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Evaluation of Climatic Attention and Land use/Land Cover Change Effects on Flooding in Some Parts of Benin City

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Abstract

This study was done by obtaining cloudless satellite imageries of Egor, Oredo and Ikpoba Okha from United States Geological Survey at different points in time (1990, 1999, 2009 and 2019) and the Secure Copy Protocol plugin on Quantum Geographic Information System (QGIS) was employed to classify these images using the supervised classification method. ROIs were created and assessed, then classes (Water bodies, Built Up areas and Vegetation) were assigned to them so as to be able to properly represent them for the study and a change detection was done for the years to get a proper detailed result to show the effect of Urbanization in Benin City and its Environs under the Land Cover Classes employed in this study. The noticeable changes were tabulated, and the percentage differences were then calculated. Precipitation data were collected from previous work while runoff was calculated from the precipitation data. It was noted that vegetation has significantly reduced over time, from 819.91mi^2 in 1990 to 213.73mi^2 in 2019 which represents a 73.93% reduction and built up areas significantly increased over time, from 93.75mi^2 in 1990 to 700.01mi^2 in 2019 which represents a 646.6% increase. Rainfall also increased significantly within the period (700mm to 2105mm per annum) under review as the three year moving average showed no cyclicity in the pattern of rainfall. Antropogenic activities has greatly impacted on the soil and the bare surfaces are either paved or made impervious with little or no infilteration after precipiation. This has resulted into flooding and it was recommended that government agencies should ensure that land developers stick to environmental friendly approach in carrying out their work.

Keywords: *Flood, Temperature, Rainfall, Climate, Urbanization.*

1. Introduction

Flooding is essentially the most tragic of all the recent cases of recurrent extreme events in Nigeria as a whole. In the summers of 2012 and 2021, most of the nation, including Edo state, was submerged, and millions of people were forced to flee because of unheard-of flooding events (Ehiorobo, 2012). Between July and October of 2012, torrential rainfall episodes, rising water levels, and water releases from impoundment reservoirs like the Lagdo dam on the Benue River in Cameroun and the Kiri dam on the Gongola River all contributed to the floods. According to the Federal Government of Nigeria (2013), these scenarios led to $16.9 billion in property and human life losses. However, less severe flood events, particularly in 2010 and 2011, were widely reported in years prior. Nevertheless, the 2010 flooding events alone were responsible for about 1555 recorded fatalities (Abe et. al., 2018; Qi et. al., 2020). Flooding has been observed in the basin on a yearly basis in varying degrees over the years.

The frequency of floods in Benin City (Egor, Oredo and Ikpoba Okha) suggested that the downstream catchments were significantly more affected than the upper catchments, but the recent flooding had a significant negative impact on the local governments of Egor, Oredo, and Ikpoba Okha. One person died because of the flood, which also submerged several hectares of farmland in some communities. People were forced to flee after more than 100 homes along Benin Abraka Road were destroyed (Prokop et. al., 2020; Ramani et. al., 2021). This is concerning and could get worse in the future, so researchers are focused on the need to offer solutions based on their findings. To make inferences about the hydrological regimes of the river systems in response to climatic and Land Use/Land Cover (LULC) changes, previous studies within this basin, however, used geospatial analysis of Landsat images, morphometric analysis, and possibly trend analysis of hydro-meteorological parameters at regional scale (Reager et. al., 2015).

Two significant environmental stressors that have a significant impact on the hydrology of Benin City's watershed are LULC and climate change. However, because of their heavy reliance on industries that are sensitive to climate change as a source of income and as a means of escaping poverty, developing countries like Nigeria are more vulnerable to these risks (Koneti et. al., 2018; Ehiorobo, 2012). When compared to developed nations, these regions frequently have insufficient human, institutional, and financial resources to implement the necessary adaptation measures to decrease vulnerability and exposure to hazards related to climate change. Wide-ranging data and research gaps, which expressly impede decision-making processes to build resilience, reduce vulnerability, and frequently impede the necessary implementation strategies, further exacerbate Nigeria's apparent adaptation deficits. Overall, it is anticipated that climate-related risks will worsen in the future, necessitating informed sustainable management (Langat et. al., 2019; Lambin and Meyfroidt, 2011).

