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Original Research Article

Mapping land use diversity in new GRA, Idah local government area, Kogi, State: Towards sustainable township development

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ABSTRACT

In light of swift urbanization and the lack of precise land use maps in urban regions, comprehending land use patterns becomes vital for efficient planning and promoting sustainable development. The objective of this study is to assess the land use pattern in order to catalyze sustainable township development in the study area. The procedure adopted involved acquiring the cadastral layout plan of the study area, scanning, and digitizing it. Additionally, satellite imagery of the area was obtained, and both the cadastral plan and satellite imagery were geo-referenced and digitized using ArcGIS 9.2 software. These processes resulted in reasonable accuracy, with a root mean square (RMS) error of 0.002 inches, surpassing the standard of 0.004 inches. The digitized cadastral plan and satellite imagery were overlaid to produce a layered digital map of the area. A social survey of the area was conducted to identify the specific use of individual plots. Furthermore, a relational database system was created in ArcCatalog to facilitate data management and querying. The research findings demonstrated the approach's effectiveness in enabling queries for the use of any particular plot, making it adaptable to a wide range of inquiries. Notably, the study revealed the diverse purposes for which different plots were utilized, including residential, commercial, educational, and lodging. An essential aspect of land use mapping is identifying areas prone to risks and hazards, such as rising sea levels, flooding, drought, and fire. The research contributes to sustainable township development by pinpointing these vulnerable zones and providing valuable insights for urban planning and risk mitigation strategies. This is a valuable resource for urban planners, policymakers, and stakeholders, enabling them to make informed decisions to optimize land use and promote sustainable development in the study area.

Keywords: land use pattern; sustainable development; GIS (Geographic Information System); remote sensing; urbanization

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1. Introduction

The imperativeness of establishing a land use baseline is high in urban environments. This is due to the influx of people from rural settlements towards urban and semi-urban ones. This problem is further heightened by the near absence of adequate land use planning, which is borne out of the absence of accurate land use maps of these urban areas. Land cover refers to the vegetation and artificial constructions covering the land, while land use refers to the human activities that take place on the land[1]. International concerns over land use mapping have been stepped up due to the link between ecological processes and climate change. Land use and climate change adversely impact the Earth's energy and water cycles, which have unfavorable or adverse effects on sustainable development[2]. The use of GIS to process satellite imagery has recently gained more prominence for the modelling and analysis of environmental dynamics. Through this, defined habitats like woodland, grassland, and grazing areas have been mapped. This forms the basis of Land Use Mapping. Making use of this combination of GIS and remote sensing, various types of thematic variables have been mapped and assessed for varied purposes[3–6]. This is evident from the ease of operation, timeliness, and accuracy, among others. Added to these advantages is the digital nature of satellite data, which is amenable to computer-based analysis both for classifying land use and land cover patterns at a cost-effective rate for developing nations around the world. This, when further integrated with terrestrial/photogrammetric methods for land use mapping, would make the cost-effectiveness more appreciated. The accessibility to high-quality satellite images provides added potential for elaborate land use mapping, confirming the prediction in 1996 that over 50% of the aerial photo market would be replaced by high-resolution satellite images[7]. In addition to the above, there is the advancement in information technology (IT) and the availability of image processing equipment, which has reduced the exorbitant cost that has hitherto prohibited digital analysis.

