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GEOSPATIAL ANALYSIS OF LAND CHARGE BILLING SYSTEM IN KWARA STATE GEOGRAPHIC INFORMATION SERVICE (KW-GIS), ILORIN, KWARA STATE, NIGERIA

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ABSTRACT
This study examined the Geospatial Land Charge Billing System developed by the Kwara Geographic Information Service (KW-GIS), focusing on Ilorin West, Ilorin East, and Ilorin South Local Government Areas. The aim was to assess the system's operational efficiency, spatial coverage, and administrative effectiveness, and to explore how Geographic Information Systems (GIS) can strengthen transparency, accountability, and revenue generation in land charge administration. We acquired spatial and non-spatial datasets, including cadastral maps, parcel boundaries, land-use information, and property ownership records, from KW-GIS and supplemented them with field observations. We analyzed these datasets using ArcGIS 10.8 and QGIS 3.28 to visualize land parcel distributions, classify land uses, and evaluate the spatial pattern of billed and unbilled properties. The study found that although KW-GIS has made notable progress in automating billing processes and digitizing cadastral information, challenges persist in data completeness, spatial updating, and integration between billing and geospatial databases. It was observed that gaps in property registration and the prevalence of informal land developments continue to hinder full revenue coverage and equitable taxation. The study concluded that adoption of a robust GIS-based billing framework improves land charge management by increasing data accuracy, monitoring efficiency, and fiscal accountability. It recommended regular geospatial data updates, improved institutional coordination, and enhanced staff training to achieve sustainable land administration and revenue optimization across Kwara State.

Keywords: *Cadastral Data Quality, Revenue Administration, Property Taxation, Data Completeness, Land Administration.*

INTRODUCTION

Land, as a fundamental resource, plays a pivotal role in a nation's economic development and social well-being. Effective land administration systems are crucial for ensuring tenure security, facilitating land transactions, generating revenue, and supporting sustainable urban and rural development (United Nations Economic Commission for Europe [UNECE], 2005; Zevenbergen, 2010). In many developing countries, including Nigeria, land administration systems are often inefficient, opaque, and reliant on outdated manual processes, leading to land disputes, revenue leakage, and difficulties in urban planning (Agajie & Okeke, 2016; Nwosu & Okereke, 2019).

Land charges, which are taxes or levies imposed on land and property, represent a significant potential revenue stream for State and local governments. However, inaccurate land records, inadequate valuation methods, and inefficient billing and collection mechanisms often hamper the collection of these charges (Ayodele & Aguda, 2018). The absence of a robust, transparent, and

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efficient system for managing land charges can lead to substantial financial losses for governments and discourage investment due to uncertainties in land ownership and taxation.

Geospatial technology, encompassing Geographic Information Systems (GIS), Global Navigation Satellite Systems (GNSS), remote sensing, and spatial analysis, offers a powerful suite of tools and methodologies for managing, analyzing, and visualizing spatial data. The integration of geospatial technology into land administration, often referred to as Land Information Systems (LIS) or Cadastral Information Systems (CIS), is globally recognized as a transformative approach to improving land management practices (Dale & McLaughlin, 1999; Rajabifard et al., 2006). By providing a precise spatial framework for property information, geospatial technology can significantly enhance the accuracy and completeness of land records, streamline valuation processes, and facilitate the development of more efficient and transparent billing and collection systems for land charges.

Kwara State, like many other states in Nigeria, has historically faced challenges in its land administration and revenue generation from land-based charges. Recognizing these challenges, the Kwara State Government established the Kwara State Geographic Information Service (KW-GIS) in 2021. KW-GIS was created with an explicit mandate to modernize land administration, improve land titling and documentation, and enhance revenue generation through geospatial technology and digital processes (Kwara Geographic Information Service 2020). KW-GIS introduced a digital cadastral framework for land administration in Kwara State. However, limited empirical evidence exists regarding the effectiveness of the geospatial land charge billing system implemented by KW-GIS in improving revenue administration and billing efficiency.

This study examined the geospatial land charge billing system implemented by KW-GIS in Ilorin, Kwara State, Nigeria. Specifically, it evaluated cadastral data quality, spatial patterns of billing inefficiency, and the extent to which the system has improved revenue generation and transparency in land charge administration.

The study aimed to:

i. assess the completeness and accuracy of property data within the KW-GIS geospatial database for land charge billing in Ilorin;
ii. examine spatial patterns of inefficiencies in the geospatial land charge billing workflow, focusing on data integration, valuation, and revenue collection; and
iii. evaluate the system's impact on revenue generation, transparency, and administrative efficiency in land charge management.

In Nigeria, several studies have examined GIS applications in property taxation and land administration. Augustine and Ngere (2013) observed that GIS improved property enumeration and taxation efficiency in Rivers State, while Ezeigbo et al. (2015) demonstrated that GIS-supported property databases enhanced property rating processes in Enugu State. Similarly, Bello and Bello (2017) reported that geospatial technologies strengthened revenue administration and cadastral management in Kaduna State. Adebiyi et al. (2019) further noted that GIS-based property taxation systems improved transparency, accountability, and internally generated revenue in Osogbo, Osun State.

