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# MORPHOLOGICAL RESPONSE OF RIVER NGADDA TO URBANIZATION IN MAIDUGURI METROPOLIS, NIGERIA

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## Abstract

This study examines the River Ngadda channel morphology response to urbanization in Maiduguri Metropolis, Northeastern Nigeria. Sample sites were selected in a basin with different levels of urbanization. Field measurements of channel full dimension and reach dimension parameters were assessed in the three segments of the basin. Data on the channel morphological variables were collected through field measurement of the cross sectional area characteristics of the river from where the longitudinal characteristics were defined. 15 sample sites were established along 22.9km stretch of the river channel. Five sites each in urban, semi urban and rural segments respectively were selected. The results shows all the six parameters of full channel dimension shows that the urban segment is larger than the semi-urban and rural segments. The result also shows that the width and depth parameters increase in the downstream direction in the urban and semi urban segments, while cross sectional area and wetted perimeter increases in the rural segment. Analysis of variance for the comparison of the regression lines in the three segments revealed that variations occurred in all the six parameters downstream for all the channel form variables [redacted] indicated that there are variations. The result further provide F ratio which implies the extent of variation showed that the bed slope F ratio 37.18 and wetted perimeter F ratio 28.14 were the most variables downstream among the morphologic parameters considered followed by channel depth 14.01, channel 13.09 and width to depth ratio 10.25. While the cross-sectional area is the least variable with an F ratio of 6.72. The bed slope with F ratio as

**Key words:** Urbanization; Impervious surface cover; channel full dimension; channel segment; sample sites.

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high as 37.57 is the most widely varied downstream, less variations occur in cross sectional area downstream with F ratio of 6.72. However, bed slope reflected a statistical insignificant difference at 0.05 α-level with p-value of 4.28. While all other parameters varying downstream (e.g., width, depth, wetted perimeter, cross sectional area and width to depth ratio) exhibited significant difference at 0.05 α-level.

## Introduction

Urbanization is a pervasive and rapidly growing form of land use change. More than 60% of the world's population will live in urban areas by the year 2030, much of this growth occurring in developing nations (UN Population Division 1997, US Census Bureau 2001). Whereas the overall land area covered by urban growth remains small (2% of earth's land surface), its ecological footprint can be large (Folke *et al.* 1997). Urbanization is the anthropogenic process of changing the land cover through urban development. This implies additional (new) buildings and houses, and significant modification of water pathways through different networks such as roads, storm water gutters and pipes, constructed channels, which may also interact with the network of potable water and sewer systems.

Urbanization produces numerous changes in the natural environment it replaces. The impacts include hydrological, morphological and sedimentological changes. The amount of storm water runoff is generally increased due to the removal of vegetation and the rise in impervious areas, resulting in a rise in the frequency and magnitude of floods. Moreover, the increased stream powers alter the shape of channels and sediment supplies are disturbed. The reduction of perviousness also results in a reduction in groundwater. Finally, the quality of water is lowered due to urban sources of pollution. The major factors controlling the effects of urbanization are the impervious proportion of the drainage basin, the size of the catchment and the nature of rainstorms.

Urban Rivers, commonly display flashy flow due to rapid runoff from impervious surfaces. The flashy stream flow can alter the bed and banks of the stream channel considerably over time. The erosive power that is generated in urban streams often leads to degradation and widening of stream channels, bank failure, increased sediment supply, and instability of riffle and pool features along the channel profile (Paul and Meyer, 2001). Urbanization produces numerous changes in the natural environment it replaces. The impacts include hydrological,

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morphological and sedimentological changes. The amount of storm water runoff is generally increased due to the removal of vegetation and the rise in impervious areas, resulting in a rise in the frequency and magnitude of floods. Moreover, the increased stream powers alter the shape of channels and sediment supplies are disturbed. The reduction of perviousness also results in a reduction in groundwater. Finally, the quality of water is lowered due to urban sources of pollution. The major factors controlling the effects of urbanization are the impervious proportion of the drainage basin, the size of the catchment and the nature of rainstorms.

Channel morphology of urbanized rivers are often heavily degraded of ecological functioning, an, issue that was initially ignored. This is not confined to a particular geographic region of the world, but common to all areas subject to urbanization (Morley and Karr 2002). Initially, such waterways were managed as a resource for human benefit, including water supply, flood mitigation, disposal of wastewater and minimization of disease (Walsh 2000). However, this has led to the degradation of stream ecological functioning, an issue that was initially ignored. Urban streams in general tend to have enlarged cross-sectional dimensions, accelerated bed and bank erosion (Neller, 1988; Roesner and Bledsoe, 2003), decreased amounts of large woody debris (LWD) and other roughness elements (May *et al.,* 1997; Finkenbine *et al.,* 2000), and simplified morphology (Pizzuto *et al.,* 2000). The grain size distribution commonly shifts to smaller sizes in urban streams (Booth and Jackson, 1997); conversely, smaller grain sizes may be selectively removed in highly urbanized systems where transport capacity greatly exceeds sediment supply (Finkenbine *et al.,* 2000). Built-up area modifies runoff to streams along with the resulting rate, volume and timing of stream flow. Other urbanization implications include modifications to peak flow, total runoff, stream morphology, and water quality. The magnitude of these changes is the result of the spatial arrangement of urbanization (Miltner *et al.,* 2004; Jacobson, 2011). Urban streams can be especially impacted by rapid and short-term runoff rates, mainly as a combined result of sewers and storm water overflows (Tetzlaff *et al.,* 2005). Also, the majority of urban landscape components are complex and strongly interconnected with adjacent ecosystems, change in land use along the river system in the transition zone between ecosystems in urban basins can affect functional processes (Radford and James, 2013; Lauff *et al*., 2014; Dobbs *et al*., 2014).

Channel morphological changes are among the most common and readily visible effects of urban development on natural stream systems in humid environments. Since channel adjustment does not necessarily occur uniformly basically due to variability in local boundary materials or the direct perturbations to the channels. Even though, there is much communality that can be expected with urbanization. The response of stream to urbanization may differ (Gregory, 1992).

