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A Comprehensive Evaluation of Urbanization Impact on Land Cover in Benin City

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Abstract

This study examines the impact of urbanization on land cover in Benin City, Nigeria, using satellite imagery and GIS analysis. The research aims to identify changes in land use and vegetation cover that could potentially threaten valuable ecosystems and biodiversity, and to suggest conservation and management strategies for the region. The study utilized cloudless satellite images from different periods (1990, 1999, 2009, and 2019), and classified them into water bodies, built-up areas, and vegetation using the supervised classification method in Quantum Geographic Information System (QGIS). The results showed that vegetation cover (in m2) significantly reduced over the three decades, from 819.91m^2 in 1990 to 213.73m^2 in 2019, indicating a 73.93% reduction while built-up areas significantly increased from 93.75m^2 in 1990 to 700.01m^2 in 2019, representing a 646.6% increase. These results revealed the negative effect of urbanization on Benin City and its environment, as bare lands and vegetative cover are removed for infrastructural development. The study recommends promoting sustainable development practices to mitigate the negative effects of urbanization which includes adopting green infrastructure and monitoring land use and land cover change to make informed decisions on future urban planning. Also, the results from this study provide insights into the impact of urbanization on land cover in Benin City, which is essential in the development of effective conservation and management strategies for the region.

1. Introduction

Urbanization is the process of moving from rural to urban areas, resulting in an increase in the number of inhabitants and a growth in urban centers. However, this process is often accompanied by diversification of natural resource utilization, leading to environmental degradation. Africa, which is often considered the least urbanized continent, has a pace of urbanization that is twice as high as Latin America and Asia. Urbanization is a major public and environmental health problem globally, especially in developing countries, where it is associated with difficulties such as unemployment, poverty, poor health facilities, and environmental deterioration. As a result, the sustainability of the current trend of urban expansion, particularly in developing countries is highly questioned.

Population growth rates have slowed down in many countries, but by 2020, 62 percent of the world's population will live in urban areas, with the Asia-Pacific Region having 49 percent of the urban population [1,2 and 3]

Africa has the lowest level of urbanization but the fastest urban growth[4]. Urbanization can affect the built and natural environment, and its impacts may occur at local, regional and global scales. The environment can be viewed from different perspectives and is multi-disciplinary, encompassing physical and non-physical, external, living, and non-living conditions that determine the existence, development, and survival of organisms at a particular time. Sustainability is also highlighted as the ability of the environment to meet the basic requirements for the sustenance of the living and non-living components of the ecological, economic, and socio-cultural systems.

A spectacular impact of urbanization in many parts of Nigeria is the outward expansion of cities and results in changes in land use whereby urban residents buy up prime agricultural land for residential or commercial purposes. The conversion of farmlands and watersheds for residential purposes has negative consequences on food security, water supply as well as the health of the people in the cities and urban areas.

Several studies [2, 3, 4, 5, 6, 7, 8, and 9] have identified many of the environmental problems in Nigerian cities as having serious adverse socio-economic and ecological implications. Most of these problems, it is argued, are traceable to a number of factors. These include the colonial antecedent of most Nigerian Cities [10 and 11] the high rate of urbanization [12], the bad psychological orientation of urban residents on the environment as well as poor environmental management practices [13] and 14]. In 1997, [15] and [16] 2001, clearly indicated that the spatial structure of Nigerian cities evolved before, during and after the colonial rule in the country made the introduction of modern infrastructural facilities very difficult and expensive especially when dealing with areas having the bulk of ancestral homes of indigenous people. It is also suggested by demographic experts that the high rate of urbanization put at 5.3 percent in Nigeria, which is among the highest in the world, has the tendency of spurring up environmental degradation [17]
.
The aim of this study is to evaluate the impact of Urbanization on Land Cover in Benin City as this would help identify changes in land use and land cover that could potentially threaten valuable ecosystems and biodiversity, and to suggest conservation and management strategies for the region.

