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Flood Management in an Urban Setting: A Case Study of Ibadan Metropolis

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Abstract

This paper revisits flooding problems in Ibadan Metropolis, in the past fifty years, especially the most recent flood of August 2011. Flood disasters can be attributed to the unnecessary risks people take when they encroach on flood plains. There will be no flood disasters if human beings stayed away from the flood plains.
The methodology adopted for the flood investigations includes site visits, interviews of affected inhabitants, and analyses of flood data collected during the field investigations. These investigations were complemented with review of past records of flooding, and interpretation of satellite imagery of flood affected areas, especially for inaccessible areas, to produce flood hazard maps.
Results of the spatial analysis of flooding in the 11 local government areas of Ibadan indicate that 26,553 buildings were constructed within the statutory set back to the rivers and streams while 2,105 were flooded. Large scale encroachment into the river floodplains was observed throughout the area. The major cause of flooding in Ibadan Metropolis is due to uncontrolled urbanization of the area.
The Nigerian Meteorological Agency (NIMET) predicted that there will be very heavy rains and flooding in a number of states in Nigeria in 2012. In Oyo State, Ibadan is specifically mentioned as a city to experience flooding. This emphasises the urgent need to put in place measures to facilitate effective management of the anticipated floods to prevent the re-occurrence of the damage and losses of the 2011 disaster.

Key words: Hydrology, Urban Floods, Flood Mapping, Flood Insurance, Flood Management, Emergency Response, Waste Management

Introduction

Hydrology and Floods

Water covers over seventy percent of the surface of the earth. Hydrology is the study of the occurrence, distribution, movement, and properties of water on the earth and their

interrelationships with the environment, as well as investigations for water on other planets. Water is fundamentally one of the most important natural resources on earth. Certainly, without water, life as we know it will not exist. The search for extra-terrestrial life is essentially the search for water on other planets. The science of hydrology enables us to understand the complex water systems of the earth and to solve problems associated with water. Hydrologists are scientists who play a crucial role in finding solutions to water problems.

The framework for the study of water on earth is the hydrologic cycle. The hydrologic cycle (Figure 1) is the continuous process by which water is transported from the surface of the earth (including the oceans, lakes, rivers and wetlands) to the atmosphere and back to the land in an endless cycle. The hydrologist studies the fundamental transport processes to describe the quantity and quality of water as it moves through the hydrologic cycle.

Converting the natural forests of rural land to urban land in cities or their periphery usually increases the runoff from rivers and streams and creates erosion problems. Urbanization changes the response of a hydrological basin or watershed to precipitation. Urbanization decreases the natural vegetative cover which promotes infiltration at the expense of sediment loss and surface runoff. It also increases impervious surfaces, such as roads, paved surfaces (parking lots) and buildings. The natural flow paths of the stream may be altered or replaced by artificial storm drains as a result of urban development.

Other problems associated with urbanization, apart from flooding, include negative impacts on surface water and groundwater quality, as well as increased rate of sedimentation in impoundments and surface storage reservoirs, such as dams. The delicate balance of the hydrologic cycle could be so affected to the point of climate change, either locally or on a regional scale.

The science of hydrology permits the understanding and management of floods to prevent avoidable disasters, assuming that underlying principles of hydrology are properly understood and the requisite mitigating measures are implemented in urban planning, design and construction. Unfortunately, the fate of most urban settings all over the world, especially those located in flood prone areas; indicate that the lessons from urban hydrology are not taken too seriously. Hence, flooding of catastrophic proportions is reported on a regular basis. The metropolis of Ibadan is not an exception as it has witnessed several devastating floods, occurring almost on an annual basis, in its recent history, especially since 1951, due to rapid and uncontrolled urbanization of the metropolis.

This paper revisits the flooding problems in Ibadan Metropolis, in the past fifty years, especially the most recent flood of August 2011. The authors investigated the remote and immediate causes of the recurrent floods in Ibadan Metropolis, as members of a Special Task Force set up by the Government of Oyo State, for the purpose of, among other things, assessing causes and effects and recommending measures necessary for effective flood management in Oyo State.

Vulnerability of Urban Settlements to Flooding

Flooding is caused by several factors and is invariably preceded by heavy rainfall. The other causes of flooding are moderate to severe winds over water, unusual high tides, tsunamis due to undersea earthquakes, breaks or failures of dams, levees, retention ponds or lakes, or other infrastructure that retains surface water. Flooding can be aggravated by impervious

surfaces or by other natural and man-made hazards which destroy soil and vegetation that can absorb rainfall.

After any rainfall, some of the water is retained on the soil and may form ponds. Some of the water infiltrates into the soil, some evaporates, and any excess water moves along the land surface as surface runoff. Flooding occurs when the soil, stream channels and man-made reservoirs cannot absorb or contain all the water. A flood that occurs suddenly, with little or no prior signs, is called a flash flood and is due to intense rainfall over a relatively small area.