2. Methodology

2.1 Study Area.

The study area encompasses three major local government areas in Edo state, which is also known as Benin city: Oredo, Ikpoba Okha, and Egor. The geomorphology is relatively flat and gentle, and the elevation ranges from 37 to 66 meters above mean sea level. Surface and underground water resources can be found in the area. Major rivers and streams like the Ikpoba River and the Ogba River are among the surface water resources. The climate is close to the equator with a two-modal system that alternates between dry and wet seasons. Rainfall data for the region between 1996 and 2020 shows that July has the highest average rainfall (400 mm), while January has the lowest (17 mm). The wettest months in the project area are July and September, while high temperatures are typically felt in March and April and low temperatures in November and December. Around 230 degrees Celsius is the minimum and 290 degrees Celsius is the maximum temperature. All year long, there is cloud cover and extremely high relative humidity (RH). The proximity of the project location to the Atlantic Ocean accounts for the relatively high relative humidity.

Deposits from the Cretaceous and Tertiary periods were laid down at the project location. The region's soils range in size from coarse to very fine grains, are poorly sorted, and have subangular to rounded particles with streaks and fragments of lignite. The groundwater is refilled by infiltration processes that occur during rainfall and from nearby water bodies. The wet season sees an increase in groundwater levels, while the dry season sees a decrease. The study area is shown in Figure 1.

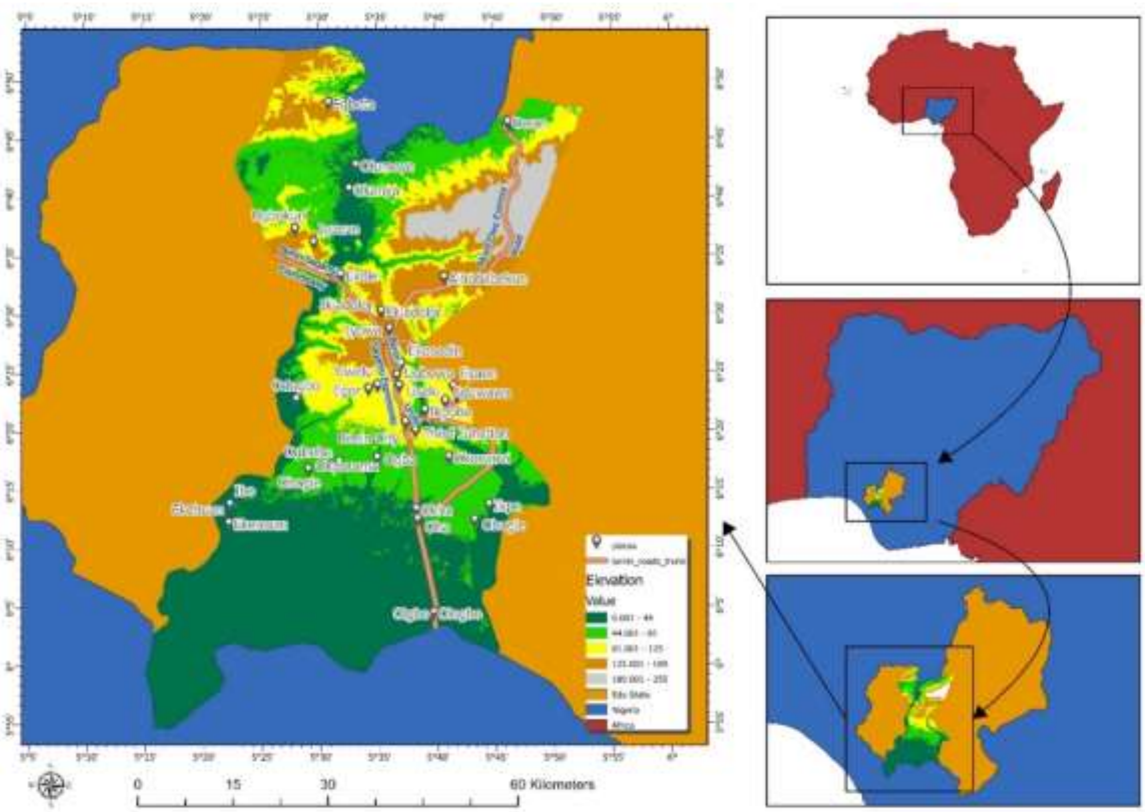

Figure 1: Map of Study Area

2.2 Geospatial Data Collection

To account for the various data sources and methodologies used, the methods for this study have been broken down into several steps. The methodology used can be classified into:

