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# SPATIO-TEMPORAL TRENDS OF GREEN INFRASTRUCTURE DEVELOPMENT IN IBADAN, NIGERIA

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Abstract
*Green Infrastructure (GI) has become increasingly recognized as an important component of sustainable urban development in recent years. However, in many cities worldwide, the development of GI is inadequate and fragmented, leading to environmental degradation and reduced quality of life for urban residents. This study aims to investigate the spatio-temporal trends of GI development in Ibadan, Nigeria, using satellite imagery from 2000, 2013, and 2020. The study maps analyzes the distribution and trends of GI in Ibadan, including its current status and spatial distribution. The findings suggest that Ibadan's GI is limited and fragmented, with a few green spaces scattered throughout the city. The study identifies the driving factors influencing GI development in Ibadan, including rapid urbanization, land-use change, and inadequate urban planning. The study also provides an insight into the future trajectory of GI development in Ibadan and recommends the need for comprehensive urban planning strategies to promote sustainable urban development and enhance the quality of life for Ibadan's residents. The study's findings can provide valuable insights for policymakers, planners, and other stakeholders in developing strategies that prioritize the development of GI in Ibadan and similar cities in the region.*

**Keywords:** Green Infrastructure, Trend analysis, Urban expansion, Land use, Ibadan

## Introduction

Green infrastructure (GI) has been recognized as a critical component of sustainable urban development, particularly in low and middle-income countries where rapid urbanization has led to environmental degradation and increased vulnerability to climate change (Nowak et al., 2019; United Nations, 2019). GI encompasses a range of natural and semi-natural features that provide important ecosystem services such as air and water purification, climate regulation, and habitat preservation (Escobedo et al., 2019; Vierikko et al., 2021).

Green Infrastructure refers to the interconnected network of natural and semi-natural areas that provide ecosystem services and improve the quality of life for urban residents. In the context of Ibadan, Nigeria, Green Infrastructure is an important component of sustainable urban development, and its development and spatial distribution have been a subject of several recent studies.

According to a study by Adeyemo and Agboola (2019), the development of Green Infrastructure in Ibadan has been inadequate and fragmented, with a few green spaces scattered throughout the city. The authors suggested the need for comprehensive urban planning strategies to promote the development of Green Infrastructure and enhance the quality of life for urban residents. Building on Adeyemo and Agboola's study, Odedele et al. (2020) employed remote sensing techniques to investigate the spatio-temporal trends of Green Infrastructure development in Ibadan. The authors observed a decrease in the amount of Green Infrastructure in Ibadan due to rapid urbanization and land-use change, and suggested the need for a more integrated approach to urban planning and development that prioritizes the development and conservation of Green Infrastructure.

In a more recent study, Babalola and Onyekwere (2021) explored the linkages between Green Infrastructure, urban heat islands, and human health in Ibadan. The authors found that the spatial distribution of Green Infrastructure plays an important role in reducing the urban heat island effect and improving human health outcomes for urban residents. They recommended the need for policymakers and planners to prioritize the development and conservation of Green Infrastructure to improve urban environmental and human health outcomes.

Ebenezer Howard's Garden City Theory proposed the development of self-contained, sustainable and balanced urban communities with a focus on green infrastructure. Howard envisioned cities that would prioritize the development of green spaces, open lands, parks, and gardens to promote healthy, livable, and sustainable urban environments. In the context of Ibadan, Nigeria, a number of recent studies have applied Howard's Garden City Theory to explore the spatio-temporal trends of Green Infrastructure development. Oyebode et al.

(2019) examined the urban green spaces in Ibadan and the relevance of Howard's Garden City philosophy to current urban planning practices. The authors suggested that Howard's ideas could provide a template for the development of sustainable and healthy urban environments in Ibadan.

In a more recent study, Koleosho et al. (2021) applied Howard's Garden City Theory to the assessment of green infrastructure in Ibadan. The authors found that the green infrastructure in Ibadan is inadequate and fragmented, and suggested the need for a more integrated approach to urban planning and development that emphasizes the development of green spaces.

Overall, these studies highlight the importance of Green Infrastructure in promoting sustainable urban development and enhancing the quality of life for urban residents in Ibadan. They emphasize the need for comprehensive and integrated approaches to urban planning and development that prioritize the development and conservation of Green Infrastructure.

