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INTEGRATING GIS AND SURVEY-BASED DATA TO EVALUATE URBAN GREEN INFRASTRUCTURAL DEVELOPMENT IN THE CONTEXT OF URBAN PLANNING IMPLEMENTATION AND CHALLENGES

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ABSTRACT

Globally,urban green infrastructural development contributes to urban environmental sustainability through the effective implementation of strategic actions, including urban planning.However,in the Global South, including Sub-Saharan Africa, urban planning implementation for protecting and providing existing and new urban green infrastructures, respectively are being confronted with key challenges such asland use zoning, institutional failures, and lack of data.The current study, therefore, aimed to integrate data from experts' surveys and Geographic Information Systems to investigate the level of urban green infrastructural development under key challenges forurban planning implementationto support strategic actions for urban environmental sustainability.Focusing on Abuja, Nigeria, data were generated from the urban land use plan, observed urban green space map, and experts' surveys to analyze the performance level of urban planning implementation on urban green infrastructural development and relate the implementation level to the spatial association between observed urban green spaces and those designated by the urban plan. Also, to identify key challenges

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confronting the implementation and ways to improve urban green infrastructures for urban environmental sustainability.Key findings showed that the performance of urban planning implementation for urban green infrastructural development is perceived to be at a moderate level. Also, the findings showed that the implementation performance level and spatial association support each other to some extent. Additionally, the findings identified key challenges for urban planning implementation on urban green infrastructural development, includingthe illegal conversion of greens for other uses, political interference, a lack of political will, unsustainable funding, redesign of green spaces, etc. The findings provided by the current study are crucial for urban strategic decision-making processes on improving urban green infrastructural development and supporting urban environmental sustainability in the Global South.

Keywords: Strategic Actions,Urban Plan,Urban Green Space,Urban Environmental Sustainability, Sub-Saharan Africa, Global South

1. INTRODUCTION

The developmentof urban green infrastructures through the protection and provision of existing and new urban green spaces, respectively, cannot be over-emphasized due to the cultural, social, economic, and environmental functions provided by these infrastructures for urban dwellers (Cheshmehzangi et al. 2021; Kuklina et al. 2021; Puchol-Salort et al. 2021; Gelan and Girma 2021; Russo and Cirella 2020; Meijering et al. 2018). Regarding environmental functions, urban green infrastructures contribute to improving urban environmental sustainability through the mitigation of climate change (Vargas-Hernández et al. 2018), mitigation of storm runoff (Li et al. 2021; Abass et al. 2020; Song et al. 2020; Vargas-Hernández et al. 2018), cooling of urban heat (Shah et al. 2021; Masoudi et al. 2021), regulation of air quality, and reduction of noise pollution (Misiune et al. 2021; Park et al. 2021; Song et al. 2020; Emechebe and Eze 2019). Urban environmental sustainability in this context can be seen as a condition that allows urban dwellers to maximize the utilization of functions provided by urban green infrastructures without compromising the healthy condition of the green infrastructures for future urban uses.

The sustainability of urban green infrastructures can be improved usingstrategic actions such as urban planning, policies, and programs(Ogunyombo & Odunlami 2017; Jibril 2015; Jibril 2010).Previous urban studies (e.g., Dinda et al. 2021;Enoguanbhor 2021;Puplampu and Boafo 2021;Narh et al. 2020; Abass et al. 2020) identify different challenges for urban green infrastructural development and management in general and/or in the context of urban strategic actions in particular but did not evaluate the level of urban green infrastructural development. For example, Dinda et al. (2021)report the encroachment of urban green spaces by urban

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expansion resulted from the non-implementation of conservation policy of green infrastructures and proper land use zoning for Kolkata city of India.Narh et al. (2020)opine that the major reasons for the loss of green spaces in Kumasi City of Ghana are institutional failures associated with the development, protection, and management of park spaces. Although Enoguanbhor (2022)shows a high and moderate level of protectionof individual parks and gardens within the implemented urban planned areas of Abuja city phases I-II, Mahmoud et al. (2016) and Enoguanbhor (2023)demonstrate how urban vegetation/green spaces transitioned into built-up areas in phases I-III and beyond, respectively of the same city. Adegun et al. (2021)report that thelands allocated for the development of parks and green spaces through the Abuja Master Plan are inadequate. For effective evaluationof urban green infrastructural development under urban planning implementation and its key challenges, there is a need to integrate data from different sources.

