THE IMPLICATION OF URBANIZATION ON LAND USE/LAND COVER AND RUNOFF TRENDS DYNAMICS IN ABEOKUTA (1988-2018)

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Abstract

This paper investigates the implication of urbanization on land use/land cover and runoff in Abeokuta from 1988-2018. Land use/Land-cover changes in the study area were quantified by extracting data from satellite imagery; the flow data of the Ogun River from 1988-2018 was also evaluated. The study shows gross changes in the 6 land cover types identified in the study area which were estimated for Landsat imagery (1988, 1998, 2008, and 2018); with some of the land cover types increasing while others decreased. An estimated increase in the built-up area occurred within the space of 30 years from 38.8km2 in 1988 to 109.3km2 in 2018; light forest increased from 6.1 8km2 in 1988 to 118km2 in 2018 while dense forest/swamp decreased from 66.8 8km2 in 1988 to 398km2 in 2018. The Mann-Kendall statistical technique was used to identify significant decreasing, increasing, and stable trends in time series data. The study shows both increasing and decreasing trends in the different land use types identified; also that urbanization affects the trend of runoff in Abeokuta from 1988 - 2018, it was discovered that the increase in runoff trend is directly proportional to the increase in impervious surfaces. The implication of this is the recurrent incidence of flood, loss of lives and properties, loss of arable lands, and human displacement. The paper suggests ways of reducing impervious surfaces in the study area like increasing green spaces, land reclamation, etc. and mitigating the effects of floods like legislation against building on floodplains, introduction of forest reserves, etc.

Keywords: *Abeokuta, Land use/Land cover, Runoff, Trends, Urbanization.*

1 Introduction

Urbanization is the gradual increase in the number of people living in urban areas; it is the process by which towns and cities are formed and become larger as more people move to the area (Adeoye, 2012; Odjugo, Enaruvbe, and Isibor, 2015.). Urbanization is one of the most powerful and visible anthropogenic forces on the earth; it is a worldwide trend, with more than 50% of the world's population currently living in cities, and over 500 cities now having more than 1 million inhabitants (O'Driscoll, Clinton, Jefferson, Manda and McMillan, 2010; Fletcher, Andrieu, and Hamel, 2013). Man in history has always tried to modify his environment from time immemorial to make it more conducive for living; although the rate of change, exploration and exploitation then may not be compared to what is obtainable in recent times. The world, particularly developing countries have experienced its fastest rate of urbanization since the second half of the twentieth century. According to population growth projection, about 60% of the world population is expected to live in towns in 2030 (Paul and Meyer, 2001).

Urbanization has been a major process through which the physical landscape over most areas of the world has been altered; the change in the land use pattern due to rapid urbanization adversely affects the hydrological processes in a catchment, (Ayoade, 1988) leading to a deteriorating water environment. The process of urbanization has caused changes in watershed hydrology that include increased runoff rates and volumes, losses of infiltration and base flow, declines in the natural filtering capacity of river systems (e.g., channelization of headwater streams, loss of floodplains and wetlands) and regulation of flows due to the construction of dams and impoundments. Such changes have resulted in globally altered watershed sediment and solute export (O'Driscoll, et. al., 2010, Fletcher, et. al., 2013). The high concentration of people in a relatively small portion of the world's land area has been shown to have significant influences, especially on environmental and hydrological processes.

Several authors have described the changes in a hydrological cycle which occur when an initially rural catchment area is subject to urbanization, the infiltration capacity of the surface changes, the natural drainage systems change with the construction of artificial ones and the pollution of water resources on both surface and groundwater (Oyegoke and Sojobi, 2012; O'Driscoll, et. al., 2010; Ologunorisa, 2004; Ologunorisa and Adeyemo, 2005; Paul and Meyer, 2001; Ayoade, 1988). Most of the effects of urbanization and industrialization on the hydrological cycle (evaporation, condensation, precipitation, infiltration, surface runoff and sub-surface flow) are undesirable so there is a need to prevent or minimize these effects (Ayoade, 1988).

Urbanization impacts changes in land use/land cover types and interaction between land and water because as urbanization proceeds, an increasing proportion of the total land area becomes covered with impermeable surfaces such as roofs and pavement. The effects of urbanization on the hydrological cycle include changes in peak flow characteristics, changes in total runoff, changes in water quality and changes in hydrological amenities. Urbanization most significantly causes the loss of permeable surface, reduces infiltration and storage capacity reduces evaporation and transpiration; and increases runoff thereby increasing flood (Leopold (1972; Fletcher, et. al., 2013).

Floods are phenomena associated with changes in climatic and edaphic factors especially urbanization (Akintola and Ikwuyatum 2006; Akintola, 1978, 1982). Flooding may occur when there is an overflow of water from water bodies resulting in some of that water flowing out of the channel; it may occur due to accumulation of rainwater on the saturated ground; flooding also occurs in river basins when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway (Ologunorisa and Adeyemo, 2005).

