DEVELOPMENT OF WEB-BASED CADASTRAL INFORMATION SYSTEM FOR SECURE LAND ADMINISTRATION IN GVH MATOLA, TA MATOLA, BALAKA DISTRICT.

ALICE CHIMANGENI (GIS/200/21)

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DEPARTMENT OF EARTH SCIENCES

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DECLARATION

I, Alice Chimangeni, hereby confirm that the research project titled "Web-Based Cadastral Parcel Information System for Secure Land Administration In GVH Matola, TA Matola, Balaka District, Malawi" is my original work. I have never submitted it to any other institution for academic purposes. Any information sourced from other authors has been properly acknowledged and referenced.

DISSERTATION APPROVED BY:

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Ms. Agness Hamisi



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DATA DISCLAIMER

The parcel data used in this study were provided by the Department of Surveys, Malawi, strictly for academic purposes related to this dissertation. The author does not claim copyright or ownership of the data. Any reproduction, redistribution, or commercial use of the data is prohibited without explicit permission from the Department of Surveys.

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ACRONYM/ABBREVIATION	MEANING
API	Application Programming Interface
CLI	Customary Land Institution
CLCs	Community Land Committees
CSS	Cascading Style Sheets
DCLIS	Digital Cadastral Land Information System (Pakistan)
DFD	Data Flow Diagram
EPSG	European Petroleum Survey Group
ERD	Entity Relationship Diagram
FFPLA	Fit-For-Purpose Land Administration
GeoJSON	Geographic JavaScript Object Notation
GESI	Gender Equality and Social Inclusion
GIS	Geographic Information System(s)
GPS	Global Positioning System
GVH	Group Village Head
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
ID	Identification
ILRG	Integrated Land and Resource Governance (USAID program)
JS	JavaScript
JSON	JavaScript Object Notation
LADM	Land Administration Domain Model
LAIS	Land Administration Information System
LIS	Land Information System

MAST	Mobile Application to Secure Tenure (World Bank/GLTN)
MSDC	Malawi Spatial Data Client
MWK	Malawian Kwacha (currency)
NLIMS	National Land Information Management System
OGC	Open Geospatial Consortium
PostGIS	PostgreSQL Spatial Extension
PostgreSQL	Postgres Structured Query Language
QGIS	Quantum Geographic Information System
REST	Representational State Transfer
RLS	Row-Level Security
RMSE	Root Mean Square Error
SDG	Sustainable Development Goal (especially SDG 5)
SMS	Short Message Service
SQL	Structured Query Language
TA	Traditional Authority
TLMA	Traditional Land Management Area
UML	Unified Modeling Language
UPIN	User Personal Identification Number
WGS 84	World Geodetic System 1984

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ABSTRACT

Rural land administration in Malawi remains paper-based, causing missing records, boundary disputes, fraud, delays, and non-compliance with land use plans. This study developed a web-based cadastral system, named Matola LandInfo, for secure land administration in GVH Matola, TA Matola, Balaka District. The specific objectives were to: (i) create a comprehensive digital cadastral database; (ii) integrate land use planning data with parcel information through spatial overlay analysis; and (iii) develop a secure parcel management system that links each parcel to verified owners and tracks payments and rent status

The methodology followed a hybrid systems development life cycle combining Waterfall and Agile elements. Using 1,557 GPS collected parcel records, spatial data was topologically cleaned and validated in QGIS. Riparian buffers (15 m) were generated to assess land use compliance The database was built on PostgreSQL and migrated to Supabase cloud platform. A Python backend on Render, and an HTML5/CSS3/JavaScript frontend with Leaflet.js on Netlify. System validation encompassed data integrity, API functionality, performance, and user acceptance testing.

Results showed zero geometric overlaps after cleaning. Payment records indicated 70.1% of parcels fully paid. The land use overlay flagged 35% of parcels violating buffer zones. The client portal enabled public verification, reducing fraud. All queries returned results in under three seconds.

Matola LandInfo demonstrates that low-cost, fit-for-purpose web GIS can transform customary land administration, offering a replicable model for tenure security, transparency, and compliance monitoring in Malawi without requiring costly physical inspections.