There are as many approaches as there are models employed by various researchers to assess urbanization impact on stream channels and river regulation. The complexity of urban land use and the varying responses reported present challenges for understanding the mechanisms by which urban impacts change structure and function (Booth *et al., 2004*). Hence, relationship between urbanization and channel morphology is one area that seeks further investigations for better understanding. Obviously, no single study can cover all settings in which urban-induced channel change is observed. However, even a geographically limited set of new data can increase our understanding and predictive ability of this threat to system integrity. 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). There is growing literature on the impact of urbanization on stream channel morphology in Nigeria notably by Ajewole (2003), Aziegbe (2006), Mogborukor (2014), Nabegu (2014), Fashae and Faniran (2015). However, virtually, no attempt has been made at documenting the changes in channel morphology of River Ngadda in Maiduguri metropolis. This study examined the relationships between urbanization and channel morphological change. The output has contributed to our understanding of sustainable urban watershed management practice. Also, the research contributed to a better understanding of the appropriate scales at which to direct land management efforts for purposes of protecting and enhancing stream conditions.

## LOCATION OF THE STUDY AREA

Maiduguri is located between latitudes 11°46´18"N and 11°53´21"N and longitudes 13°02´23"E and 13°14´19"E. Maiduguri is located in the Sudano-Sahelian belt of Borno State and is part of the Chad Formation. The study area is characterized by semi-arid climate with two distinct seasons. The rainy seasons starts from January

to September. The Harmattan season precede dry season from October to February. This is a period of very low temperature and cold dry Harmattan wind. The hot season starts from March to May marking the driest period with intense heat (Bankole *et al,.* 1994). The months of March and April are usually the hottest months, while November and January are the cold and dry periods of Harmattan.
Rainfall in the area is limited and short-lived and surface water flow is confined almost entirely within the channel of River Ngadda and its tributary Ngaddabul flows mainly during the peak of the rainy season in August. The area has mean annual rainfall of less than 750 mm with mean maximum of 32.2 – 35$^o$ and minimum temperatures of 18.3 - 21.1$^o$C (Grema and Hess, 1994). The mean monthly minimum temperature is lowest 13.5$^o$ during the period of strongest and most constant northeast winds [Harmattan (popularly known as Binim in Kanuri)] in December and January; and highest 24.7$^o$C in April (National Meteorological Office Maiduguri, 2008).
Ngadda catchment is underlain by the sediments of the Chad Formation. The oldest sediment in the Chad Basin is the Bima Formation deposited unconformable on the Precambrian Basement Complex. The catchment consists of a vast open plain known to have developed on young sedimentary rock of the Chad formation consisting of loosed sand, gravels and clays. These sedimentary deposits are believed to have lain down during the quaternary period. The soil types are predominantly sandy at the surface and this may be the underlie problem of soil management in the region. The Chad Formation which is the youngest sediment is a variable sequence that includes quaternary sediments of lacustrine origin. The Formation consists essentially of argillaceous sequence in which persistent arenaceous horizons occur. Within the Chad Formation, three distinct zones of aquifers separated by clay deposits are recognized (Odada *et al*., 2006). These are known as the Lower, Middle and Upper aquifer zones. The Lower aquifer occurs at depths of 420 to 650 m. The Lower River Ngadda is characterized by low slope angle and extensive floodplains with marshes and swamps.
Urbanization in Maiduguri was dated back to when the city was selected in 1907 by the British to be the capital of the Borno Emirate, which was the surviving traditional ruling structure after the end of the Kanem Borno Empire (1380 – 1893). Maiduguri functioned as the divisional and provincial headquarters of Borno Native Authority and Borno Province respectively during the colonial administration. After Nigeria proclaimed independence from British rule in 1960, Maiduguri became the capital of North Eastern state in 1967 and that of Borno State since 1976.1 Maiduguri city has grown over the years in line with Nigeria's

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general urbanization trends, primarily driven by rural to urban migration (Marissa and Katja, 2021). Progressive urbanization of Ngadda River watershed has contributed to increase in the erosive momentum of the accumulated storm runoff from concretes, tarmacs, pavements, zinc roofs and the denuded and compacted soil surfaces. The various peculiar urban surfaces in the drainage basin reduce infiltration capacity of the urban space through surface and sub-surface sealing generated by the eluviation's processes of rain water.

