Campus Landuse Monitoring Using Geographic Information Systems (GIS) and High Resolution Satellite Imagery (HRSI): A Spatio-temporal Analysis of the Federal Polytechnic Mubi – Adamawa State, Nigeria

Audu, J. Bawa, D.B., Kadala, S.O.
Department of Urban & Regional Planning
The Federal Polytechnic
Mubi, Adamawa State, Nigeria
E-mail: jibiraudujanga@gmail.com
Phone: +2348030407098

ABSTRACT

The physical footprints of the Tertiary Education Trust Fund (Tetfund) remain evident in almost all our public tertiary institutions in Nigeria. The initiative has intervened massively in physical development of Nigerian campuses. The rush for assessing these funds saw institutions concentrating more on designs of building plans and submission of bills of quantities whereas less concentration has been given to monitoring the way and manner in which such developments are put in place. Although many researchers have worked on understanding the dynamics of our regions and urban centers using Landsat and imaging software systems, such approaches tend to overgeneralize the different urban landuses to built-up environment, because of the coarse nature of such imageries. This study zoomed into one of the urban landuses (i.e. institutional); the study required the utilization of high resolution satellite imagery for more granular explication of the campus fabrics. Georectified HRSIs of the Federal Polytechnic Mubi at different epochs were harvested from Google earth using SmartGIS software system. Advanced vector-based processing methodology in ArcGIS desktop was conducted to digitize the campus land uses for vector classification and assessment. The result shows that HRSI provide the needed mechanisms that warrant detailed understanding of campus features, revealing precise development pattern, and needs of our emerging campuses.

Keywords: GIS, High Resolution Satellite Images, Campus, Landuses, Change Detection, Management

24th iSTEAMS GoingGlobal Multidisciplinary Conference Proceedings Reference Format
Jibir, A., Bawa, D.B., Kadala, S.O. (2020): Campus Landuse Monitoring Using Geographic Information Systems (GIS) and High Resolution Satellite Imagery (HRSI): A Spatio-temporal Analysis of the Federal Polytechnic Mubi – Adamawa State, Nigeria. Proceedings of the 24th iSTEAMS GoingGlobal Multidisciplinary Conference Proceedings. The University of Ghana/Council for Scientific & Industrial Research Ghana – Vitually Stationed in June, 2020. Pp 77-86. www.isteams.net/ghana2020

1. INTRODUCTION

Detection of changes in landuses remains one of the formidable tools used in monitoring and evaluating urban development [1]. The growth and development of campuses are therefore better monitored when a mechanism for understanding how landuses were ones spatially spread and how they reflect today [2], [3]. Therefore, the sustainable development of campus growth is a mandatory challenge to be addressed, and this requires suitable and sustainable planning strategies [3], as well as systematic and timely monitoring of landuse expansion and effects [1]–[6]. To this aim, the availability of reliable information on past and current conditions is a critical point for defining and planning potential future scenarios [7].

Over the years, institutions of higher learning in Nigeria such as Colleges of education, Polytechnics, and Universities have witnessed dramatic interventions in physical development by Tertiary Education Trust Fund (Tetfund) [8]. As a subset in the general urban landuses, campus landuses fall under public and semi-public landuses though sometimes discretely referred to as institutional landuses. Beside the overall urban master planning processes, campus master plans are specially treated in details to subdivide spaces for different campus activities or uses. Campuses are designated spaces where advance teaching and learning with associated physical activities such as living, recreating, marketing, and socio-psychic activities take place [9]. Designations of these activities are done in a planned manner so as to ensure improved learning condition, convenience, aesthetics, and general physical wellbeing of both passive and active populace in the campuses [10].

Competitively, most institutions have concentrated on how fast architectural and structural designs are made with bills of quantities in a quest for accessing funds and the immediate erection of structures at the detriment of weather the siting of such structures conform to the laid down provisions of master plans prepared for such campuses. It is reported that some campuses have either reluctantly or not prepared master plans for their new campuses, as such, development within the campuses remain haphazard causing environmental disorderliness and increased hardship to students and staff [11]–[13].