This study was executed using the integration of terrestrial survey, social survey, GIS, and remote sensing techniques to provide a land use map for planning enhanced economic productivity and sustainable development. The United Nations Conference of Rio in June 1992 on Environment and Development was a turning point, attracting delegates from about 183 countries and regions worldwide. Soon after this, countries around the world began to think about the formulation and implementation of strategies for sustainable development that were hitherto threatened by the encroachment of urban development on farmlands in some countries, including China[8]. Orderly use of land resources would be enhanced when urban expansion is driven by the concept of sustainable development using geospatial techniques. This is so because environmental information systems have been used as vehicles for planning sustainable land use]. However, generally, there has been a lack of operational models for the implementation of the concept of sustainable development in GIS. One of the objectives of this paper is to adopt an operationally sustainable land development model using geospatial techniques to curb unnecessary land loss[8]. This will create a balance between development and conservation such that the needs of the present and future are adequately catered for by sustainable development and land use. The concept proposed in the preceding is an enhanced derivative of the popular concept of the limit to growth and carrying capacity[9–11]. This concept aims to awaken people's attention to how to grow in harmony with the environment, which is the background of existence and growth[12]. The bottom line is that developments are allowed only if the environment is not hampered. Sustainable development, therefore, is development that meets the needs of the present without compromising the ability of future generations to meet their own needs[13]. In order to sustain development, the supply and quality of significant consumables and inputs to daily lives and economic well-being, like air, water, food, land, etc., must be cared for. Land is the most critical asset, as almost all our daily needs emanate from it. Sustainable land use is that which satisfies the needs of the present as well as those of the future. This has three criteria:

1) Maintenance of equity between generations in the use of land resources;
2) Consumption of the amount of cultivated land as little as possible with the maintenance of economic growth;
3) When it is necessary to sacrifice an amount of cultivated land, it should be that of less value to agriculture.

2. Sustainable land development model

The model presented is given in **Figure 1** below[8].

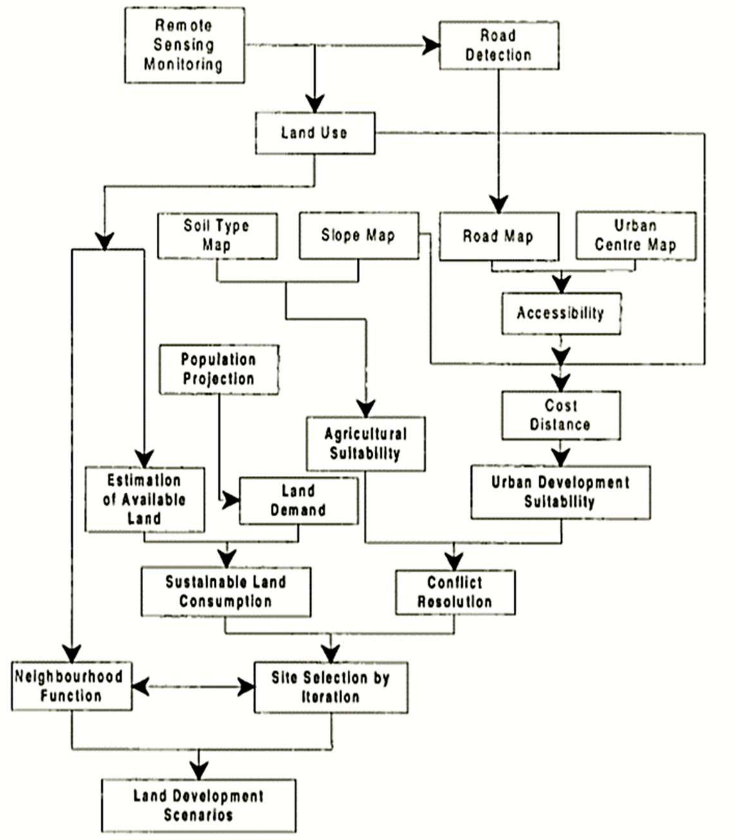

Figure 1. Sustainable land development model[8].

The preceding criteria of sustainable land use can be developed into a sustainable land development model that is concerned with the demand and supply of land. The geospatial approach is used in implementing the model. The demand for land is estimated using population projections, which are readily available in the designed database. Remote sensing provides information on the amount of land available for urban use. The GIS computes the suitability of the land, and then GIS modelling is applied to allocating land supply using the principles of sustainable development in **Figure 1**.