Despite these advancements, several challenges continue to affect GIS-based land administration systems in Nigeria. Previous studies identified incomplete cadastral records, inconsistent attribute data, weak institutional coordination, and inadequate spatial updating as major constraints on the

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effectiveness of digital billing and revenue systems (Okafor et al., 2016; Nwosu & Okereke, 2019). Poor-quality cadastral data often result in omitted properties, inaccurate billing, and revenue leakages, thereby reducing administrative efficiency and fiscal performance.

Despite the increasing application of Geographic Information Systems (GIS) in property taxation and cadastral management, empirical research integrating cadastral data quality assessment with spatial analysis of land revenue performance remains limited in developing contexts. Existing land administration systems have largely emphasized cadastral digitization and GIS adoption, with comparatively less focus on spatially evaluating billing inefficiencies and revenue performance. This reflects broader limitations in effectively using spatial data infrastructures for land governance and taxation in developing countries (Enemark, 2007). This study addresses this gap by examining cadastral data quality, spatial billing inefficiencies, and revenue performance within the KW-GIS land charge system in Ilorin Metropolis, Kwara State.

The effectiveness of GIS-driven land charge administration depends largely on the quality and completeness of cadastral datasets. Previous studies indicate that incomplete parcel records, inconsistent attribute information, and outdated spatial databases contribute to billing inefficiencies and revenue leakages (Potsiou & Navratil, 2024; Višnjevac et al., 2024). However, limited empirical attention has focused on the spatial relationship between cadastral data quality and unpaid land charge patterns within emerging digital land administration systems in Nigeria. This study examines this relationship in the context of KW-GIS in Ilorin Metropolis to evaluate the effectiveness of the geospatial land charge billing system.

STUDY AREA

The study was conducted within Ilorin Metropolis, Kwara State, Nigeria. Ilorin, the capital city of Kwara State, is located in the north-central region of Nigeria, often referred to as part of the Middle Belt. Geographically, Ilorin lies approximately between latitude 8°24′N and 8°36′N and longitude 4°28′E and 4°36′E (Google Earth/ArcGIS Geospatial Coordinates Confirmation, and Figure 1). The city is strategically situated at the transition zone between the forest and savannah belts, which influences its vegetation, climate, and agricultural activities.

Ilorin is about 306 kilometers northeast of Lagos and around 500 kilometers southwest of Abuja, Nigeria's federal capital (Aderamo, 2008). The city serves as a major administrative, commercial, and educational center in the region and plays a pivotal role in interconnecting the southern and northern parts of Nigeria. Ilorin is undergoing significant urban development and land administration reforms, making it a critical location for analyzing the impact of KW-GIS's initiatives. As the administrative and commercial hub, Ilorin contains a high concentration of properties and is expected to be the primary focus of land charge collection efforts, providing a representative sample for the study.

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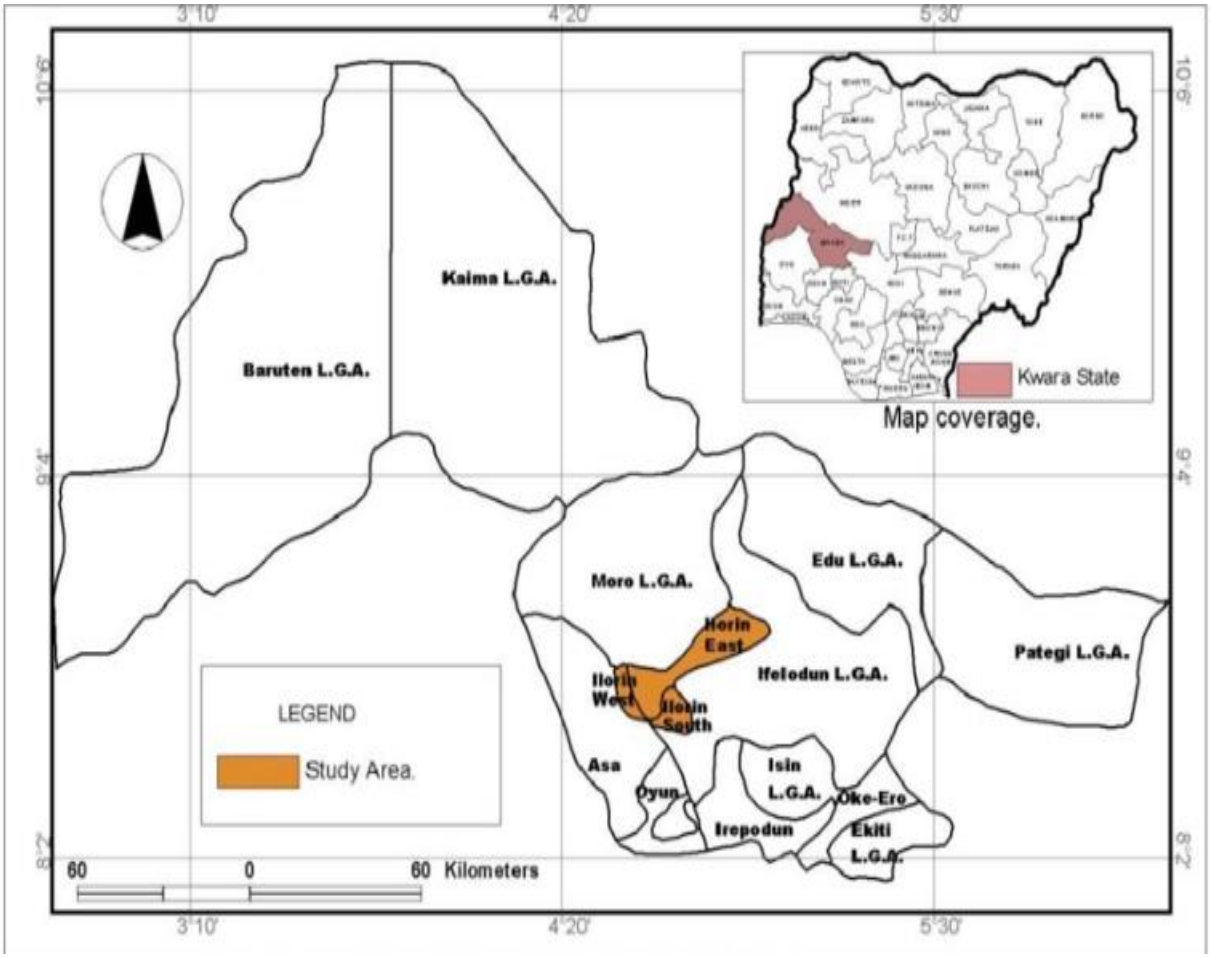