The current study, therefore, aims to integrate data from experts' surveys andGeographic Information Systems (GIS) to investigate the level of urban green infrastructural development under key challenges of urban planning implementation to support strategic actions for urban environmental sustainability. The specific objectives are to:

1. Use surveys of experts to analyzethe performance level of urban planning implementation on protecting and providing existing and new urban green spaces, respectively;
2. Relate the performance level of urban planning implementation on protecting and providing existing and new urban green spaces to the GIS outcome on the spatial association between observed urban green spaces and those designated by the urban plan;
3. Identify key challenges for urban planning implementation on urban green infrastructural development, and;
4. Identify ways to improve urban green infrastructural development for urban environmental sustainability.

2. MATERIALS AND METHODS

2.1 Study area

The study area coversAbuja urban development phases I and II (about 171.66 km^2) of the Federal Capital City (FCC) in the Federal Capital Territory (FCT)of Nigeria (Figure 1).The area was chosen for the current study due to the design of the urban plan to be implemented consecutively from phase I (Gumel et al. 2020).The preparation of the urban plan by the International Planning Associates (IPA) was in 1979 (FMITI 2015; Fola Consult Ltd 2011)and provisions for developing urban green infrastructures are covered by the plan (Fola Consult Ltd

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2011; AS&P and Elsworth 2008; Abubakar 2014; Enoguanbhor 2019). Before relocating the seat of the Federal Government from Lagos, the formal capital to Abuja in 1991, the implementation of the plan already startedin the early 1980s(Adama 2020; Sufiyan et al. 2015; Abubakar 2014; Ejaro and Abubakar 2013; Idoko and Bisong 2010).Thealready developed parks and gardens as urban green infrastructures are the Millennium Park, Eden Park and Garden, Zone 6 Neighbourhood Park, National Arboretum, Jabi Recreational Park and Garden, City Park, Harrow and Lobito Cr Park, etc. (Enoguanbhor 2022).

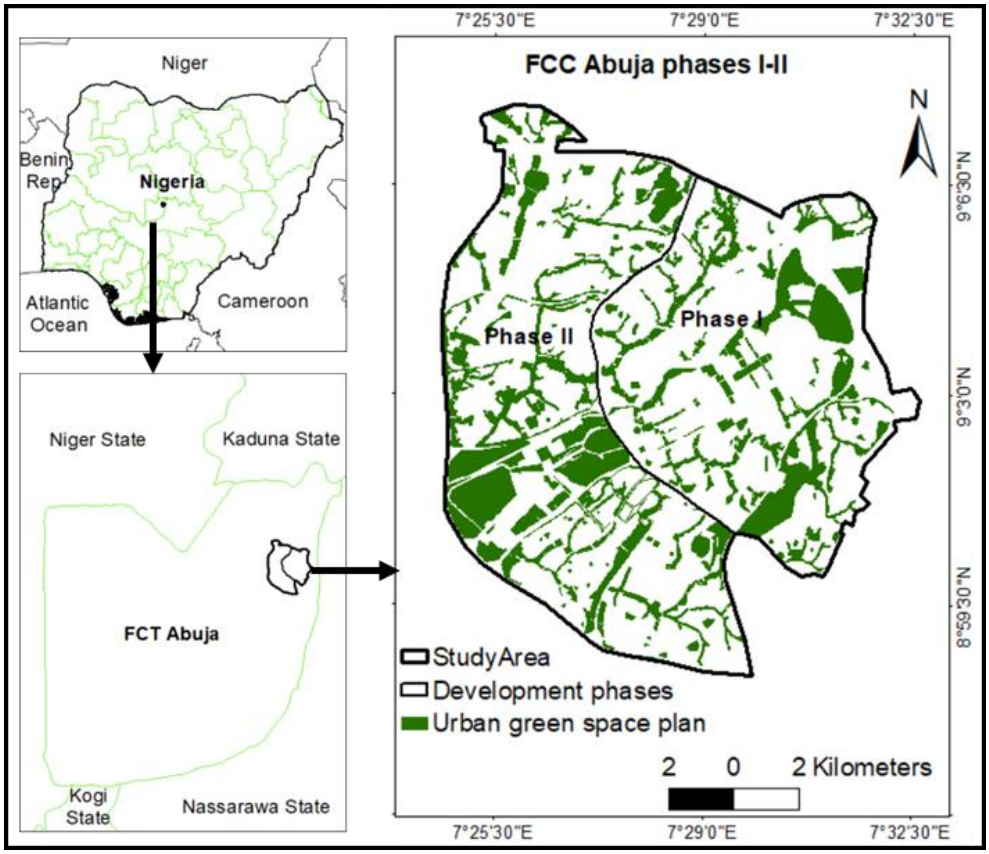

Fig. 1: Map of Abuja urban development phases I and II.

Source: Modified from Enoguanbhor (2022).