INTRODUCTION

1.1 BACKGROUND INFORMATION

Land is the most fundamental asset for rural communities in Malawi, serving as a source of livelihood, shelter, and cultural identity. In GVH Matola, located within Traditional Authority Matola in Balaka District, land remains the primary means of survival for households engaged in subsistence agriculture and small-scale economic activities. Despite its critical importance, land administration in the area has historically been managed through traditional, paper-based systems that are increasingly failing to meet the needs of a growing population facing modern pressures such as land scarcity, population growth, and climate-related challenges (Chilonga, 2018).

The current land management system in GVH Matola is characterized by fragmented record-keeping, where boundary descriptions are often verbal or documented on deteriorating paper files vulnerable to fire, water damage, and pests (Chilonga, 2018). This lack of secure, centralized records has led to persistent challenges including boundary overlaps between neighboring parcels, fraudulent land transactions where the same piece of land is sold multiple times to unsuspecting buyers, and excessive delays in processing land registrations that can take months or even years to complete (Lisec & Ferlan, 2022). Furthermore, without integration with approved land use plans, the community experiences improper land utilization where residential development occurs on land designated for agriculture or protected areas, requiring costly physical inspections that are rarely conducted due to resource constraints at the local level (Yılmaz et al., 2023).

The consequences of these systemic failures are severe. Families lack documented proof of ownership, making them vulnerable to displacement and land grabbing (Bennett et al., 2021). Boundary disputes frequently escalate into conflicts that strain community relationships and consume valuable time of traditional leaders who could otherwise focus on development matters (Azie et al., 2024). Fraudulent transactions erode trust in the land administration process, while registration delays discourage formal documentation, pushing community members toward informal arrangements that offer no legal protection (Uşak et al., 2024). Additionally, the absence of accurate spatial data hinders development

planning by the Traditional Authority and Balaka District Council, limiting their ability to make informed decisions about infrastructure development, service delivery, and climate adaptation strategies (Uşak et al., 2024).

In response to these challenges, the Government of Malawi has prioritized land reform through the National Land Policy, which emphasizes the need for modern, technology-driven land administration systems that can secure tenure rights and support sustainable development (ILRG, 2023). Geographic Information Systems (GIS) and web-based technologies have emerged as powerful tools for transforming land management, offering capabilities for accurate mapping, spatial analysis, and transparent record-keeping (Chigbu et al., 2021). These technologies enable the creation of digital cadastral databases that can map parcel boundaries with precision, detect overlaps through automated topology validation, link parcels to verified owners with immutable transaction histories, and overlay land use plans to ensure compliance without requiring physical inspections (Obe & Hsu, 2021).

1.2 PROBLEM STATEMENT

GVH Matola, under Traditional Authority Matola in Balaka District, continues to rely on a manual, paper-based land administration system that has proven fundamentally inadequate for secure and efficient land management. This outdated approach has resulted in five critical challenges: missing files where land records are frequently lost or destroyed due to lack of proper storage and backups (Chilonga, 2018); boundary overlaps causing disputes between neighbors because there are no accurate maps showing where one parcel ends and another begins (Lisec & Ferlan, 2022); fraudulent transactions where dishonest people sell the same parcel to multiple buyers or forge ownership documents due to lack of reliable verification (Bennett et al., 2021); excessive delays in registration where processing can take months or years because staff must manually search through paper records and conduct physical site inspections that rarely happen due to limited resources (Uşak et al., 2024); and improper land usage where people build on land meant for

farming or protected areas because there is no system to check parcel information against approved land use plans (Yılmaz et al., 2023).

These systemic failures have created an environment where land tenure is insecure, disputes are common, and community members cannot trust the registration process (Azie et al., 2024). Families lack documented proof of ownership, fraud goes undetected, and traditional leaders spend valuable time resolving conflicts instead of focusing on development (Chilonga, 2018). Without accurate digital records linking each parcel to verified owners and land use plans, the Traditional Authority cannot effectively plan for development or ensure compliance with regulations (Uşak et al., 2024). There is an urgent need for a web-based cadastral information system that can map all parcels, overlay them with land use plans, enable real-time verification of transactions, and allow owners to track their registration status bringing transparency, efficiency, and security to land administration in GVH Matola (Chigbu et al., 2021).