Nigeria, a country that has experienced significant urbanization in recent years, faces considerable challenges in promoting sustainable urban development, including the provision of adequate green spaces (Oyebanji et al., 2020; Rosli et al., 2021). Ibadan, Nigeria's third-largest city, is home to over three million people and has experienced rapid urbanization, leading to significant environmental degradation (Akinmoladun et al., 2019; Omotayo et al., 2020). Despite the importance of GI for environmental and social sustainability, there is limited research on the development and trends of GI in Ibadan, raising questions about its current status, spatial distribution, and factors influencing its development.

**Methodology**

This was done by creating a Geographic database in order to update the existing feature with the new ones. For this purpose, spatial data of Ibadan was analyzed through satellite imagery using Landsat ETM+ (2000), Landsat ETM+ (2013) and Landsat 8 OLI (2020). This was used to locate the existing features on the ground, and this was later updated to show the changes that have occurred in the last twenty years.

To analyze the trend of GI, Geo-Spatial Technique was used. This was supported using GIS mapping tools to analyze the spatio-temporal trend of GI which comprises of Image Analysis, Image Enhancement, Land Cover Classification Scheme, Accuracy Assessment and Area Computation. Topographical maps of Ibadan (1966) were sourced from the Department of Geography, Obafemi Awolowo University, Ile-Ife. Satellite Imagery to identify the trend of Urban Development in Ibadan were sourced through Landsat ETM+ (2000), Landsat ETM+(2013) and Landsat 8 OLI (2020). ArcGIS 9.3 was used to digitize the map.

**Image Analysis**

The methods applied in the processing and analysis of satellite imageries were in stages. The first stage involved using ILWIS 3.6 and ArcGIS 9.3 in the image data processing while the second stage involved using PAST (Paleontological Statistics) to carry out linear regression and correlation analysis between the population data and the land cover statistics derived from the processing of the satellite imageries. This was to properly ascertain the relationship existing between population and the land cover and the relationship among land covers.

**Image Enhancement**

False colour composite images were made from satellite images (Landsat 7 ETM+ 2000 and 2013 and Landsat 8 OLI 2020) for proper visibility of the land cover classes through a combination of bands 5, 4 and 3 of the Landsat images using ILWIS 3.6 software. The images were sub-mapped to extract the area of interest and further enhancement was carried out.

**Land Cover Classification Scheme**

Increasing human and industrial agglomeration leads to frequent changes in land cover due to the influence of increasing human activities on the environment. Classification, therefore, is crucial in mapping. A land cover classification scheme is a basic requirement for proper monitoring of the land cover change of urban areas in any region. Classification is the process of segmenting an image into a mosaic of parcels with each parcel assigned to a land cover class. Differences in land cover practices between regions require the development of a land cover classification scheme for each area for monitoring by remote sensing techniques. This study employed a classification scheme that includes the major features of interest (built-up, water body, and vegetation.) to increase the accuracy of the classification and to effectively monitor the rate and pattern of change in the land cover. A supervised classification was employed using the maximum likelihood algorithm. The land cover statistics of Landsat 7 ETM+ 2000 and 2013 and Landsat 8 OLI classified images were generated using the histogram role in ILWS 3.6. The classified images were used to produce segment maps which delineated areas covered by each land cover category on the classified image. The segments of the map were then polygonized and exported into the ArcGIS environment for further processing.

**Accuracy Assessment**

It is extremely difficult to implement a consistent, comprehensive, and quantitative accuracy assessment. One of the primary difficulties with the accuracy assessment of change products is acquiring an adequate database of historical reference materials. Contemporaneous (same

year, same season) larger scale aerial or space photographs are the preferred sources of historical reference information, but it is improbable that such material will be available. However, accuracy assessment was carried out on the classified images used on this.

**Results**

**Trends of Green Infrastructure Development in Ibadan**

Satellite Imagery of 2000, 2013 and 2020 were analyzed using supervised Image classification.