2.2 Data collection and analysis

The first author conducted an online experts' survey with the use of a questionnaire between 30 August to22 September 2022 to generate empirical data for the study. The questionnaire was designed as a mixed questionnaire that included closed-ended and open-ended questions (Babbie

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2013; Secor 2010). The questionnaire was distributed to experts using non-probability sampling, which is a method of purposive sampling where the most representatives of the population are selected by the researcher (Babbie 2010).Urban and Regional Planning experts were selected from different government departments/agencies, including the Department of Development Control (DDC), Department of Urban and Regional Planning (DURP), Department of Urban Affairs of Abuja Metropolitan Management Council (AMMC), Abuja Environmental Protection Board (AEPB), Department of Park and Recreation (DPR), and the Federal Housing Authority (FHA). The questionnaire was distributed to 22 experts and 18 of them responded. The respondents' work experience includes 10 years and below (12.5%), 11-20 years (50.0%), 21-30 years (25.0%), and 31 years and above (12.5%). The respondents' highest academic level completed includes Bachelor's degree/Higher National Diploma or equivalents (12.5%), Master's degree or equivalents (75.0%), and PhD or equivalents (12.5%).

The questionnaire data analysis included qualitative and quantitative (descriptive) methods. While the use of coding, sorting, synthesizing, and ranking as qualitative methods were applied for open-ended questions, frequency calculation as a descriptive method wasused for closed-ended questions(Visser and Jones III 2010; Maxwell 2013; Bryman 2016;Secor 2010).The ranking method was developed and explained in detail by Enoguanbhor et al. (2021). While the performance level of urban planning implementation for protecting and providing existing and new urban green infrastructures, respectively was analyzed with the frequency's calculation, key challenges for urban planning implementation on urban green infrastructures and suggestions or ways to improve urban green infrastructures for urban environmental sustainability were identified using coding, sorting, synthesizing, and ranking.The implementation level of urban planning on urban green infrastructures was related to the GIS outcome on the spatial association between the observed urban green space and land use designated for urban green space by the urban plan.The GIS outcome on the spatial association between the observed urban green space and land use designated for urban green space by the urban planwas initially analyzed by Enoguanbhor (2022), where a supervised classification with the maximum likelihood algorithm(Vijayalakshmi et al. 2021; Campbell and Wynne 2011;Lu et al. 2011; Tso and Mather 2009;Enoguanbhor et al. 2022)was deployed on the Sentinel 2 satellite image (ESA 2021).Additionally, Euclidean distance modeling(Yenisetty and Bahadure, 2021), and linear regression modeling(Fotang et al. 2021)were deployed for the analysis at the urban development phase levels.For the current study, the same analysis was performed by extending from the urban development phase level to the entire study area.

3. RESULTS

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The results (Figures 2a and b) showedthe performance level of urban planning implementation forprotecting and providing existing and new urban green infrastructures, respectively. Regarding protecting existing urban green infrastructures, most experts perceived the level of urban planning implementation to be moderate level with 87.50%. Other experts (12.50%) opined that the implementation level is high. No expert perceived the level of implementation to be very high, low, or very low levels. Regarding providing new urban green infrastructures, most experts gave contradicting opinions on urban planning implementation, which they perceived to be high and low levels with 37.50% each. 25% of the remaining experts opined that the implementation is at a moderate level.

Fig. 2: Performance level of urban planning implementationfor (a) protecting existing urban green infrastructures and (b) providing new urban green infrastructures.

The results (Table 1 and Figure 3) showed the spatial relationship/association between the observed urban green space and the land use designated for urban green space by the urban plan.The spatial relationship/association is significant and positive at 99.9% and 0.26 coefficient, respectively.The good models' fit can be deduced from the standard errors of 0.04 and the Adjusted R-squared of 0.31.Relating this result to the performance level of urban planning implementation for protecting and providing existing and new urban green infrastructures, respectively based on experts' survey, it can be deduced that they support each other to some extent.

Table 1: The association between the observed green space and that of the urban plan.

Urban Development Phases I-II	Coef.	P-value	Std. error
Phase I-II	0.26	0.00***	0.04
Residual standard error:138.4 on 3998 degrees of freedom			
Adjusted R-squared: 0.31			