Figure 1: Map of Kwara State showing the Study Area (Inset: Map of Nigeria).
Source: KW-GIS Directorate of Survey, 2025

METHODOLOGY

This study adopted a case study design of the Kwara Geographic Information Service (KW-GIS), Ilorin Metropolis, using a GIS-based mixed-methods approach to assess cadastral data quality, billing efficiency, and revenue performance across Ilorin West, Ilorin East, and Ilorin South Local Government Areas (LGAs). The study relied primarily on geospatial and administrative datasets obtained from KW-GIS and the Kwara State Internal Revenue Service (KWIRS), complemented by institutional insights from questionnaires, key informant interviews, and field observations. Secondary datasets included digital cadastral maps, parcel boundaries, billing records, land-use information, satellite imagery, policy documents, and relevant academic literature, while primary data were used mainly to validate institutional workflows and contextualize findings derived from spatial analysis.

The study targeted institutional personnel and cadastral parcels within Ilorin Metropolis. The primary analytical units for the spatial assessment were parcel-level cadastral records in the KW-GIS database. The study purposively selected KW-GIS and KWIRS officials based on their direct involvement in cadastral management, valuation, billing operations, and revenue collection. Key informant interviews with senior personnel provided institutional perspectives on operational

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workflows, data management practices, and challenges affecting land charge administration. Questionnaire items were designed primarily to validate institutional workflows and contextualize findings derived from spatial analysis.

Because access to the complete cadastral register and full inventory of registered properties in the KW-GIS database was limited, the study could not establish an exact sampling frame. Consequently, the study adopted a spatially stratified purposive sampling approach designed to ensure adequate representation across Ilorin West, Ilorin East, and Ilorin South LGAs. The sampling emphasized areas with varying levels of cadastral completeness, land-use intensity, property registration status, and administrative relevance to land charge operations.

To evaluate cadastral data quality, we developed a Data Completeness Index (DCI) based on the availability of three key parcel attributes relevant to land charge administration: land size, land use, and payment status. Each attribute received a binary score: available information scored 1, and missing information scored 0. Composite parcel-level quality scores were computed by summing the available attributes and normalizing by the total expected attributes. We then classified parcels into four categories: complete records, land size missing only, partially missing records, and completely missing records. This classification provided the basis for spatial assessment of cadastral data quality and its relationship with land charge billing inefficiencies.

$$DCI = \frac{\sum A_i}{n} \quad \text{..... (eq. 1)}$$

where:

A_i represents the availability score of each attribute (1 = available, 0 = missing); and

n represents the total number of expected parcel attributes.

The DCI framework provided a standardized measure for evaluating parcel-level cadastral completeness and enabled spatial comparison of data quality patterns across the study area. The resulting Data Completeness Index (DCI) values ranged from 0 to 1 and were classified into four categories to reflect varying levels of cadastral data quality. Parcels with a DCI value of 1.00 (100%) were classified as Complete Records (all data present), indicating that land size, land use, and payment status were fully available. Parcels with a DCI value of 0.67 (67%) were classified as Land Size Missing Only, representing cases where only one attribute was missing (i.e., land size), while land use and payment status remained available. Parcels with a DCI value of 0.33 (33%) were classified as Partially Missing Records, indicating that two of the three required attributes were missing and only one attribute remained available. Parcels with a DCI value of 0.00 (0%) were classified as Completely Missing Records, where all required attributes were absent. We established these thresholds based on the proportion of available cadastral attributes and used them to generate the spatial data quality classification map.