Studies on the effect of changes in land use patterns and flood have been analyzed by various scholars (Du, Rompaey, Shi, and Wang, 2005; Knebi, Yang, Hutchison and Maidment, 2005; Bruce, 2010; Olang, Kundu, Ouma and Furst, 2012; Halwatura and Najim, 2013; Huong and Pathirana, 2013; Patil, 2015.).The use of historical rainfall data, flood records, and land use satellite maps have been used in some of the studies to validate the relationships between land use changes and direct runoff generation (Du et. al., 2005; Knebi, et al 2005; Olang et al., 2012; Huong and Pathirana, 2013; Wang et, al,., 2014). These studies on urban flooding show that urbanization has a dual effect on hydrological processes, that is an increase in runoff generation and its frequency, a decrease in evapotranspiration, and an increase in quick flow, infiltration, and baseflow (Du et. al., 2005; Huong and Pathirana, 2013; Wang et, al., 2014).

There have been a lot of changes in the land use/land cover pattern of the Abeokuta catchment (Awoniran et. al., 2014; Sobowale and Oyedepo, 2013; Ufoegbune et al., 2008; Odunuga and Oyebande, 2007; Bello et al., 2016.) in the last 50years, which has been attributed to increasing in population and urbanization. These various land uses have effects on infiltration and the level of runoff which has resulted in incessant flooding within the catchment and the surrounding areas. The dynamics and trend of land use types, and runoff trend for a period of 30 years (1988-2018) therefore deserve an appraisal.

1.1 Objectives of the Study

In a broad sense, the paper aims to assess the implication of urbanization on the land use/land cover and runoff trend of Abeokuta. However, the specific objectives include to:

i. Determine the land use/land cover types of Abeokuta from 1988 to 2018 at an interval of ten years;

ii. Examine the trend of runoff in the study area for the year under review; and

iii. Assess the impact of urbanization on the runoff trend of Abeokuta.

Materials and Methods

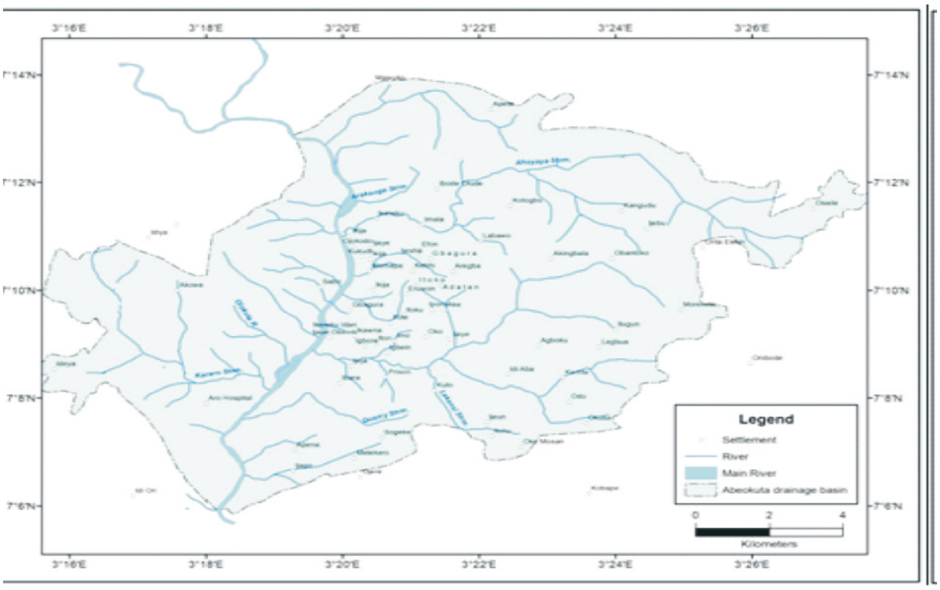

Figure 1: Map of the Study Area

Abeokuta is located between latitude 7ï6'N-7ï14'N and longitude 3ï16'E-3ï26'E, the land area covers about 879 km2. It lies within Ogun State in southwestern Nigeria. According to the 2006 census the population of Abeokuta and the surrounding area was 446,088, the last know population in 2015 was 494,700. The indigenous dwellers of the area are mainly the Egbas (a Yoruba sub-group). Abeokuta town lies in the fertile country of wooded savanna, it has a tropical climate that is influenced by two air masses (the warm rain-bearing south-west monsoon wind which has its source from the Atlantic Ocean and the cold continental air mass which is from the Sahara desert). Mean annual rainfall is high ranging from 900 mm in the north to 2000 mm towards the south with an average of 1300mm. Seasonal characteristic of rainfall is attributed to the fluctuation of the boundary between the moisture-laden Tropical Maritime (mT) airmass and the dry Tropical continental (cT) air mass which controls the climate of Nigeria (Babatolu, 1996). The dry period occurs from November to February, while the wet season lasts for about 8 months, from March to October. The major vegetation is the high forest vegetation. The average temperature is about 27oC highest in March at 29.1oC and lowest in August at 25.1oC.