1. Define the study area.
2. Data Collection.
3. Analysis of data.
4. Evaluation of results.
5. Develop recommendations.

a. **Define the study area**:

The geographic area that was to be studied was defined. A shapefile of the was downloaded to mark the extent and a study area map, showing direction to the area was produced from this.

b. **Collect data:**

The major data that was collected is the satellite imagery of the study area and this was Landsat 8 data gotten from the Earth explorer website, https://earthexplorer.usgs.gov/

c. **Analyze the data.**

The data was analyzed to determine the various land uses in the region. A significant analysis was performed on image classification. This was done with the help of Landsat images from four different time periods (1990, 2000, 2010 and 2020), which were obtained and put through an image classification process in ArcGIS 10.8. Prior to further processing, the images were cleaned up to remove geometric distortions, sensor noise, and atmospheric effects. Following that, the Supervised Classification was performed by first defining training samples for each type of land use, which were based on actual data. The entire image was then subjected to the classification algorithm, which classified each pixel according to the land use of the trained class. Post processing was carried out on the classification to remove small errors or inconsistencies and generate a land use map.

d. **Evaluate the results.**

The results of the analysis was evaluated to determine the significance of the impact of land use changes on flooding. This was done by comparing the results to historical flood events and other relevant data.

e. Develop recommendations.

Develop recommendations based on the results of the analysis. These recommendations may include changes to land use practices, such as reducing impervious surfaces or promoting the use of green infrastructure.

Overall, this methodology provides a framework for understanding the impact of land use changes on flooding and developing strategies to mitigate these impacts.

2.3 Acquisition of Rainfall and Temperature Data

The Nigerian Meteorological Agency, NIMET, provided rainfall and temperature data from 1960 to 2020, including for Benin City. Using the Kosla's equation, runoff in the catchment was calculated from the rainfall and temperature data. The rainfall intensity duration curve for Benin City was plotted using data from NIMET and is shown in figure 9.

3.0 Results and Discussion

3. 1 Land Use Change Detection

This study used change detection analysis to identify changes in land use and land cover in the study area over time, as well as to understand the nature and extent of these changes. The land use land cover map of Benin City in 1990 as shown in figure 3 was created using Landsat satellite imagery and GIS software. The map shows three land cover classes, vegetation, water bodies and built-up areas. The built-up area land use class includes areas of high- and low-density urban development, while the vegetation land use class includes croplands, orchards, and grazing lands. The map covers an area of approximately 900 square miles and is presented at a scale of 1:20,000. The map also highlights the importance of agricultural land use in the region, with large areas of cropland and grazing land surrounding the urban areas.

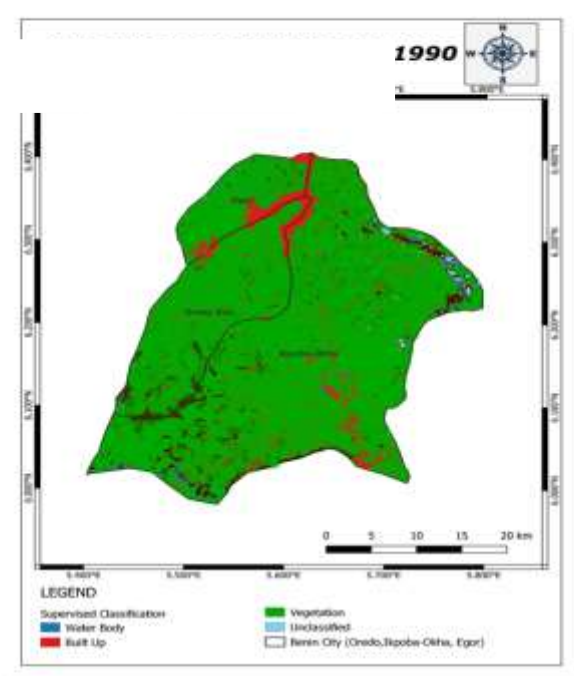

Figure 3: Land Use Land Cover Map of 1990

The land use land cover map of Benin City in 1999 as presented in figure 4 was created using Landsat satellite imagery and GIS software. The map legend includes four land cover classes, and the map covers an area of approximately 900 square miles at a scale of 1:20,000. The map reveals significant changes in land use and urbanization patterns compared to the 1990 map, including a further increase in urban land use and a decrease in agricultural land use.