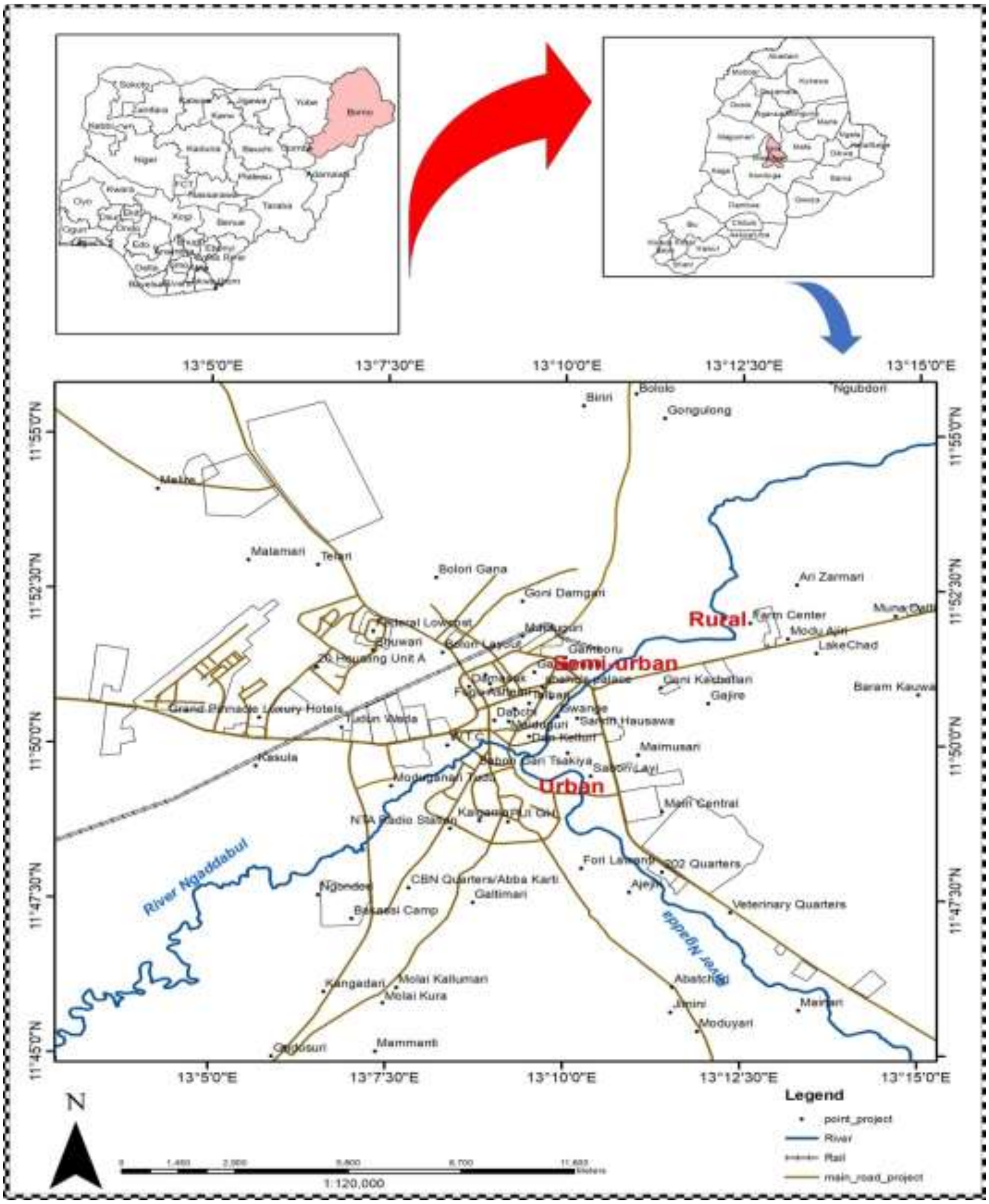


**Figure 1:** Maiduguri showing the study Area

Source: Department of Urban and Regional Planning, Ramat Polytechnic Maiduguri.

## MATERIALS AND MEHODS

Morphological response of river Ngadda channel was compared by analyzing three segments of the channel under different level of urbanization.

### Segment and sites selection

River Ngadda channel was divided into three segments based upon the degree of urbanization as shown below: (i) The urban segment dominated by urbanization (Fori, New GRA, Galtimari, Gwange Sabonlayi, Sabongari, Kingar Makka) (ii) The semi urban segment that is undergoing urbanization (Gamboru market, Shokari, Abattoir, Faria, College of Agric) and (iii) The rural segment that is primarily rural (Farm center1, Farm center 2, Garden 1, Garden 2, Muna Kumburi).

The length of reach was based on the recommendation of Rosgen (1994) who stated that channel reaches at least 10 to 20 times the channel width in length define a useful scale over which to relate stream morphology to channel processes, response potential, and habit characteristic. This involves the division of each of the three study segments along the channel into five sample sites (i.e., the urban, semi urban and rural segments). The rural segments are parts of the stream segments where the percent of impervious surface cover is very little. The urban and semi urban segments are the modified parts of the drainage basins where urbanization process has brought about changes in land use pattern. Thus, a total of 15 sites were identified for the entire catchment for detailed study (Figure 2).

The fifteen selected sample sites were then used to measure the morphological variables. The following channel morphological variables were measured in the profiles at each of the six selected segments: Channel full dimension parameters: Width; Depth; Cross section; Wetted perimeter; slope and width/depth ratio. Variables of channel morphology was measured using tape, level rod and hand leveler to acquire detailed cross sectional data. Impervious surface cover was estimated from Landsat imagery of Maiduguri metropolis using GIS Imagery (Fig 2).

