



Evaluation of the Extent of Land Use-Land Cover Changes of Benin City, Edo State, Nigeria from 1987-2019

FABOLUDE; G; *AIGHEWI; IT

Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Edo State, Nigeria

*Corresponding Author Email: isoken.aighewi@uniben.edu; Tel: +234 9092863976
Second Author Email: faboludegtb@gmail.com

ABSTRACT: Human growth and development occur at the expense of our natural resources. The ancient city of Benin, the capital of Edo State, Nigeria has been experiencing a surge in population hence this study was initiated to evaluate the extent of land use-land cover (LULC) changes over a 32-year period (1987-2019), using remote sensing and Geographic Information Systems (GIS) techniques. USGS Landsat data were acquired for 1987, 2002, and 2019, pre-processed and classified using ENVI 5.2 software and exported into ARC-GIS platform for further analysis. The results of the 1987-2019 LULC classifications were also used to forecast Benin City's LULC for 2050 using the Markov and CA-Markov models in TerrSet 17.0 software. The results showed that 284.56 km² of forest lands were lost over a 32-year period (1987-2019), while built-up and barren lands increased rapidly by 153.96km² and 81.58km², respectively. By 2050, the built-up area is expected to increase by 236.92km², while barren land is expected to maintain its percentage cover. Grassland increased by 52.16 km², while water decreased by 3.60 km², both of these classes are expected to decrease by 157.58km² and 0.45km² by 2050, respectively. The increase in population and built-up areas in Benin City contributes to deforestation and increased urban heat, as well as reduced ecosystem services and biodiversity loss. As a result, it is recommended that the Benin City Urban Planning Authority encourage the planting of ornamental trees, shrubs, and lawns in order to restore more carbon sequestration to the ecosystem and thus reduce global warming.

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The dynamic nature of urban environment resulting from the influx and efflux in most parts of the world is well known (Olayiwola and Igbavboa, 2014). Rapid urbanization in emerging and old cities has led to unrestricted growth which has been described as Urban sprawl by Foubert (2012). Urban sprawl is often attributed to human population growth that leads to several negative consequences on the environmental components of the area (Stephen and Colin, 2015). As the urban population increases exponentially its impact on the natural and physical environment will continue to increase significantly with respect to land use, energy consumption, water, security, air quality, food demand, and climate change (Koop and Van Leeuwen 2017). The effects of urban

sprawl and overpopulation do not support the concept of sustainability, hence the study of urban change trends. Changes that occur in an urban environment ultimately leads to increase in the depletion of natural resources and a high rate of habitat fragmentation which are a major threat to biodiversity. Apart from population growth, one of the major factors that lead to urban sprawl in developing countries is rural-urban migration (Malik, 2015). Local or international migration drives urbanization, presenting opportunities and difficulties to cities, migrants, and governments (MDP, 2021). However, at the city level, migration is mostly influenced by local authorities and state government as resources from the government are often prioritized at the urban areas (Tacoli *et al*,

*Corresponding Author Email: isoken.aighewi@uniben.edu

2014). In addition, with overstressed existing social and infrastructural services in the urban areas, the rate of rural-urban migration has rapidly surpassed the rate of employment growth in Nigeria and as a result, the poverty rate has continued to accelerate (Johnson and Ifeoma, 2018). According to the 2006 national population census, Nigeria has one of the world's fastest population growth rates, especially in the urban areas; this backs up the claim by the World Bank that 50% of the world's population lives in urban areas and is predicted to further increase by 1.5 times (World Bank, 2020). Recently, Worldometer ranks Nigeria as the 7th most populous nation in the world as of July 20, 2022. Benin City, Nigeria is one of the ancient cities whose origin can be traced back to the 12th century; over time, the population of Benin City has shown an increasing trend with more than 40% increase over the last two decades (Olayiwola and Igbavboa, 2014). Moreover, it has been reported that the city is experiencing urban sprawl which has led to the depletion of natural resources like forests and water. To sustain our natural resources, there is the need to protect vital environmental resources such as the forest cover which possesses the most dynamic ecosystem among others (Brockerhoff *et al.*, 2017). Geospatial information technology presents the appropriate tool for assessing such changes in our environmental components in order to regulate and put measures in place for control. The objective of this study therefore were to evaluate the extent of land use-land cover (LULC) changes of Benin City, Edo State, Nigeria

over a 32-year period from 1987 to 2019 using remote sensing, and Geographic Information Systems techniques, and future changes projected through 2050 using the Markov and CA-Markov model.