Descriptive statistics summarized institutional responses and billing characteristics, while we analyzed qualitative information from interviews and field observations thematically. We conducted geospatial analysis, including cadastral data quality assessment, hotspot analysis, and overlay mapping, using ArcGIS 10.8 and QGIS 3.28.

We conducted spatial hotspot analysis using the Getis-Ord Gi* statistic in ArcGIS 10.8 to identify statistically significant clusters of unpaid land charges and examine their spatial relationship with

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cadastral data quality. We adopted a fixed-distance band conceptualization to define neighborhood interactions among cadastral parcels.

The Getis-Ord Gi statistic is expressed as:

$$G_i^* = \frac{\left(\sum_j w_{ij}x_j - (X)\sum_j w_{ij}\right)}{S\sqrt{\frac{\left(n\sum_j w_{ij}^2 - \left(\sum_j w_{ij}\right)^2\right)}{(n-1)}}} \quad \text{..... (eq. 2)}$$

..... (eq. 3)

where: x_j represents the attribute value for feature j;

w_{ij} denotes the spatial weight between features i and j;

$\bar{X}$ is the mean of the attribute values;

S represents the standard deviation of the dataset; and

n denotes the total number of spatial features.

Positive Gi* values indicate hotspots of unpaid land charges, whereas negative values indicate cold spots. We evaluated statistical significance at 90%, 95%, and 99% confidence levels.

RESULTS AND DISCUSSION

Data Completeness and Accuracy

The first objective of the study assessed the completeness and accuracy of key attribute data, namely land size, land use, and payment status, associated with cadastral parcels within the KW-GIS database. These attributes constitute the core inputs for land charge assessment, equitable billing, and effective revenue management; therefore, their availability and Reliability are critical to the overall performance of the geospatial land charge billing system.

Parcel-level attribute completeness revealed variability across the cadastral database based on the presence of land size, land use, and payment status fields. The derived composite quality scores indicate heterogeneous data integrity across the study area, with spatial clustering of high- and low-quality records. High data completeness is concentrated in Ilorin West, while Ilorin East and Ilorin South show higher proportions of incomplete and missing attribute records.

The study classifies cadastral parcels into four data quality categories based on the completeness of land size, land use, and payment status attributes, ranging from fully complete records to parcels with all critical information missing (Figure 2). The classification framework provides a structured basis for evaluating spatial variability in cadastral data quality across the study area.

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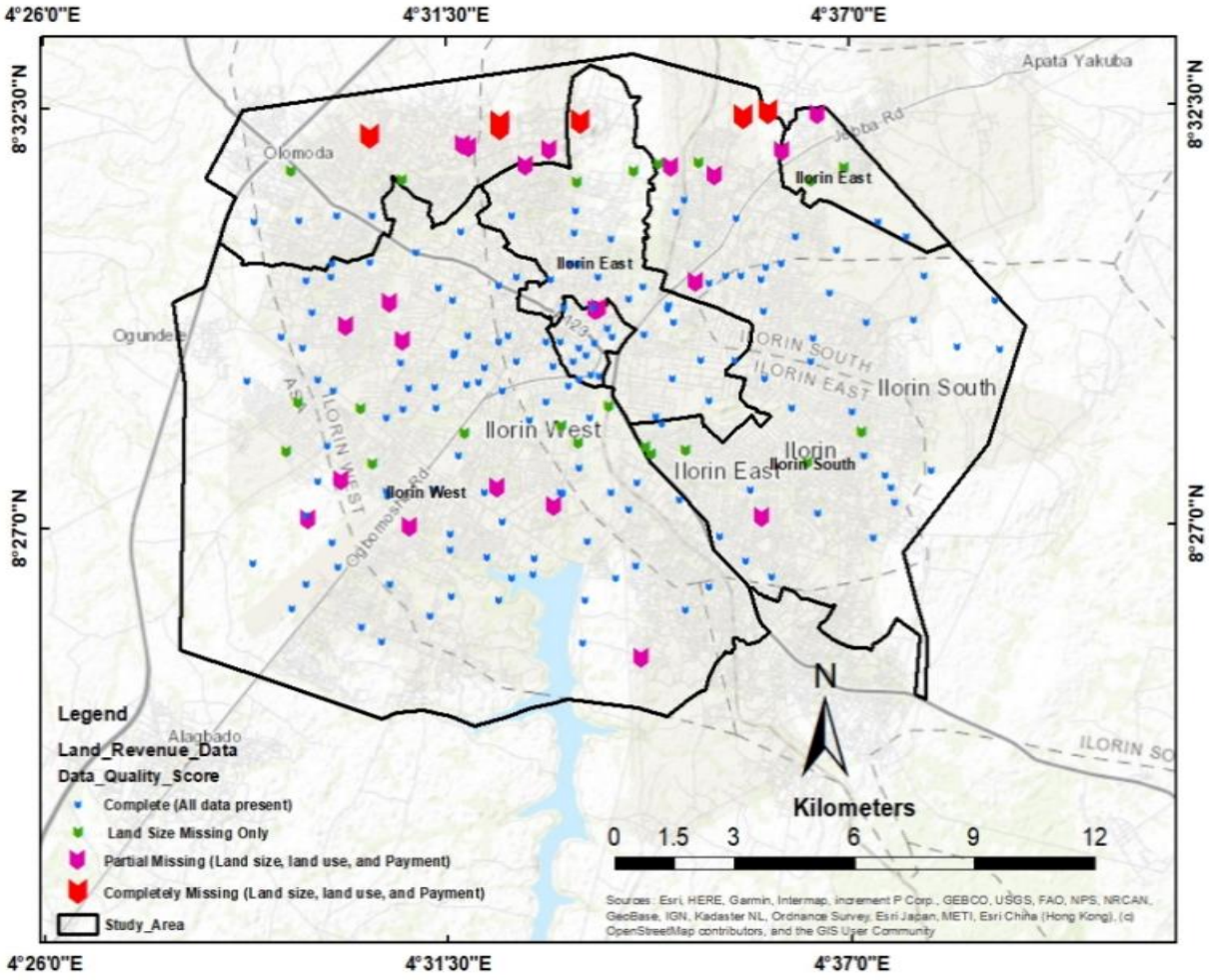