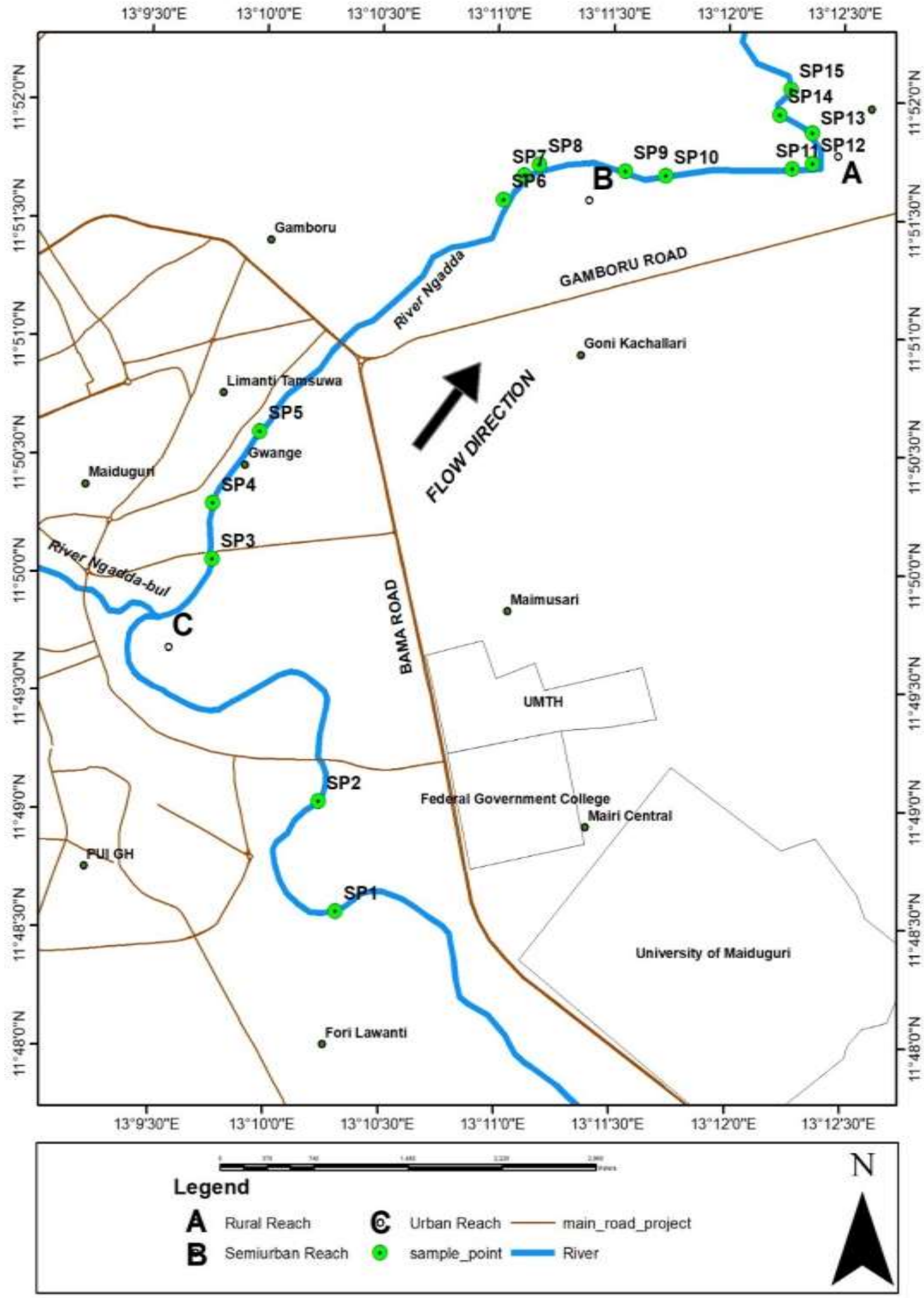


*Figure 2: Sample Sites along River Ngadda Channel*
Source: Landsat Imagery Data

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## RESULTS AND DISCUSSION

### Urbanization of Maiduguri Metropolis

Urbanization in Maiduguri was dated back to when the city was selected in 1907 by the British to be the capital of the Borno Emirate, which was the surviving traditional ruling structure after the end of the Kanem Borno Empire (1380 – 1893). Maiduguri functioned as the divisional and provincial headquarters of Borno Native Authority and Borno Province respectively during the colonial administration. After Nigeria proclaimed independence from British rule in 1960, Maiduguri became the capital of North Eastern state in 1967 and that of Borno State since 1976.1 Maiduguri city has grown over the years in line with Nigeria's general urbanization trends, primarily driven by rural to urban migration (Marissa and Katja, 2021). Moreover, the rapid expansion of Maiduguri was said to have begun in 1960s when the city rapidly expanded in landmass and population. The population of Maiduguri was 10,000 in 1910. This figure according to the National Population Census rose to 139, 965 in the 1963 and 654, 400 in 1991 (Kawka, 2002). In 1995 Population Census put the total population of the Maiduguri urban (MMC and Jere LGA) at 537,972 with a growth of 8,309 at 1.52% growth rate. In 2005 the population was increased to 625,229 with a growth of 9309 at 1.51 growth rate (Marissa and Katja, 2021). The demographic data from the 2006 census estimates the population to be 748,123 (Jere and MMC LGAs), which means Maiduguri is categorized as a 'medium' size city in the Nigerian urban. Maiduguri is composed of two local government areas (LGAs) namely: Maiduguri metropolitan council (MMC) and Jere LGA, with some sources including Konduga and Mafa LGAs into 'greater Maiduguri. These areas combine to cover a total land area of 543 $km^2$ (Marissa and Katja, 2021). The growing urban population results in large areas of land surface covered with roofing materials, concrete and bitumen pavement which reduce infiltration of rainwater and increase surface runoffs leading to flood in the cities with adverse economic effect and health impact Ogbonna *et al.*, (2008).

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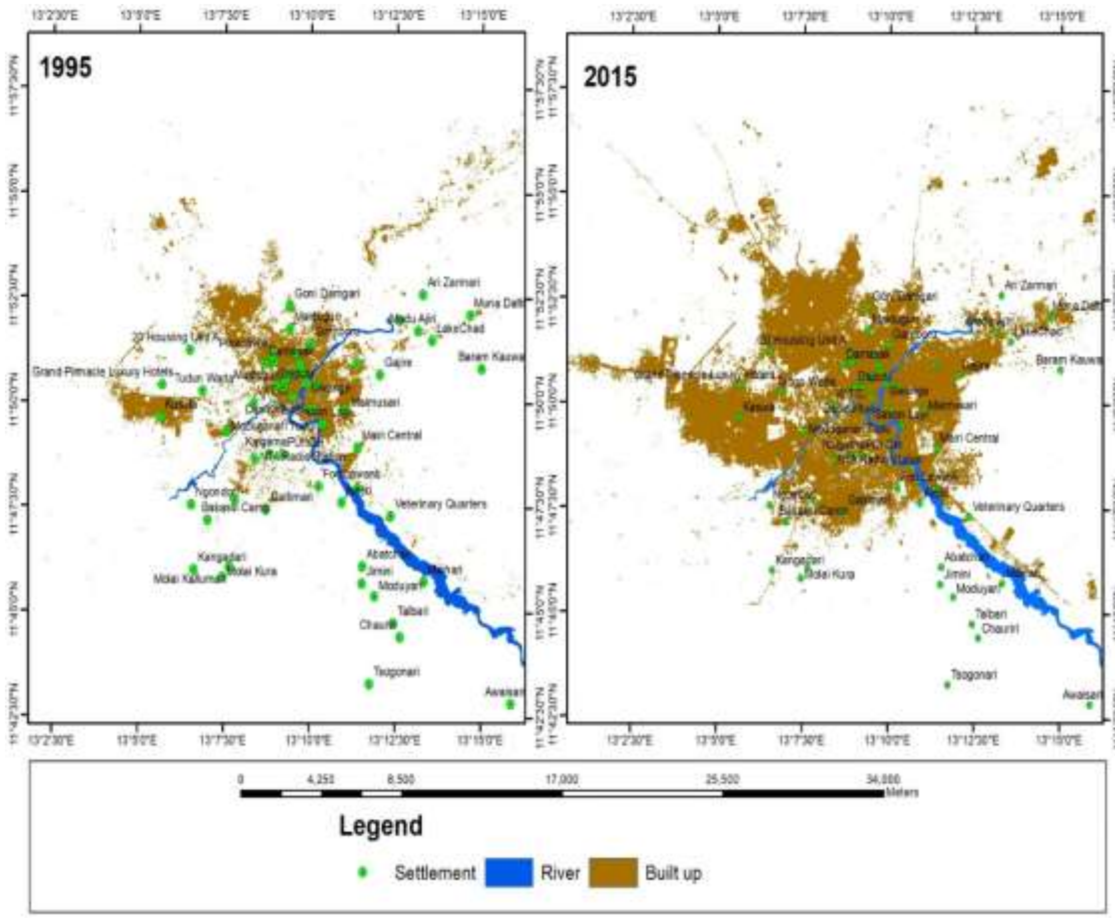


**Figure 3:** Urbanization of Maiduguri Metropolis from 1995 - 2015
Source: Landsat Imageries of Maiduguri for 1995 and 2015

**Channel Morphological Dimension Parameters**

Comparison of full channel dimension parameters in the fifteen sample sites reveals mean depth is 0.61m with standard deviation of 0.17. A coefficient of variance is 27.9% and a range of 0.36. Mean width is 20.25 with standard deviation of 9.89 and coefficient of variance of 48.8% and a range of 35.59. The mean cross sectional area is 11.33m$^2$ with standard deviation of 3.45, coefficient of variation of 30.5% and a range of 10.79. The mean wetted perimeter is 11.72m, standard deviation of 4.57 and coefficient of variation of 38.9% and a range of 14.59.The mean slope, is 0.28%, standard deviation of 0.10, coefficient of variation of 35.7% and a range of 0.30. The mean width-to-depth ratio is 40.42, standard deviation 35.01, coefficient of variation 86.7% and a range of 113.7.