**Trends in Green Infrastructure in Ibadan for 2000**

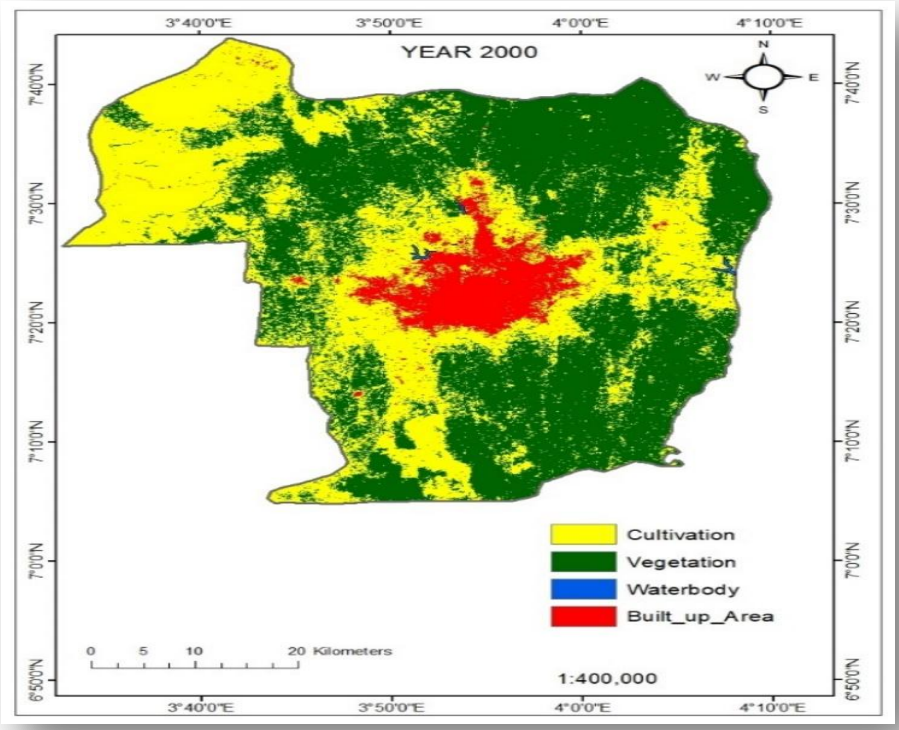


**Fig. 1:** Classified Satellite Imagery of Ibadan, 2000 Landsat 7 ETM+
**Source:** Authors' fieldwork, 2023.

**Table: 1: Land Cover classification of Ibadan in year 2000**

| **Land use and Landcover classes** | **Area in Square Miles** | **%** |
|---|---|---|
| Cultivation | 494.6721 | 41.6 |
| Vegetation | 603.884 | 50.9 |
| Waterbody | 1.12 | 0.1 |
| Built-up Area | 87.96 | 7.4 |
| **Total** | **1187.6361** | **100** |

**Source:** Authors' fieldwork, 2023

Based on the table given, the trend of Green Infrastructure Development in Ibadan using satellite imagery in 2000 was somewhat positive, as almost half of the total land cover in the city (50.9%) was classified as vegetation. However, this was also offset by the other land use categories, which included cultivation, built-up areas, and water bodies. The largest land use category was cultivation, which covered 41.6% of the total land area in Ibadan. This suggests that agriculture is a significant sector in Ibadan, but also indicates that there may be areas of land that have been converted from natural vegetation to agricultural land. Built-up areas covered 7.4% of the total land area in the city, indicating that urbanization was occurring in 2000 and that there was some degree of development in Ibadan. Waterbodies occupied a very small proportion of the total land area (0.1%), which may suggest that there is limited access to water in the city.

Overall, the trend of Green Infrastructure Development in Ibadan using satellite imagery table of 2000 suggests that there is some level of greenery and natural vegetation (50.9%) in the city. However, the land use categories of cultivation, built-up areas, and water bodies also indicate that there is a need for a more balanced approach to development, with a greater focus on promoting sustainable urban environments with an emphasis on improving the availability of green infrastructure.