Also, in order to adequately adapt to climate change, there is a need to build a sustainable and spatially enabled land administration system. This enables the control of access to land and the use of the land. Land use mapping identifies all areas prone to risks and hazards, including sea level. rise, flooding, drought, fire, etc., as well as other measures to prevent the impacts of predicted climate change. The dividends accruable from these include the protection of citizens by avoiding the concentration of the population in vulnerable areas.

From a conceptual viewpoint, land use is the use of land by humans. It also includes the management and modification of the natural environment or wilderness into a built environment like fields, pastures, green and reclaimed areas, and settlements. Also, it can be seen as the arrangements, activities, and contributions people make to some land cover type to either provide change or maintain it[14]. Land use data can be obtained from imagery, but the interpretation requires skills. Again, it can be obtained from aerial photography, but this also has certain limitations, as even a skilled interpreter may at times not deduce correctly what is on the photographs, and by inspection or ground mapping, which is also liable to variation by those involved.

2.1. Classification

Classification of land means the percentage usage of land for any particular purpose or activity. In the early 1990s, the United Nations Food and Agricultural Organization postulated that 13% of the earth was arable, 26% as pasture, 32% as forests and woodland, and 1.5% as urban areas[15]. For effective land use mapping, there is a need for a holistic means of classification. The World Land Use Survey, an organ of the International Geographic Union, was approved for use as a classification in 1947 with a tilt towards agricultural interests. The classification employed nine categories as follows: settlements and associated non-agricultural land, horticulture, trees and other perennial crops, cropland, improved permanent pasture, unimproved grazing land, woodlands, swamp and marshes, and unproductive land[14].

On the other hand, the United States Standard Land Use Code is oriented toward human activities and also uses nine classifications, including residential, major manufacturing, minor manufacturing, transportation, communication and utilities, trade, services and culture, entertainment and recreation, resource production, and extraction, and undeveloped land water areas. Also, another alternative classification was made for the United States by the U.S. Geological Survey[16] in 1976, with nine categories as follows: agricultural lands, range land, forest land, water area, wetland, barren land, tundra, urban or built-up land, and perennial snow or ice. The difficulty of having a universal classification model is therefore highlighted. It is only such a thing a thing that can stand the test of time. In the United Kingdom, the national land use survey classification was carried out in 1975 to meet the demands of administering town and country planning challenges. Again, this was not mandatory and, hence, had a limited impact. Another approach to classification was developed using six colors, namely: yellow (moorland and health), light green (grassland), dark green (woodland), brown (arable), purple (garden), etc., and red (agriculturally unproductive)[17]. Another classification borrowed a leaf from the stamp's model but differed by making a more detailed classification with sixty-four categories grouped into thirteen[18]. In Nigeria, four categories are used: cultivable areas, permanent pastures, forests and woodlands, and buildings, roads, or wastelands[19].

Within the land information system/land use mapping, it is essential to record the current land use and to show the land use zone within which every land parcel falls. Land use mapping information has valuable impacts on the value and need of any land, as well as in land use planning. The information there should be entered in the cadastre whenever planning applications are submitted and approved. Where licenses or permits are granted for businesses or other purposes, they should be linked to the cadastral record/cadastre. With a context established regarding the significance of land use mapping and its role in sustainable development, this research embarks on distinct objectives. The process involved acquiring the analogue cadastral layout plan for the study area, encompassing scanning, geo-referencing, and digitization through the utilization of ArcGIS 9.2 software. This was followed by the acquisition and subsequent digitization of satellite imagery. The integration of the cadastral plan with the digital satellite imagery resulted in a comprehensive dataset. Then, this operation is followed by field surveys of the individual plots for the purpose of field verification or validation.