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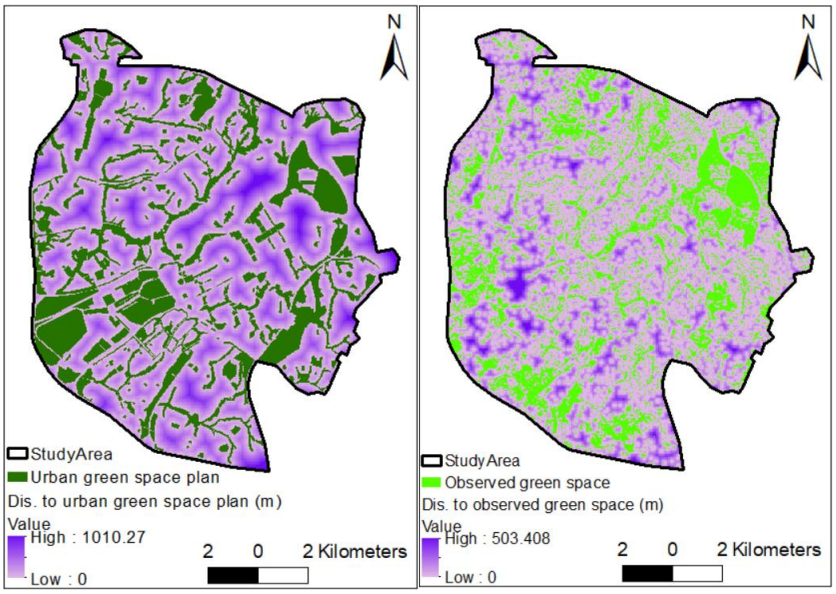

Fig. 3: Maps showingEuclidean distances to (a) land use designated for urban green space by the urban plan and (b) the observed green space.

Source: Modified from Enoguanbhor (2022).

Table 2 presents key challenges for urban planning implementation on urban green infrastructures. The major challenge ranked "High" is the illegal conversion of greens for other uses. Other challenges ranked very "Low" include political interference,a lack of political will, unsustainable funding, redesign of green spaces, a lack of infrastructure maintenance of green by the authority, poor development of designated green areas, high demand for housing, poor use of green due to some cultural beliefs, and low level of law enforcement.

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Table 2: Key challenges for urban planning implementation on urban green infrastructures.

	Identified variables	Ranking
1	Illegal conversion of greens for other uses	xxxx
2	Political interference	X
3	Low level of law enforcement	X
4	Poor development of designated green areas	X
5	Poor use of green due to some cultural beliefs	X
6	Redesign of green spaces	X
7	High demand for housing	X
8	Unsustainable funding	X
9	Lack of political will	X
10	Lack of infrastructure maintenance of green by the authority	
Ranking: x = "Very low"; xx = "Low"; xxx = "Moderate", and; xxxx = "High"		

The results in (Table 3) showed suggestions/ways to improve urban green infrastructures for urban environmental sustainability.Major suggestions that are ranked "High" are grassroots enlightenment and effective law enforcement. Another important suggestion is the adequate funding of agencies responsible for green development, which is ranked "Moderate". Other suggestions that are ranked "Very low" include effective government control, encouraging vertical urban development, political will, implementing land swaps to protect and provide urban green spaces, and introducing tree planting exercise programs.

Table 3: Suggestions to improve urban green infrastructures for urban environmental sustainability.

	Identified variables	Ranking
1	Grassroot enlightenment	xxxx
2	Effective law enforcement	xxxx
3	Adequate funding of agencies responsible for green development	xxx
4	Effective government control	X
5	Encouraging vertical urban development	X
6	Political will	X
7	Implementing land swaps to protect and provide urban green spaces	X
8	Introducing tree planting exercise programs	X
Ranking: x = "Very low"; xx = "Low"; xxx = "Moderate", and; xxxx = "High"		

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4. DISCUSSION

The current study integrated data from experts' surveys and GIS to investigate the level of urban green infrastructural development under key challenges of urban planning implementation to support strategic actions for urban environmental sustainability. The findings on the performance level of urban planning implementation for protecting urban green infrastructures (Figure 2a) showed that the implementation is at a moderate level.This indicates that most experts believe that urban planning has not been implemented effectively even if the implementation protects urban green infrastructure to a larger extent, considering the remaining experts that perceived the implementation at a high level.This finding supports Enoguanbhor (2022)who reported that despite the large extent of urban green space protection, urgent interventions are required to improve the protection of some parks and gardens that are under moderate protection in Abuja, Nigeria.The finding on providing new urban green infrastructures under urban planning implementation (Figure 2b) shows that it is moderately provided, which can be deduced from the contradicting opinions of most experts whoperceived such provisions to be high and low, as well as the remaining experts who perceived to be moderate. This finding supports to an extent those of Adegun et al. (2021)whoreport that the lands allocated for the development of parks and green spaces through the Abuja Master Plan are inadequate.

The findings of the spatial association between the observed urban green space and the land use designated for urban green space by the urban plan(Table 1 and Figure 3) showed a significant and positive association.The finding is in line with the initial findings at the urban development phase levels that already indicated a high level of urban planning implementation on urban green infrastructures in the study area. However, while relating this finding to the performance level of urban planning implementation for protecting and providing existing and new urban green infrastructures, respectively based on experts' survey, it can be deduced that they support each other to some extent but not to a large extent.The reason can be linked to experts' opinions on protecting the existing urban green space from moderate to high levels and providing the new urban green space from low to high levels with an average of moderate level.