Figure 2: Spatial Distribution of Property Attribute Data Quality
Source: Authors' Compilation, 2025

The spatial distribution of these categories revealed pronounced disparities in data quality across the study area. Parcels with complete attribute records are predominantly concentrated in western Ilorin, particularly within Ilorin West LGA. Conversely, large areas of Ilorin East and Ilorin South, particularly around the Apatā Yakuba district, have partially complete or entirely missing attribute data. This pattern indicates that large contiguous zones lack the fundamental information required for accurate billing, thereby posing significant constraints on the efficiency and equity of the geospatial land charge billing system.

Spatial Analysis of Billing Workflow Challenges

The second objective focused on identifying spatial patterns of inefficiency in the geospatial land charge billing system, with particular emphasis on the distribution of unpaid bills and their relationship to the data quality patterns established under Objective 1. To achieve this, a spatial statistical approach was used to detect areas where billing inefficiencies are spatially concentrated.

Specifically, a Getis-Ord Gi hotspot analysis was conducted to identify statistically significant clusters of high levels of unpaid land charges (hot spots) and areas with relatively low levels of unpaid bills (cold spots). This method enabled the systematic delineation of spatial concentrations of

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non-compliance and efficiency, thereby providing empirical evidence of where billing challenges are most pronounced and setting the stage for interpreting their association with underlying data completeness and accuracy.