Geologically, Abeokuta town falls within the basement complex of the geological settings of SW Nigeria. The basement complex rocks of the Pre-Cambrian age are made up of older and younger granites, with the younger and older sedimentary rocks of both tertiary and secondary ages. It has a wide area of undulating lowlands belonging to the coastal sedimentary rocks of western Nigeria. The remnants of a large plantation are the outcrop of inselbergs at the southern edge of the western uplands. The area spread over an extensive area with an elevation of 67m with the surface broken by masses of grey granite.

Abeokuta town is drained majorly by River Ogun. The Ogun River takes its source from the Iganran hills at an elevation of about 530m above mean sea level and flows directly southwards over a distance of about 480 km before it discharges into the Lagos lagoon (Martins, 1987). The tributaries flowing into the Ogun River include Rivers Oyan, Ewekoro, Opeki, Eredu, Iwofin, Sokori, Owiwi, and Ajire amongst others. Located in the southwest region of Nigeria, it discharges through a chain of dendritic systems (Idowu and Martins, 2007) into the Atlantic Coast via the coastal sedimentary plains in Lagos State. Other smaller water bodies include Tigba, Ajigbaytin, Alabata, Olorunsogo, Abiola and Lafaru.

2 Data

Data for this study was from secondary sources only. The land use/land cover types and changes that have occurred in the last 3 decades (from 1988-2018) at 10 years intervals in the study area were assessed using Landsat multi-spectral imagery. Discharge data for the period of 30 years (1988-2018) taken on a daily basis within the Abeokuta catchment was also obtained from Ogun-Osun River Basin Development Authority (OORBDA). Missing data from the sources were extrapolated.

2.1 Data Analysis

The Landsat ETM imageries covering the Abeokuta catchment for 1987, 1998, 2008 and 2018 were obtained from Landsat Global Land-Use and Land Cover Facility (www.glfc.com). Six different classes of land use/land cover types were used adapting Anderson et al, (1976) classification scheme. The classification scheme was used to develop the classified land use/land cover maps. However, generalization was made to several categories in this study to obtain consistent land use/land cover classes over the study period. Land use/land cover classification scheme used and their general description according to Anderson et al., (1976), are Built Up Area, Open spaces, Forest, Farmland and Water bodies.

The land use/land cover classification was performed using Idrisi Selva. Landuse modelling tool was employed to calculate changes in land use metrics across the Abeokuta catchment. Based on the supervised classification, major land use/land cover types within the Abeokuta catchment were identified and temporal changes were calculated for the years under study (1988-2017).

The trend of discharge (either positive, negative or null) for the period of 30 years was analyzed using non-parametric Mann-Kendall statistics used for the detection of statistically significant trends in variables like rainfall, temperature and stream flow.

Mann-Kendall statistic (S) is given as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

3 Result and Discussions

3.1.1 Land Use / Land Cover Types in the study area in 1988

Table 1 shows the breakdown of land use types in the study area, land use types that were identified are open space, built-up area, light forest, dense forest/swamp, farmland and water body. Anderson et al, (1976) classification scheme was used to develop the land use/land cover maps. The table shows that open space covered an area of 9.2 km2, (5.3% of the area), the built-up area covered an area of 38.8 km2 (22.2%), light forest covered an area of 6.1 km2 (3.5%), dense forest/swamp covered an area of 66.8 km2 (38.3%), farmland covered an area of 52.3 km2, (30.0%), while water body covered an area of 1.3 km2 (0.8%). This shows that dense forest/swamp areas covered a larger part of the area in 1988.

Table 1: Land Use/Land cover types in the Study Area in 1988

Category	Area (Km2)	Percentage %
Open Space	9.2	5.3
Built-Up Area	38.8	22.2
Light Forest	6.1	3.5
Dense Forest / Swamp	66.8	38.3
Farmland	52.3	30.0
Water Body	1.3	0.8
Total	174.5	100.0