The findings on key challenges for urban planning implementation on urban green infrastructures (Table 2) show that the major challenge is the illegal conversion of greens for other uses. This indicates that the institutional instruments used for the protection of urban green spaces have not been implemented effectively. This finding supports Narh et al. (2020)who opined that the major reasons for the loss of green spaces in Kumasi City of Ghana are institutional failures associated with the development, protection, and management of park spaces. Other identified challenges are political interference, a lack of political will, unsustainable funding, redesign of green spaces, a lack of infrastructure maintenance of green by the authority, poor development of designated

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green areas, high demand for housing, poor use of green due to some cultural beliefs, and low level of law enforcement. The finding of high demand for housing indicates the need for urban expansion. This finding supports those of Enoguanbhor (2023) andMahmoud et al. (2016)whodemonstrated how urban vegetation/green spaces transitioned into built-up areas in phases I-III and beyond, respectively of Abuja, Nigeria. The finding also supports those of Dinda et al. (2021)who reported the encroachment of urban green spaces by urban expansion in Kolkata City, India.

The findings on the suggestions/ways to improve urban green infrastructures for urban environmental sustainability (Table 3) show that major suggestions are grassroots enlightenment and effective law enforcement. This indicates that more awareness should be created ofthe cultural, social, economic, and environmental benefits of urban green space(Cheshmehzangi et al. 2021; Kuklina et al. 2021; Puchol-Salort et al. 2021; Gelan and Girma 2021; Russo and Cirella 2020;Meijering et al. 2018) and the strict law enforcement on violation should be implemented to avert misuse while deriving such benefits. Other findings, e.g., adequate funding of agencies responsible for green development, effective government control, encouraging vertical urban development, political will, implementationof land swaps to protect and provide urban green spaces, and introduction of tree planting exercise programs indicate that urban green space can be protected effectively if incorporated into urban strategic actions and implemented effectively.

The general implication of the current study is detailed insights into urban planning implementation on urban green infrastructural developments through the protection of existing and the provision of new green spaces using the integrated experts' survey and GIS analysis. The methodological approach can be transferred to other study areas in Sub-Saharan Africa in particular and the Global South in general, where a similar situation may be the case. Even if both methods support each other only to some extent, the awareness of the protection and provision levels is crucial to inform urban strategic decision-making processes, including urban policies, planning, and programs for protecting and providing existing and new urban green infrastructures to support urban environmental sustainability.Also, the identified key challenges (e.g., the illegal conversion of greens for other uses) and suggestions (e.g., the grassroots enlightenment and effective law enforcement) are crucial to improving urban planning implementation on urban green infrastructural development in cities found in the Global South, including Sub-Saharan Africa.By integrating experts' surveys and GIS to explore key challenges for urban green infrastructural development, especially byevaluating the urban planning implementation performance in protecting and providing existing and new urban green spaces, respectively, this study contributes to urban planning as a strategic instrument for urban environmental sustainability.

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This study is limited by the number of experts available to respond to the questionnaire. The opinions from other experts that were not available could not be incorporated into the study. However, 18 out of 22 experts available who responded to the questionnaire is acceptable for such analysis, considering advanced statistics were not used for experts' survey data. Also, the study could not classify different types of urban green infrastructures from the observed urban green space. Additionally, over one year and six months,the time difference between the acquisition of the GIS data and experts' surveys may have an impact on the comparisonof the results due to the real-world changes during this period.

Based on the limitation of the current study and in addition to the suggestions from experts on how to improve urban green infrastructural development, the following recommendations are put forward: First, many experts should always be willing to respond to surveys to ensure incorporating the large volume of data on perceptions or opinions into the analysis. This may help to minimize the contradicting opinions on the subject matter. Second, the urban plan should be revised by updating all accepted changes, if any between built-up and urban green spaces. The urban plan used for the current study was revised (phase I) in 2008 for phase I only.Third, the time gap between the GIS data acquisition and experts' surveys should be reduced during proceeding research of the same subject matter to improve the transparency interpretationof experts' surveys and GIS comparison. Finally, future research should focus on a similar evaluation of different types of urban green infrastructures by using the revised urban plan.

The information provided in this study through the detailed insights is crucial to inform urban strategic decision-makers on improving urban green infrastructural development and to support urban environmental sustainability in Sub-Saharan African cities, as well as in other parts of the Global South.