Table 1: Summary of Channel Morphological Dimension Parameters

| Reach | Mean Depth (m) | Bankfull Width (m) | Cross Sectional Area ($m^2$) | Wetted Perimeter (m) | Slope (%) | Width/Depth Ratio |
|---|---|---|---|---|---|---|
| 1 | 0.68 | 23.35 | 15.88 | 21.2 | 0.31 | 34.34 |
| 2 | 0.59 | 25.61 | 15.11 | 12.4 | 0.28 | 43.41 |
| 3 | 0.36 | 47.30 | 17.03 | 9.66 | 0.30 | 131.41 |
| 4 | 0.32 | 35.12 | 11.24 | 15.3 | 0.20 | 109 .8 |
| 5 | 0.40 | 26.04 | 10.42 | 14.5 | 0.21 | 65.10 |
| 6 | 0.57 | 11.71 | 6.67 | 8.50 | 0.15 | 20.54 |
| 7 | 0.53 | 11.80 | 6.25 | 7.90 | 0.16 | 22.26 |
| 8 | 0.49 | 12.74 | 6.62 | 3.21 | 0.20 | 26.00 |
| 9 | 0.52 | 15.30 | 7.96 | 5.20 | 0.18 | 29.42 |
| 10 | 0.68 | 15.68 | 10.66 | 7.10 | 0.22 | 23.06 |
| 11 | 0.79 | 15.80 | 12.48 | 13.35 | 0.40 | 20.00 |
| 12 | 0.73 | 15.76 | 11.50 | 14.62 | 0.39 | 21.59 |
| 13 | 0.69 | 16.00 | 11.04 | 16.86 | 0.42 | 23.19 |
| 14 | 0.88 | 15.62 | 13.74 | 17.20 | 0.38 | 17.75 |
| 15 | 0.86 | 15.90 | 13.67 | 17.80 | 0.45 | 18.49 |
| **Mean** | 0.61 | 20.25 | 11.33 | 11.72 | 0.28 | 40.42 |
| **Standard Deviation** | 0.17 | 9.89 | 3.45 | 4.56 | 0.10 | 35.01 |
| **Variance** | 27.9 | 48.8 | 30.5 | 38.9 | 35.7 | 86.7 |
| **Range** | 0.36 | 35.59 | 10.79 | 14.59 | 0.30 | 113.65 |

Source: Field Survey 2017

**Table 1** the results of variability in channel width revealed mean width of 20.25m with high coefficient of variability 48.8% between the three reaches and a range of 35.59. This suggest that the study river exhibits moderate variability in width. Though, the channel width computed shows a minimum value of 11.71m and maximum of 47.30m from the (study site 01) to the last (site 15) with a study stretch of 22.9km. It has a range of 35.59 and standard deviation of 9.89. There was a general downstream trend of decreasing channel width from urban segment in the downstream to rural segment, The results illustrates that the first segment of the study reach, (sampled sites 1-5) have uniform spatial distribution with oscillations of wide sections at sites 3 and 4 and narrowed at site 5, implies a fluctuating channel width in the downstream direction.

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The variability for channel width between the three segments is discernible, as such, channel width are expected to widen owing to large volume of runoff from the impervious surface cover. However, this result shows variability even within the same segment. For instance, samples sites 1 and 2 (Figure 2 table 1) which have the least values of the channel width located in areas where houses are constructed from both sides of the river banks. The observed channel widening in the urban segment of this study was corroborated by other authors who also reported urban land use influence on channel morphology (Walsh *et al,* 2005; Jordan *et al,* 2010; Trimble, 2009). In urban catchments, channel widening is often attributed to increased impervious surfaces and engineered waterways that connect impervious surfaces directly to stream channels (Walsh *et al,* 2005).

**Depth**

The respective range in the mean depth for the urban, semi urban and rural sites were 0.32m - 0.68m, 0.49 - 0.68, and 0.69 - 0.88m (Figure 4). This disparity can be attributed to the fact that the variability in depth is determined by the land use and human activities in the adjacent upslope in each sample sites. For instance, the land use in sampled site 04 with minimum range (0.32m) is a downstream of confluence tributary while the maximum range (0.68) is a downstream of Fori Bridge. The semi urban has a uniformly increasing channel depth in downstream to the middle portions of the segment followed by deep sections towards last part of the study sites. All the five sections of the rural reach are generally deeper than the semi urban and urban sections. The mean depth of the rural reach is 0.79m. In the urban segment, the shallow points occurred in sites 3, 4 and 5 which are situated in a section downstream of tributary confluence that debouch the large amount of water into Ngadda main channel through sewers system, culverts and tributary channel around the urban center. Generally speaking, the river is wider and shallower in its urban reach, while narrow and deeper in its rural reach and narrow and shallow at the semi urban reach.