2.2. Materials and methods

The study area is part of the New GRA, Idah Local Government Area of Kogi State. This portion of the New has 291 plots. The New GRA lies within the main township of Idah and has approximate geographic coordinates of 07°05′ N and 05°45′ E in latitude and longitude, respectively[20]. Idah is an ancient historical town in Kogi State and home to all Igala sons and daughters. It is the seat of the exalted throne of Ata'Gala, the ruler of the Igala kingdom. His influence stretches throughout the eastern flank of Kogi State and beyond; all the people of Igala extraction at home and in diaspora owe him allegiance, including those called Ebu people in Delta and other states who may be called by any other name across the country and beyond.

The method used in the research was the collection and manual tracing of the hard-copy cadastral plan of the area. This plan traced out was scanned, geo-referenced, and digitized in ArcGIS 9.2 software. The Google Earth satellite imagery of this study area was downloaded, geo-referenced, and digitized using the same software version. The cadastral layout plan, as digitized, was overlaid on the digitized imagery. Through this, a relational database was created to manipulate and analyse the data.

2.3. Data acquisition and preprocessing

The total station instrument was used to extend the horizontal controls into the study area from the Federal Polytechnic Idah premises. This and the social survey data formed the primary data. A social survey was conducted on the site to identify the use of each plot. The secondary data included the cadastral layout plan obtained from the Ministry of Environment, survey division, Idah zonal office, and Google imagery of Idah. After geo-referencing and digitizing, the coordinates of all beacons and corner points were generated and automatically stored in the ArcGIS 9.2 software. The flow chart is presented in **Figure 2** below:

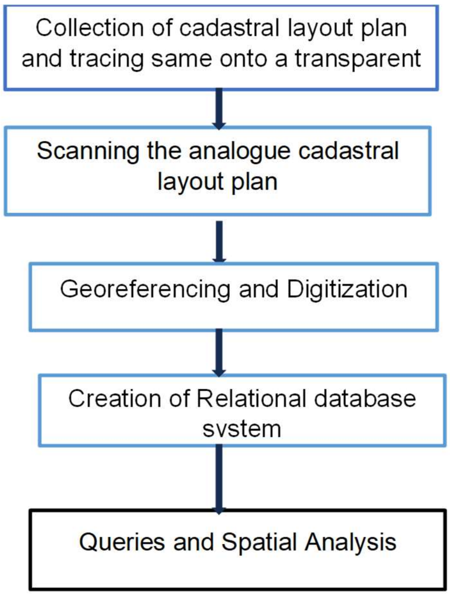

Figure 2. Methodological flow chart of the research.

2.4. Geo-referencing and digitization

The analogue cadastral plan, as traced out, was scanned using the AO HP scanner. Four TIC points were used in the geo-referencing of both the layout plan and the imagery. These gave a reasonable accuracy, i.e., a root mean square (RMS) error of 0.002 inches against the standard of 0.004 inches. The beacons were represented in the digitised plan with points, while lines represented boundaries and roads. Parcels of plots, fields, and other areas were represented with polygons. **Figure 3** shows the cadastral overlay of the area. The cadastral layout plan is fitly overlaid on the digitised image map. The actual usage data of selected parcels was recorded and tabulated. The cadastral overlay of the study area is shown in **Figure 3**.

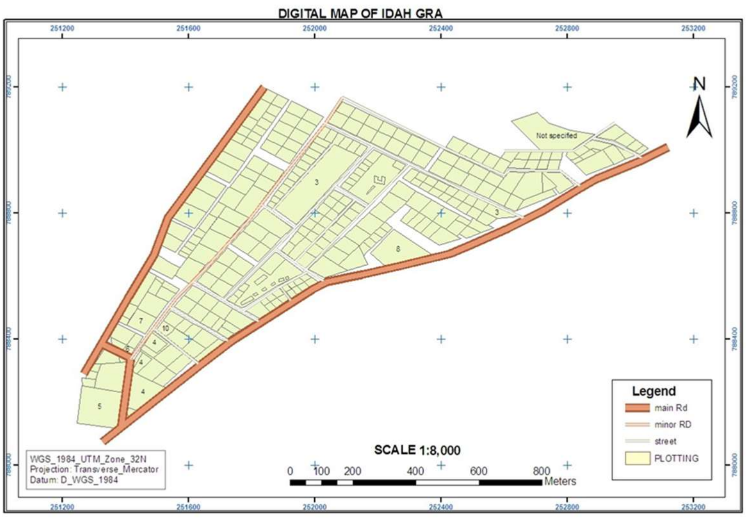

Figure 3. Digital map of study area.