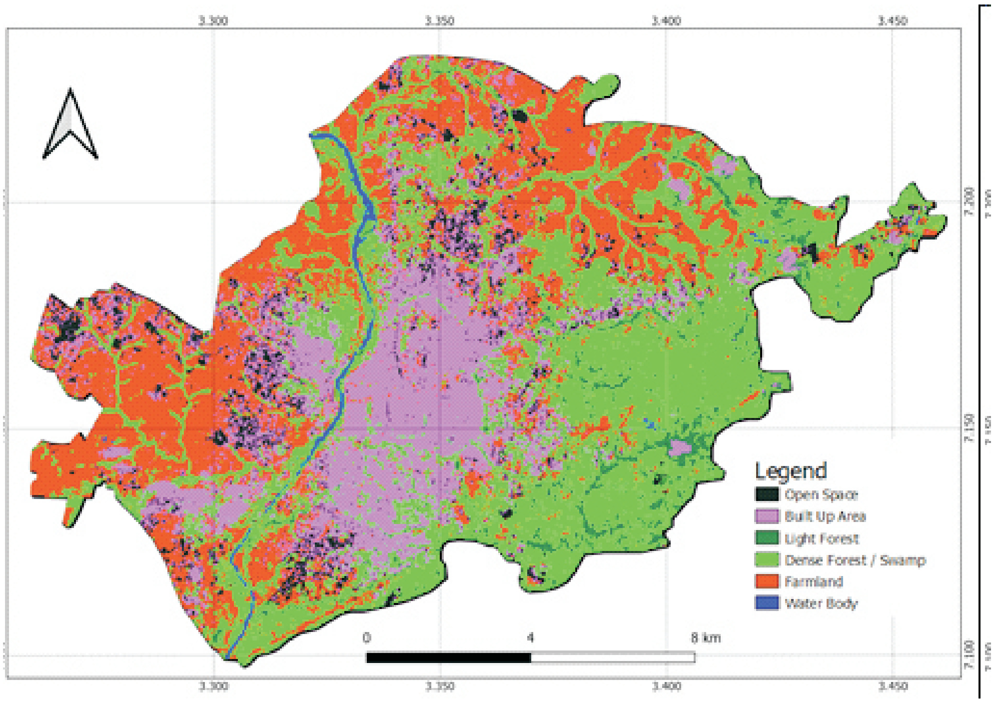

Figure 2: Land Use/Land Cover in 1988

3.1.2 Land Use / Land Cover Types in the study area in 1998

Table 2 shows the breakdown of land use types in the study area in 1998; it shows that open space has reduced to 1.6 Km2, which is about 0.9% of the area, and built-up area increased to 42.1 Km2 is about 24.1% of the area, light forest increased from 6.1 Km2 to 12.0 Km2 (6.8%) due to human encroachment into the dense forest for different uses making the dense forest now light forest, dense forest/swamp decreased to 59.8 Km2 from 66.8 Km2 (34.4%), farmland increased from 52.3 Km2 to 57.6 Km2, which is about 33.0% of the area, while water body increased to 1.5 Km2 (0.9%) which could be as a result of the increase surface runoff This shows that dense forest/swamp covered the largest part of the study area in 1998.

Table 2: Land Use/Land cover types in the Study Area in 1998

Category	Area (Km2)	Percentage %
Open Space	1.6	0.9
Built-Up Area	42.1	24.1
Light Forest	12.0	6.8
Dense Forest / Swamp	59.8	34.3
Farmland	57.6	33.0
Water Body	1.5	0.9
Total	174.5	100.0

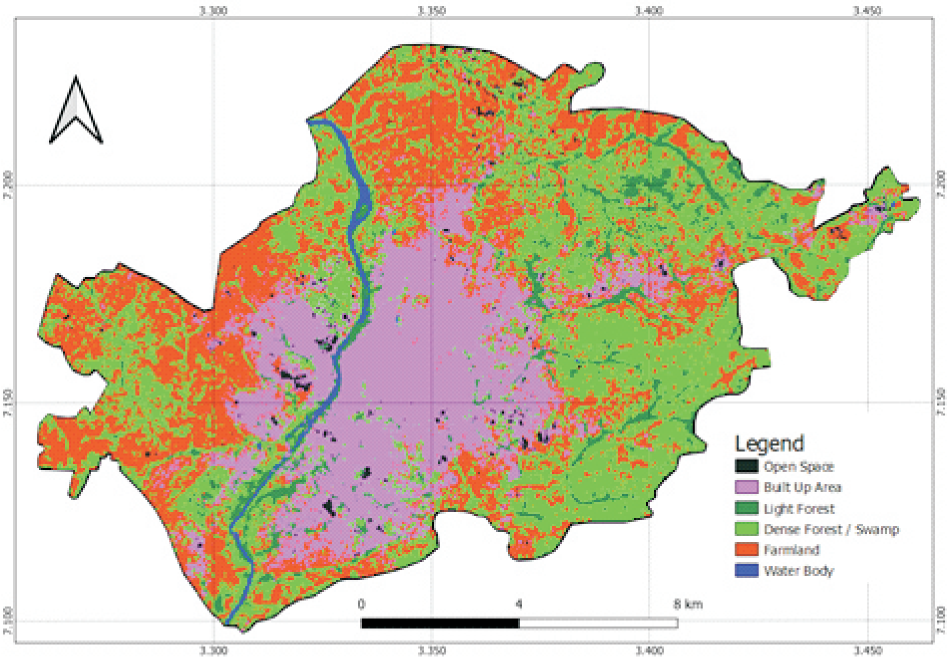

Figure 3: Land Use/Land Cover in 1998

3.1.3 Land Use / Land Cover Types in the study area in 2008

Table 3 shows the analysis of land use types in the study area in 2008; it shows that open space increased from 1.6 Km2 to 16.7 Km2 (9.6% of the study area) within the space of ten years indicating a high level of clearing for various developmental purposes. Built up area increased to 62.0 Km2 (35.5%) from 42.1 Km2 in the study area showing an increase in urbanization. Light forest increased to 14.8 Km2 (8.5%), while dense forest/swamp decreased to 52.4 Km2 (30.0%), farmland decreased to 27.3 Km2 (which is about 15.6% of the study area), showing a decline in agricultural practice and increased urban sprawl. The water body now covered an area of 1.4 Km2 (0.8%), a decrease in the water body again as a result of increased urbanization. This shows that the built-up area covered the largest part of the study area in 2008.

