

ABSTRACT

In the face of rapid urbanisation, understanding the intrinsic characteristics of urban landscapes is pertinent for maintaining ecosystem well-being and implementing proactive measures against uncontrolled landscape transformation and climate change. Consequently, this study assessed the changes in urban landscape structure and their impact on ecosystem regulating services (ERS) in the Rainforest (Akure and Owerri) and Guinea savanna (Markurdi and Minna) ecoregions of Nigeria between 1986-2022. It analysed the spatial and temporal patterns of landscape fragmentation and aggregation, model ERS distribution, identify drivers of ERS, and predict future effects of landscape changes on ERS sustainability. The study integrated machine-learning-based geospatial techniques, ecological metrics, biophysical models and socioeconomic techniques. Supervised classification using the random forest (RF) machine-learning classifier was performed on Landsat images in the Google Earth Engine (GEE) environment to assess the land use and land cover (LULC) patterns. The LULC layers were deployed into FRAGSTAT to evaluate the degree of landscape fragmentation (patch density, PD and edge density, ED) and landscape aggregation (aggregation index, AI). LULC, biophysical, and meteorological datasets were incorporated into the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) platform to model the spatiotemporal pattern of ERS including carbon storage and sequestration, heat mitigation (HMI) and stormwater retention. A household survey, involving the administration of a semi-structured questionnaire to 1552 participants, was conducted to investigate the nature and drivers of the changing urban landscape and ecosystem services based on the perspective of urban inhabitants. The future LULC pattern was simulated using the Cellular Automata–Artificial Neural Network (CA-ANN) model for 2042. Accuracy validation and assessment for all reported models showed results exceeding 70%. The highest rate of built-up area expansion was observed in Makurdi ($0.74\% \text{ year}^{-1}$), followed by Akure ($0.42\% \text{ year}^{-1}$), Owerri ($0.35\% \text{ year}^{-1}$), and Minna ($0.32\% \text{ year}^{-1}$). Landscape fragmentation (ED) showed an increasing trend for built-up class (from 6.41 m/ha to 44.80 m/ha) in cities but with fluctuations for Makurdi and Minna. AI for the built-up class slightly decreased in Akure and Owerri while Makurdi and Minna underwent an increment, showing increasing densification of the built-up landscape in these cities. Residential expansion, agricultural practices, transport and infrastructural development, and fuelwood production were recognised as the principal drivers of landscape changes, especially within a 5 km–10 km radius of the urban core, resulting in an 8.60%–33.83% decline in carbon storage and a 5%–13% decline in HMI across cities. This corroborated the perception of over 54% of the respondents who noted a considerable decline in landscape ecological health. Climate variability/change reportedly contributes to 28.5%–34.4% (Nagelkerke R^2) of the changing status of landscapes in Akure and Makurdi, as indicated by multinomial logistic regression modelling, while population growth/migration and economic activities account for 19.9%–36.3% in Owerri and Minna. Moreover, future LULC prediction between 2022 and 2042 suggested that built-up areas might expand by 6.63% (Akure), 5.99% (Owerri), 1.01% (Makurdi), and 1.20% (Minna) with the Rainforest cities showing a higher tendency for more rapid urban growth, landscape fragmentation and decline in ERS. It was concluded that variations in developmental processes and activities have considerable impacts on altering landscape characteristics and ERS than ecological settings. Urban residents should be integrated into management policies geared towards formulating and enforcing urban planning regulations, promoting urban afforestation, and establishing sustainable waste

management systems. Also, there is a need to embrace the proposed city-specific ecological management alongside informed urban and regional landscape conservation and planning.