2. Materials and Methods

2.1 Study Area

The Study area is in Benin City, Edo State which lies between Latitude 06°19' E to 6°21' E and Longitude 5°34' E to 5°44' E, and consists of three major local governments, Ikpoba Okha, Oredo and Egor Local Government area.

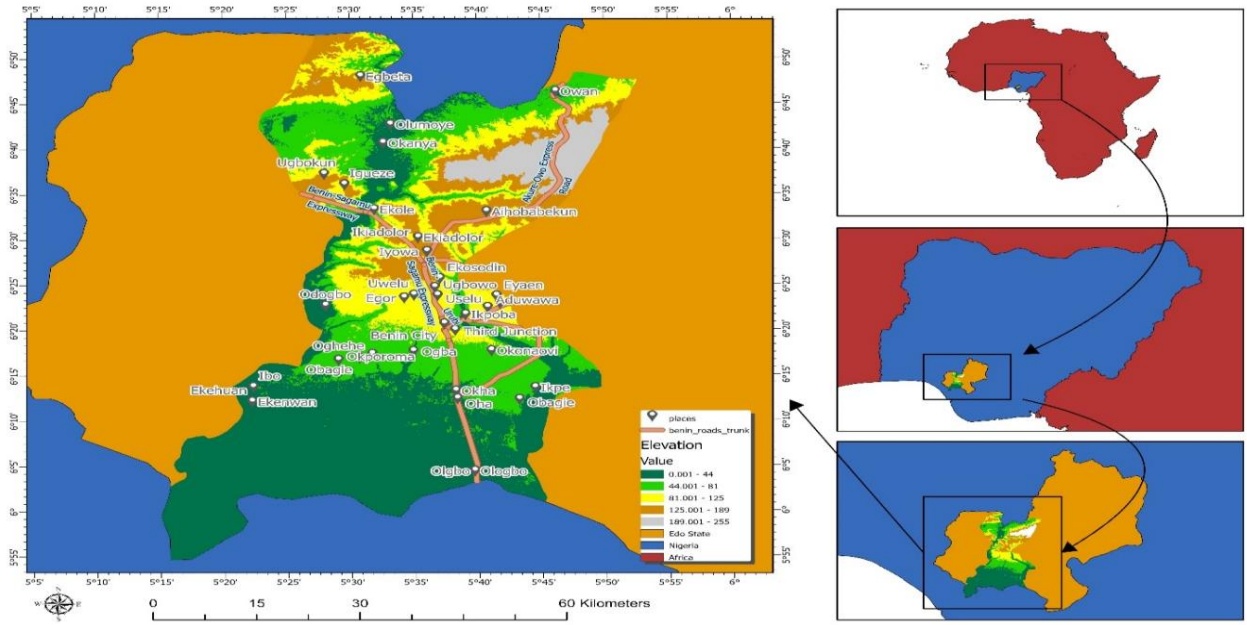

Figure 1: Study Area

2.1 Pre-Processing Stage

To evaluate the rate of urbanization in Benin City between 1990 and 2020, four cloudless satellite images were searched out and downloaded from USGS and imported into QGIS and all the numbered bands are assigned to the respective layers panel. The directory in which the data is saved is loaded into the SCP plugin. A layer is then created containing all the bands, this is called the band set.

2.2 Supervised Classification

Supervised classification is a machine learning technique where a model is trained on labeled data to predict the class or category of new, unseen data. The model learns the relationship between the input features and the output labels from the labeled training data. This method was employed in this study and for this to be carried out the system needs to know what specific areas of the image – and what underlying values – belong to which class. Classification is a remote sensing technique which categorizes the pixels in the image into classes based on the ground cover. This is done by comparing the reflection values of different spectral bands in different areas. In *supervised classification*, the user determines sample classes on which the classification is based while for *unsupervised classification* the result is solely the outcome computer processing. In this case supervised classification is done. Therefore, training inputs will have to be established.

2.2.1 Classes

In this study, the goal of the analysis is to find out how much vegetation has been lost between 1990 and 2020 and how much built-up areas has increased during this period. Classes are created using the training input in the SCP dock. The classes that are used in this study are Vegetation, Built Up areas and water bodies.