Table 3: Land Use Types in the Study Area in 2008

Category	Area (Km2)	Percentage %
Open Space	16.7	9.6
Built-Up Area	62.0	35.5
Light Forest	14.8	8.5
Dense Forest / Swamp	52.4	30.0
Farmland	27.3	15.6
Water Body	1.4	0.8
Total	174.5	100.0

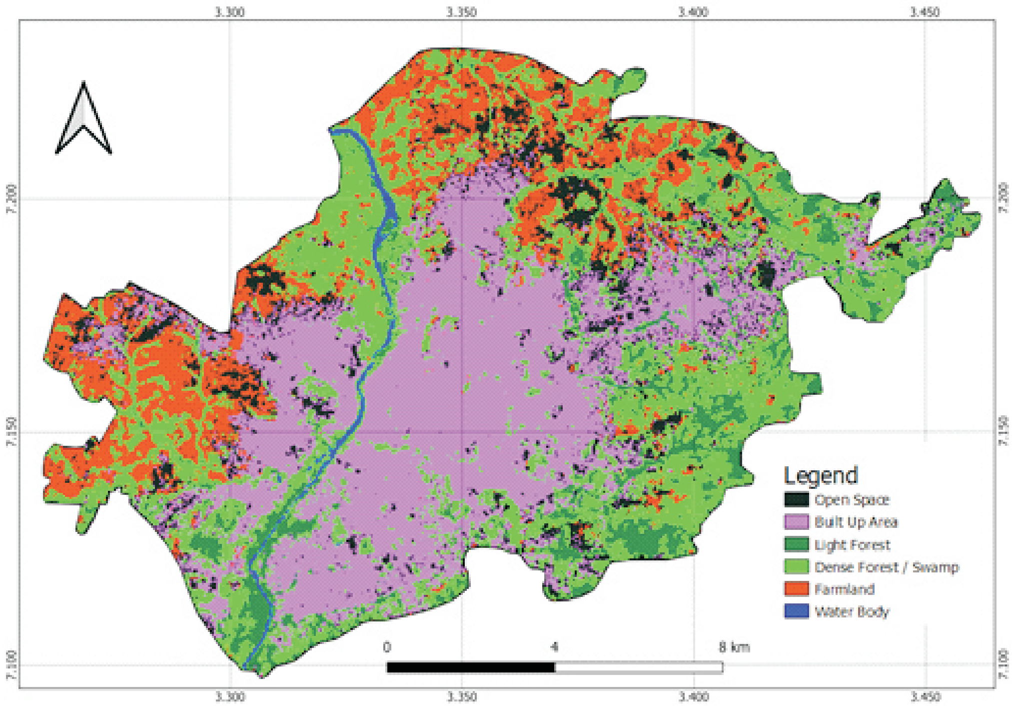

Figure 4: Land Use/Land Cover in 2008

3.1.4 Land Use / Land Cover Types in the study area in 2018

Table 4 shows the breakdown of land use types in the study area in 2018, it shows that open space reduced drastically from 16.7 Km2 in 2008 now covering 0.1 Km2 (0.1% of the study area); built-up area increased significantly covering an area of 109.3 Km2 (62.7%) as against 62Km2 in 2008, that is almost 50% increase in built-up area showing a serious urbanization process. Light forest decreased to 11.0 Km2 (6.3%), dense forest /swamp reduced to 39.0 Km2 (22.4%), so also farmland reduced from 27.3 Km2 in 2008 to 12.5 Km2 (7.2%) in 2018 in the study area. Waterbody covered an area of 2.5 Km2 (1.4%), an increase in what was obtainable in 2008. This shows that the built-up area covered the largest part of the area in 2018.

Table 4: Land Use Types in the Study Area in 2018

Category	Area Km^2	Percentage %
Open Space	0.1	0.1
Built-Up Area	109.3	62.7
Light Forest	11.0	6.3
Dense Forest / Swamp	39.0	22.4
Farmland	12.5	7.2
Water Body	2.5	1.4
Total	174.5	100.0