For many decades ago, mapping of earth features relied on disciplined tenets such as geodesy, cartography and later transformed to interpretation of coarse satellite based imageries in extracting Digital Surface Models (DSF) [2], [5], [14], [15]. The initial exercise was an embodiment of a multitude of challenges faced. About 50 years back, the advent of satellites technologies embedded with multiple scanners that register in bands of different spectral signatures promised in a new paradigm of understanding the dynamics of urban and rural fringes [1], [2], [5]–[7], [15], [16]. Landsat Multispectral Scanner System (MSS) was the first satellite imageries with multiple bands that were used in conjunction with Geographic Information Systems (GIS) to study landuse/landcover changes at urban and regional scale [17]–[19].

To increase the usefulness of satellite imaging in change detection studies, images captured using subsequent sensors were archived at different acquisition periods. Till date, Landsat imageries ranging from MSS, Thematic Mapper (TM), Enhanced Thematic Mapper (ETM), and Operational Land Imager (OLIR) and Thermal Infrared Sensor (TIRS) have been captured, archived, and processed using advanced GIS and imaging software systems to map landuses/landcovers and perform change detection analysis [19]–[21].

Resolutions of Landsat sensors had limited the extraction of landuses at district scales; hence geographic features from such images are defined by pixel information i.e. surface reflectance, and classified as landcovers (e.g. water bodies, built up areas, forests, vegetation, cropland, marshes, woodland, bare surfaces, rock outcrop, and the host of others) [4], [16], [18], [19], [22]–[26]. These types of images although very powerful in change detection analysis, do not provide grained photorealistic details of building footprints at campus level [3].

Lately, advanced very high resolution sensors lunched in the late nineties and early 2000 provided access to high resolution satellite data that reveal building footprints, tree canopies, and roof colors [1]. HRSI such as IKONOS was between 1m to 4m resolution, which later improved by Quickbird sensors that provided satellite data at 0.6m to 2.4m resolution. Subsequent sensors and satellite data are SPOT, Geo-eye and few others [1], [3], [6], [7], [16], [27]–[29]. These crops of spatial data coupled with advanced vector processing tools such as CAD systems and GIS have invigorated technical capabilities in extracting urban features with increased spatial details [3].

Nowadays, production of urban landuse maps that demarcate urban activity spaces within the dictum of built-up area such as commercial, residential, circulation, landscape, open spaces, public, and semi-public areas become doable, precise, easier and faster with HRSI and GIS. In a more detailed manner, campus landuses are enshrined within public and semi-public domain, meaning that studying the dynamics of these types of uses is hinged on very HRSI and a professional application of a methodology that combines advanced vector processing tools and a robust database management system.

The campus which is an institutional landuse, an integral part of urban landuses comprises of different landuses that are always planned in a blue print called campus master-plan. These include: student housing, staff housing, academic area/buildings, administrative area/buildings, sports and recreation, landscape, parking lots, circulation, commercial area/buildings, organized open spaces, and land for future uses. It is the responsibility of town planners to plan and design every campus to accommodate the present and future developments to be injected into it.

The master-plan prepared by town planners serves as a compass that guides the physical development of any campus [10], [30]. However, most physical planning units of campuses are vested with the responsibility of checkmating the adherence of physical development to the master-plan provisions. For institutions that are not planned, the same unit is responsible for initiating a process for the preparation of a fresh master-plan or updating an expired one evidenced by different monitoring capabilities.

Researches on landuse/landcover change analysis had always centered on the use of Landsat and imaging software systems in studying urban and regional growth, and understanding the dynamic nature of our ecosystem [10], [30]. Presently, there are no scholarly studies on campus landuse changes using HRSI and GIS in Nigeria that specifically target on the monitoring of campus development in a spatio-temporal space. However [1]–[7], [15], [27], [31], shade significant insights on how HRSI could be used in extracting urban features and demarcation of fringes at a coarse scale.