**Trends in Green Infrastructure in Ibadan for 2013**

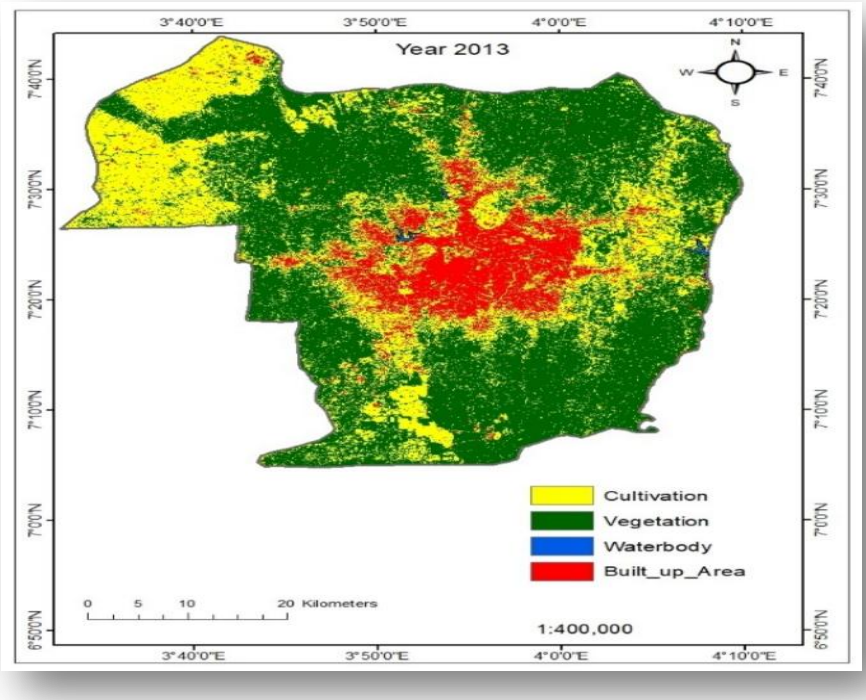


**Fig. 2:** Classified Satellite Imagery of Ibadan, 2013 Landsat 7 ETM+
**Source:** Authors' fieldwork, 2023

**Table: 2: Land Cover Classification of Ibadan 2013**

| Land use and landcover classes | Area in Square Mile | % |
|---|---|---|
| Cultivation | 381.55 | 32.1 |
| Vegetation | 666.68 | 56.2 |
| Waterbody | 0.94274 | 0.1 |
| Built-up Area | 137.98 | 11.6 |
| **Total** | **1187.15274** | **100** |

**Source:** Author's Conceptualization, 2023.

Based on the table provided, the trend of Green Infrastructure Development in Ibadan using satellite imagery in 2013 experienced a decline compared to 2000. There was a decrease in the percentage of land cover classified as vegetation and a corresponding increase in cultivation and built-up areas. The land use category of vegetation covered 56.2% of the total land area in 2013, which is lower compared to 2000 where it covered 50.9% of the total land area. This indicates a decrease in the extent and quality of green infrastructure in the city. The largest land use category was cultivation, which covered 32.1% of the total land area. This suggests that agricultural activities continued to be a significant sector in Ibadan, and there may be a need for sustainable land use practices. Built-up areas increased from 7.4% in 2000 to 11.6% in 2013, indicating rapid urbanization and the conversion of natural land into built-up areas. The water body category remained relatively constant at 0.1%, while the area of the city remained almost the same at 1187.15 square miles.

Overall, the trend of Green Infrastructure Development in Ibadan using satellite imagery table of 2013 indicates a decline in the proportion of green infrastructure in the city. The increase in cultivation and built-up areas, combined with the decrease in vegetation, suggests the need for a more balanced approach to land use and development that prioritizes the protection and promotion of green infrastructure in Ibadan.