2.2.2 Region Of Interest

Once the classes were created, ROIs were added from the ROI signature list by drawing a polygon of an area which you can clearly see belongs to a specific class then QGIS will automatically select the surrounding pixels which have the same or similar reflection values. The image was then classified using The Minimum Distance Algorithm.

2.2.3 Change Detection

The change detection was run by using the older classification layer as reference layer to the latest classification layer making sure that the pixels are unchanged as this provides valuable information for the interpretation.

3. Results and Discussion

This study used change detection analysis to identify changes in land use and land cover in a specific 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 2 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.

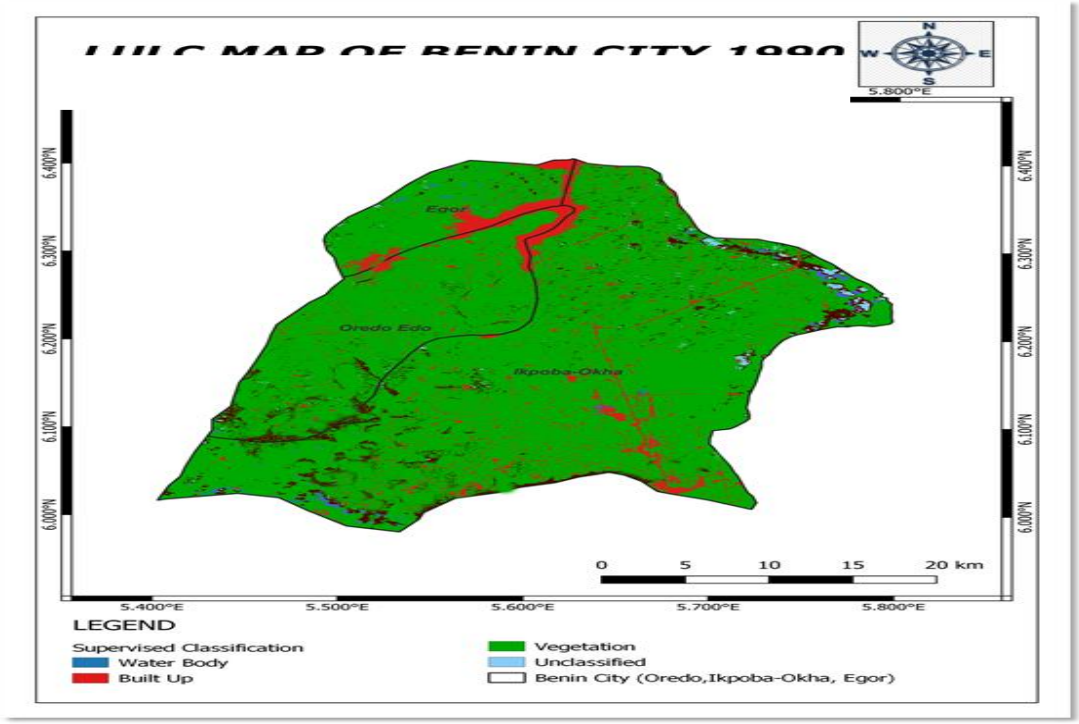

Figure 2: Land Use Land Cover Map of 1990

The land use land cover map of Benin City in 1999 as seen in Figure 3 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.