To this end, this paper is devoted to using HRSI and GIS as a monitoring mechanism to studying the spatio-temporal changes in campus landuses of the Federal Polytechnic Mubi. The paper is poised to understanding "what were the extent and coverage of campus landuses in FPM in the past 12 years", and "at what rate are the campus landuses pervading the perimeter of the campus and the attendant effects"

2. METHODOLOGY

2.1 The Study Area

The study area is the Federal Polytechnic Mubi campus located in Mubi Metropolis, Adamawa state Nigeria. Mubi is the second largest commercial nerves of Adamawa state in the Northern senatorial region of the state. The metropolis is made up of the contiguously dense built up areas of Mubi south and North local government areas commonly referred to as Mubi town with its satellite hinterlands. The metropolis stretches roughly between 13°13'34.427"E, 10°14'2.225"N and 13°18'59.938"E, 10°19'0.728"N; covering an area of 89.163305 Square Kilometers. The Federal Polytechnic Mubi falls within Mubi North LGA covering **595.5** Square meters. It is one of the pioneer first colleges of higher learning established since 1979. It comprises 7 and 44 accredited schools and departments respectively. The institutions campus Masterplan was prepared since 1987 and is recently receiving serious physical developmental intervention by Tetfund.

2.2 Material and Methods

Primary data were obtained from the site by means of direct field observation in the course of establishing both horizontal and vertical controls. Dual Frequency GPS was used to obtain coordinate position of a fence corner for proper geometric rectification of the high resolution georeferenced image captured with SmartGIS. Other primary data collected during the field survey are the names of structures and campus landuses in the institution.

The secondary data obtained was the shapefile representing the existing perimeter of the campus, Adamawa state maps, Mubi North and South Local government area shapefiles, and high resolution satellite images of the campus in 2006, 2012, and 2020 from Google Earth using SmartGIS desktop. Digital Elevation Model (DEM) covering the entire campus area was also acquired. The Adamawa state, and Mubi North LGA maps were sourced from recommended spatial data vendors such as Systscript Nig. Ltd. The maps were important as they show the location of the campus in both the context of the state and the local governments.

Table 1: Data Types and Sources

Data	Resolution	Source
QuickBird image 18th November 2006	0.61m	Google Earth
QuickBird image 28th December 2012	0.61m	Google Earth
QuickBird image 28th March, 2020	0.61m	Google Earth
Shuttle Radar Topographic Mission (SRTM)	30m	USGS Earth Explorer
Perimeter Survey Plan		Physical Planning Unit, FPM
The Campus Master plan		Physical Planning Unit, FPM