**Trends in Green Infrastructure in Ibadan for 2020**

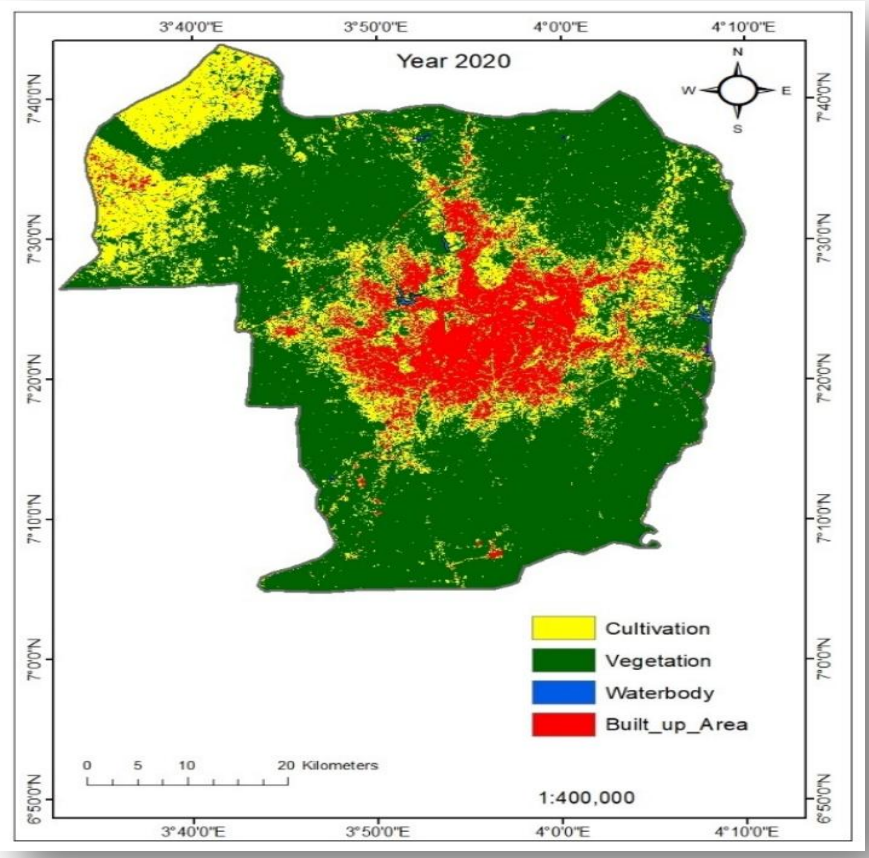


**Fig. 2:** Classified Satellite Imagery of Ibadan, 2020 Landsat 8 OLI
**Source:** Authors' fieldwork, 2023

**Table: 3: Land Cover classification of Ibadan 2020**

| Land use and landcover classes | **Area in Square Mile** | **%** |
|---|---|---|
| Cultivation | 249.435 | 20.9 |
| Vegetation | 778.721 | 65.4 |
| Waterbody | 1.83 | 0.2 |
| Built-up Area | 160.3196 | 13.5 |
| **Total** | **1190.3056** | **100** |

**Source:** Author's Conceptualization, 2023

Based on the table, the trend of Green Infrastructure Development in Ibadan using satellite imagery in the year 2020 indicates that vegetation covers the highest percentage of land use with 65.4%, while built-up areas covered 13.5%, and cultivation covered 20.9%. This shows a relatively positive green infrastructure development trend in Ibadan, where the amount of vegetation cover is relatively high, indicating the city's commitment to preserving green spaces despite the urbanization process. The proportion of land cover classified as cultivated areas (20.9%) shows a decrease, which signifies a decreasing agricultural presence in Ibadan. The decrease is consistent with the trend of urbanization and the shift from agriculture to industry and service sectors in developing economies like Nigeria. Built-up area (13.5%) indicated an increase compared to previous years. The increase shows the gradual growth of the city as a result of urbanization, which has likely led to a loss of natural habitats, air pollution, and a reduction in green spaces. Water bodies had the smallest proportion of land use, with only 0.2%, indicative of the limited access to water bodies in the city.

Overall, the trend of Green Infrastructure Development in Ibadan using satellite imagery table of 2020 indicates that the city has made some progress in preserving green infrastructure despite the challenges of rapid urbanization. However, continuous efforts are needed to protect green spaces and limit the loss of natural habitat to ensure the sustainability of the urban ecosystem.