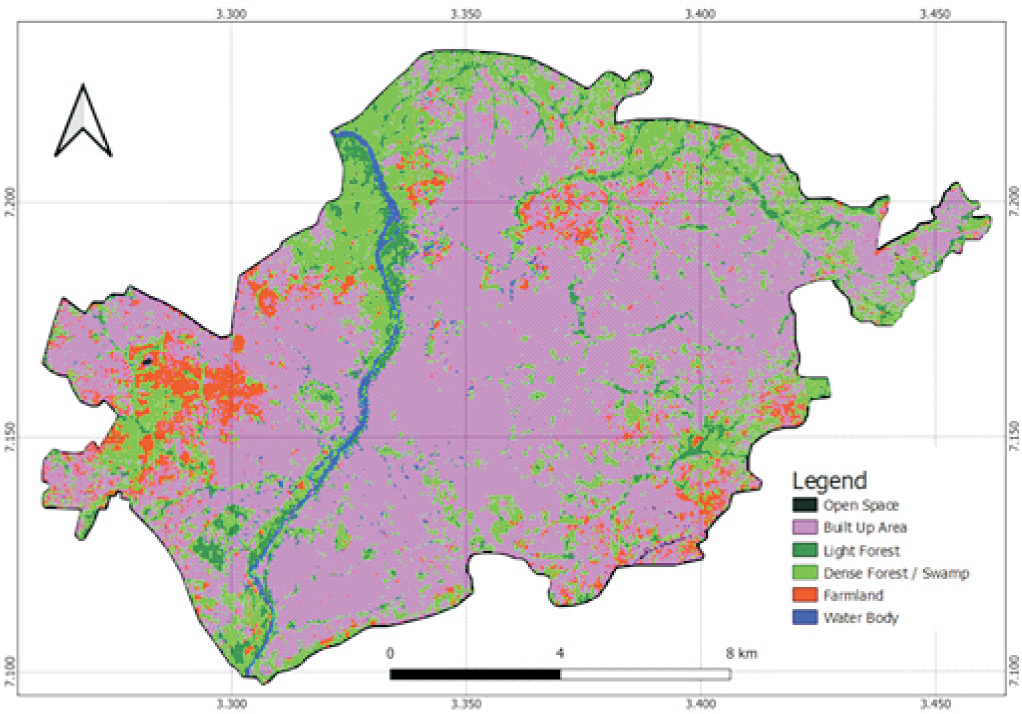

Figure 5: Land Use/Land Cover in 2018

3.1.5 The summary of land use change is presented in Tables 1 to 4

The spatiotemporal analysis of the area revealed that there was an observable increase in a built-up area in the area, which denotes land use for residential, administrative and commercial purposes, in addition, there was a decrease in the farmland and vegetation covers (light and dense). The notable reduction in forests and farmlands shows depletion in green spaces in the area which has a hazardous impact on the ecosystem. If the current rate of reduction in the dense forest area is allowed to linger, there may be no high forest again in the area in the coming years, jeopardizing the need of the future generation and causing greater harm to the environment. Forest removal has been observed as one of the key factors enhancing global warming that is threatening the global environment. Plants are carbon sinks; they make use of carbon dioxide (a greenhouse gas) during photosynthesis thereby reducing its concentration in the atmosphere.

The high rate of development in settlement during the study period poses health threats to the inhabitants of the study area. This corroborates the findings of Patz et al. (2000) that suggested that current local land-use actions such as irrigation farming, urban sprawl, or road construction, in combination with other causative proximate and underlying factors are responsible for the altered risk of many diseases such as malaria. Another effect of the urban sprawl noted in the area is alteration in the atmospheric chemistry of the area, although not directly measured this could result from the release of greenhouse gas which is attributed to urban areas (Mann et al. 1999). Another effect of land use change in the area as a result of a reduction in green space is a decline in animal and plant species and extinction (Van Laake and Sdnchez-Azofeifa 2004) as a result of habitat destruction, degradation and fragmentation in the area.

Similarly, other possible impacts of the land use change in the study area could be related to health problems and disease risks. This is confirmed by the Millennium Assessment booklet (2003) which posited deforestation governs the distribution of disease-transmitting insects and of irritants and pathogens in water and air (Millennium Assessment, 2003). A study in Southern Uganda shows changes from cotton and coffee plantations to the uncultivated bush, resulting from social and economic upheaval, created ideal tsetse habitat, leading to a substantial sleeping sickness outbreak in the 1980s (Gashumba and Mwambu, 1981). In the past, negative impacts such as those on water and air quality conditions were more or less limited to local to regional scales, affecting millions of people though. The "Black Death", for example, did not occur at a global scale but affected many countries at the same time, notably in 1347 around the Mediterranean. Accumulating evidence, however, suggests that current local land-use actions - such as irrigation farming, urban sprawl, or road construction, in combination with other causative proximate and underlying factors are responsible for the altered risk of many diseases such as malaria (Patz et al. 2000).