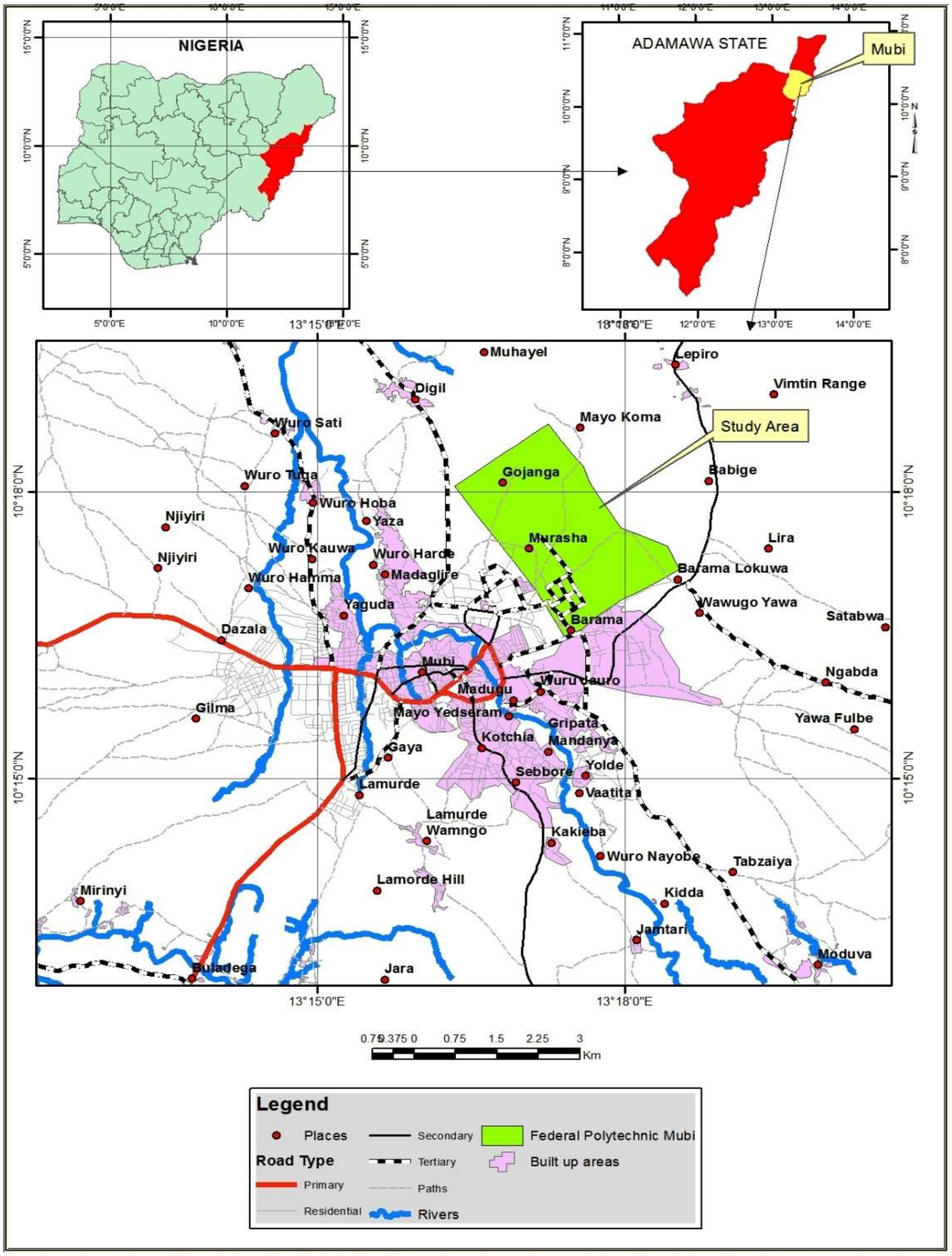

Figure 1: Location Map of the Study Area

2.3 Data Processing

Feature representations were created in ArcCatalog of the ArcGIS Desktop to depict all campus landuses noticed in the study for year 2006, 2012, and 2020. All identified campus landuses were painstakingly digitized using Donut polygons editing strategy for the three epochs. Fields were created in each composite polygon representing each epoch after which campus landuse types were registered. Each row and column represented the type of building and campus landuse found in the area. The 2006 feature accommodated information extracted from a 2006 image, while 2012, and 2020 features accommodated information extracted from the 2012, and 2020 images respectively.

The landuses were classified in the 'symbology' tab of the features properties in ArcMap after which 'value field' of 'landuse' type was selected. Different color schemes were used to represent individual uses. Each image offered its own spatial structures which were digitized and the geometries stored in separate geodatabases. Unlike the landuse/landcover classes usually extracted from Landsat, this study concentrated on monitoring the rate of development within the fringes of the campus's perimeter and thus classified landuses as 'Developed area', 'Open spaces', 'Encroached land'   The total used spaces for each epoch was tabulated, graphed, and compared using histograms, while the graphics are displayed on the map.

3. RESULT AND DISCUSSIONS

3.1 Trends, Rates, and Densities in the Campus Development from 2006 through 2020.

The landuse maps and databases of years 2006, 2012, and 2020 (seen figure 2 and table 3) reveal the trend and a most dedicated path at which development is channeled. From 2006 to 2012, most developments were focused towards the Northern flank of the campus, foundations of these new developments were made between that period; where some buildings were completed and others still under construction as can be seen on the landuse maps. The rate of development between these periods moved from 10.98ha to 14.42ha. From 2012 to 2020 most new developments were radial in nature, and equally the completion or continuation of ongoing projects. The rate of development between these periods moved from 14.42ha to 18.37ha

Presently, the density of buildings at the campus is the fraction of the total land area used as spatial campus fabrics by the total land area (distorted and original) of the entire campus (see campus map as at March 2020). Thou some encroached areas of the campus are already built, we do not see them as part of the institutions' development hence, in the analysis that concerns the original area, we consider them as vacant areas From the table above the current area covered by buildings and other associated structures is 18.37hectares, and the existing (distorted) area of the entire Campus is 595.5; therefore, the density of buildings on the campus is 17.12/595.5 = 0.03