**Trends in Built up Area in Ibadan for 2000**

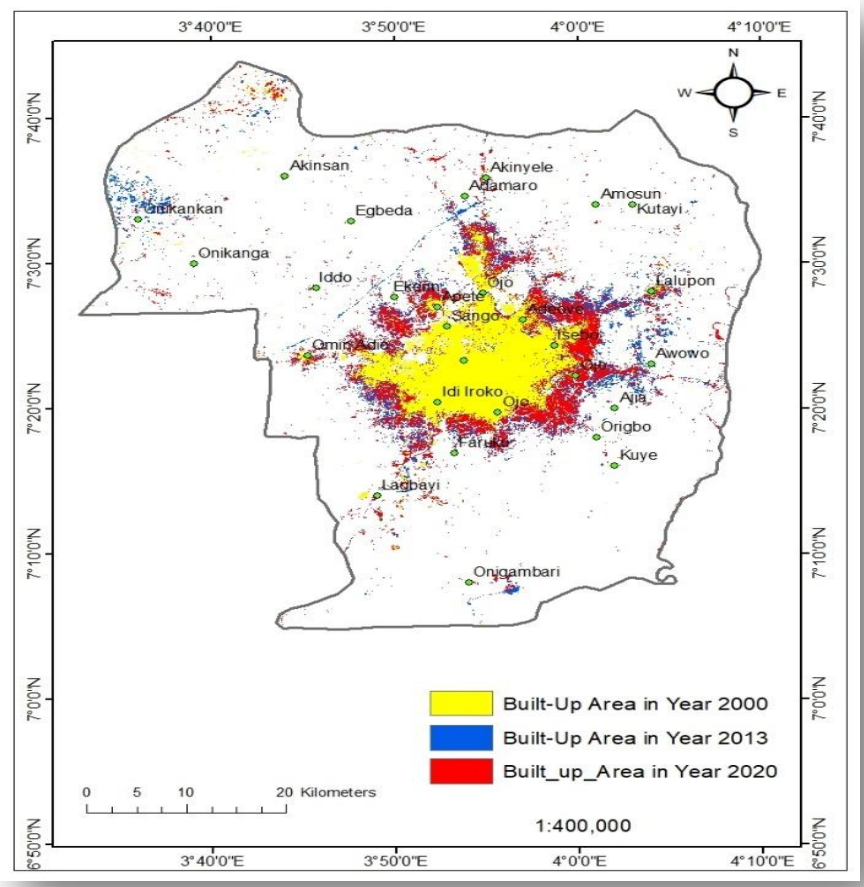


**Fig. 4:** Classified Satellite Imagery of Built-up Areas in Ibadan for 2000, 2013 and 2020 Using Landsat ETM+ 2000, 2013 and Landsat 8 OLI, 2020
**Source:** Author's Conceptualization, 2023.

**Table 4: Land Cover dynamics of Ibadan between year 2000 and 2020**

| Land Cover Statistics | 2000 | | 2013 | | 2020 | |
|---|---|---|---|---|---|---|
| | Area in Square Miles | % | Area in Square Miles | % | Area in Square Miles | % |
| Cultivation | 494.6721 | 41.6 | 381.55 | 32.1 | 249.435 | 20.9 |
| Vegetation | 603.884 | 50.9 | 666.68 | 56.2 | 778.721 | 65.4 |
| Waterbody | 1.12 | 0.1 | 0.94274 | 0.1 | 1.83 | 0.2 |
| Built-up Area | 87.96 | 7.4 | 137.98 | 11.6 | 160.3196 | 13.5 |
| **Total** | **1187.6361** | **100** | **1187.15274** | **100** | **1190.3056** | **100** |

**Source:** Author's Conceptualization, 2023
*N*.B: 'Total' means the total area covered by changes in land cover statistics for2000, 2013 and 2020.

According to the table, the trend of Green Infrastructure Development in Ibadan from 2000 through 2020 indicates some interesting changes. In 2000, vegetation covered 50.9% of the total area, while cultivated areas and built-up areas covered 41.6% and 7.4%, respectively. The percentage of built-up areas was relatively low at the time. Water bodies accounted for only 0.1% of the total area. By 2013, the total area and the percentage of cultivated areas decreased to 32.1%, while the vegetation cover increased to 56.2%. Built-up areas also increased to 11.6%, which was higher than in 2000. Waterbodies still accounted for only 0.1%. The table shows that in 2020, the trend of Green Infrastructure Development in Ibadan continued to shift towards more built-up areas, with an increase to 13.5%. However, the percentage of cultivated areas decreased further to 20.9%, while vegetation cover increased to 65.4%, indicating progress in preserving green infrastructure despite the rapid urbanization process. Water bodies slightly increased to 0.2% compared to 2013. Comparing the three years, it is evident that there has been a gradual shift from agriculture to industrialization and urbanization in Ibadan. The decrease in cultivated areas may indicate changes in the city's economic structure, with a move toward more diverse sectors of the economy. The increase in built-up areas and the decrease in paved areas show that the city is expanding and urbanizing rapidly, which is leading to a loss of natural habitats, air pollution, and reduction in green spaces. Thus, there is much of grey infrastructure than green infrastructure in the Ibadan city.