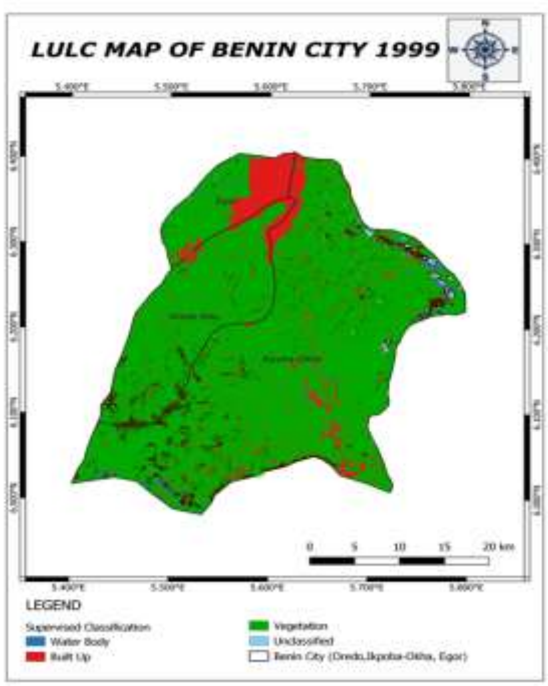

Figure 4: Land Use Land Cover Map of 1999

In Table 1, during the period of 1999 to 2009 in Benin City, there was a significant expansion of urbanization. Built-up areas increased, while vegetation cover and water bodies decreased. Population growth, economic development, weak urbanization policies, lack of environmental regulations, and urban sprawl were some of the main drivers of this urbanization. Additionally, events such as the city becoming the capital of Edo State and the upgrade of the airport contributed to the urbanization process. The impact of urbanization was evident in the degradation of natural resources. Additionally, social, and political issues, such as political instability during the 1990s, created an environment of uncertainty and insecurity.

Table 1: Land Use Land Cover Change from 1999 to 2009

Land Use Land Cover Classes	1999		2009	
	AREA (mi^2)	AREA (%)	AREA (mi^2)	AREA (%)
VEGETATION	707.70	77.45	452.20	49.49
WATER BODY	0.12	0.01	0.07	0.01
BUILT- UP	205.90	22.54	461.50	50.50
TOTAL	913.72	100	913.77	100

In table 2, between 2009 and 2019, the urbanization rate in Benin City, Edo State, Nigeria accelerated significantly, with vegetation coverage and water bodies declining while built-up areas expanded. The main drivers of this trend were population growth, economic development, urban planning, and social and political factors. The population of Benin City grew from 1.15 million in 2006 to 1.81 million in 2019, resulting in increased demand for housing and infrastructure. During this period, the state government initiated several policies aimed at attracting foreign investment and improving the business environment, which led to the establishment of more industries and businesses in the city. The urban planning was not adequately executed, leading to poor implementation and management of urban development projects. The city experienced an influx of people from neighboring towns and villages due to insecurity and political instability in those areas.

Table 2: Land use Land Cover Changes from 2009 to 2019

Land Use Land Cover Classes	2009		2019	
	AREA (mi^2)	AREA (%)	AREA (mi^2)	AREA (%)
VEGETATION	452.20	49.49	213.73	23.31
WATER BODY	0.07	0.01	0.05	0.005
BUILT- UP	461.50	50.50	700.01	76.69
TOTAL	913.77	100	913.79	100

These changes in land cover over time may be due in part to the impact of urbanization on the area. As Benin City becomes more urbanized, natural areas such as forests and grasslands may be converted to built-up areas to accommodate the needs of a growing population. This can lead to a decrease in the amount of land covered in vegetation, as well as an increase in the amount of land covered in man-made structures such as buildings and roads. Urbanization can also impact land cover in other ways, such as changes in the amount and distribution of water bodies or the presence of impervious surfaces such as roads and buildings.