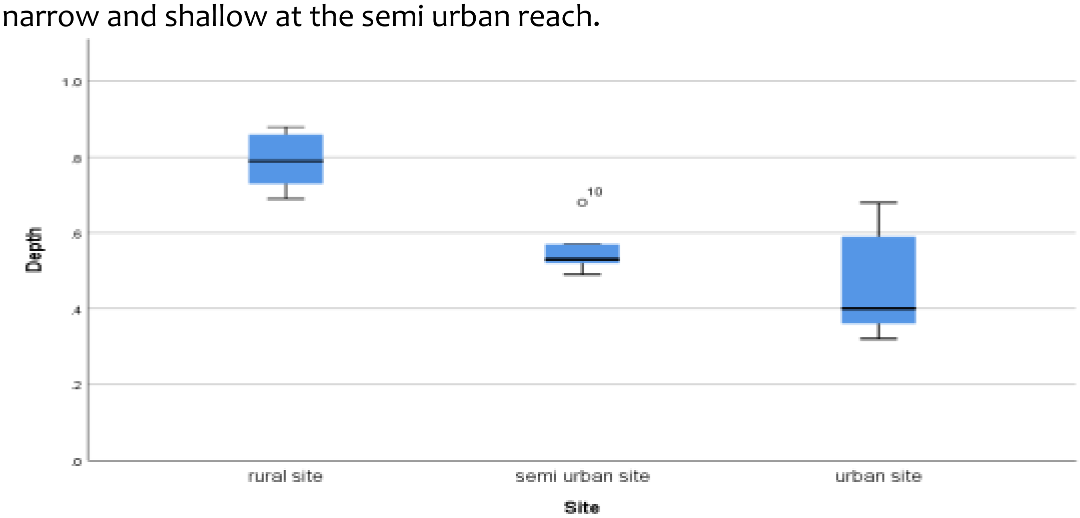


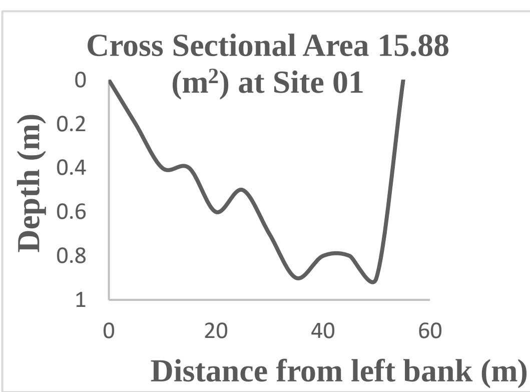

**Figure 4:** Boxplots showing depth along river Ngadda Channel

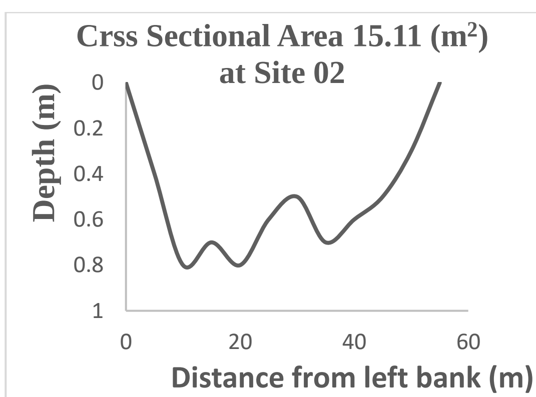
Source: Author's Computer Analysis

***Cross Sectional Area***

Cross-sectional area was generally larger in the urban sites compared with the semi urban and rural sites. The results show cross sectional area along the study stretch exhibits a minimum ranged of 6.25m in site 07 at semi urban to 17.03m in site3 at the urban reach. From table 1 it indicates low variability of 30.5% cross sectional area. The mean cross sectional area is 11.33m$^2$ and standard deviation of 3.45 and a total range of 10.79. Wetted perimeter is 11. 72m indicates low coefficient of variance 38.9% and range of 14.59 respectively. The results also indicated minimum cross sectional area of 6.25m$^2$ in semi urban sites and maximum of 17.03m$^2$ in the urban sites. Detailed of the cross sectional area in the three reaches of urban, semi urban and rural are illustrated in Figures 5 below.

The urban sites with the largest percent impervious surface cover of 95.1% produced the larger cross sectional area 17.03m$^2$ (Figure 4). This is attributed to the large amount of runoff from impervious cover from urban land surfaces have induced to defer channel width, depth, area, wetted perimeter, slope and width to depth ratio from urban reach. Although, the results indicate variability even within the same reach. For instance, the urban sites from site 01 to 05 shows site 03 has the largest cross sectional area of 17.03m2. This followed by cross sectional area of 15.88m$^2$ at site 1, 15.11m$^2$ at site 2, 11.24m$^2$ at site 4 and the least 10.42m$^2$ at site 5. This result suggest, cross sectional area decreases as percent impervious cover decreases from upstream urban sites to downstream rural sites, but there is considerable difference for sites even within a reach. This implies that greater percentage of the catchment surfaces in the urbanized areas supported the generation of high volume of runoff. This relationship agrees with the observation of Paul and Mayer (2001) that increases in impervious surface has direct effect on water movement in the system.



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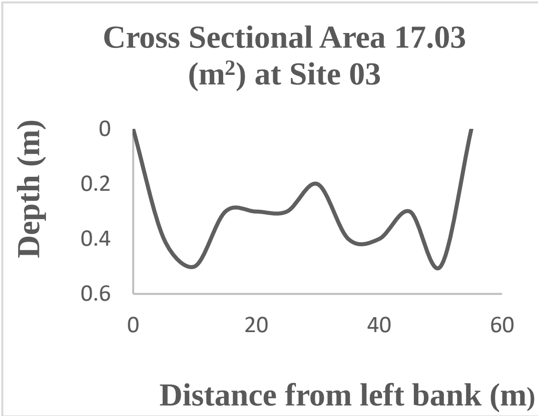


