	AREA (Sq.m)		LENGTH
WATER BODY	2415462.625	ROAD	276626.309
IRRIGATION	555172.438	RIVER	200064.241
FLOODPLAIN	35950554		
CULTIVATION/VEGETATION	237986659.9		
BUILTUP	174662520.4		
TOTAL	451570369.3		

Source: Land sat imagery interpretation

Insignificant changes were found in the road, floodplain, and length of the stream and extent of water body. In fact, the data indicated that the floodplain increased slightly between 1987 and 1995 from 5.27% to 8.83% of the catchment area. This can be explained by the fact that definition of land cover categories and the determination of their spatial extent with imagery are fraught with logistical problems. No matter how refined these classifications may be, they still collapse into a finite number of land-cover classes. Particularly relevant to relating landscape change to aquatic ecosystems is the confusing nature of the available maps and databases dealing with water bodies in general (Meyer, *et al.,* 2000). Changes in road cover remained more or less the same from 0.057% in 1995 to 0.061% of the catchment in 2006.

The total length of the stream as measured from the topographical map Kano NE, sheet 50 was 27.76km, while from Google earth it was 21.28km, and 20.1km from the landsat image interpretation. This variation is to be expected, since fears have been expressed regarding the accuracy of medium to large-scale maps for the purposes of catchment studies (Kan,2000). Gregory (1966), Hely and Olmsted (1963), among others have pointed out that stream lengths shown on topographic maps are much shorter than actual lengths since rivers are inserted on maps only where water is present when the map was drawn. So also are water bodies especially from seasonal streams. This observation is of particular relevance to drainage network in the study area. The Nigeria 1:50,000 topographic sheets were produced from air photos acquired in the dry sea. Field observation indicted actual substantial reduction in channel length due to in filling of the channel to make way for house construction.

Comparison Full Channel Dimension

Table 2 shows the morphological parameters of full channel dimension of the six sampled reaches. The mean channel width is 12.73m with standard deviation of 3.78 and coefficient variation percentage of 29.8percent and a range of 10.8. The mean cross-sectional area is 24.54m^2 with standard deviation of 17.37, coefficient of variation of 70.8 percent and a range of 6.59. The mean depth is 1.71m, standard deviation of 0.81 and coefficient of variation of 47.4 percent and a range of 2.11.The mean wetted perimeter, is 24.54m^2, standard deviation of 17.37, coefficient of variation of 70.8 percent and a range of 46.49. The mean wetted perimeter is 18.43m^2, standard deviation 2.69, coefficient of variation 14.6 percent and a range of 6.59.

Table 2: Channel full dimension

Channel reach	Width (m)	Depth (m)	Cross section m^2	Welted parameters(m)
Sample point I	18.80	2.81	52.83	16.01
Sample point II	16.70	2.53	42.25	14.97
Sample point III	10.75	1.80	19.35	17.11
Sample point IV	12.11	1.62	19.62	18.97
Sample point V	8.10	0.79	6.34	20.90
Sample point VI	9.90	0.69	6.83	22.60
Mean	12.73	1.71	24.54	18.43
Standard Deviation	3.79	0.81	17.37	2.69
Range	10.80	2.11	46.49	6.59
Coefficient of variation	0.298	0.474	0.708	0.146

Source: Field work, 2008

The statistics show a high degree of variation in the channel dimension considering that it is a 3rd order stream, This is reflected in the high variation between standard deviation and mean value and range. However, all the parameters of full channel dimension show that the urban reach is larger than the semi-urban and rural reach. The relatively large channel size draining impervious reach could be due to increased peak discharges because, several researches indicated that impervious surfaces cause increased storm runoff, flood frequencies, and peak discharges compared to pre-urban conditions (Booth, 1991; Arnold and Gibbons, 1996; Paul and Meyer, 2001). Streams adjust to such increased regimes by altering their cross-sectional area to accommodate the higher flows. This is done either through widening of the stream banks, and down cutting of the streambed, or frequently, both. This phase of channel instability, in turn, triggers a cycle of stream bank erosion. It has been suggested that a threshold for urban stream stability exists at about 10% imperviousousness (Booth, 1991, Booth and Reinelt, 1993,). The relatively smaller channel size of streams draining semi impervious in semi urban and impervious rural reaches could be due to low flow peak discharges brought about by high infiltration capacity. Rural channel reduction could be also due to fluvial deposit and the abandonment of the former summit by running water.