MATERIALS AND METHODS

Study area: Figure 1 shows the study location-Benin City. Benin City is the capital of Edo State, Nigeria. It is situated in the country's south, between latitudes 6^o 12' 38.36" N and 6^o 27' 25.00" N, and longitudes 5^o 29' 46.03" E and 5^o 45' 00.41" E. The city is composed of five Local Government Areas (LGAs): Egor, Ikpoba-Okha, Oredo, Ovia North East, and Uhumwonde. The city is located in the tropical rainforest region teeming with rich and rare forest species that has continued to be exploited for several centuries. The soils are mostly acid, deep and very highly leached and reddish to brown in colour due to the predominance of oxides of iron and aluminium (Aighevi, 1999). Forest species and plantation crops such as Oil Palm (*Eleais guinesis*), Cocoa (*Theobroma cacao*) and Rubber (*Hevea brasiliensis*) are major plantation crops grown in addition to arable crops in the Sothern section of Edo State where Benin City is located. The city's distinctive radial road network pattern improves interconnectivity between the core and other parts of the city-a significant development factor that distinguishes Benin City from others in Nigeria (Olayiwola and Igbavboa, 2014).

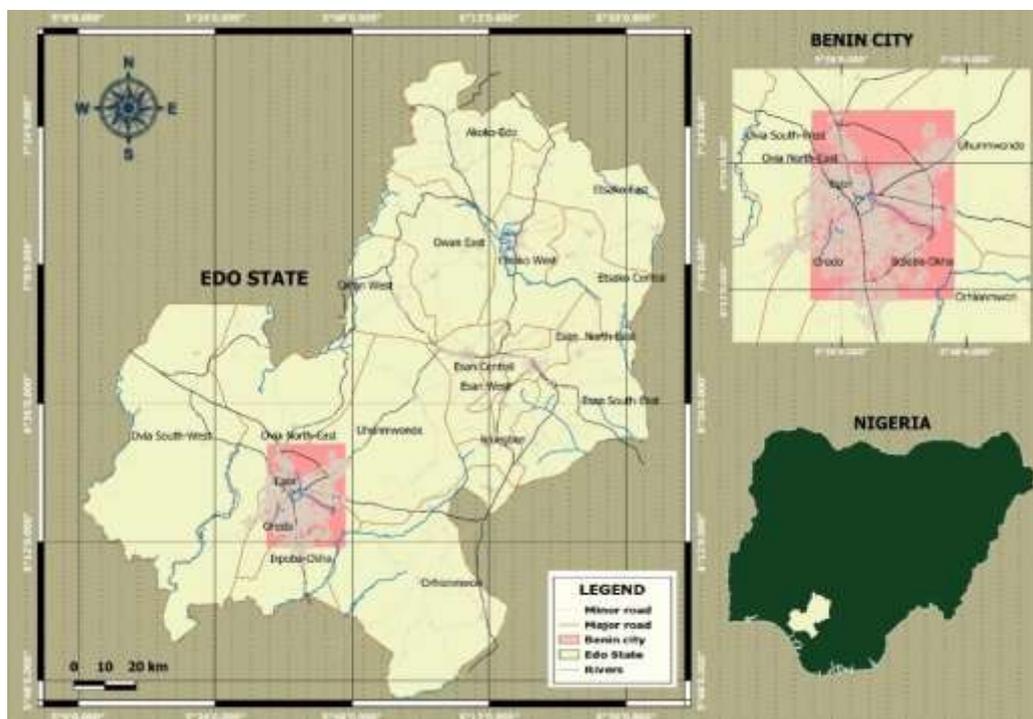


Fig 1: Map of Benin City, Edo State, Nigeria.