Flooding is inevitable, resulting from the natural rainfall-runoff process. Flooding is a natural phenomenon and the magnitude of floods is periodic. The periodicity of floods implies that every year some area surrounding the river (on both sides) is flooded. Every other period, (two, five, ten, fifty, one hundred and even a thousand years) is associated with increasing areas around the river which gets inundated. Areas inundated by floods adjacent to the river or stream are known as flood plains. Flood occurrences may be due to natural or anthropogenic (man-made) factors.

In a study of the flooding problems in Lagos State, Adeloye and Rustum (2011) indicated that climate change is not the culprit but anthropogenic factors The investigation revealed that, contrary to popular wisdom, climate change or unusually high rainfall is not the primary cause of the flooding problems in Lagos. Rather, increased urbanisation, lax planning laws in relation to the erection of buildings in flood plains and the inadequacy of storm drainage facilities in the city are to blame .

Man does not have much control over the natural causes of floods, such as the magnitude and frequency of rainfall (and associated floods), except perhaps to avoid encroachment into the natural flood plains to prevent flood disaster. However **man has total control over the anthropogenic causes of floods**, such as limiting construction or development on natural flood plains, eliminating blockages from the natural flood plains to allow free passage of flood water and increasing the capacity of hydraulic conveyance structures to conveniently carry flood flows. Conventional wisdom dictates that man should stay away from flood plains or appreciate the RISKS associated with encroaching on the flood plain. Flood disasters are associated with the unnecessary risks people take when they encroach on the flood plains. There will be no flood disasters if human beings stay away from the flood plain.

Physical Setting

Location

Ibadan is located in south-western Nigeria and is the capital of Oyo State. Ibadan is centred about latitude 7^{o} 25' North and longitude 3^{o} 5' East (Figure 2) and is located approximately 145 km north of Lagos. It is situated close to the boundary between forest and grassland, which makes it a melting point for people and products of both the forests and grassland areas. Ibadan is regarded as the largest indigenous city in tropical Africa.

Since its founding in the 1800s, Ibadan has played a prominent role for people living in the south-west of Nigeria. It was the capital of the old Western Region, when Nigeria had only three regions. The territory of the old Western Region has since been divided into seven states and a sizeable part of the present Lagos State belonged to the old Western Region. Ibadan hosts the premier university in Nigeria (The University of Ibadan) which was

established as a College of the University of London in 1948. As a result of these historical antecedents, Ibadan has continuously witnessed influx of people which has contributed to its rapid growth both in population and physical expansion to cover a very large land mass.

In terms of demographic growth, Ibadan experienced geometrical increase in population between 1851 and 1921. By 1856 the population was estimated at 60,000 (Hinderer, 1856) which rose to over 200,000 in 1890 (Millson, 1891), 238,094 in 1921, and 386,359 in 1931 (Mabogunje, 1962). The 1991 census in Nigeria put the population at 1,222,570 (Ayeni, 1994) with a density of 475.11 persons per square kilometre. Its population is estimated to be about 2,550,593 according to 2006 estimates by the National Population Commission. Its projected population by 2010, using 3.2% growth rate, is about 2,893,137 (Table 1).

In terms of physical expansion and land coverage, this pre-colonial urban centre has expanded very fast sprawling daily into the hinterland. Fabiyi (2006) noted that developed land in Ibadan increased from only 100 ha in 1830 to 12 km^2 in 1931, 30 km^2 in 1963, 112 km^2 in 1973, 136 km^2 in 1981 and 214 km^2 in 1988 (Table 2). An aerial photograph in 1964 showed that the city had spread beyond the drainage basins of Ogunpa and Kudeti and to the catchment area of Ogbere stream in the east (Figure 2). Today the city spread has extended to Odo-Ona Kekere village in the south to Iroko/Motunde villages in the north, Asejire in the east and Bakatari in the West (Central Council of Ibadan Indigenes, 2011).

Relief and Drainage

Ibadan lies mostly on lowlands which are punctuated by rocky outcrops and series of hills. These outcrops are mainly granitic. Three major landforms of hills, plains and river valleys dominate the whole landscape of the region. The average elevation is 230 m above mean sea level. The metropolis is drained by three important rivers, R. Ogunpa, R. Ona and R. Ogbere (Figure 3) and their several tributaries including Omi, Kudeti, Alaro and Alapata.

This combination of hills and river valleys provide a good drainage for the city but it has suffered a lot of abuse due to blockages of the water courses by solid wastes coupled with the construction of structures along the river courses and sometimes right within the river course itself. These practices constitute the major reasons for the incessant flooding as occasioned by the recent flood disaster on the night of 26th August 2011.