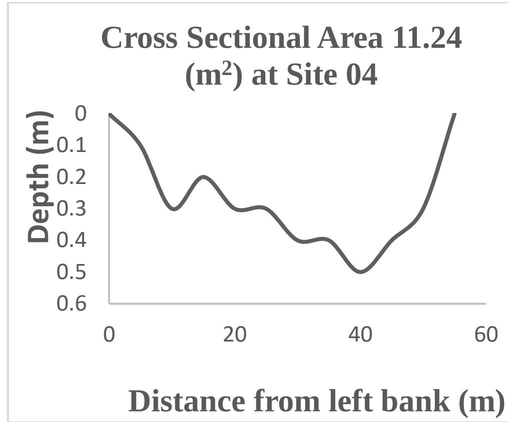


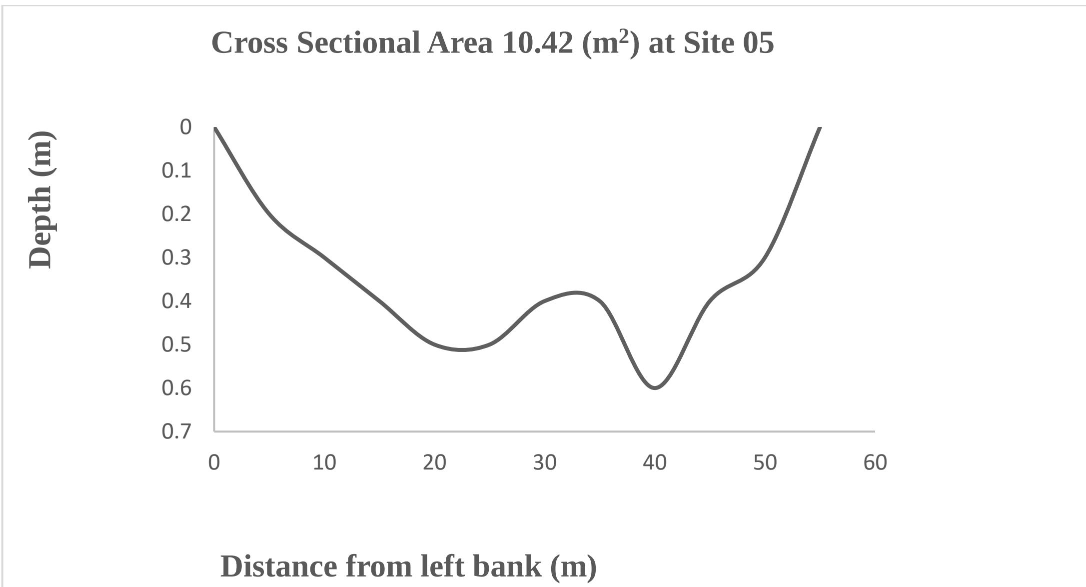


**Figure 5:** Spatial variation of the cross sectional area ($m^2$) in urban segment (sites 1-5)
Wetted Perimeter
Source: Author's Computer Analysis

Wetted perimeter of 11.72 with minimum wetted perimeter of 3.21at site 08 in the semi urban sites and the maximum range was 21.1 at site 01 in the urban reach. The findings further revealed a coefficient of variation of 38.9% with a standard deviation of 4.56 and a range of 14.59. The wetted perimeter illustrates larger mean wetted perimeter in the urban reach with 15.97m than the rural 13.21m and semi urban 6.38m reaches. This results of this study contradicts mostly cited smaller wetted perimeter of urban streams in previous studies (e.g., Nabegu, 2010). The wetted perimeter of a stream is the fraction of the total cross-sectional

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area of the channel that is covered by flowing water during dry-weather periods, and is an important indicator of stream change in urban watersheds. It is logical that wetted perimeter of the stream during low flow declines. Given that urban streams develop a larger channel cross-section while their base flow rates decline, it follows that the wetted perimeter becomes smaller. Thus, for many urban streams, this result in a very shallow low flow channel that "wanders" across a very wide stream bed, often changing its lateral position in response to storms.

***Slope (%)***

This results also demonstrated that urban and semi-urban segments were characterized by lower mean slopes of 0.31% and 0.15 %, whereas at the rural segment, mean slope was up to 0.4 %. This implies, mean slope value is higher in the rural reach than both the urban and semi-urban segments respectively. The results exhibit low slopes with some variation across land use types, indicating the uniformity of geology within the watershed.

***Width Depth Ratio***

Width to depth ratio with an average of 40.42 with standard deviation of 35.01. Width to depth ratio was the only variable that have exhibit very high coefficient of variability 86.7% and a range of 113.7. This implies urbanization surrogate to impervious cover has greatly impacted the variability of change in width-depth ration of River Ngadda channel. The variation in width-depth ratio within the three segments reveals that urban reach has the highest with-depth ratio. 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. The increase in width-depth ratio within the urban reach is due to urbanization which has initially widened the channel considerably (Trimble, 1997). The impact of urbanization has been linked to increase in channel width (Nabegu, 2012; Kabiru and Maiwada, 2015). This suggests that the channel efficiency is at its maximum here within the urban section as it can accommodate increase in volume of discharge within this section (Olusola, 2012). The higher value of width to depth ratio suggests that impervious surface cover surrogate to urbanization influences to great extent the width to depth ratio in the urban segments when compared to both semi urban and rural segments respectively. Width to depth ratio have minimum range of 17.75 in site 14 rural reach and maximum range of 131.41 in site 03 at urban sites.

**CONCLUSION**

The findings of this research showed that channel morphologic variables response to the impervious surface cover from urbanization along the Ngadda River channel. This is attributable to altered hydrological and geomorphic processes of the catchment through artificial straightening of some part of urban segment, installation of artificial transport elements like gutters, pipes, and other sewers, construction activities within the catchment and improper waste disposal within the channel corridors. Such modifications cause remarkable changes in channel width, depth and channel cross sectional area. Additionally, altering the stability of the aforementioned parameters is an invitation to flooding, channel widening among others.

The study recommends construction of storage site or detention basin that delays the flow of water downstream and infiltration of rainwater should be done in order to reduce surface run off and thereby increase rate of infiltration. This can be done by establishing wide riparian corridor, providing riparian vegetation. Also, management of waste in and around the river channel corridor should be improved through better organization to ensure there are no heaps of disposed refuse. These call for the need to increase the capacity of State Environmental Protection Agency (BOSEPA) in terms of machineries and personnel in order to carry out this task. Refuse collection centers should be restricted to specified collection centers and provide the areas that none exist so that proper waste management program should be properly operated and managed.

**Areas of Future research**

Obviously, this study has some limitations. It is necessary to improve the quantity and quality of the data and enhance the credibility of explaining channel changes and controlling factors. Yet it has contributed to the academic discourse on the impact of urbanization on river channel morphological change by providing an understanding of the spatial changes in river channel. The study employed the Google Earth Engine data and morphologic approach to examine and explain the river channel dimension, cross sectional and planform dimensions respectively. Nevertheless, there are several ways future research could build upon the findings presented here. Therefore, the following areas are recommended for further research:

The results from this study do not examine temporal variability of hydrological processes and substrate composition. Thus, results may not reflect the total influence of past and present land use alterations that are expected to continue to alter hydrology and substrate composition over long time periods. Future work focused on re-measuring catchment hydrological processes and sediment composition may elucidate relationship between land use change and subsequent alterations to stream physical habitat.

Also, more research is required to evaluate the changes in the hydrological and riverbed topography of the river in its natural state and the channelized river sections. This can help obtain a deeper understanding of the evolution of the river channel, prevent the degradation process of the river channel, and improve the sustainability of ecological environment of the basin.