3. Database creation

The tabulated use of individually selected parcels was made into a relational database as shown in **Table 1** below. This table has other attributes of each plot, as shown. The vital one in this discourse is the use column.

Table 1. Present the attributes of the plots.

Parcel(M}	Area in Sq(M)	BliD	Use	Value (₦)million	Address	Pop	Fid
Plot 1	15,356.850	5	Filling Station commercial	40	No. 1 Okpachala Rd	30	2
Plot 2	8739.607	4	Cornear Shop	10	No 2 Okpachala Rd	10	4
Plot GTC	12,044.757	8	Playing field	5	Opp GTC Ajaka Rd	-	101
Plot 8	1816.738	4	Residential StoryBld	30	67, Ajaka Rd	-	10
Catholic	15,888.225	-	Bishop House	100	Opp School of Health	-	253
Kogi Sanitary ware industry	24,267.505	3	Quarters	102	KWS Staff Quarters	50	216
Plot 2 Lona Estate	237,457	3	Residential	250	No.1 Kogi Govt. Lodge Rd	30	130
Plot 2 Local Govt lodge	4,174,812	7	Lodging	150	Ibro Rd	31	-
Plot 6	2,413,812	4	Residential	230	Ibro Rd	10	21
Plot 7	1547.837	-	Educational	100	No. 6 lbro Rd	-	266
Plor 1Blk 6	683.952	6	Residential	150	-	-	-

4. Data analysis

Four principal queries were applied to the database, namely: commercial, educational, lodging, and residential. The query for use equals Bishop House, showing the location of the Bishop House concerning other plots graphically. This is shown below, along with the attribute table of the plot in ArcGIS. attribute table format in **Table 1**. Results for the other queries yielded corresponding results with the details of the plots. **Figure 4** shows the result of the query for the religious/bishop house.