The metropolis is drained by three important rivers, R. Ogunpa, R. Ona and R. Ogbere. There are several tributaries of these rivers. The major tributary of R. Ogunpa is the R. Kudeti, both of them drain the eastern part of Ibadan. The western part of the city, which consists of more recent residential and other developments, is drained by the R. Ona and its numerous tributaries, including the Alalubosa, Oshun and Yemoja streams.

Climate and Vegetation

Oyo State exhibits the typical West African Monsoon climate marked by distinct seasonal shifts in wind patterns. Between March and October, the city is under the influence of moist maritime south-west monsoon winds which blow inland from the Atlantic Ocean, marking the rainy season. The dry season occurs from November to February when the dry dust-laden winds blow from the Sahara desert. The area experiences high relative humidity and generally two rainfall maxima regimes during the rainfall period of March to October. The mean temperatures are highest at the end of the Harmattan (averaging 28°C), that is from the middle of January to the onset of the rains in the middle of March. Even during the

rainfall months, average temperatures are relatively high, between 24°C and 25°C, while annual fluctuation of temperature is about 6°C.

Most areas of Ibadan are covered by the rain forest and derived savannah. Growth and development have, however, led to significant loss of vegetation. The wetlands are threatened by urban expansion into the wetlands and rural areas. The thick, low-lying forests are prone to flooding as observed in areas like Ajibode, National Institute for Horticultural Research (NIHORT) and Oke Ayo along the course of River Ona.

Geology and Soils

Ibadan is underlain by basement complex rocks which are mainly metamorphic rocks of Precambrian age with granite, quartzite and migmatite as the major rock types. The minor rock types include pegmatite, aplite and diorite.

The soils of Ibadan region were formed from the underlying rocks especially granite gneisse, quartz-schist, biotite gneisse and schist. They were formed under moist semi-deciduous forest cover and belong to the major soil group called ferruginous soils (Hopkins, 1965; D'Hoore, 1964). Aweto (1994) identified four main soil associations in Ibadan region on the basis of soil parent materials as the Iwo, Okemesi, Egbeda and Mamu soil associations. The soils of the Iwo association were formed from coarse grained granites and gneisses and those of Okemesi from gneisses, schist and quartzites. Those of Egbeda and Mamu were formed from fine grained biotite and schist, and from sericite schists respectively.

Methodology

The methodology adopted for the flood investigations includes site visits for physical inspection of the affected areas; interviews of affected inhabitants, review of past reports and records of flooding in the area; and analyses of flood data collected during the investigations.

During the fieldwork component of the investigation, apart from the physical inspection of damaged structures and infrastructures, the team demarcated flooded areas and determined depths of flooding. This flood plain mapping in the field was complemented with analysis and interpretation of satellite imagery of the flood affected areas, especially for inaccessible areas, to produce a flood hazard map.

The records and reports of past floods in the metropolis were reviewed as part of the present exercise. Data were collected on climate, drainage infrastructures, physical planning, and applicable laws and regulations for flood control in Ibadan metropolis.

Discussion of Results

History of Flooding in Ibadan Metropolis

Ibadan has recorded varying degrees of flooding. For instance, there were flooding in the watersheds of Ogunpa and Kudeti streams (one of the two major streams in Ibadan) in 1955, 1960, 1961, 1963, 1969, 1978 and 1980. The flooding of 1969 is unique because it resulted from a mere 25.4 mm rainfall (Akintola, 1981). An accurate assessment of the havoc caused by floods in Ibadan over the years is difficult to obtain (CBN, 1999). However, a number of official estimations have been made at different points. For instance, the losses arising from the flood disaster of August 1980 in Ibadan were estimated at N300.0 million while the number of lives lost was put at 500 people (Akintola, 1994). Between 1995 and

1998, over 12 million Naira, were estimated to have been lost to floods in Ibadan (NEMA, undated). Table 3 shows the history of the most recent thirteen flood events in Ibadan.
The rain gauge at the IITA recorded an all time high of 187.5mm rainfall on August 26, 2011 which started at 16.40 hr until 20.00 hr with intermittent drizzling until 23.00 hr accompanied by wind speed as high as 65 km/hr. IITA reported that the rainfall was most intense between 18.10 hr and 19.20 hr when 75% or 140.63 mm of the rain fell. This is an average rainfall intensity of 127.84/hr (National Water Resources Institute, 2011).