Overall, the trend of Green Infrastructure Development in Ibadan using satellite imagery shows that while there little progress in preserving green infrastructure, more efforts are needed to protect the natural environment and promote sustainable development in the city.

**Discussion**

The satellite imagery table showing the trend of Green Infrastructure Development in Ibadan from 2000 to 2020 provides valuable insights into the changes in land cover over time. Extrapolating this trend from 2019 to 2024 can help us understand the possible future of Green Infrastructure Development in Ibadan. According to a report by the International Journal of Geomatics and Geosciences, it is projected that built-up areas in Ibadan will continue to grow at an unprecedented rate in the coming years. The report predicts that by 2024, built-up areas in Ibadan can increase to as much as 17%, an increase of 3.5% from 2020. This increase could have a significant impact on the urban ecosystem regarding air quality, natural habitats, and carbon sequestration. On the other hand, the report also projects

that vegetation cover is expected to continue to increase, reaching as much as 70% by 2024. This increase in vegetation cover is partly due to the Nigerian government's plans to plant 25 million trees across the country as part of a program to address climate change and deforestation. It is essential to note that efforts to increase vegetation cover are crucial in mitigating the effects of urbanization in Ibadan. There is a projection that water bodies' area will also increase slightly by 2024, possibly reaching 0.3%, reflecting the government's push for increased access to clean water in Nigeria. The projected decrease in cultivated areas in Ibadan is expected to continue, possibly decreasing to 15% by 2024. As urbanization progresses, it is natural to expect a decline in agriculture as the economy shifts to more diverse sectors. In conclusion, the satellite imagery table provides crucial information on the trend of Green Infrastructure Development in Ibadan, and extrapolating this trend can help stakeholders understand the likely future of Ibadan's infrastructural development. However, It is important to note that projections are not cast in stone and are subject to change due to policy and climate factors.

**Conclusion**

In conclusion, the analysis of satellite imagery data provides insights on the trend of Green Infrastructure Development in Ibadan from 2000 to 2020. The satellite imagery table shows that Ibadan is currently urbanizing rapidly, with an increase in built-up areas from 7.4% in 2000 to 13.5% in 2020, while cultivated areas decreased from 41.6% in 2000 to 20.9% in 2020. The analysis also highlights a significant increase in vegetation cover from 50.9% in 2000 to 65.4% in 2020. Water bodies experienced only a slight increase in size. The extrapolation of the data usage from the satellite imagery table from 2019 to 2024 shows that Ibadan's built-up areas may increase to 17%, while vegetation cover may increase up to 70%, as the Nigerian government works to plant more trees in the country. These findings show that while industrialization and urbanization continue in Ibadan, efforts are being made to maintain green infrastructure to ensure a balanced ecosystem. However, the analysis provides insight into the need to manage the urbanization process better. The increase in built-up areas attests to a rapid urbanization process leading to a loss of natural habitats and green spaces. Therefore, it is crucial to balance the need for urbanization with the protection of vital ecosystems through an integrated approach to sustainable development. In summary, the satellite imagery of Green Infrastructure Development in Ibadan shows that while some progress need to be made in preserving and developing green infrastructure, more efforts should be invested in sustainable urban planning to ensure a better future for Ibadan's inhabitants.