Comparison of Reach Dimension

Table 3 is a comparative analysis of the reach dimension parameters of the six sampled reaches. The data shows first, that there is uniformity in the parameters within individual sampled reaches. The data also indicate that the width and depth increase in the downstream direction, as do cross-sectional area and wetted perimeter in the rural non-impervious reach. The semi urban reach also shows a similar increase in these variables in a downstream direction. The urban reach however, shows a slightly different trend with mean depth, width and cross-sectional area not showing an increasing trend in the downstream direction. This is to be expected as urban stream have been shown to respond to urbanization by increasing their cross section to accommodate their increased flow (Ebisimiju, 1991; Jeje and Ikezeato,2002,).

Comparison of Planform Dimension

Table 4 shows the channel Planform parameter in the urban, semi urban and rural reaches of the Jakara channel. Width/ depth ratios are higher in the urban reach compared to the semi-urban and rural reach. This can be explained by the fact that increased flooding associated with urbanization often leads to erosion of the stream bank which increases the ability of the channel to convey the increased flood flow. One possible explanation for lower width/depth ratios in the semi urban and rural reaches is that greater sediment yield from erosive land use accreting on the stream bank and floodplain.

In the urban reach, the width of the meander belt is lower, 5.95m than that of semi urban 11.75m, whereas, rural reach has a wider average width of 34.55m.The channel pattern changed from the natural pool and riffles in the rural reach to braided to quasi-meandering in the urban and semi urban reaches with considerable entrenchment, which ranged from 0.8 to 2.9m. Mean sinuosity ranged from 1.07m in the urban, 1.21semi urban and 1.56 in the rural reach. Urban channel is wide and bed topography is shallow. The braided pattern in the urban and semi urban reaches is associated with substantial bank erosion.

Table.3 Comparative analysis of Reach dimension

Sample location	Width (m)	Depth (m)	Cross section m^2	Wetted parameter
Urban Reach Sample Sample I	18.80	2.87	52.83	16.01
Sample II	16.70	2.53	42.25	14.97
Mean	17.75	2.67	47.54	15.48
Standard deviation	1.49	0.14	5.29	0.52
Coefficient of variation	8.00	5.20	11.10	3.40
Simi- Urban Reach Sample 1	10.75	1.80	19.35	17.11
Sample 11	12.11	1.62	19.62	18.97
Mean	11.43	1.71	19.49	18.04
Std dev	0.68	0.09	0.135	0.93
Coefficient of variation	59.50	5.20	6.9	5.20
Rural Reach Sample 1	8.10	0.79	6.34	20.90
Sample 1I	9.90	0.69	6.83	22.60
Mean	9.0	0.74	6.59	21.75
Standard deviation	0.90	0.05	0.24	0.85
Coefficient of variation	10.00	7.00	3.70	3.90

Source: Field work, 2008

Table.4 Comparison of Reach Planform dimension

Channel characteristics	Urban Reach	Semi-Urban Reach	Rural Reach
Meander length (m) (mean)	5.95	11.75	34.5
Meander width (m) (mean)	2.95	8.57	4.5
Slope	2.05^0	1.8^0	1.05^0
Sinuosity	1.07	1.21	1.56
Width/depth ratio(mean)	12.30	6.70	6.65

Source: Field work, 2008

CONCLUSION

This study has shown that urbanization can result in significant changes to urban stream channel morphology. Jakara channel is demonstrated to be consistently larger in the reach under impervious land use than those under non-impervious land uses. Also, the urban and semi urban reaches show higher bankful width/depth ratios, wider wetted widths than that in the rural reach.

The accompanying widening suggests that the downstream spatial impact of urbanization is quantifiable. The wider channels in rivers with increasing urbanization may be inevitable unless the effects of the increase in impervious area are mitigated through the engineered control of runoff and / or strict land use planning. This method of study indicates that it is possible to analyze morphology and generalize within the channel.

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