3.2 Analysis of Meteorological Data

3.2.1 Analysis of Precipitation Data (1980 to 2010)

The moving average curve was superimposed over the original rainfall series. Though the variation in the original data was smoothened out to some extent in the moving average curve, no apparent trend or cyclicity is visible in the moving average curve. In figure 5, what was well noticed is that in the last decade, rainfall has been on the increase which supports the meteorological proof that there have been changes in the climatic condition of the study area. Precipitation in this decade and the other preceding it was highest, this also coincided with the period of massive flooding in most places in the study area. From 1980 to 2010, flooding was recorded in Benin city on annual basis especially from July to September which is the period of peak rainfall.

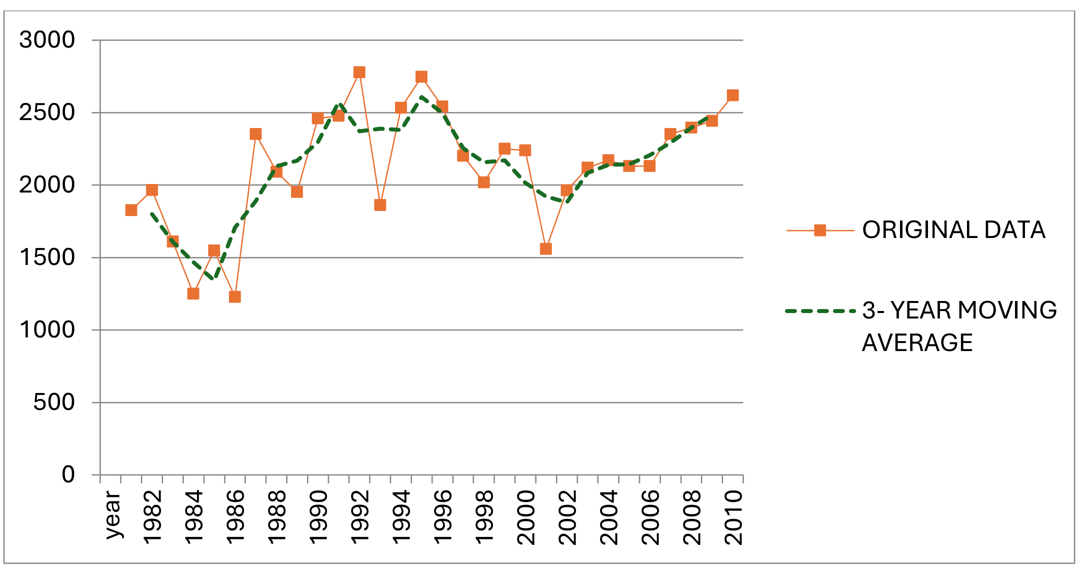

Figure 5: Three-year Moving Average Curve of Benin City Rainfall Data (1980-2010)

3.2.2 Temperature Analysis

The decade 1971-1980 recorded maximum annual mean temperature range of 28.1°C (1976) to 30°C (1973) and minimum annual mean temperature of 24.4°C (1976) to 24.65°C (1971). The minimum, maximum and mean values increased slightly over the decade as shown in Table 3. The decade 2001-2010 recorded the highest decadal range of 1.42°C for maximum annual mean temperature, while the decade 1971-1980 as the lowest decadal range of 0.9°C of maximum annual mean temperature of 23.9 °C (1983). Abe et. al., (2018) describes the climate in Nigeria to be dramatic climate. The last decade (2001-2010) recorded the highest annual mean temperature of 30.8°C (2010) with a decadal range of 2.3°C. This is also the world warmest years ever recorded by World Meteorological organization (WMO, 2011). In Nigeria, the decade 2000 to 2010 is the hottest decade ever recorded.