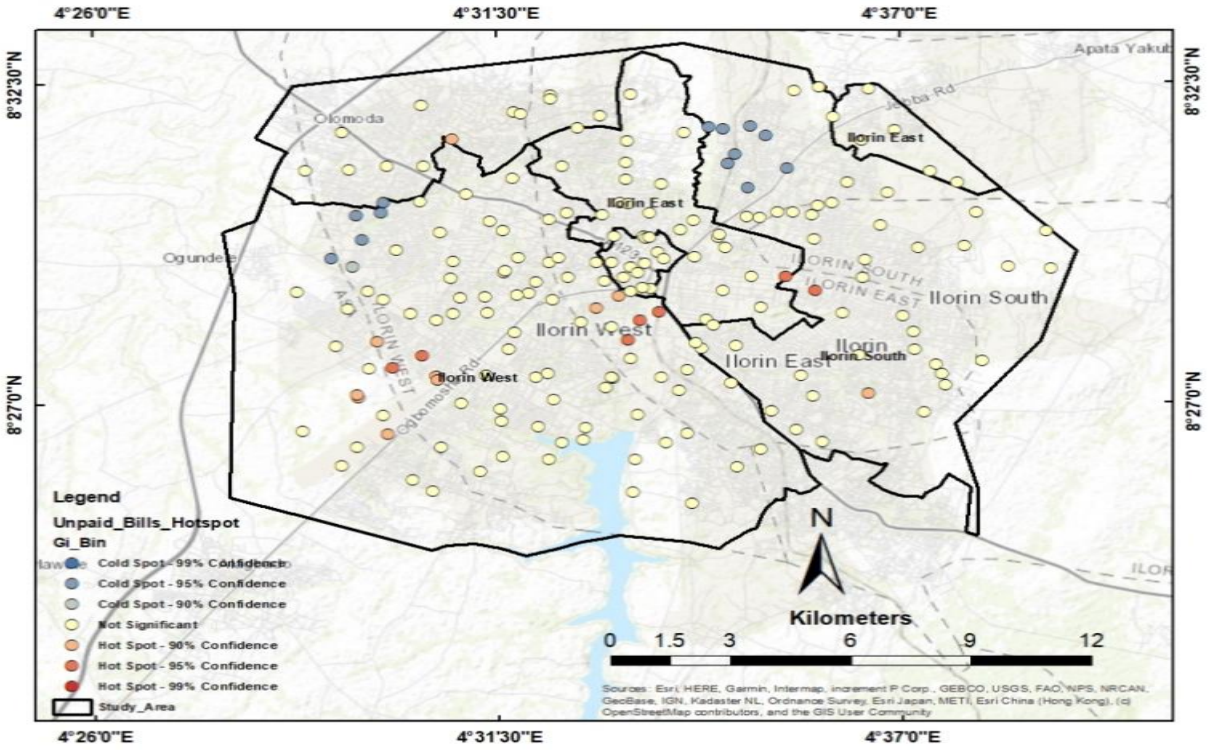

Figure 3: Hotspot Analysis of Unpaid Land Charges
Source: Authors' Compilation, 2025

A primary hotspot zone at a 99% confidence level was identified in Ilorin South and Ilorin East LGAs, indicating a statistically significant clustering of unpaid land charges (Figure 3). This indicates a severe, non-random cluster of revenue leakage. Conversely, "Cold Spots" (areas with significantly low arrears) are found in the western parts of the study area.

Figure 4 explicitly visualizes the correlation between data quality and revenue collection. The study directly overlays unpaid-bill hotspots with data quality categories (Figure 4). Overlay analysis reveals a strong spatial correspondence between cadastral data quality and unpaid land charge distribution. Areas with missing or incomplete attribute data coincide with unpaid-bill hotspots, while areas with complete datasets correspond to cold spots. This pattern is more pronounced in Ilorin East and Ilorin South, where poor data quality aligns with higher billing inefficiencies.

The overlay analysis in Figure 4 revealed a clear, spatially consistent relationship between cadastral data quality and the distribution of unpaid land charges. Areas with poor or missing attribute data strongly coincide with hotspots of unpaid bills, while zones with complete, reliable data correspond to cold spots, indicating effective billing and collection.

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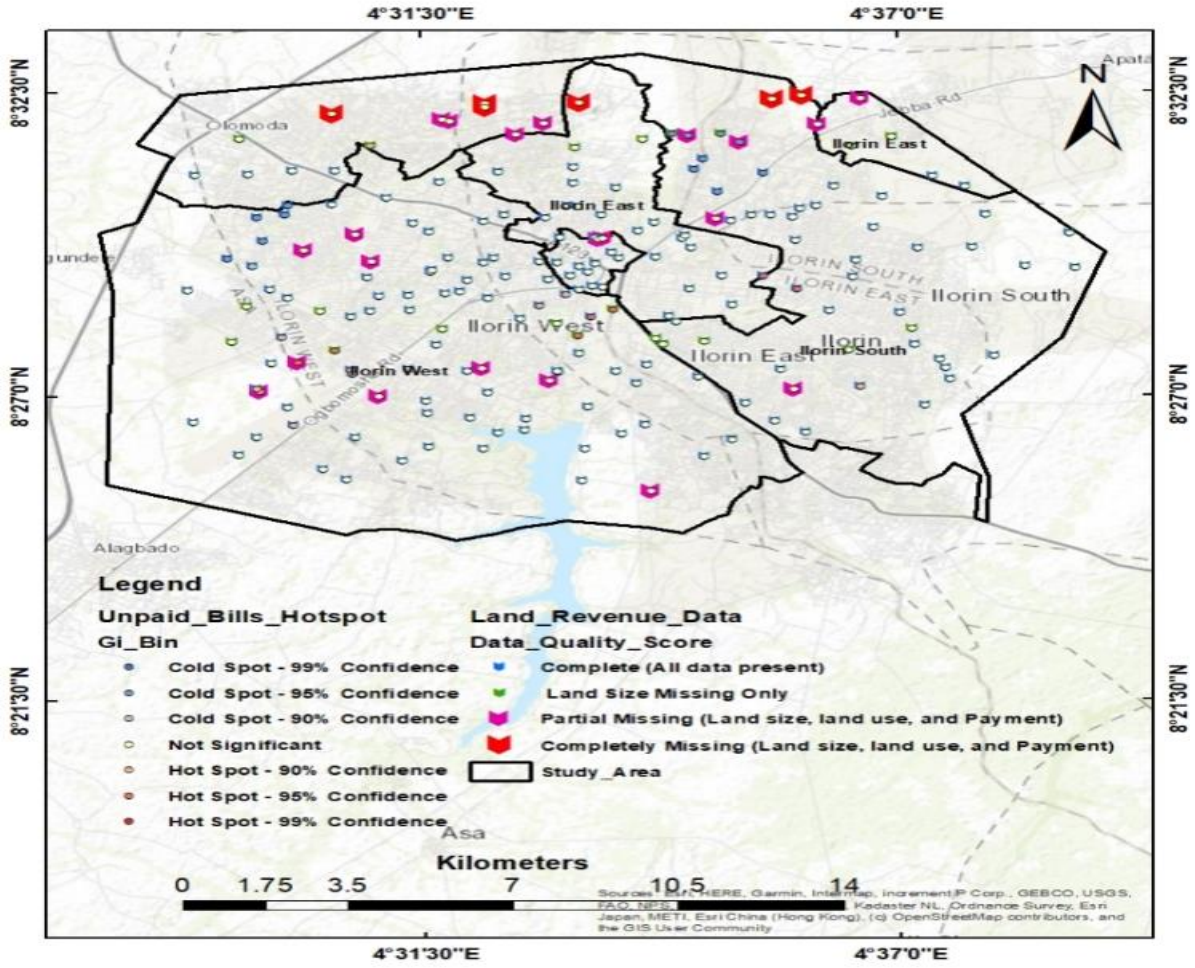