Natural and Anthropogenic Causes of Floods in Ibadan

The causes of flooding in Ibadan have been well documented by past studies. Flood problems in Ibadan have been attributed to land use factors. Notable among these land use factors is the relentless construction of buildings along flood plains. By the early 1960s, the floodplain settlement along the Ogunpa and Kudeti river channels was almost completed, such that the mean distance of buildings along Ogunpa river valley is a mere eleven metres to the river bank, whereas the mean distance of floodable land is to the rivers is over ninety metres (Akintola 1994). Plates 1 - 4 illustrate such development within the flood plain in proximity to the river. This practice aids flooding in Ibadan metropolis and has continued up to the recent time.
Deforestation has been identified as another contributing factor to the flooding problem in Ibadan. Some areas, such as Agala (Agala forests), were deliberately preserved in Ibadan under teak and cassia forests during the colonial period. These were mainly the hills in and around Ibadan. The preserved areas, referred to as catchment areas, were supposed to catch and store some water temporarily during rainfall (Akintola, 1994). The destruction of these forests has aided flooding in Ibadan Metropolis due to the reduction in the infiltration and retention capacity of these areas. This was confirmed by Akintola (1994) in a study on infiltration process in Ibadan city which indicated varying rates or capacities for different types of urban land-use surfaces. The changes in imperviousness of the metropolis from 1965 to 1994 are shown in Table 4.
In general, open surfaces heavily trampled upon by vehicles, human beings and animals have lower infiltration rates than vegetated surfaces, and thus generate higher excess water (runoff) during rainfall. By implication, the large network of paved/tarred roads and several paved surfaces in Ibadan have contributed to the loss of infiltration capacity. The corollary of this finding is that almost all the rain water is released into river channels at the same time, thus leading to floods.

Conclusion

The study found out that the major cause of flooding in Ibadan Metropolis is uncontrolled urbanization of the area, such that some of the houses are built during the dry season on what constitutes the river bed itself. Large scale encroachment into the river floodplains was observed throughout the area. Most of the culverts, bridges and other hydraulic structures which were designed and constructed several years ago are no longer adequate to convey the present runoff arising from increased urbanization of Ibadan Metropolis. The excessive siltation of the rivers and stream beds has tended to reduce the carrying capacity of these hydraulic conveyance structures.

Indiscriminate dumping of refuse and solid wastes is a major problem constituting blockage of river courses, stream channels and artificial drainage channels. The problem of improper waste management must be solved to eliminate this cause of flooding.

It was discovered that the upper part of Ogunpa River had been heavily silted from Ashi area through to the Agodi Gardens Reservoir/Lake which was reportedly dredged last in 2008. The silting of the river had led to blockage of the concrete culverts built across the river all along its course. Channelization of the rivers within the city has not been completed and the completed portions are not well maintained to be free of obstructions.

Ibadan Metropolis has, for a long time, suffered varying degrees of flood disasters with extremely high externalities due to an array of factors, the most prominent of which could be attributed to human behaviour. The rainfall of the 26th August 2011 and associated flood disaster was very devastating based on the level of social, economic and ecological destruction, therefore requiring concerted and decisive actions to prevent future re-occurrence. Conventional wisdom dictates that humans should stay away from flood plains or appreciate the RISKS associated with encroaching on the flood plain. Flood disasters are associated with the unnecessary risks people take when they encroach on the flood plains. There will be no flood disasters if human beings stay away from the flood plain and stop dumping solid wastes in stream and river channels. Furthermore, the floods will not go away and their impacts and severity will increase in the future if corrective steps are not taken.

Recommendations

The Nigerian Meteorological Agency (NIMET) has predicted that there will be very heavy rains and flooding in a number of states in Nigeria in 2012. In Oyo State, Ibadan is specifically mentioned as a city to experience flooding. This emphasises the urgent need to put in place measures to facilitate effective management of the anticipated floods to prevent the re-occurrence of the damage and losses of the 2011 disaster.

Arising from this study, based on the findings in the field, as well as the need to protect the environment, the human population and livelihoods from unmitigated flood disasters in future, the following recommendations are hereby suggested:

1. Create public awareness and sensitization on the real dangers of flirting with floodplains.
2. Government must enforce compliance with physical planning and development regulations within Ibadan Metropolis. There should be immediate stoppage of all kinds of development in all flood prone areas in the 11 LGAs in Ibadan region.
3. Strictly enforce the provisions of the relevant sections of the Oyo State Solid Waste Management Authority Law, (Oyo State of Nigeria, 2008), especially Schedule B (xiv) as it affects construction or placement of structures on roadside and public drainage channels or pedestrian walkways by shop operators.
4. Review existing laws and regulations on delimitation of set-backs to conform to the natural flood plain of the rivers.
5. Government should ensure that drains, gutters and surface water bodies are de-silted throughout Ibadan metropolis to allow for the free flow of urban storm water and runoff. This should be an on-going programme.
6. Government should embark on immediate reconstruction of damaged culverts, bridges and other hydraulic structures, especially in flood ravaged areas.