1.3 MAIN OBJECTIVE

To design and develop a web based cadastral parcel information system for secure land administration.

1.4 SPECIFIC OBJECTIVES

i. To create a comprehensive digital cadastral database with accurate boundary coordinates linked to ownership information.
ii. To integrate land use planning data with parcel information through spatial overlay analysis.
iii. To develop a secure cadastral management system that links each land parcel to verified owners, tracks transaction history and distinguishes between paid and unpaid rental statuses.

1.5 RESEARCH QUESTIONS

i. To what extent can a web-based cadastral information system reduce land disputes and boundary conflicts in GVH Matola through automated overlap detection and accurate digital mapping?
ii. What impact does an integrated land use planning overlay have on compliance with district land use regulations in GVH Matola?
iii. How effective is a cadastral parcel management system in preventing fraudulent land transactions, registration processing duration, and ensuring secure ownership verification in Traditional Authority Matola?

1.6 SIGNIFICANCE OF STUDY

This study is significant to the GVH Matola community as it will provide secure digital land records that protect families from displacement, fraud, and boundary disputes (Bennett et al., 2021). For the first time, every landowner in the area will have verified proof of ownership accessible through a transparent system, empowering vulnerable groups including women and the elderly who are often most affected by land grabbing. The client tracking portal will make registration process less stressful, allowing community members to monitor their applications without relying on middlemen or incurring additional costs (Uşak et al., 2024). By reducing boundary overlaps and eliminating missing files, the system will help traditional leaders resolve disputes more quickly and fairly, restoring trust in the land administration process and bringing peace to the community (Azie et al., 2024).

Additionally, this study directly supports Sustainable Development Goal number 5 which talks about Gender Equality because Balaka District is a matrilineal area where land inheritance and ownership traditionally pass through women. However, the paper based system has failed to document women's rights, leading to disputes when male relatives or outsiders challenge female ownership. By linking each parcel to a verified owner (with National ID and gender recorded), Matola landInfo provides legally defensible proof of

women's land rights, reducing gender-based land conflicts and empowering women as secure landholders.

For Traditional Authority Matola, Balaka District Council, and Malawi as a whole, this study will establish a replicable model for modern land administration that enhances governance and supports national land reform goals (ILRG, 2023). The system's ability to distinguish paid from unpaid parcels ensures accountability in rental collections, while the land use overlay module enables effective development planning without costly physical inspections (Chigbu et al., 2021). The methodologies developed for parcel mapping, overlap detection, and client tracking can be scaled to other traditional authorities across Balaka and beyond, supporting the government's commitment to secure land tenure for all Malawians as envisioned in the National Land Policy (Chilonga, 2018). Ultimately, this study demonstrates how low-cost web-based GIS solutions can transform land administration, contributing to reduced land disputes, faster registrations, and sustainable development across the country (Yılmaz et al., 2023).

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents a systematic and critical examination of contemporary literature on cadastral information systems, with a focus on web-based solutions for secure land administration in developing countries. The review progresses from global trends to regional experiences across sub-Saharan Africa, and finally to the specific policy and implementation context of Malawi.

For each thematic section, the review evaluates existing research by examining methodological strengths, successful case studies, validated theories and also limitations, gaps and conflicting findings. The analysis pays attention to research designs, theoretical frameworks, and methodological choices. By synthesising evidence from literature published mainly between 2020 and 2026 with Chilonga 2018 as the sole pre 2020

exception, this chapter establishes the theoretical and empirical foundations for the Matola LandInfo system, while identifying the specific research gaps that this study addresses.

2.2 GLOBAL TRENDS IN CADASTRAL SYSTEMS

2.2.1 From Paper to Digital

Positive contributions: Recent systematic reviews (Uşak et al., 2024) have established that open-source spatial databases (PostgreSQL/PostGIS) and web mapping libraries (Leaflet, OpenLayers) have significantly lowered the technical and financial barriers to cadastral systems in resource-constrained settings. The Fit for Purpose Land Administration (FFPLA) framework has been validated through multi country studies. Chigbu et al. (2021) presented case studies from Ghana, Kenya, and Namibia, providing evidence that FFPLA using participatory boundary demarcation, general boundaries, and low cost technologies offers a realistic path to tenure security in Africa. Their action research methodology (researchers embedded in local land administration projects) lends credibility to the findings.