Figure 4: Correlation Map between Unpaid Bills Hotspots and Data Quality
Source: Authors' Compilation, 2025

This spatial alignment demonstrated that data quality deficiencies primarily drive workflow inefficiencies within the geospatial land charge billing system. In Ilorin East and Ilorin South, incomplete or missing cadastral information undermines the ability to generate accurate, enforceable bills, resulting in persistent revenue losses. Conversely, the western parts of the metropolis, where data quality is robust, exhibited more efficient revenue collection. The findings suggest that administrative and data quality issues significantly contribute to billing inefficiencies.

Assessment of Revenue Generation Improvement

The final objective assessed the impact of KW-GIS implementation on land charge revenue by comparing aggregated pre- and post-KW-GIS revenue across Ilorin, with results aggregated and visualized at the Local Government Area (LGA) level.

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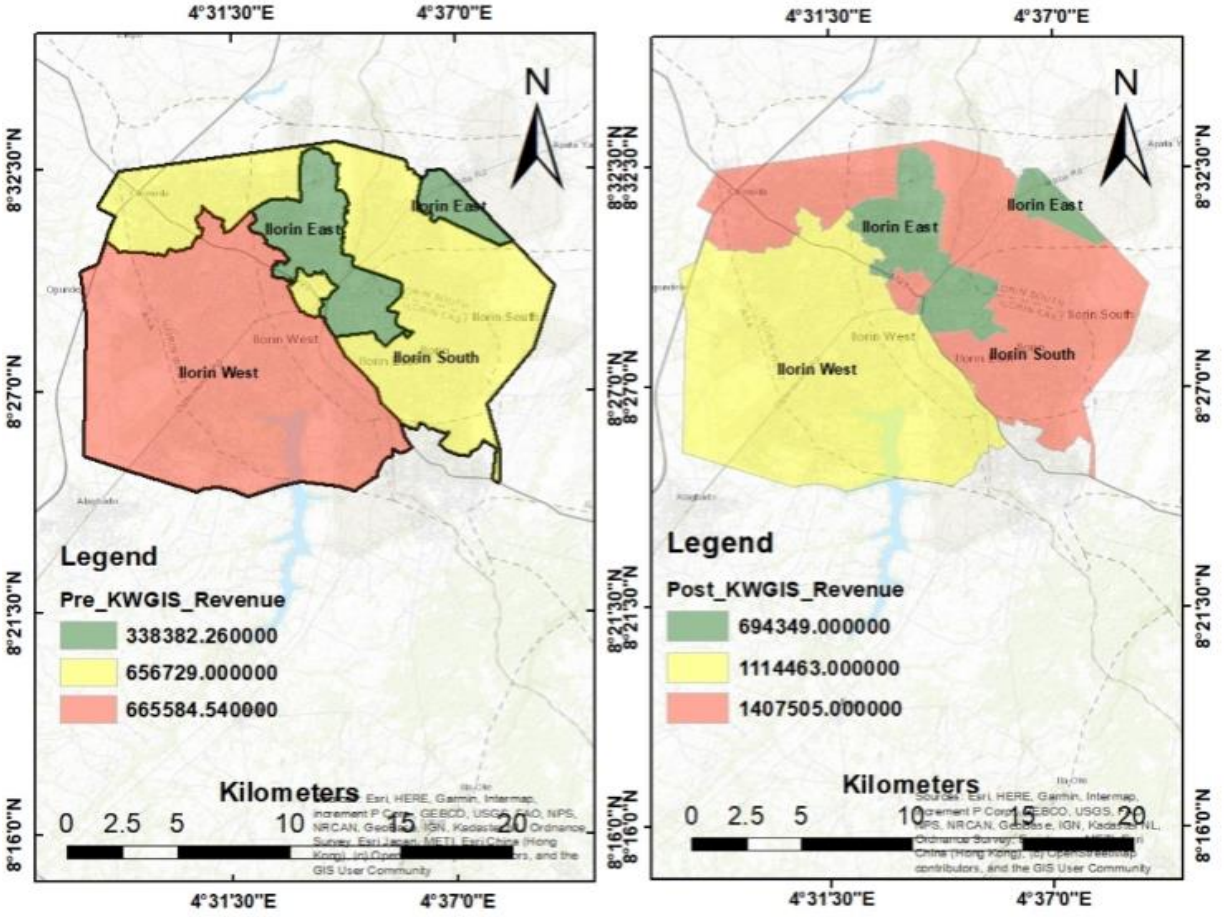