REFERENCES

[1]. Abass, K., Buor, D., Afriyie, K., Dumedah, G., Segbefi, A. Y., Guodaar, L., Garsonu, E. K, Adu-Gyamfi, S., Forkuor, D., Ofosu, A., Mohammed, A. and Gyasi, R. M. (2020). Urban sprawl and green space depletion: Implications for flood incidence in Kumasi, Ghana. *International Journal of Disaster Risk Reduction, 51*, 101915. https://doi.org/10.1016/j.ijdrr.2020.101915

[2]. Abubakar, I. R. (2014). Abuja city profile. *Cities, 41*, 81–91. https://doi.org/10.1016/j.cities.2014.05.008

[3]. Adama, O. (2020). Abuja is not for the poor: Street vending and the politics of public space. *Geoforum, 109*, 14–23. doi:https://doi.org/10.1016/j.geoforum.2019.12.012

ISSN: 2456-1851

Volume: 08, Issue: 03 "May-June 2023"

[4]. Adegun, O. B., Ikudayisi, A. E., Morakinyo, T. E. and Olusoga , O. O. (2021). Urban green infrastructure in Nigeria: A review. *Scientific African, 14*, e01044. https://doi.org/10.1016/j.sciaf.2021.e01044

[5]. AS&P (Albert Speer & Partner GmbH)and Elsworth, D. (2008). *Federal Capital City of Abuja: Review of the Abuja Master Plan - Master Plan for Abuja North Phase IV-West/Structure Plan for Abuja North Phase IV-East Urban Area.*Frankfurt am Main: AS&P - Albert Speer & Partner GmbH.

[6]. Babbie, E. (2010). *The Practice of Social Research* (Twelfth ed.). Belmont: Wadsworth.

[7]. Babbie, E. (2013). *The Practice of Social Research* (Thirteenth ed.). Madrid: Wadsworth.

[8]. Bryman, A. (2016). *Social research methods* (Fifth ed.). New York, NY: Oxford University Press.

[9]. Campbell, J. B. and Wynne, R. H. (2011). *Introduction to Remote Sensing* (Fifth ed.). New York: The Guilford Press.

[10]. Cheshmehzangi, A., Butters, C., Xie, L. and Dawodu, A. (2021). Green infrastructures for urban sustainability: Issues, implications, and solutions for underdeveloped areas. *Urban Forestry & Urban Greening, 59*, 127028. https://doi.org/10.1016/j.ufug.2021.127028

[11]. Dinda, S., Chatterjee, N. D. and Ghosh, S. (2021). An integrated simulation approach to the assessment of urban growth pattern and loss in urban green space in Kolkata, India: A GIS-based analysis. *Ecological Indicators, 121*, 107178. https://doi.org/10.1016/j.ecolind.2020.107178

[12]. Ejaro, S. and Abubakar, A. (2013). The challenges of rapid urbanization on sustainable development of Nyanya, Federal Capital Territory, Abuja, Nigeria. *Journal of Applied Sciences and Environmental Management, 17*, 299-313. http://dx.doi.org/10.4314/jasem.v17i2.13

[13]. Emechebe, L. C. and Eze, C. J. (2019). Integration of Sustainable Urban Green Space in Reducing Thermal Heat in Residential Area in Abuja. *Environmental Technology & Science Journal, 10*, 24-32. Retrieved 08 03, 2021, from http://repository.futminna.edu.ng:8080/jspui/handle/123456789/6826

[14]. Enoguanbhor, E. C. (2021). *Urban land dynamics in the Abuja city-region, Nigeria: Z integrating GIS, remotely sensed, and survey-based data to support land use planning (Doctoral dissertation).*Berlin: Humboldt-Universität zu Berlin. https://doi.org/10.18452/23620

[15]. Enoguanbhor, E. C. (2022). Geospatial Assessments of Urban Green Space Protection in Abuja City, Nigeria. *Eximia Journal. 5*, 177-194. Retrieved from https://eximiajournal.com/index.php/eximia/article/view/147

ISSN: 2456-1851

Volume: 08, Issue: 03 "May-June 2023"

[16]. Enoguanbhor, E. C. (2023). Assessing Urban Spatial Patterns within the Implemented Urban Planned Areas using GIS and Remote Sensing Data. International Journal of Multidisciplinary Perspectives, 04(01), 87-96.Retrieved from https://www.journalbinet.com/testijmp-040123-14.html

[17]. Enoguanbhor, E. C., Gollnow, F., Nielsen, J. O., Lakes, T. and Walker, B. B. (2019). Land Cover Change in the Abuja City-Region, Nigeria: Integrating GIS and Remotely Sensed Data to Support Land Use Planning. *Sustainability, 11*(5), 1313.https://doi.org/10.3390/su11051313

[18]. Enoguanbhor, E. C., Gollnow, F., Walker, B. B., Nielsen, J. O. and Lakes, T. (2021). Key Challenges for Land Use Planning and its Environmental Assessments in the Abuja City-Region, Nigeria. *Land, 10*(5), 443. https://doi.org/10.3390/land10050443