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Data collection and analysis: Remotely sensed Landsat 4-TM and Landsat 7-ETM+ images were acquired for Benin City, Nigeria (Path 189, row 56) from the United States Geological Survey (USGS) for the month of December in 1987, 2002, and 2019. However, we could not maintain a perfect temporal variability due to cloud cover hence we obtained data for 21st, 30th, and 28th December for 1987, 2002, and 2019 respectively. After image collection, the data were pre-processed using the ENVI 5.3 software which corrected radiometric and atmospheric distortions and the study location was clipped from the

map data acquired before classification. The maximum likelihood supervised classification method was employed in the classification of the image into 5 classes under the Anderson level-1 classification system. These classes include: built-up area (Urban), barren lands, forest land, and cultivated/grassland. Training samples were carefully collected from the enhanced images for each year by identification of the land use-land cover classes (Table 1). This was achieved by multiple band combinations which aided visual interpretation.

Table 1. Land use-Land cover classification names, description, and number of trained samples for each class of Landsat datasets

Class	Description	Number of training samples 1987	Number of training samples 2002	Number of training samples 2019
Built-up Area	A concrete structure such as residential, industrial, roads and other uses.	59	61	65
Barren land	Open or exposed soil	25	27	22
Surface water	Reservoirs and rivers	44	52	42
Cultivated/grassland	Grass vegetation and cropland	48	43	53
Forest land	Forest cover (trees)	52	47	49

Accuracy assessment: The accuracy assessment for 1987, 2002, and 2019 classified images was carried out using the confusion matrix and the ground truth image tool in ENVI software. The confusion matrix assessment method basically uses reference data for a connection check with the classified images and produces an overall accuracy result, producers and user accuracy, and a multivariate Kappa coefficient which shows the connectivity accuracy between the ground truth data and classified map with a range of 0-1 (Comber, 2013). Ground truth data were collected from a high-resolution image for each year assessed on Google Earth ©.

Future Projection Using Markov and CA-Markov modelling: After a 32-year spatio-temporal classification, the classified image data were used for the future projection of Benin City through 2050 using the Markov and CA-Markov model of the Land-use modeler in TerrSet 17.0 software. A transitional matrix was first generated between the 1987 and 2019 classified images using the Markov model as described by Tadese *et al.*, (2013). The model depicts changes between an earlier classified image and the latter in a matrix format for predicting the future. After generating the prediction matrix, the future image simulation was carried out by using the CA-Markov model. The CA-Markov model simply predicts the future LULC by using the conditional probability matrix (Sang *et al.*, 2011, Bello *et al.*, 2018). Validation

of this model result was achieved by predicting a simulation of 2019 using the 1987 and 2002 LULC images generated. The model was simulated using the same method for the 2050 projection. After the modelled 2019 LULC image was extracted, the modelled image was compared to the initial classified 2019 map using the Error matrix function; the spatial agreement between the simulated and actual LULC can be assessed using the Kappa coefficient value from the error matrix result (Nath *et al.* (2020). Classified images were exported to ARC-GIS platform for further analysis to determine Changes in the LULC during the period under investigation.

RESULT AND DISCUSSION

Table 2 shows the numerical changes in LULC of Benin City with respect to the built-up area, barren land, cultivated/grassland, and forest land cover over a 32-year period, while Figure 2a to 2c shows the actual LULC for 1987, 2002 and 2019 respectively.