Negative aspects: Despite theoretical appeal, implementation challenges remain. Musinguzi, Enemark and Mwesigye (2021), drawing on data from Uganda's national FFPLA strategy development, identified that uncoordinated pilot projects are potential sources of inconsistencies in data and products, which may be difficult to harmonise at a national level. A methodological weakness in FFPLA literature is that many evaluations are conducted by the same organisations that implement the projects, creating potential conflicts of interest seldom acknowledged.

2.2.2 Land Administration Domain Model (LADM) and Standards Adoption

Positive contributions: Yılmaz, Gürsoy Sürmeneli and Alkan (2023) proposed a spatial land-use planning system data model for LADM Edition II using a design science research methodology (cross-country analysis of OECD land-use databases plus UML schema design). Their work demonstrates how cadastral and land use data can be theoretically integrated a concept directly relevant to the buffer overlay analysis in Matola LandInfo. Recent developments (Lemmen, van Oosterom & Kara, 2025) have seen the first five parts

of LADM Edition II published as ISO standards, with Part 5 specifically addressing spatial plan information.

Negative aspects: LADM adoption in developing countries remains limited and largely aspirational. Azie, Egolum and Emoh (2024), studying Southeast Nigeria, found that while LADM provides an excellent conceptual framework, implementation faces translation problems – the gap between ISO standards and on the ground realities. Their study is largely descriptive rather than evaluative, lacking quantitative metrics on implementation success. Furthermore, Yılmaz et al.'s proposal did not include field or empirical validation, raising questions about practical feasibility.

2.2.3 3D Cadastres (Brief Note)

Positive contributions: Shahidinejad, Kalantari and Rajabifard (2024) conducted a systematic literature review of 3D cadastral database systems, establishing a useful taxonomy of architectural patterns and data models.

Negative aspects: Most 3D cadastre research remains conceptual or prototype based, with limited large-scale empirical validation. Moreover, 3D cadastre research is almost exclusively focused on urban contexts and has limited relevance to rural customary land administration where basic 2D parcel mapping remains an unmet priority.

2.3 WEB BASED CADASTRAL SYSTEMS IN DEVELOPING COUNTRIES

2.3.1 Pakistan's Digital Cadastral Land Information System (DCLIS)

Positive contributions: Hassan, Munir, Yue, Ahmed and B.G. (2024) developed a web-based Digital Cadastral Land Information System (DCLIS) for Pakistan, integrating geo-referencing and land information systems. The study's methodological strength lies in its use of tools ArcGIS for geo-referencing, data visualisation, interactive queries and the validation of 20 % of cadastral plots against field measurements. The authors demonstrated that web based cadastral systems can improve land policy planning and streamline ownership verification.

Negative aspects: The DCLIS validation protocol validated only 20 % of parcels, leaving 80 % of the cadastral database unchecked for positional or attribute errors. The study does

not specify the sampling method used nor report the types or frequencies of errors detected. Performance metrics like query response times and user satisfaction are absent. The publication venue a low impact journal with unclear peer review standards further limits the weight of its findings.

2.3.2 Cameroon's Tier 3 WebGIS Cadastre

Positive contributions: A 2024 study developed a tier 3 WebGIS system using open-source platforms QGIS, PostgreSQL and GeoServer, providing a replicable technical blueprint.

Negative aspects: The study is reported as a book, not a peer reviewed journal article, raising concerns about review rigour. The research design is unclear it does not specify whether the system was deployed and tested with real users. No error rates, validation results, or user acceptance metrics are reported.

2.4 SUB-SAHARAN AFRICAN EXPERIENCES WITH CUSTOMARY LAND ADMINISTRATION

2.4.1 Ghana: Customary Land Secretariats and Interoperability Challenges

Positive contributions: Approximately 80 % of Ghana's land is held under customary tenure. A 2024 study by Kwakye et al. examined determinants of sustainable Customary Land Secretariats using an econometric modelling approach, providing quantitative evidence on factors predicting long term viability.