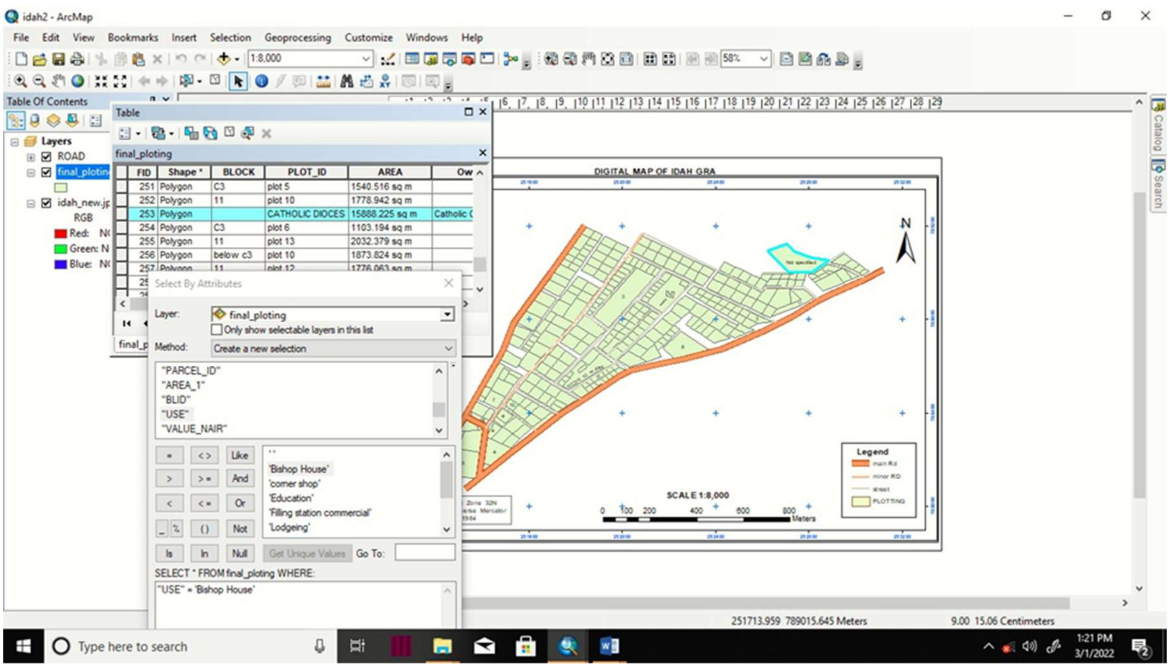

Figure 4. Result of query for religious (Bishop House).

5. Discussion of results

This approach gave corresponding answers to the queries raised. It showed that any query could be raised to solve any defined problem. The use of any particular plot of land compared to other plots can easily be seen and assessed, making it possible to determine the appropriateness or otherwise of the use of any plot. Also, whenever agricultural land is jeopardized, it could be easily noticed and appropriate action taken to avert it. Land use mapping identifies all areas prone to risks and hazards, including sea level rise, flooding, drought, fire, etc., as well as another measure to prevent the impacts of predicted climate change. The dividends accruable from these include the protection of citizens by avoiding the concentration of the population in vulnerable areas.

Queries like the type of buildings in each parcel could be applied to give a corresponding result, and this approach can be adapted to quite several queries for corresponding solutions to challenges ravaging urban and semi-urban as well as rural township developments. In order to sustain land use to satisfy the needs of present and future generations, using this approach, the population of the area, which is readily available from the developed database, is estimated/projected. Remote sensing gives the amount of land available, while the GIS computes the suitability of the land and the modelling for the allocation of the land. The use of each plot was identified.

6. Conclusion

This research indisputably demonstrates that employing queries within the framework of land use mapping enables accurate and precise identification of facilities and activities geotagged to specific parcels of land. Notably, the overlay test successfully identified six plots designated for residential usage, vividly showcasing the adaptable nature of land use mapping in uncovering specific interests related to parcel-based activities. Recognizing this adaptability holds significant promise for enhancing land use planning, efficient risk management against challenges like epidemics and flooding, and the judicious utilisation of land resources. Additionally, this foundational approach offers a solution-oriented avenue for addressing the intricacies of land allocation matters. The research solidifies the effectiveness of query-based land use mapping. A robust methodology has emerged for accurately linking activities to specific properties by integrating cadastral plans, satellite imagery, and social surveys using Geographic Information Systems (GIS). The successful overlay test, pinpointing residential plots with precision, underlines the substantial potential of such mapping in identifying distinct parcel-based activities. The ramifications extend broadly, encompassing optimised land use planning, effective risk management, and prudent resource exploitation.

For further research, there is a need to explore streamlined approaches to hastening mapping processes that could enhance efficiency while maintaining accuracy. Investigating automation techniques and machine learning for land use classification might expedite mapping. Moreover, exploring emerging technologies like 3D modelling and LiDAR for enhanced accuracy and detail in mapping is worth considering. Therefore, combining innovation, technology, and interdisciplinary collaboration will equip planners with advanced tools for shaping sustainable urban landscapes.

Author contributions

Conceptualization, AE; methodology, AE and FO; software, AE and FO; validation, FO and OSS; formal analysis, AE and OSS; investigation, AE and FO; resources, AE; data curation, AE; writing—original draft preparation, AE; writing—review and editing, OSS; visualization, AE, OSS and FO; supervision, FO; project administration, AE. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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