Changes in Built-up land in Benin City, 1987 –2019: The changes in LULC of the built-up areas of Benin City during the period is also shown in Figure 3. Built-up land cover was 18% of the city in 1987, covering an area of 151.44km². However, built-up land increased by 65.3 km² in 2002, resulting in a 25% increase in area size. In 2019, the trend continued, with the built-up area increasing by 88.66km² or 36%. Furthermore, the LULC map for 2050 was generated

using the CA-Markov model (see Figure 4); the model predicted that the built-up land-use area would increase by 236.92km², bringing the total built-up area to 542.32km² by 2050. The majority of new development during the period will occur at the city's outskirts, with no change occurring from the city center. This pattern of development increases built-up land in comparison to other land cover types such as forest and cultivated/grassland land. According to Odjugo et al., (2015), urbanization in Benin City can be attributed to rapid population growth and an increase in rural-urban migration that creates demand for housing. Over time, the city has seen a massive influx of migrants from rural areas searching for employment, education, health care, and other opportunities (Magnus and Esegibe, 2012) Furthermore, the population of Benin City was approximately 641,000 in the late 1980s, with a 7.37% growth rate, however,

this trend has continued, with the population rising to 1,032,000 in 2002 and then to 1,676,000 in 2019. (UNWPP, 2022). Most emerging and old cities are accommodating an increasing population, which is constantly changing urban landscapes and posing a significant environmental risk (Bai et al., 2017). According to Turok and McGranahan (2013), the economic impact of rapid urbanization in African cities is not a simple linear relationship because productivity is dependent on the long-term growth of institutional facilities. However, there is a well-established positive relationship between population growth and increased urban land use in Benin City (Olayiwola and Igbavboa, 2014). As a result, the vegetative land cover decreases. If the population continues to grow without major and effective urban planning, Benin City's urban cover could reach 542.35km² by 2050 using the prediction model.

Table 2. Land use- Land Cover of Benin City: 1987 to 2019 and Future Projection for 2050

LULC TYPES	TOTAL AREA AND PROJECTED BY YEAR (km ²)				Net change 1987-2019 (km ²)
	1987	2002	2019	2050	
Urban	151.44	216.74	305.4	542.32	153.96
Barren Land	10.17	14.15	91.75	86.85	81.58
Forest Land	403.36	310.86	118.8	44.81	-284.56
Cultivated/grassland	280.92	306.39	333.08	175.5	52.16
Water	6.05	3.79	2.90	2.45	-3.60

Table 3. Accuracy results showing the Kappa coefficient, producer, user, and overall accuracy for all classified images from 1987 – 2019.

Class	1987		2002		2019	
	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy
Urban	91.65	92.34	89.84	91.53	89.25	82.50
Barren land	94.50	92.67	79.76	81.76	84.50	83.67
Forest	89.51	86.55	87.10	86.73	90.50	86.55
Grassland	91.72	96.42	93.65	88.72	90.82	93.42
Water	80.99	96.40	93.58	96.74	82.99	85.40
Overall Accuracy (%)	87.40		89.77		94.80	
Kappa Coefficient	0.84		0.83		0.88	

Kappa coefficient values 0.81 -1.0 = perfect agreement, 0.61 – 0.80 = substantial agreement, 0.41-0.60 = moderate agreement and 0 – 0.4 = poor agreement

Changes in Forest Lands in Benin City 1987 -2019: In 1987, forest vegetation occupied 403.36km² (47 percent) of the city's land area. However, this decreased by 10% in 2002 to 310.86 km². This trend continued, with forest land shrinking dramatically to 118.80km² in 2019. Owing to the fact that forest land depreciated massively from 1987 - 2019, it was predicted that forest land would decrease further to 44.81 km² in 2050. Between 1897 and 2002, forest land contributed the most to urban growth. Benin City is located in the rainforest region of Nigeria, making it rich in tree species such as *Terminalia catappa*, *Delonix regia*, *Terminalia ivorensis*, and *Milicia excelsa* etc (Ogwu et al, 2016). Deforestation in urban areas results in increased carbon emissions,

biodiversity loss, threats to watersheds, and an increase in urban heat (Ruth et al, 2010, Franco et al, 2011). However, the concept of the grey-green divide has a significant impact on deforestation in urban areas. This simply explains the metropolitan area's increased greenness (Corbane et al, 2020). Green spaces in cities are important ecosystem components that contribute to the transformation of the urban landscape, increasing air quality, lowering noise pollution, and lowering the ambient temperature (Szaraz, 2014, Puplampu et al, 2021). The amount of green space in urban areas has been shown to have a very substantial link with socio-economic factors, serving as an indication of urban poverty levels. (Dempsey, 2016). In Benin City however, only