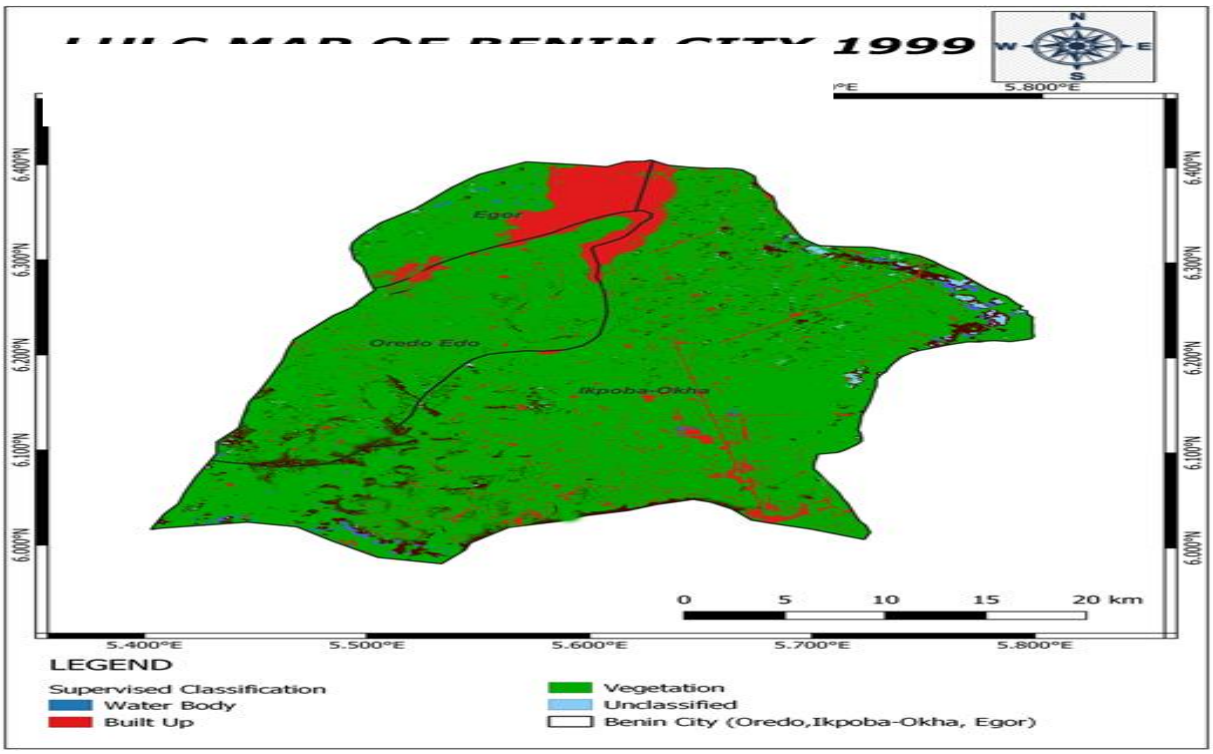

Figure 3: Land Use Land Cover Map of 1999

The land use land cover map of Benin City in 2009, created using Landsat satellite imagery and GIS software, provides a visual representation of land cover and land use in the study area. The map reveals significant changes in land use and urbanization patterns compared to the 1990 and 1999 maps, showing a continued increase in urban land use and a further decrease in agricultural land use. The map has important implications for urban planning and management efforts, as it can help inform decision-making and provide insights into the impacts of urbanization on the environment and natural resources in Benin City.