Table 3: Mean, Maximum and Minimum Temperature of Benin City (1970-2010)

Decade	Total Mean Temperature (°c)	Max Temperature	Min Temperature
1971-1980	26.7-27.2	28.2-29.2	24.7-25.3
1981-1990	27.3-27.6	29.5-30.6	25.2-25.2
1991-2000	27.2-27.6	28.9-29.8	25.3-25.3
2001-2010	27.6-27.7	29.49-30.8	25.19-25.1

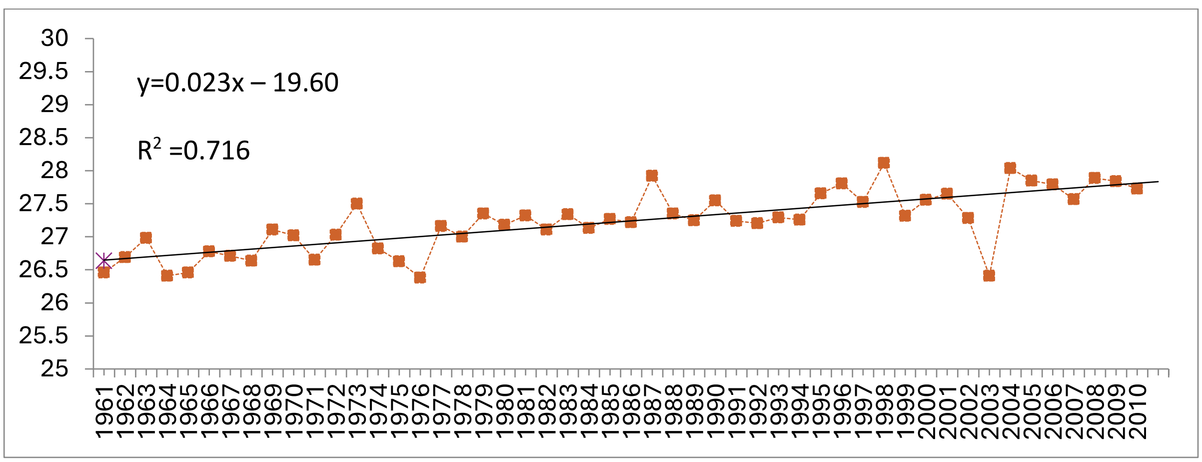

Figure 6: Mean Temperature over Benin City (1961- 2010)

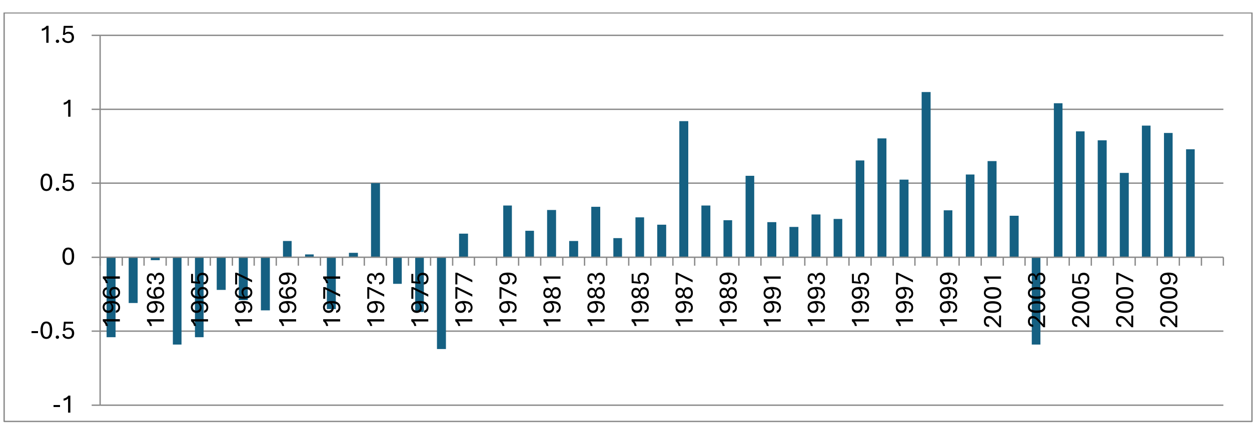

Figure 7: Temperature Anomaly over Benin City (1961-2010)

The data obtained for temperature distribution variation in Benin shows that the mean temperature over the area has increased considerably from an average value of 26.7°C in 1971 to 30.3°C in 2010.The annual trend graphs presented in figure 6 and 7 confirms this by showing an upward trend in the temperature values plotted against the respective year with an average increase of 0.058°C per annum. From Table 3, the temperature pattern for the period under consideration (1961-2010) has a wide variation. The maximum annual temperature column shows that the maximum mean temperature has risen from 28.2°C in the first (1971 – 1980) decade to 30.8°C in the last decade (2001 – 2010) indicating an increase of 0.04°C and 1.42°C per decade.