Figure 5: Comparative Analysis of Land Charge Revenue (Pre- and Post-KWGIS Implementation)
Source: Authors' Compilation 2025

Table 1: Land Charge Revenue Growth Post-KWGIS Implementation

Local Government Area (LGA)	Pre-KWGIS Revenue (₦)	Post-KWGIS Revenue (₦)	Revenue Increase (₦)	Percentage Growth (%)
Ilorin West	338,382	694,349	355,967	105.2%
Ilorin South	656,729	1,114,463	457,734	69.7%
Ilorin East	665,585	1,407,505	741,920	111.5%
TOTAL	1,660,696	3,216,317	1,555,621	93.7%

Source: Author's Compilation, 2025

The implementation of KW-GIS significantly increased land charge revenue across all Local Government Areas, with total collections rising by 93.7%. Ilorin East recorded the highest growth (111.5%), followed by Ilorin West (105.2%) and Ilorin South (69.7%). Variation in revenue performance across LGAs corresponds with differences in cadastral data availability and the extent of digitized records integrated into the billing system.

The study showed that KW-GIS has significantly improved land charge revenue in Ilorin, but its effectiveness depends heavily on data quality. Spatial analysis revealed that areas with complete cadastral data, primarily in Ilorin West, correspond with low arrears and efficient billing, whereas

data-poor zones in Ilorin East and South coincide with unpaid bill hotspots, highlighting systemic inefficiencies. Revenue gains, including a 93.7% overall increase, largely reflect improvements in areas with existing records, while persistent data gaps limit further optimization. These findings underscore that geospatial billing success depends not only on technology but also on comprehensive data capture and validation. Targeted remediation in data-deficient hotspots is therefore essential to sustain revenue growth, reduce inequities, and maximize KW-GIS's fiscal impact.

This study faced limitations that may influence the interpretation of the findings. Data confidentiality policies restricted access to some administrative and fiscal records within KW-GIS and KWIRS, limiting financial verification and historical revenue comparisons. In addition, inconsistencies in cadastral updating across some parts of Ilorin Metropolis may have affected the completeness of spatial and attribute datasets used for analysis.

Furthermore, the lack of a publicly accessible, fully updated cadastral inventory limited the use of probability-based sampling techniques within the study area. Temporal limitations also constrained the study, as the assessment relied on available records from the post-KW-GIS implementation period and may not fully capture long-term trends in land charge performance and spatial database evolution. Consider these limitations when interpreting the findings.

CONCLUSION AND RECOMMENDATIONS

The integrated analysis shows that KW-GIS effectiveness in Ilorin depends largely on the completeness and accuracy of cadastral data. Data quality emerges as the primary determinant of system efficacy: complete datasets enable efficient billing and revenue collection, as observed in Ilorin West, while data-poor areas in Ilorin East and South remain hotspots of unpaid bills, revealing entrenched spatial inequalities. Although overall revenue increased substantially (93.7%), and Ilorin East experienced a notable 111.5% growth, these gains largely reflect improvements in areas with partially available data, highlighting the limitations imposed by persistent data gaps. KW-GIS has also served as a powerful diagnostic tool, effectively mapping areas of operational failure and providing a clear evidence base for targeted interventions. Overall, the system has been partially successful, improving revenue generation and administrative clarity, yet constrained by foundational data deficiencies.

To consolidate gains and enhance the long-term effectiveness of KW-GIS, three key recommendations were proposed:

i. **Targeted data remediation:** Prioritize field data collection and community enumeration in areas identified as "Completely Missing" or "Partially Missing" that overlap with high unpaid bill hotspots. Deploy mobile GIS technologies for on-site capture of land size, land use, and ownership information, complemented by provisional billing measures and limited-time amnesty programs to encourage compliance and rapidly bring properties into the revenue net.

ii. **Institutionalize data governance:** Establish a formal Data Governance Unit within KW-GIS responsible for enforcing data standards, conducting continuous audits, and integrating new information from surveys, planning permissions, and property transactions into the live database. This will ensure sustained data quality and operational efficiency over time.

iii. **Enhance Analytical and Integrated Systems:** Develop KW-GIS into a fully integrated Land Information System with advanced spatial decision support capabilities. This would enable predictive modeling of arrears hotspots, optimize field operations, and prioritize revenue

interventions based on data, while also facilitating cross-validation of property records with other institutional databases to improve accuracy and currency.

CONTRIBUTIONS TO KNOWLEDGE

This study contributes to the literature on geospatial land administration by establishing the critical link between data quality and revenue performance. It provides a methodological framework for integrating spatial analysis with administrative data to identify operational inefficiencies and informs future research avenues, including socioeconomic drivers of non-compliance, longitudinal analyses of revenue and data trends, cost-benefit evaluations of data remediation campaigns, and the potential application of machine learning to predict missing cadastral attributes. These insights offer both practical and theoretical foundations for enhancing land charge systems in developing urban contexts.

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