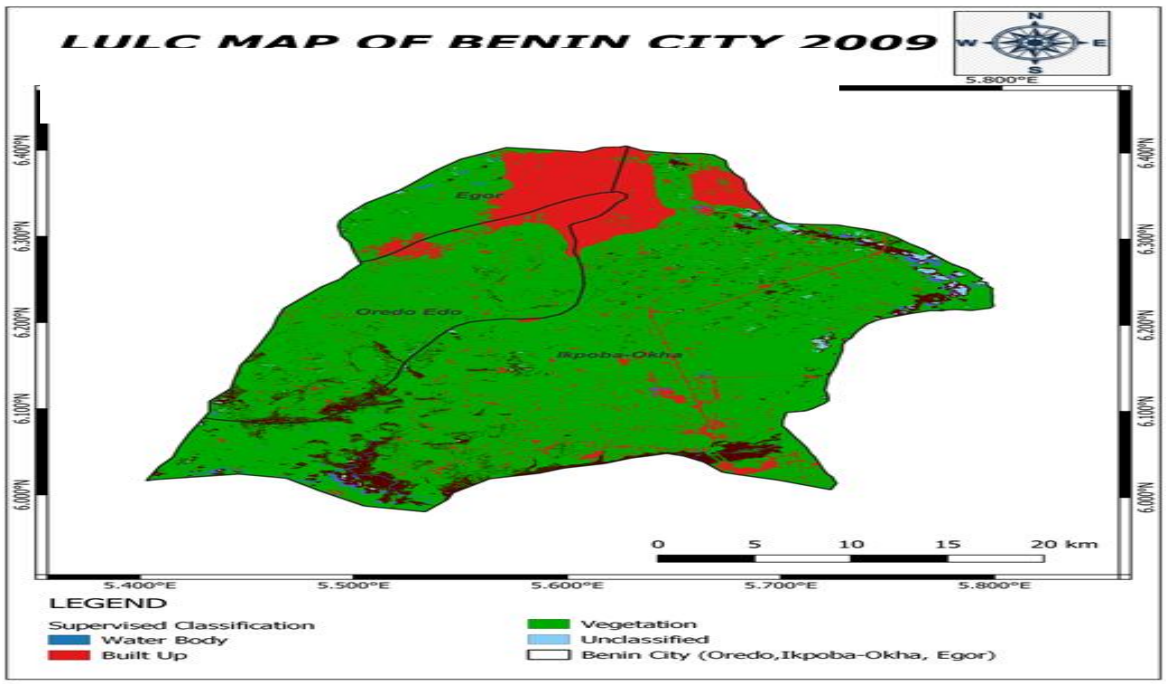

Figure 4: Land Use Land Cover Map of 2009

The land use land cover map in Figure 5 was created using Landsat imagery and QGIS software. The map legend covers ten land cover categories, and the map covers an area of around 900 square miles at a scale of 1:20,000. The map's findings demonstrate significant changes in land use and urbanization patterns in comparison to the 2009 map, such as a continued increase in urban land use, a substantial decrease in agricultural land use, and the conversion of natural areas into built-up areas.