[19]. Enoguanbhor, E. C., Gollnow, F., Walker, B., Nielsen, J. and Lakes, T. (2022). Simulating Urban Land Expansion in the Context of Land Use Planning in the Abuja City-Region, Nigeria. *GeoJournal*, 87, 1479–1497. https://doi.org/10.1007/s10708-020-10317-x

[20]. ESA (European Space Agency). (2021). *Copernicus Open Access Hub*. Retrieved 07 10, 2021, from https://scihub.copernicus.eu/dhus/#/home

[21]. FMITI (Federal Ministry of Industry, Trade and Investment). (2015). *Resettlement and social audit: Abuja technology village project.* Abuja: FMITI.

[22]. Fola Consult Ltd. (2011). Federal Capital City: revised land use plan - 2011 phases I, II & III. Abuja: Federal Capital Development Authority.

[23]. Fotang, C., Bröring, U., Roos, C., Enoguanbhor, E. C., Dutton, P., Tédonzong, L. R., Yuh Y. G. and Birkhofer, K. (2021). Environmental and anthropogenic effects on the nesting patterns of Nigeria–Cameroon chimpanzees in North-West Cameroon. *American Journal of Primatology*. http://doi.org/10.1002/ajp.23312

[24]. Gelan, E. and Girma, Y. (2021). Urban green infrastructure accessibility for the achievement of SDG 11 in rapidly urbanizing cities of Ethiopia. *GeoJournal*. https://doi.org/10.1007/s10708-021-10404-7

[25]. Gumel, I. A., Aplin, P., Marston, C. G. and Morley, J. (2020). Time-Series Satellite Imagery Demonstrates the Progressive Failure of a City Master Plan to Control Urbanization in Abuja, Nigeria. *Remote Sensing, 12*, 1112. https://doi.org/10.3390/rs12071112

[26]. Idoko, M. A. and Bisong, F. E. (2010). Application of Geo-Information for Evaluation of Land Use Change: A Case Study of Federal Capital Territory-Abuja. *Environmental Research Journal, 4*(1), 140-144. http://dx.doi.org/10.3923/erj.2010.140.144

[27]. Jibril, I. U. (2010). The Return of the Greens in Abuja, Nigeria's New Capital City. Sydney: FIG Congress 2010. Retrieved from

https://fig.net/resources/proceedings/fig_proceedings/fig2010/papers/ts09e/ts09e_jibril_4638.pdf

[28]. Jibril, I. U. (2015). Planning and Land Administration Challenges in Developing New Cities:-The Abuja Experience in Nigeria. Sofia: FIG OICRF (International Office for Cadaster and Land Records). Retrieved from https://www.fig.net/resources/proceedings/fig_proceedings/fig2015/papers/ts06i/TS06I_jibril_7723.pdf

[29]. Kuklina, V., Sizov, O. and Fedorov, F. (2021). Green spaces as an indicator of urban sustainability in the Arctic cities: Case of Nadym. *Polar Science*, *29*, 100672. https://doi.org/10.1016/j.polar.2021.100672

[30]. Li, C., Liu, M., Hu, Y., Zhou, R., Wu, W. and Huang, N. (2021). Evaluating the runoff storage supply-demand structure of green infrastructure for urban flood management. *Journal of Cleaner Production*, *280*, 124420. https://doi.org/10.1016/j.jclepro.2020.124420

[31]. Lu, D., Weng, Q., Moran, E., Li, G. and Hetrick, S. (2011). Remote Sensing Image Classification. In Q. Weng (Ed.), *Advances in Environmental Remote Sensing: Sensors, Algorithms, and Applications* (pp. 219-240). Boca Raton: Tailor & Francis Group.

[32]. Mahmoud, M. I., Duker, A., Conra, C., Thiel, M. and Ahma, H. S. (2016). Analysis of Settlement Expansion and Urban Growth Modelling Using Geoinformation for Assessing Potential Impacts of Urbanization on Climate in Abuja City, Nigeria. *Remote Sensing, 8*(3), 220. https://doi.org/10.3390/rs8030220

[33]. Masoudi, M., Tan, P. Y. and Fadaei, M. (2021). The effects of land use on spatial pattern of urban green spaces and their cooling ability. *Urban Climate*, *35*, 100743. https://doi.org/10.1016/j.uclim.2020.100743

[34]. Maxwell, J. A. (2013). *Qualitative Research Design: An Interactive Approach* (Third ed.). Los Angeles, London, Washington DC: SAGA Publications, inc.