To calculate density with encroached land inclusive, we will say 18.37/750 = 0.024

The ratio of used space and unused space in the campus is principally the proportional percentage usage of the combined activity area with those that are inactive (unused) within the dictum of campus usage in respect to the overall area of the campus. A combined area of 92.87ha is considered to be utilized, while 502, 63 of the new area (distorted) is said to be unutilized. The ratios are 1:5 and 1:7 for distorted and original areas respectively

Table 2: Summary of Landuses in 2006, 2012, and 2020

	Nov., 2006	**Dec., 2012**	**March, 2020**
Landuses	**Area (ha)**	**Area (ha)**	**Area (ha)**
Developed Area	10.98	14.42	17.12
Open Space	582.56	579.12	576.43
Encroached Land	154.51	154.51	154.51
River	1.94	1.94	1.94
Total (encroached land inclusive)	**750**	**750**	**750**
Total (encroached land exclusive)	**595.5**	**595.5**	**595.5**

4. CONCLUSION

For many years back, researchers have given more to the use of Landsat imageries in change detection studies. Such researches were necessitated by the proliferation of spatial data and the development of remote sensing software systems. Landuse landcovers usually classified are more or less clusters of spectral signatures. This project however tried to take advantage of the available historical high resolution satellite images in more detailed analysis of urban landuses like the institutional landuse otherwise called campus landuse of the Federal Polytechnic Mubi.

To respond to the questions raised at the beginning of this paper, that is, "what were the extent and coverage of campus landuses in FPM in the past 15 years", and "at what rate are the campus landuses pervading the perimeter of the campus and the attendant effects", the following were detailed: high resolution satellite imageries of the campus were captured georectified to reveal building footprints. Advanced use of GIS editing tools was deployed to painstakingly digitize the various images. A robust database recording attributes of all digitized structures was developed for each epoch after which vector based classification was used to produce base maps of each epoch. Rates and densities of structures per total area were equally computed which revealed the extent of development and the particular period that saw such rapid expansion.