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relatively few real estate properties have designed landscapes with lawns and florals, while a majority of the land owners either concrete the empty spaces around their buildings or leave the land bare, rendering them susceptible to erosion; over time, erosion exposes the foundation of the buildings.

Changes in Cultivated/Grassland Land in Benin City 1987 – 2019: The 1987, Cultivated/grassland covered 280.92km² (33%) of the land area of Benin City. However, this increased by 65.3 km² in 2002, but the

percentage cover decreased by 25% in relative to other classes. Cultivated/grassland area increased by 26.69km² in 2019, with a 39% increase in percentage cover over 2002. Furthermore, the cultivated/grassland class as seen in Figure 4 is expected to shrink rapidly to 175.50km² by 2050. Agriculture, as one of several deforestation factors, plays a significant role in the loss of forest land in urban areas (Benhin, 2006).

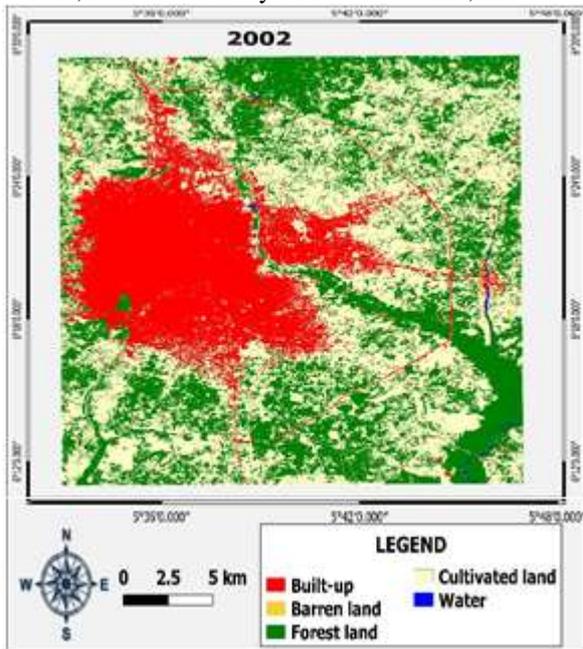


Fig 2a: Land Use – Land Cover map for Benin City in 1987

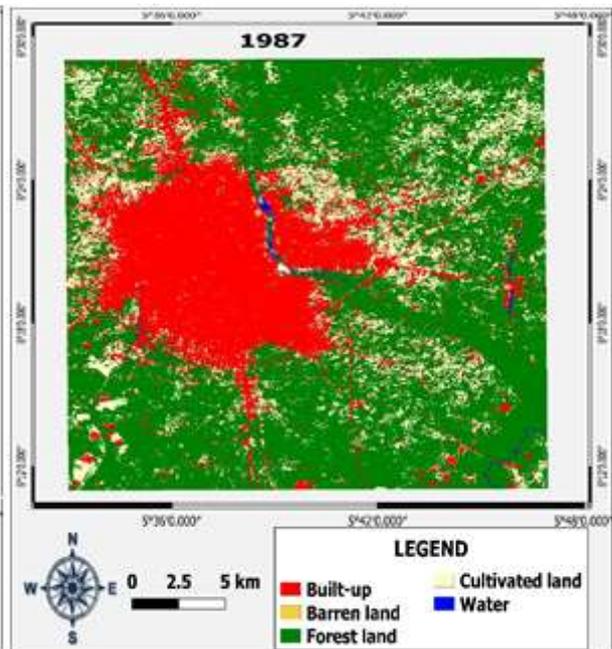


Fig 2b: Land Use – Land Cover map for Benin City in 2002

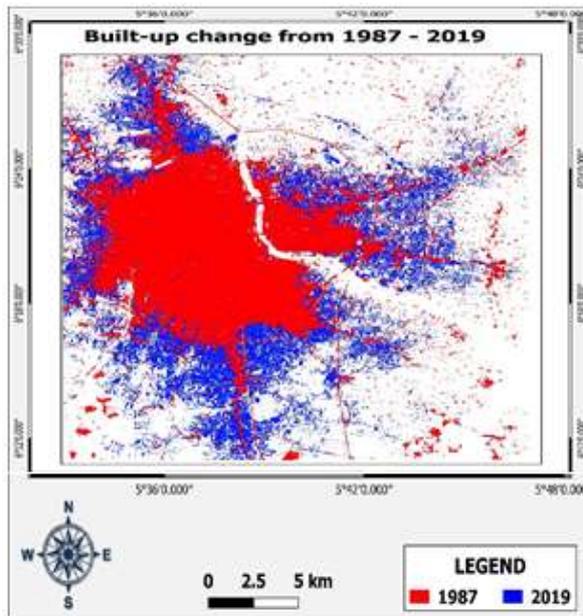


Fig 2c: Land Use – Land Cover map for Benin City in 2019

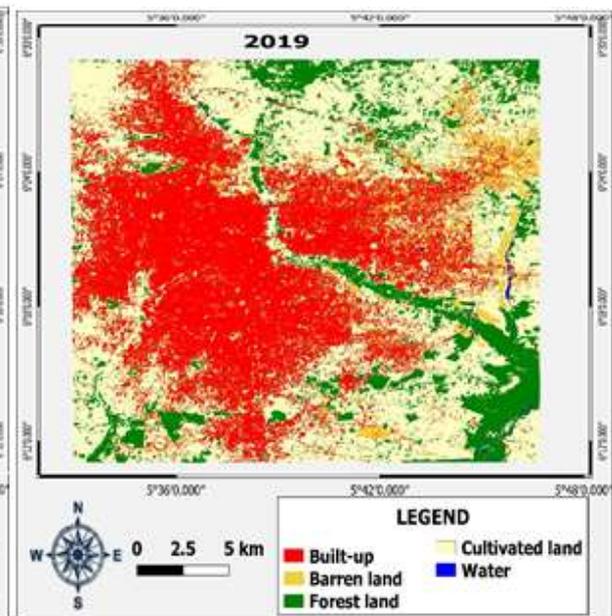


Fig 3: Changes in LULC of Built-up Areas of Benin City from 1987 - 2019

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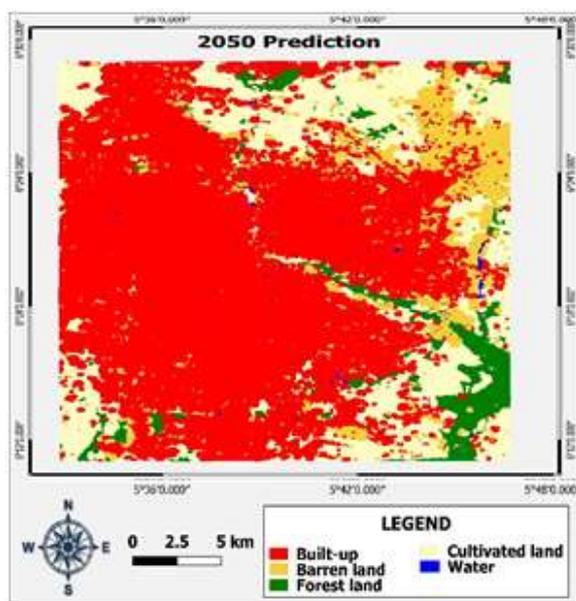


Fig 4: Projected Land Use-Land cover map of Benin City - 2050.