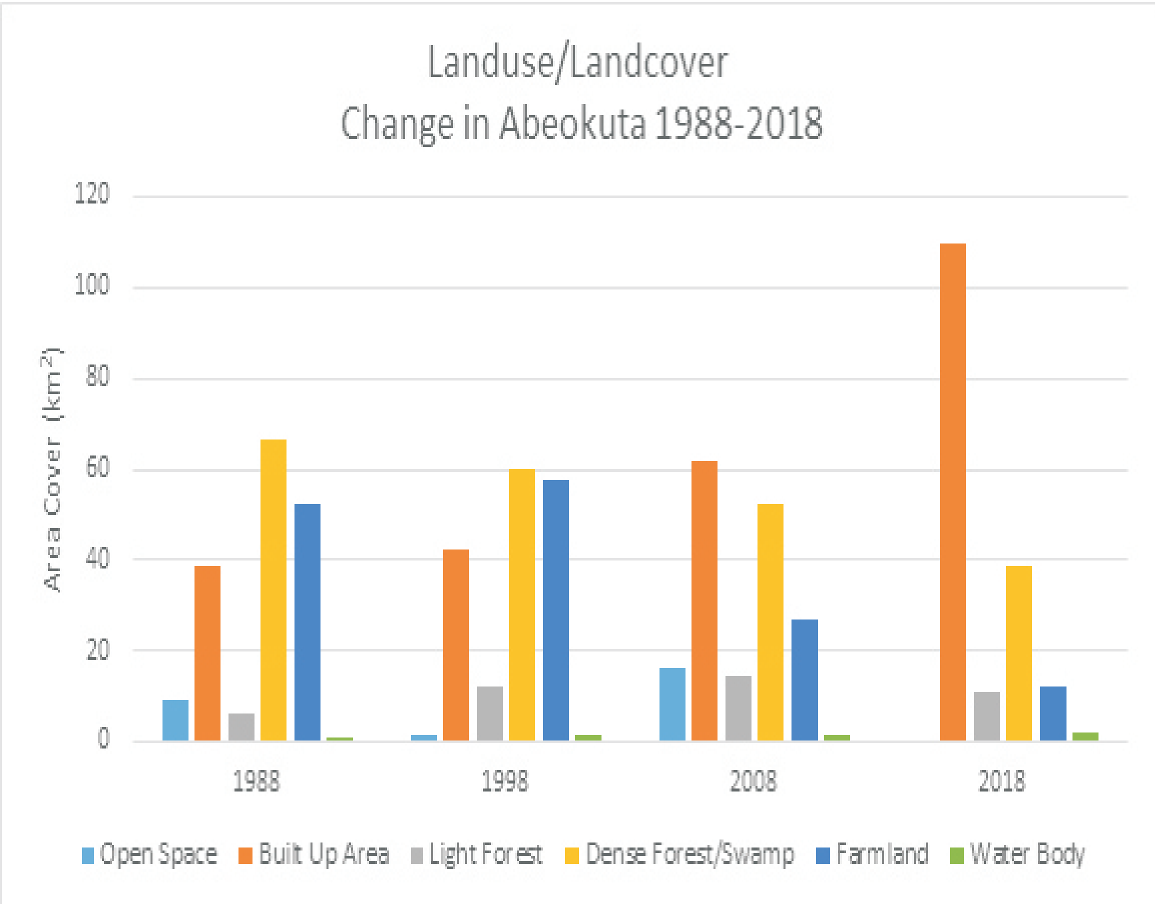

Figure 6: Land Use/Land Cover Change in Abeokuta 1988-2018

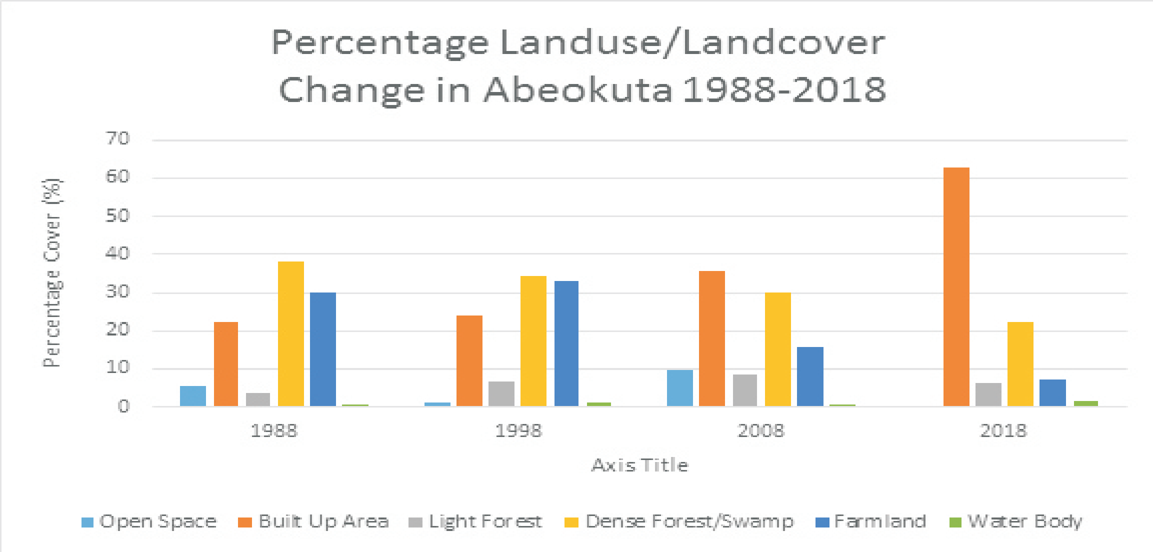

Figure 7: Percentage of Land use/Land cover Change in Abeokuta 1988-2018

3.2 Trend Analysis of Runoff in the Study Area

Fig 8 shows the annual variation of runoff at the Abeokuta gauge station. All the time series plots indicate that there are systematic changes known as trends. In addition, the plots revealed that there are some irregularities in all the series, which indicates that the series is not stationary. There was a decreasing trend in runoff from 1988 to 1991 with a little rise in 1992. However, the fluctuation in the runoff trend continues from the succeeding year till 1997 with an alternate decrease and increase in runoff. There was a very sharp rise in runoff trend in 1998 and 1999 respectively but decreases towards the years 2000 and 2001. The runoff trend shows significant variation from 2002 to 2010 with alternate rising and falling in the volume of runoff. The year 2011 marked the highest peak of runoff while the year 2018 has the least runoff in the study area under the reviewed period. Runoff was also low in the years 2004 and 2005 respectively.