[35]. Meijering, J. V., Tobi, H. and Kern, K. (2018). Defining and measuring urban sustainability in Europe: A Delphi study on identifying its most relevant components. *Ecological Indicators*, *90*, Ecologi38–46. https://doi.org/10.1016/j.ecolind.2018.02.055

[36]. Misiune, I., Julian, J. P. and Veteikis, D. (2021). Pull and push factors for use of urban green spaces and priorities for their ecosystem services: Case study of Vilnius, Lithuania. *Urban Forestry & Urban Greening*, *58*, 126899. https://doi.org/10.1016/j.ufug.2020.126899

[37]. Narh, S. N., Takyi, S. A., Asibey, M. O. and Amponsah, O. (2020). Garden city without parks: an assessment of the availability and conditions of parks in Kumasi. *Urban Forestry & Urban Greening, 55*, 126819. https://doi.org/10.1016/j.ufug.2020.126819

[38]. Ogunyombo, O. E. and Odunlami, D. (2017). Exploring the Awareness-Perception Profile of Operation Green Lagos Campaign in Lagos, Nigeria. *Covenant Journal Communication (CJOC), 4*(2), 33-54. Retrieved from https://journals.covenantuniversity.edu.ng/index.php/cjoc/article/view/758

[39]. Park, M. S., Shin, S. and Lee, H. (2021). Media frames on urban greening in the Democratic People's Republic of Korea. *Forest Policy and Economics, 124*, 102394. https://doi.org/10.1016/j.forpol.2020.102394

[40]. Puchol-Salort, P., O'Keeffe, J., van Reeuwijk a, M. and Mijic, A. (2021). An urban planning sustainability framework: Systems approach to blue green urban design. *Sustainable Cities and Society, 66*, 102677. https://doi.org/10.1016/j.scs.2020.102677

[41]. Puplampu, D. A. and Boafo, Y. A. (2021). Exploring the impacts of urban expansion on green spaces availability and delivery of ecosystem services in Accra metropolis. *Environmental Challenges, 5*, 100283. https://doi.org/10.1016/j.envc.2021.100283

[42]. Russo, A. and Cirella, G. T. (2020). Edible Green Infrastructure for Urban Regeneration and Food Security: Case Studies from the Campania Region. *Agriculture, 10*, 358. http://dx.doi.org/10.3390/agriculture10080358

[43]. Secor, A. J. (2010). Social Surveys, Interviews, and Focus Groups. In B. Gomez and J. P. Jones III (Eds.), *Research Methods in Geography: A Critical Introduction* (pp. 194-205). West Sussex: Blackwell Publishing Ltd.

[44]. Shah, A., Garg, A. and Mishra, V. (2021). Quantifying the local cooling effects of urban green spaces: Evidence from Bengaluru, India. *Landscape and Urban Planning, 209*, 104043. https://doi.org/10.1016/j.landurbplan.2021.104043

[45]. Song, P., Kim, G., Mayer, A., He, R. and Tian, G. (2020). Assessing the Ecosystem Services of Various Types of Urban Green Spaces Based on i-Tree Eco. *Sustainability, 12*, 1630. https://doi.org/10.3390/su12041630

[46]. Sufiyan, I., Buhari, A. M., Abubakar, U. S. and Ubangari, A. Y. (2015). An Overview of the Functions of Abuja Geographic Information System (AGIS) As a Tool for Monitoring Growth and Development in Abuja Nigeria. *Journal of Environmental Science, Toxicology and Food Technology, 9*, 17-24. doi:10.9790/2402-091121724

[47]. Tso, B. and Mather, P. M. (2009). *Classification methods for remotely sensed data.* (Second, Ed.) Boca Raton: CRC Press.

[48]. Vargas-Hernández, J. G., Pallagst, K. and Zdunek-Wielgołaska, J. (2018). Urban Green Spaces as a Component of an Ecosystem. In S. Dhiman and J. Marques (Eds.), *Handbook of Engaged Sustainability* (pp. 1-32). Springer, Cham.

[49]. Vijayalakshmi, S., Kumar, M. and Arun, M. (2021). Astudy of various classification techniques used for very high-resolution remote sensing [VHRRS] images. *Materials Today: Proceedings, 37*, 2947–2951. https://doi.org/10.1016/j.matpr.2020.08.703

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Volume: 08, Issue: 03 "May-June 2023"

[50]. Visser, S. and Jones III, J. P. (2010). Descriptive Statistics. In B. Gomez and J. P. Jones III (Eds.), *Research Methods in Geography: A Critical Introduction* (pp. 279-296). West Sussex: Blackwell Publishing Ltd.

[51]. Yenisetty, P. T. and Bahadure, P. (2021). Assessing accessibility to ASFs from bus stops using distance measures: Case of two Indian cities. *Land Use Policy*, *108*, 105567. https://doi.org/10.1016/j.landusepol.2021.105567