Agriculture in Benin City, on the other hand, is heavily dependent on soil that is predominantly ferric in nature and mostly supports plantation farming, as seen on the city's outskirts where oil palm plantations predominate. As a result, the vast majority of low plants classified as cultivated/grassland are grasslands. The cultivated/grassland area may decrease to 175.50km² in the next 30 years, according to the projection model in this study. This can be attributed to the City's rapidly expanding built-up areas at the expense of real estate development during the study period.

Changes in Baren Land in Benin City, 1987 – 2019: As shown in Table 2, Benin City's barren land increased from 10.17km² (1% area cover) in 1987 to 14.15km² in 2002 while maintaining its percentage area cover. However, there was a massive increase in barren land in Benin City in 2019, with the class increasing by 77.6km² (11%) from the initial 1% in previous years. Furthermore, the area covered by barren land in Benin City is expected to decrease slightly by 2050. The fact that the majority of urban roadways in residential areas are covered with asphalt or concrete contributes significantly to the expansion of barren land cover overtime. Sand mining, on the other hand, has resulted in an increase in barren land near the northeastern part of the city in Uhumwonde LGA as seen in Figure 2c. According to Pitchaiah (2017), sand dunes damage the environment by increasing the likelihood of heavy storms, erosion, and thus habitat destruction by reducing visual beauty. Furthermore, sand mining contributes to aquatic ecosystem degradation by reducing surface water bodies through siltation (Filho *et al*, 2021). The

negative impact of more barren land in Benin City can be seen in the dramatic decrease in surface water area between 1987 and 2019. Moreover, the increase in barren land over time can also be attributed to the lack of landscaping culture, particularly in the older sections of the city. In Benin City, most homes do not have lawns in their yards. Apart from the beautifying attribute of lawns, it also protects the topsoil thereby reducing exposed land and erosion.

Changes in Surface water in Benin City, 1987 – 2019: As observed in Table 3, the surface water class maintained the same percentage cover from 1987 to 2019, but its area decreased over time. Surface water occupied an area of 6.05km² in 1987, but this decreased to 3.79km² in 2002 and then to 2.90km² in 2019. Furthermore, surface water in Benin City is expected to fall even further to 2.45km² by 2050. The gradual increase in unpaved roads and blocked drainage systems can be attributed to the rapid decrease in surface area between 1987 and 2019. The exposure of topsoil encourages the occurrence of flooding and erosion, increasing the load of sand in drainage systems and, as a result, reducing the size of surface water through siltation (Kulkarni *et al*, 2009). Aside from reducing water surface area, siltation leads to eutrophication resulting in algae growth in surface water which threatens aquatic biodiversity (Rathore *et al*, 2013).

Accuracy assessment: Both the LULC assessment and the future projection were subjected to accuracy checks. The LULC accuracy result shown in Table 3 displays the overall, producer accuracy, user accuracy, and Kappa coefficient, which ranges from 0-1. The accuracy for barren land was the lowest, while the water class accuracy was the highest in 2019. Furthermore, the lowest producer accuracy was recorded for barren land in 2002, while the highest was recorded for water for 2002. The overall accuracy for the LULC analysis ranged from 87.40 % to 94.80 %, with 2019 recording the highest overall accuracy. The Kappa coefficient results, on the other hand, ranged from 0.83 to 0.88, with the highest accuracy also recorded in 2019. The accuracy of the model simulation for 2050 was determined by comparing the actual 2019 LULC result with the modeled result for 2019. The overall accuracy was 69.65%, with a Kappa Coefficient of 0.67. This indicates that the predicted future changes in the LULC of Benin City for 2050 is moderately reliable.

Conclusions: This study showed that land use-land cover of Benin City changed significantly over a 32-year period with built-up areas, barren lands, and cultivated/grasslands increasing at the expense of

forest lands and surface waters. Future projection shows that built-up areas will expand further while forest lands and surface water cover will shrink by 2050. It is suggested that Benin City Urban Planning Authority should encourage the planting of ornamental trees, shrubs, and lawns to encourage carbon sequestration while reducing global warming and preserving biodiversity

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