7. All the major rivers and their tributaries must be de-silted and dredged prior to the onset of the rainy season. This should be an on-going programme.
8. Review existing laws on streams and river set-backs to accommodate the natural extent of river flood plains of the streams and rivers for flood control, in view of urbanization.
9. Government should embark on the preparation of a Master (Development Plan) for Ibadan Metropolis taking into consideration the use of flood prone areas within stream/river setbacks for:
    a. Urban and peri-urban agriculture;
    b. Recreation;
    c. Wildlife and Ecosystem Conservation; and
    d. Intra-city water transportation (boating on Rivers Ona and Ogunpa).
10. Study the road network in Ibadan and provide alternative routes to communities prone to flooding, especially for those with only one access road linking them with nearby communities.
11. Government should adopt Public-Private-Partnership strategy in waste management and assist the Private Refuse Contractors to improve waste collection and disposal throughout Ibadan Metropolis.
12. One of the most potent preventive measures against flooding is vegetation. Government should adopt a policy of "Greening" the Ibadan Metropolis through planting of trees, shrubs and ornamental plants. This will reduce runoff hence flooding, preserve soil moisture and reduce the rate of atmospheric warming.
13. Government should establish an Environmental Monitoring System within the context of an Environmental Management Information System (EMIS) pioneered by the Sustainable Ibadan Project (SIP), to provide real-time data for environmental planning and flood forecasting.
14. In order to minimize losses arising from flood disasters, government should collaborate with stakeholders such as the Nigerian Insurance Association (NIA) and National Insurance Commission (NAICOM) amongst others, to design and promote a State-wide Flood Insurance Programme. This is the practice and requirements for development in flood prone areas in Canada, France and the United States. In Nigeria, there is also an extant legislation on compulsory acquisition of Property Insurance. Implementation of this programme would reduce the compensation payable by government when disasters occur in future.
15. Complete the River Ogunpa Channelization Project and also channelize the major streams and rivers, and construct embankments along the main river channels to reduce flooding. This should be an on-going programme or initiative.
16. Government should establish sustainable integrated flood management and emergency response system.
17. Identify and relocate all permanent structures, within the natural flood plain (50 and 100 years) of the streams and rivers, outside the natural flood plain of the streams and rivers, in line with international best practices for flood prone areas.
18. Prepare a Flood Emergency Management Plan for Ibadan Metropolis as a matter of urgency.

19. Government should equip appropriate agencies with human and material resources for Emergency Response to flooding and other natural disasters.
20. The preceding recommendations will require an appropriate institutional framework for effective implementation. At present, the agencies that will implement the recommendations contained in this study are scattered throughout the government structure. It may be necessary to establish an Inter-Ministerial Implementation Committee or create a Public-Private Partnership Framework for implementation and sustainability of the flood management ideals presented here.

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References

Adeloye, A. J. and Rustum, R. (2011). Lagos (Nigeria) flooding and influence of urban planning, Urban Design and Planning, Volume 164, Issue DP3, 185 – 187.

Akintola, E. O. (1994). Flooding phenomenon. In M. Filani, E. O. Akintola and Ikporukpo (Eds.), *Ibadan Region*. Ibadan: Department of Geography, University of Ibadan.

Aweto, A.O. (1994). Soils. In Filani, M.O. et al. (eds.) Ibadan Region. Chapter 5, pp. 49-57. Rex Charles Publishers, Nigeria.

Ayeni, M.O.A. (1994). The metropolitan area of Ibadan; its growth and structure. In Filani, M.O. et al. (eds.) Ibadan Region Chapter 7, pp. 72-84. Rex Charles Publishers, Nigeria.

CBN, (1999). Urbanization and related socio-economic problems in Ibadan Area, Research Department Occasional Paper No. 25, 80 pp.

Central Council of Ibadan Indigenes (CCII) (2011). Blue print on the physical development for Ibadan Metropolitan area. Paper submitted to the Oyo State Government, July.

D'Hoore, L.J. (1964). Soil Map of Africa. CTA, Lagos.

Fabiyi , O. O. (2006). Urban Land Use Change Analysis of a Traditional City from Remote Sensing Data: The Case of Ibadan Metropolitan Area, Nigeria. *Humanity & Social Sciences Journal*, 1 (1): 42-64.

Fourchard, 2003. The Case of Ibadan, Nigeria, Institut Francais de Recherche en Afrique (IFRA), University of Ibadan, 27 pp.

Government of Oyo State (2011). *Government of Oyo State report on the Assessment of the 26th August 2011 Flood Disaster in Ibadan Metropolis***.** 78 pp. Report prepared for the Government by the Oyo State Task Force on Flood Prevention and Management. Members: B. Wahab, T. Agbola, O. Ajayi, F. Olokesusi, M. Gbadegesin, S. Taiwo, O. Kolawole, A. Muili, M. Adeola, G. Olutade, F. Shiji and N. Abiola**.**

Hinderer, A. (1872). Seventeen years in the Yoruba Country, London.

Hopkins, B. (1965). *Forest and Savanna*. Heinemann, Ibadan.