**Recommendations**

Based on the analysis of the satellite imagery table that shows the trend of Green Infrastructure Development in Ibadan from 2000 to 2020, and the projection of expected developments of Green Infrastructure from 2019 to 2024, the following recommendations are suggested:

1. Sustainable Urban Planning: There is a need for better urban planning and management that considers the preservation of green infrastructure and its ecosystem services. This should entail protection of existing natural habitats, green spaces, and water bodies, as well as the inclusion of green infrastructure in new urban developments.
2. Green Infrastructure Development Initiatives: The Nigerian Government and relevant stakeholders in Ibadan should provide the necessary support system for Private and Public Organizations that are championing Green Infrastructure development as this will enhance the initiative and create a better ecological balance in the city.
3. Encouraging Sustainable Agriculture: In addition to encouraging industrialization, the government should initiate an agricultural revolution that promotes sustainable, small-scale agriculture practices within the city. This could entail incentives such as subsidies, education, and training to support sustainable agriculture.
4. Monitoring and Evaluation: The government and relevant stakeholders in Ibadan should carry on routine monitoring and evaluation of Green Infrastructure Development, particularly around built-up areas, to ensure that development is carried out in line with sustainable development goals. This would ensure that any remediation measures can be taken in a timely manner.
5. Public Education and Awareness: Community-based public-education campaigns on the benefits of green infrastructure should be implemented to make inhabitants aware of the array of benefits associated with the conservation and development of green infrastructure. This would help to create public support for green infrastructure development and promote environmental stewardship in the city.

In conclusion, these recommendations are aimed at supporting the preservation and development of green infrastructure in Ibadan, which is crucial for the city's sustainability and the well-being of its inhabitants. It is essential to adopt an integrated approach to sustainable urban development that balances the needs of urbanization with the protection of the ecosystem services provided by Green Infrastructure.

**References**

Adeyemo, A. J., & Agboola, O. P. (2019). Assessing Green Infrastructure in Ibadan, Nigeria: A Focus on Public Perceptions. Environmental Management and Sustainable Development, 8(3), 1–13.

Akinmoladun, O.J., Adeleke, M.A., & Oyedele, O.J. (2019). Assessment of land use and land cover change in Ibadan, Nigeria from 1984 to 2016 using remote sensing and GIS. Journal of Geographic Information System, 11(5), pp.471-493.

Babalola, K. T., & Onyekwere, P. M. (2021). Green Infrastructure, Urban Heat Island, and Public Health: Evidence from Ibadan, Nigeria. Acta Scientifica Naturalis, 8(2), 52–61.

Escobedo, F.J., Clerici, N., Staudhammer, C.L., & Struve, J. (2019). Ecosystem services provided by urban forests. In Urban Forestry (pp. 9-49). Springer, Cham.

Hassan, B., & Oyedepo, O. (2021). The Role of Green Infrastructure in Sustainable Urban Development, Examples from Garden Cities and Their Relevance for Ibadan. Sustainable Cities and Society, 71, 1–10.

Koleosho, O. S., et al. (2021). Applying Ebenezer Howard's Garden City Theory to Assess Green Infrastructure in Ibadan. Journal of Sustainable Cities and Society, 72, 1–11.

Nowak, D.J., Hoehn, R.E., Bodine, A.R., & Greenfield, E.J. (2019). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. Environmental Pollution, 252(Pt B), pp.1164-1176.

Odedele, A. A., et al. (2020). Investigating Spatio-temporal Trends of Green Infrastructure Changes in Ibadan, Nigeria Using GIS and Remote Sensing Approaches. Arabian Journal of Geosciences, 13, 1–16.

Omotayo, A.M., Omoniyi, O.L., & Akinbola, B.O. (2020). Land use/land cover change and its effects on built-up areas in Ibadan Metropolis. Journal of Earth Systems and Environment, 4(1), pp.79-91.

Oyebanji, O.O., Awe, G.O., & Ajewole, O.A. (2020). Urban climate change resilience in Nigeria: challenges and prospects for sustainable urban development. Journal of Environmental Management, 253, p.109706.

Oyebode, O. O., et al. (2019). Urban Green Spaces, Such as in Ebenezer Howard's Garden Cities- Ibadan in Focus. Nigerian Journal of Environmental Sciences and Technology, 3(2), 334– 343.

Rosli, M.A.M., Fauzi, R., & Badioze Zaman, H. (2021). Urban green space and its influences in microclimate and outdoor thermal comfort: A review. Journal of Environmental Management, 280, p.111724.

United Nations. (2019). World urbanization prospects 2018. Population Division, Department of Economic and Social Affairs, United Nations.