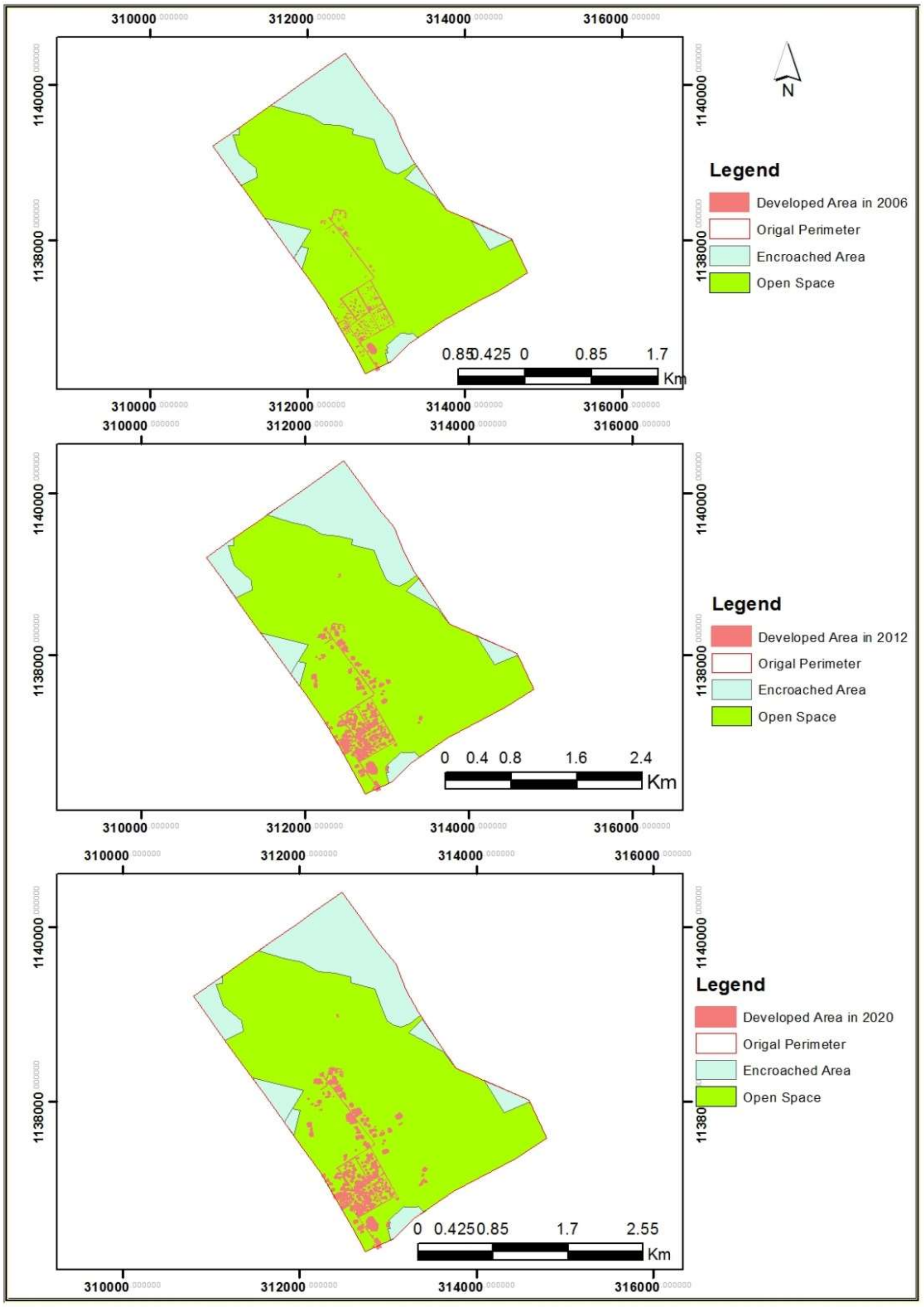

Figure 2: Analyzed Campus Landuses in 2006, 2014, and 2020

REFERENCES

[1] S. S. Rao et al., "Assessing Usefulness Of High-Resolution Satellite Imagery (Hrsi) For Re-Survey Of Cadastral Maps," vol. II, no. December, pp. 9–12, 2014.

[2] H. Dibs, "Extracting Detailed Buildings 3d Model With Using High Extracting Detailed Buildings 3d Model With Using High Resolution Satellite Imagery By Remote Sensing And Gis Analysis ; Al-Qasim Green," no. August, 2018.

[3] J. Poon and C. S. Fraser, "Quality Assessment Of Digital Surface Models Generated From Ikonos Imagery," vol. 20, no. June, pp. 162–171, 2005.

[4] D. Lu and Q. Weng, "International Journal of Remote Extraction of urban impervious surfaces from an IKONOS image," no. September 2013, pp. 37–41.

[5] N. Xia, Y. Wang, H. Xu, Y. Sun, Y. Yuan, and L. Cheng, "Demarcation of Prime Farmland Protection Areas around a Metropolis Based on High- Resolution Satellite Imagery," Nat. Publ. Gr., no. November, pp. 1–11, 2016.

[6] S. S. Rao et al., "Application Of Geo-Spatial Techniques For Precise Demarcation Of Village / Panchayat Boundaries," vol. II, no. December, pp. 9–12, 2014.

[7] Z. Ali, "Assessing Usefulness of High-Resolution Satellite Imagery (HRSI) in GIS-based Cadastral Land Information System."

[8] T. Education and T. Fund, "Osinbajo Commissions TETFund Sponsored Academic Publishing Centre in UNILAG," vol. 2, no. April, 2019.

[9] E. Özceylan, "Location and Coverage Analysis of Bike- Sharing Stations in University Campus," vol. 9, no. 2, pp. 27–29, 2018.

[10] C. Cortinovis and D. Geneletti, "Land Use Policy Ecosystem services in urban plans : What is there , and what is still needed for better decisions," Land use policy, vol. 70, no. August 2017, pp. 298–312, 2018.

[11] Y. Huang, F. Chen, W. Zhao, and J. Yang, "The Consideration of Urban Climate in Green Building Standards and Urban Planning Formulations ----A Review in China," no. 51508469, p. 51508469, 2017.