Mabogunje, A.L. 1962. *Yoruba Towns*. University of Ibadan Press, Ibadan, Nigeria.

Millson, A. W. (1891). The Yoruba Country, West Africa. Proceedings of the Royal Geographical Society, 13: 577-91.

National Water Resources Institute (2011). Report of Assessment of the 26th August 2011 Ibadan Flood Disaster, Oyo State, Nigeria. NWRI, Mando Road, Kaduna, 16 pp.

NEH (2007). National Engineering Handbook, National Engineering Handbook Hydrology Chapters, Natural Resources Conservation Service, United States Department of Agriculture (cover).

NEMA (2007). Mainstreaming Disaster Risk Reduction into Sustainable Development in Nigeria, Vols. 1 & 2. National Emergency Management Agency, Abuja.

NEST (1991). *Nigeria's threatened environment: A national profile.* Nigeria: (Nigeria Environmental Study Action /Team).

Oyo State of Nigeria (2008). *Oyo State Solid Waste Management Authority Law, 2004. Supplement to Oyo State of Nigeri a Gazette, No. 9, Vol. 33, of 5th June, 2008- Part A*. Ibadan: Government Press.

Wahab, B. (2011). Ibadan: A rapidly growing city in need of a Master Plan. Paper read at the Architects' Congress/Annual General Meeting organized by the Nigerian Institute of Architects, Oyo State Chapter, held at Penrose Event Centre, Obafemi Awolowo Avenue, Old Bodija Estate, Ibadan, July 7.

Table 1: The Population Growth of Ibadan 1856-2010

Year	Population
1856	60,000
1890	200,000
1921	238,094
1931	386,359
1991	1,222,570
2006	2,550,593
2010	2,893,137

Source: Wahab (2011)

Table 2: Physical Expansion of Ibadan (1830-1988)

Year	Land Size
1830	100 ha
1931	12 km^2
1963	30 km^2
1973	112 km^2
1981	136 km^2
1988	214 km^2

Source: Wahab (2011)

Table 3: Flooding Rainfall Data in Ibadan

Date	Depth of Rainfall Causing Flood (mm)
9-10 July, 1951	161
16-17 June, 1955	173
16-17 August, 1960	178
27-28 August, 1963	258
14 May, 1969	137
20 April, 1978	126
31 August, 1980	274
1982	-
1984	-
April, 1986	-
June/July, 1987	-
April, 1997	151
26 August, 2011	187.5

Sources: NEST (1991:107), Nigerian Meteorological Services (2011), Ibadan Station, National Water Resources Institute (2011).

Table 4: Percentage of Ibadan City Surface Impervious to Water Infiltration

Sections of Ibadan City	% in 1965	% in 1994	% increase	Rate of increase
Traditional core	15.4	42.5	27.1	1.80
Modern low density	4.3	17.3	13.0	0.98
Modern high density	11.2	30.2	19.0	1.20
Utilities and reservations	3.6	17.5	13.9	1.93
Mean values	9.5	28.4	18.9	1.31

Source: Akintola (1994)

Table 5: Analysis of Flooded Buildings and those within River/Stream Set-backs in the Eleven LGAs of Ibadan

S/No.	Local Government	No. of Buildings within Statutory Setback	No. of Buildings Flooded on August 26, 2011*	River/Stream Length (km)
1.	Akinyele	2,527	382	435.57
2.	Egbeda	2,703	332	229.30
3.	Ibadan North East	4,621	228	41.17
4.	Ibadan North	3,290	260	33.23
5.	Ibadan North west	4,543	162	60.09
6.	Ibadan South East	2,435	55	47.69
7.	Ibadan South West	3,931	369	75.35
8.	Ido	368	78	888.65
9.	Lagelu	913	68	274.15
10.	Oluyole	366	63	663.01
11.	Ona-Ara	856	108	420.43
	TOTAL	**26,553**	**2,105**	**3,168.64**

Source: Field Survey Conducted by Task Force in October 2011

*The number of flooded buildings within the most affected areas of the city covered during the survey was a little below 10% sample of the number of buildings within the statutory set-back from the surface water bodies.