## REFERENCES

Ajewole, D.O (2003) Effects of land use on morphometric properties of Drainage Basin in I/orin, Nigeria. *An unpublished M.$c project submitted to the* Department of *Geography, University* of *Ilorin*

Aziegbe, F.I. (2006). Channel and Morphological Response of Two Watersheds to Urbanization in Benin City, Edo State, Nigeria: Journal of Human Ecology, 20(3): 177-182 (2006)

Bankole N.O., Sule, O.D., Okwundu, E.C., Amadi, M. (1992) Preliminary investigation on the frame and catch assessment survey of Alau Reservoir. Annual report of NIFFRI, 1994; 28-9.

Booth, D.B., Hartley, D., Jackson, C.R., 2002. Forest cover, impervious surface area, and the mitigation of storm water impacts. Journal of the American Water Resources Association 38, 835–845.

Booth, D.B., Karr, J.R., Schauman, S., Konrad, C.P., Morley, S.A., Larson, M.G., Burges, S.J., (2004). Reviving urban streams: land use hydrology, biology and human behaviour. J. Am. Water Resour. Assoc. 40 (5), 1351–1364

Dobbs, C., Kendal, D., Nitschke, C.R., (2014). Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and socio-demographics.Ecol. Indic. 43, 44 – 55.

Falke C, Jansson A, Larsson J, Costanza R. (1997). Ecosystem appropriation by cities. *Ambio* 26:167-72

Fashae, O. A, Faniran, A (2015) Downstream Morphologic Characteristics Of The Alluvial Section Of Lower River Ogun, Nigeria, Journal Of Environmental Geography *Journal of Environmental Geography* 8 (1–2), 1–10. DOI: 10.1515/jengeo-2015-0001

Finkenbine, J.K., J.W. Atwater and D.S. Mavinic. (2000). Stream health after urbanization. *Journal of the American Water Resources Association* 36:1149-1160.Galster, J. C.,

Graf, W.L., (1996). Geomorphology and policy for restoration of impounded American rivers: what is 'natural'? In: Rhoads, B.L., Thorn, C.E. (Eds.), The Scientific Nature of Geomorphology: Proceedings of the 27th Binghamton Symposium in Geomorphology. Wiley and Sons, New York

Gregory, K., Davis, R. and Downs, P. (1992) Identification of river channel change due to urbanization. *Applied Geography*. 12:299-318.

Grema AK, Hess TM (1994). The impact of changing rainfall pattern on the efficiency of rainfall utilization in pearl millet-cowpea intercropping systems in north east Nigeria. Aspects Appl. Biol. 38: 231-238. International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 2(9) pp. 395-399, September 2012 Available online http://www.interesjournals.org/IRJAS

Jacobson, C.R., (2011). Identification and quantification of the hydrological impacts of Imperviousness in urban catchments: a review. Journal of Environmental Management 92, 1438-1448

Kabir, A, Maiwada, A. S. (2018) Spatial Dimension Of Ginzo RiverResponse To Urbanization In

Katsina Metropolis, Nigeria. International Journal Of Scientific & Technology Research Volume 7, Issue 5, May 2018

Kawka Rupert (2002) From Bulamari to Metropolitan Maiduguri: Interdisciplinary of the Capital of Borno State. Rudiger Koppe Verlag Koln, Germany.Harrison 3005

Lauff, S., Hasse, D., Kleinschmit, (2014). Linkages between ecosystem services provisioning urban and shrinkage. A modeling approach assessing ecosystem services trade-off. Ecol. Indic. 42, 73-94

Marissa. B. and Katja, Starc Card. (2021) MAIDUGURI: CITY SCOPING STUDY (IRC) African Cities Research Consortium (IRC).

May, C.W., R.R. Horner, J.R. Karr, B.W. Mar, and E.B. Welch, (1997) Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion. Watershed Protection Techniques 2(4):483-494

Miltner, R.J., White, D., Yoder, C., (2004). The biotic integrity of streams in urban and Suburbanizing landscapes. Lansc. Urban Plann, 69, 87-100 C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice,C., Ramankutty, N., and Snyder, P. K.: Global consequences of land use, Science, 309, 570–574, doi:10.1126/science.1111772, 2005.

Mogborukor J.O.A, (2014) *Morphological* Adjustment of a Tropical River to Urbanization, International Journal of Applied Science and Technology. Vol. 4, No. 4; July 2014.

Morley, S.A. and J.R. Karr, (2002) Assessing and Restoring the Health of Urban Streams in the Puget Sound Basin. Conservation Biology 16(6):1498-1509

Mustapha, M. (2022) Morphological Response of River Ngadda To Urbanization In Maiduguri Metropolis, Nigeria. A PhD Thesis Submitted to the Department of Geography, Bayero University Kano, Nigeria.

Nabegu, A.B (2010) The impact of urbanization on the Jakara channel morphology. A PhD Thesis submitted to the Department of Geography, Bayero University, Kano

Nabegu, A.B. (2012) Morphologic alterations to Jakara channel due to urbanization, *Elixir Geoscience 50, 10307-10311*

Neller, R.J., (1988). A comparison of channel erosion in small urban and rural catchments, Armidale, New South Wales. Earth Surf. Proc. Land. 13, 1–7.

Odada, E., L. Oyebande, and J. Oguntola. (2006). Lake Chad: experience and lessons learned. Retrieved November 26, 2014,

Ogbonna, D.N.; A G.T. and Itulua, P.A (2011) Study of the nature of urban flood in Benin City, Edo State; Nigeria. Global Journal of Pure and Applied Sciences. Vol. 17 No.1 p 7 -21

Olusola, A.O. (2012). Downstream variation in stream power of Ona River below Eleyele Dam Unpubl M.Sc Dissertation, Department of Geography, University of Ibadan.

Paul, M. J. and Meyer, J. L. (2001): Streams in the urban landscape, Annu. Rev. Ecol. Syst., 32, 333–365, 2001.

Radford, G.K., James, P., (2013). Changes in the value of ecosystem services along a rural-urban gradient: a case study of greater Manchester, UK. Landscape Urban Planning 109, 117 – 127.

Roesner, L. A., Bledsoe, B. P. (2003). Are best-management-practice criteria really Environmentally friendly? Journal of Water Resources Planning and Management-American Society of Civil Engineers 127:150–154

Tetzlaff, D., Grottker, M., Leibundgut, C. (2005) Hydrological criteria to assess changes of flow dynamic in urban impacted catchments. Phys. Chem. Earth 30, 426-431.

Trimble, Stanley W. 1997. Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed. Science, 278: 1442-1444.

Walsh, C.J. (2000) Urban impacts on the ecology of receiving waters: a framework for assessment, conservation and restoration *Hydrobiologia* 431 107–14