3.3 Runoff Computation in the Study Area

The runoff within the study area from 1990 to 2020 was estimated using Kosla's formulae. The result of the runoff estimation as presented in figure 8 revealed that runoff has been on the increase following the trend of increase in precipitation and reduction in vegetative area within the catchment. Also, as development increased, paved, and enhanced surfaces which reduces infiltration and percolation increased. These factors are responsible for the increase in generated runoff in the study area. Excessive runoff into receiving streams with narrow carriage capacity results in flash flooding which has been on the increase in the study area since 2010. Areas like Uselu shell (Tom line), Uwasota, Adolor, Iguosa, Mechanic village and Ekewan road are not spared from this annual disaster.

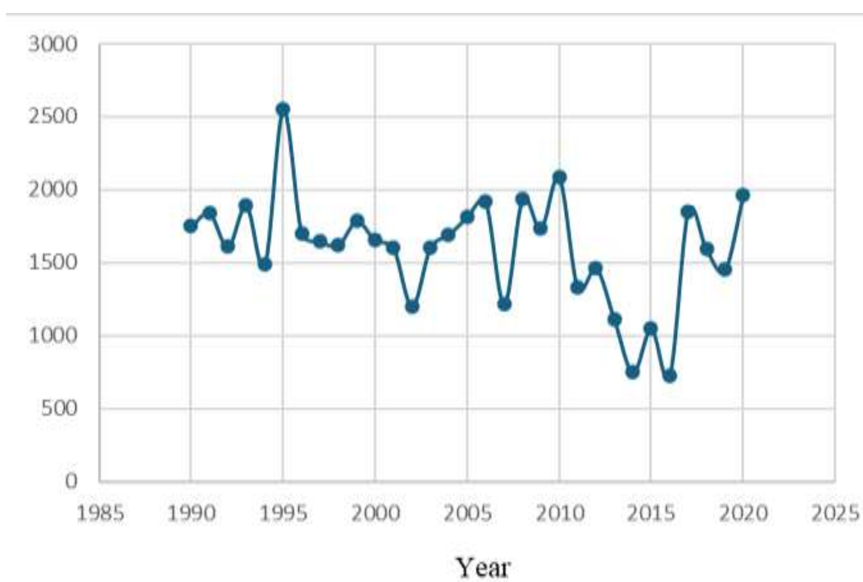

Figure 8: Graph of Runoff in the study area

The last eight years (2015 to 2023) in the study area have experienced upsurge in precipitation with high runoff accompanying it due to predicted global climate change. Several houses within low lying areas in Benin city have been submerged and rendered unlivable while properties and means of livelihood have been also lost to the flood. The absence of proper land use planning has greatly contributed to the menace of flooding in Benin city.

4.0 Conclusion

Remote sensing and GIS techniques were used in the initial section of this study to create a comprehensive and accurate satellite-derived land use and land cover maps. Findings in this study revealed that the built-up area consistently increased over time, primarily due to rising population. In analyzing data from 1990 and 2009, changes were identified in land cover in Benin City over this period, including a decrease in vegetation and an increase in built up areas. The changes in land cover may be due, in part, to the impact of urbanization on the area.

Between 2009 and 2019, further changes were observed in land cover in Egor, Oredo and Ikpoba Okha, including a further decrease in vegetation and a significant increase in built up areas. Climatic trend (rainfall and temperature) in the area also increased in the last four decades. Frequent rains reduce the infiltration capacity of soil and hence runoff and soil loss both increased. In tropical countries (like Nigeria), prolonged rainfall of short to moderate intensity lasting from 15 to 90 minutes (maximum rainfall intensity about 3mm/min), can cause landslides, gullies, and floods because of the increased run-off in the watersheds (Abe et al, 2018; Dias et. al., 2015). Runoff generated from the precipitation during the period under study revealed that as natural surfaces diminished and become impervious due to anthropogenic activities, runoff increased as infiltration and percolation decreased. The attendant effect of a reduction in both events is flooding which have ravaged the study area in the last couple of decades.

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