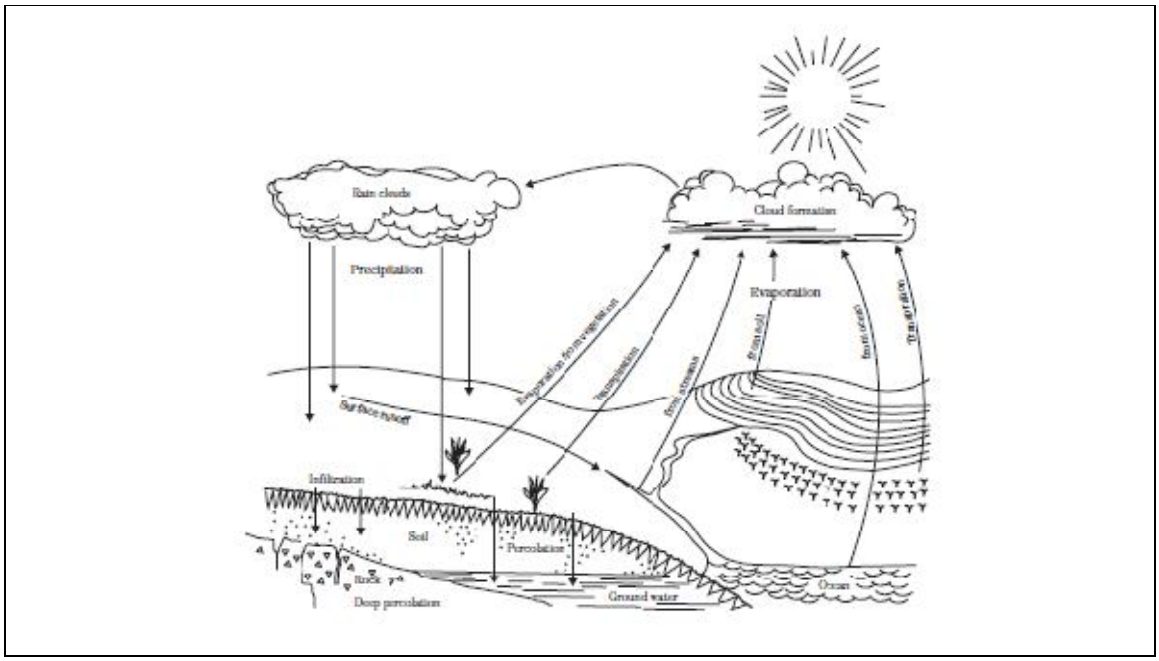

Figure 1: The hydrologic Cycle (NEH, 2007)