[12] F. D. Report, "Renewable Energy Master Plan," no. November, 2005.

[13] S. Energy and U. Planning, "State-of-the-art of Education on Solar Energy in Urban Planning."

[14] J. B. Malone, R. Bergquist, M. Martins, and J. C. Luvall, "Use of Geospatial Surveillance and Response Systems for Vector-Borne Diseases in the Elimination Phase," 2019.

[15] A. Castle, A. Elfadaly, and R. Lasaponara, "On the Use of Satellite Imagery and GIS Tools to Detect and Characterize the Urbanization around Heritage Sites : The Case Studies of the Catacombs of Mustafa Kamel in Alexandria , Egypt and the," 2019.

[16] R. D. Garg, "Classification of high resolution satellite images using spatial constraints-based fuzzy clustering."

[17] J. Didero, T. Wambo, S. Ganno, and A. A. Ngambu, "Use of Landsat 7 ETM + Data for the Geological Structure Interpretation : Case Study of the Ngoura-Colomines Area , Eastern Cameroon," no. June, 2016.

[18] M. P. Finn, M. D. Reed, and K. H. Yamamoto, "A Straight Forward Guide for Processing Radiance and Reflectance for EO-1 ALI , Landsat 5 TM , Landsat 7 ETM + , and ASTER."

[19] K. A. Mogaji, O. S. Aboyeji, and G. O. Omosuyi, "Mapping of lineaments for groundwater targeting in the basement complex region of Ondo State , Nigeria , using remote sensing and geographic information system (GIS) techniques," vol. 3, no. August, pp. 150–160, 2011.

[20] P. Taylor, P. J. Cowell, and T. Q. Zeng, "Integrating Uncertainty Theories with GIS for Modeling Coastal Hazards of Climate Change Integrating Uncertainty Theories with GIS for Modeling Coastal Hazards of Climate Change," no. January 2015, pp. 37–41, 2010.
[21] J. Escamilla-molgora, "A taxonomic-based spatio-temporal data structure for modelling biodiversity networks . An Open-Source GIS tool to help bridging ...," no. September, 2016.
[22] R. G. Thannoun, "Automatic Extraction and Geospatial Analysis of Lineaments and their Tectonic Significance in some areas of Northern Iraq using Remote Sensing Techniques and GIS," Int. J. Enhanc. Res. Sci. Technol. Eng., vol. 2, no. 2, pp. 1–11, 2013.
[23] U. L. Dano et al., "Flood Susceptibility Mapping Using GIS-Based Analytic Network Process : A Case Study of," 2019.
[24] N. O. Uluocha and I. Uwadiegwu, "Mapping gully erosion in Abia State , Nigeria using Geographic Information Systems (GIS) and remote sensing techniques," vol. 6, no. 10, pp. 284–300, 2015.
[25] F. Journal and E. Vol, "Spatial Multi-Criteria Analysis for Mapping of Flood Vulnerable Areas in Fagge Local Government Area of Kano State , Nigeria," vol. 13, no. 1, pp. 23–35, 2019.
[26] J. B. Pick, Geographic information systems in business. 2005.
[27] E. S. Elghazali, "Performance of Quickbird Image and Lidar Data Fusion for 2d / 3d City Mapping," vol. 5, no. 11, pp. 1588–1600, 2011.
[28] X. Tong et al., "ISPRS Journal of Photogrammetry and Remote Sensing Building-damage detection using pre- and post-seismic high-resolution satellite stereo imagery : A case study of the May 2008 Wenchuan earthquake," ISPRS J. Photogramm. Remote Sens., vol. 68, pp. 13–27, 2012.
[29] T. Tormos, P. Kosuth, S. Durrieu, B. Villeneuve, and J. G. Wasson, "Improving the quantification of land cover pressure on stream ecological status at the riparian scale using High Spatial Resolution Imagery," Phys. Chem. Earth, vol. 36, no. 12, pp. 549–559, 2011.
[30] G. F. Council, "Agile Cities Preparing for the Fourth Industrial Revolution," no. September, 2018.
[31] U. Regions et al., "Generating High-Quality and High-Resolution Seamless Satellite Imagery for Large-Scale."