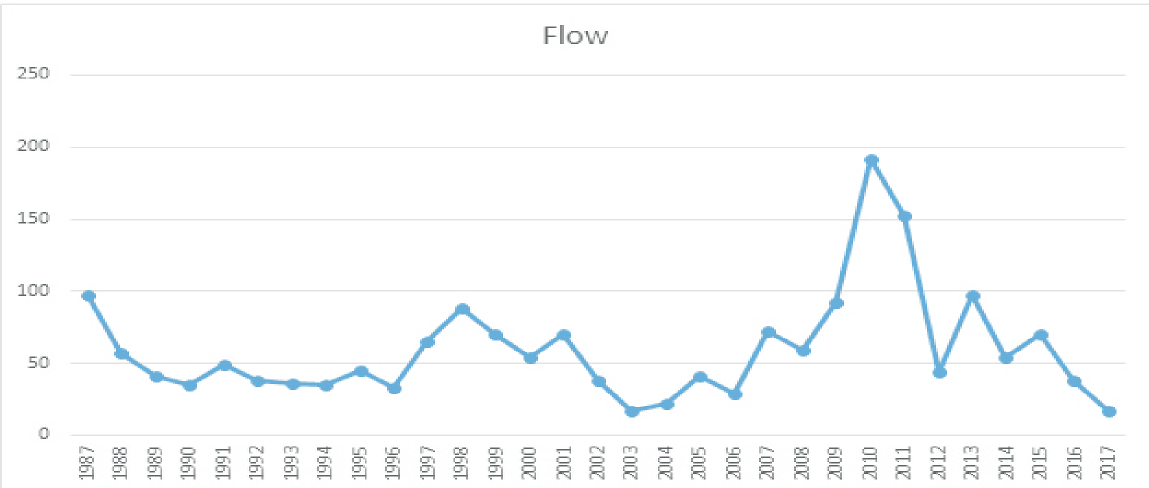

Fig. 8: Trend of Variation of Annual Runoff Series at Abeokuta Gauge Station

3.3 The Implication of Urbanization (Land Use Change) on the Runoff of Abeokuta

The variation in the runoff trend of the study area from 1988-2018 could not be disconnected from the land use pattern of Abeokuta. The low runoff observed from 1988 to 1997 could be a result of the low level of development of Abeokuta. There was much natural vegetation cover compared to the areas built up then. The implication of this is that the rate of infiltration would be high thereby preventing much runoff. In successive years (1998-2007), Abeokuta was built up more than the previous years. Light and dense forests had reduced. Built-up areas had covered a quarter (25.4% i.e., 44.3 sq km) of the landmass of Abeokuta. As a result of this, there was an increase in runoff. This could be a result of an increase in impervious surfaces that was brought as a result of development. More houses were built and floored for beautification and aesthetics. This tends to reduce the rate of both infiltration and percolation giving room to an increase in runoff.

However, the highest runoff experienced in the year 2011 cannot be separated from the fact that between 2008 and 2012 the built-up areas in Abeokuta by this period had exceeded every other land use category. Built-up areas covered 62.0 sq km of the landmass of Abeokuta. Alongside this increase in built-up areas is the decrease in available farmland in the study area. Less than 20% of the landmass is available as farmland compared to the previous years. It is a fact that development is not static, it can only grow at a slower pace. Therefore, one would expect a place like Abeokuta to experience continuous development over the years. As a result, deforestation would be on the rise, thereby exposing the land surface to exploitation by erosion. This would inevitably increase the runoff of the study area.

4 Conclusion

It could be concluded that there are both increasing and decreasing trends in the different land use types identified; there are changes in land use types and this affects the trend of runoff in Abeokuta from 1988 - 2018, as it was discovered that an increase in runoff trend is directly proportional to increase in impervious surfaces. The implication of the increasing trend in surface runoff in Abeokuta is the recurrent incidence of flood, loss of life and properties, loss of arable lands and human displacement which some parts of the study area are facing recently. The changes in land use/land cover have been seen in the form of an increase in built-up and cultivated areas and a decrease in natural forest and water bodies; which could lead to loss of biodiversity, global warming, soil erosion, increase in surface runoff, etc. Beyond runoff, the notable reduction in forest and farmlands shows depletion in green spaces in the area which has a hazardous impact on the ecosystem. If the current rate of reduction in the dense forest area is allowed to linger, there may be no high forest again in the area in the coming years, jeopardizing the need of the future generation and causing greater harm to the environment. Forest removal has been observed as one of the key factors enhancing global warming that is threatening the global environment. Plants make use of carbon dioxide (a greenhouse gas) during photosynthesis thereby reducing its concentration in the atmosphere.

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