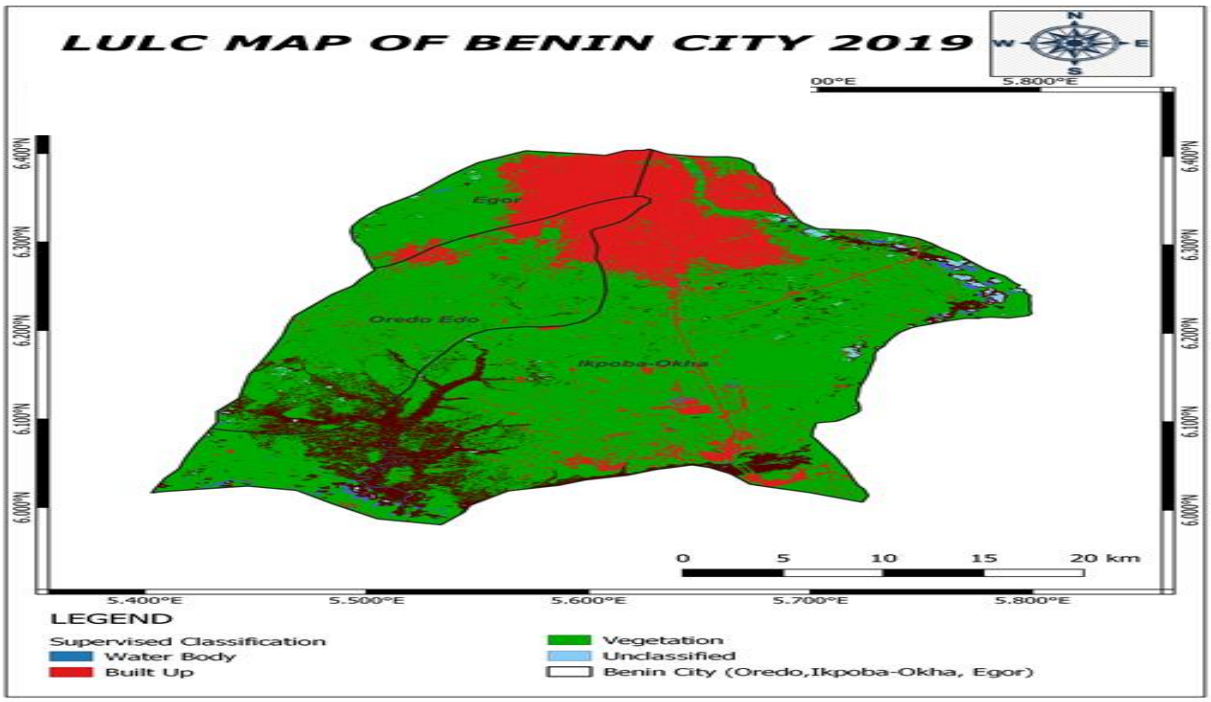

Figure 5: Land Use Land Cover Map of 2019

Table 1 shows a decrease in vegetation cover and an increase in built-up areas, while water bodies remained stable. Population growth, economic development, and urban planning policies, or the lack thereof, were major driving forces behind the urbanization process during this period.

The rapid population growth led to an increased demand for housing and infrastructure, resulting in the expansion of built-up areas and the conversion of natural vegetation areas. Economic growth led to increased investments in infrastructure, further fueling urbanization. The lack of effective urban planning policies and regulations contributed to uncontrolled development, which further accelerated the process.

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 1990 to 1999

LAND USE LAND COVER CLASSES	1990 to 1999			
	AREA (m^2)	**AREA (%)**	**AREA (m^2)**	**AREA (%)**
VEGETATION	819.91	89.73	707.70	77.45
WATER BODY	0.09	0.001	0.12	0.01
BUILT- UP	93.75	10.26	205.90	22.54
TOTAL	913.75	100	913.72	100

As seen in Table 2, 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.

Table 2: Land Use Land Cover Change from 1999 to 2009

LAND USE LAND COVER CLASSES	**1999 to 2009**			
	AREA (m^2)	**AREA (%)**	**AREA (m^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

As seen in table 3, 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 3: Land use Land Cover Changes from 2009 to 2019

LAND USE LAND COVER CLASSES	**2009 to 2019**			
	AREA (m^2)	**AREA (%)**	**AREA (m^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 in order 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.

4. Conclusions and Recommendation

This study's objective was to evaluate how Benin City's expansion will affect the vegetation cover. In order to analyze the data, descriptive and inferential statistical tools were both used. It was clear that Benin City has been urbanized significantly between 1990 and 2019 and within this period, vegetation reduced significantly while built up areas increased.
Based on the results and their analysis, the following recommendations were made:

a. Promote sustainable development practices: Urbanization can have a number of impacts on land cover, including changes in vegetation, water bodies, and built-up areas. To minimize these impacts, it may be helpful to promote sustainable development practices that aim to preserve and enhance natural resources, such as green spaces, natural drainage systems, and eco-friendly infrastructure.
b. Encourage the use of green infrastructure: green infrastructure, such as green roofs, rain gardens, and permeable pavement, can help to mitigate the impacts of urbanization on land cover by reducing the amount of impervious surface in the landscape and promoting the infiltration and retention of storm water. Encouraging the use of green infrastructure in Benin City could help to preserve natural resources and reduce the negative impacts of urbanization on land cover.
c. Monitor and analyze land use and land cover data: By continuing to monitor and analyze land use and land cover data in Benin City, it will be possible to understand and track the impacts of urbanization on land cover over time. This information can be used to inform decision-making and policymaking related to land use and land cover in the city, and to identify strategies for mitigating negative impacts and promoting sustainable development.
d. Engage with stakeholders: Engaging with stakeholders, including community members, local organizations, and government agencies, can help to ensure that the needs and concerns of all parties are considered when making decisions about land use and land cover in Benin City. This can help to build support and buy-in for sustainable land use practices and policies and can promote more effective and equitable decision-making processes.

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