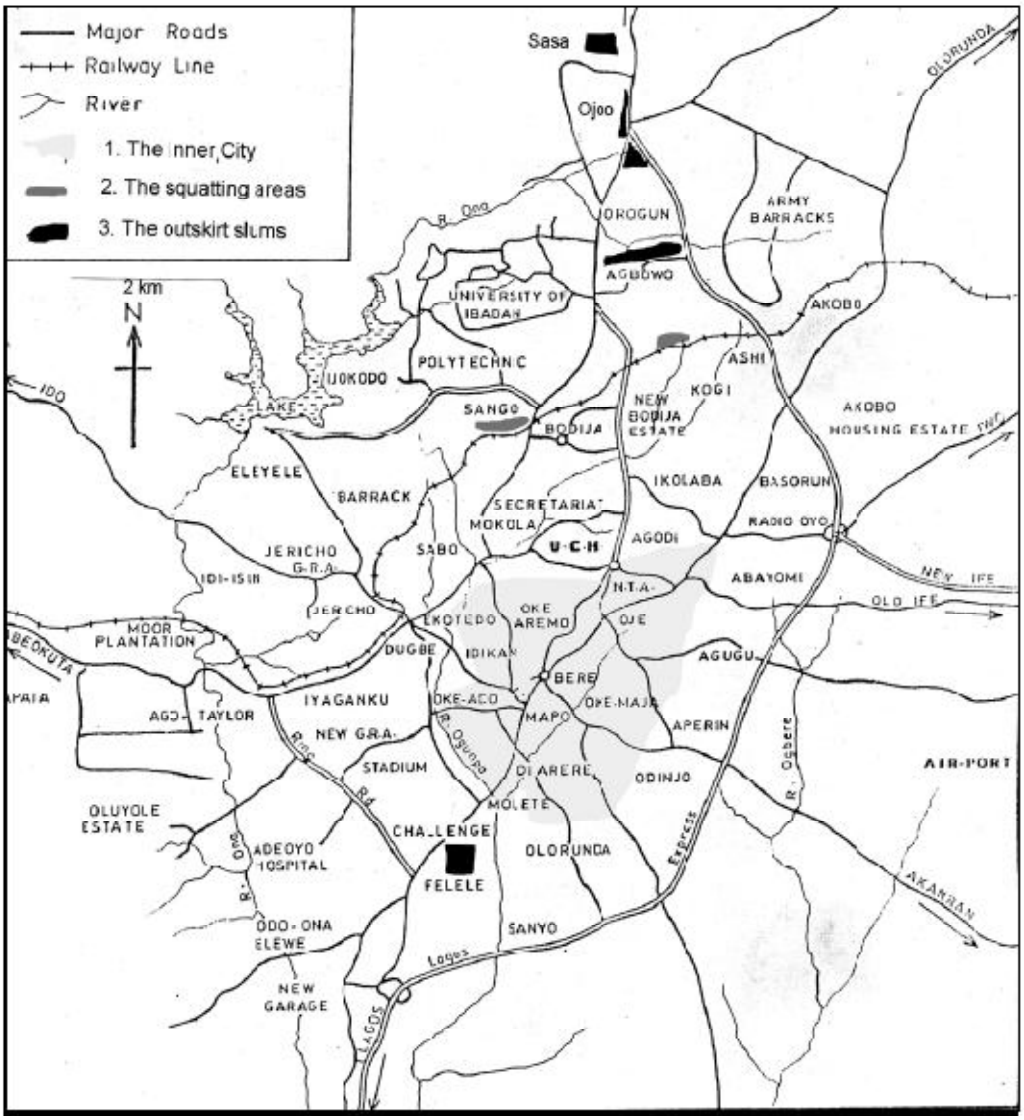

Figure 2: Map of Ibadan (Fourchard, 2003)

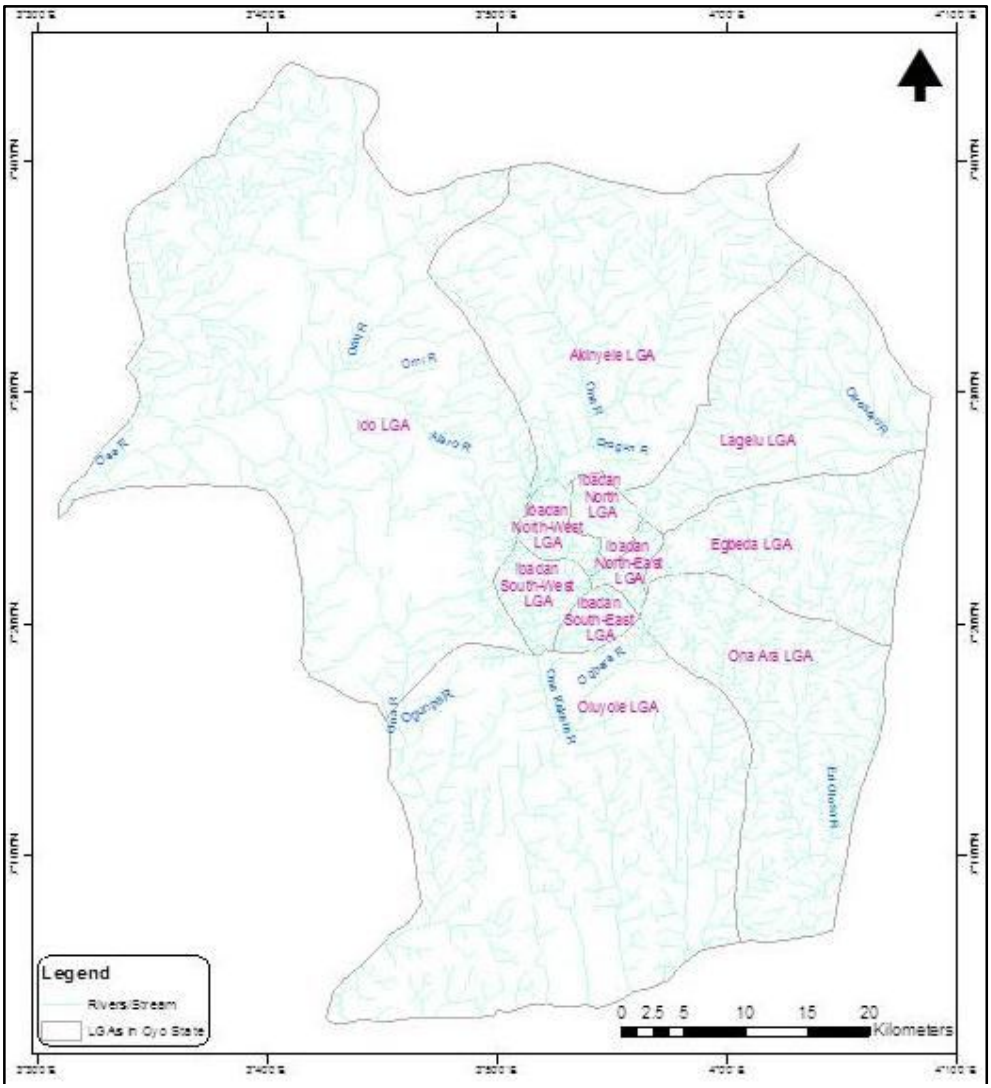

Figure 3: Drainage Map of Ibadan

Plate 1: Buildings Constructed on Flood Plain in Apete Area
Source: Government of Oyo State (2011)

Plate 2: Buildings Constructed on River bed in Apata area
Source: Government of Oyo State (2011)

Plate 3: Buildings Constructed on River bed in Oluyole area
Source: Government of Oyo State (2011)

Plate 4: Buildings Constructed on River bed in Apete area
Source: Government of Oyo State (2011)