Negative aspects: A 2024 study by University of Twente researchers assessed cadastral data interoperability among land agencies in Accra, revealing persistent challenges: semantic heterogeneities, lack of metadata, inconsistent use of data standards, absence of an integrated web-based platform, and a culture of resistance to data sharing. The proposed solution which was a five component model including interoperability governance guidelines remains theoretical, with no implementation or evaluation.

2.4.2 Nigeria: Institutional Analysis and LADM Implementation

Positive contributions: A 2023 study in Land Use Policy developed an adapted institutional analysis and development (IAD) framework specifically for customary land institutions in

sub-Saharan Africa, tested in Ile Ife. This provides a structured diagnostic tool for identifying weaknesses in customary land governance.

Negative aspects: The framework has only been tested in a single Nigerian case study and requires further exploration in other contexts. Azie, Egolum and Emoh (2024) found that despite the LADM framework, implementation in Southeast Nigeria has been slow due to institutional fragmentation and limited technical capacity. Their research is largely descriptive, lacking quantitative evaluation.

2.4.3 Uganda: National FFPLA Implementation Strategy

Positive contributions: Musinguzi, Enemark and Mwesigye (2021) conducted a rigorous evaluation of how three FFPLA pilot projects informed Uganda's national implementation strategy, using multiple data collection methods like document review, field visits and interviews. The study identified that pilot projects are beneficial for highlighting gaps in spatial, legal and institutional frameworks.

Negative aspects: The same study identified that uncoordinated pilot projects are potential sources of inconsistencies in data and products a finding directly relevant to Malawi. A methodological limitation is that the authors were direct participants in the strategy development process, creating potential bias not fully addressed.

2.5 LAND ADMINISTRATION IN MALAWI

2.5.1 Legal and Policy Framework

Positive contributions: The National Land Policy (2016) and the Customary Land Act (2016) provide a clear legal mandate for customary land documentation. A 2024 government report notes that "some of the key functions that are being devolved are local land use planning, land surveying, registration of land parcels, granting of leases and payment of ground rent."

Negative aspects: Despite strong policy frameworks, implementation has lagged significantly. Chilonga (2018) documented inadequate human resources, insufficient physical infrastructure, and limited technology adoption. The Land Information

Management System (LIMS) launched in February 2024 lacks independent, peer reviewed evaluation of its performance.

2.5.2 ILRG Customary Land Documentation Project

Positive contributions: The USAID-funded ILRG project documented customary land across an entire Traditional Land Management Area in Nkhotakota District, using an inclusive fit-for-purpose approach (MAST methodology) with community consultation, boundary mapping, dispute resolution, and public viewing periods. A gender equality and social inclusion (GESI) lens was explicitly applied.

Negative aspects: The ILRG report is grey literature (project report, not peer-reviewed). Methodological details are insufficiently specified: error rates, dispute resolution success rates, and system performance metrics are not reported. The project was externally funded, raising questions about sustainability after donor funding ends a gap that Matola LandInfo addresses.

2.5.3 Broader African Context

Positive contributions: A 2025 review of land tenure governance in 18 countries (16 in Africa, 2 in Asia) found that customary land remains under documented across most African countries. The Global Land Tool Network (GLTN) has developed open source tools (MAST, STDM) demonstrating technical feasibility of participatory, low cost land documentation.

Negative aspects: The literature is dominated by project reports and grey literature, with a scarcity of rigorous, peer-reviewed, longitudinal evaluations. There is a notable absence of studies that have tracked registered customary landowners over multiple years to measure actual improvements in tenure security or investment behaviour.

1.6 TECHNICAL METHODOLOGIES FOR CADASTRAL INFORMATION SYSTEMS

2.6.1 PostGIS for Cadastral Applications

Positive contributions: Obe and Hsu (2021) and Corti, Kraft and Kralidis (2020) provide comprehensive documentation of PostGIS capabilities: spatial data types, R-tree indexing,

geometry validation (ST_IsValid), overlap detection (ST_Overlaps, ST_Intersects), buffer generation (ST_Buffer), and spatial overlay. Lisec and Ferlan (2022) conducted a comparative case study in North Macedonia and Slovenia, using survey coordinates as ground truth to assess digitised cadastral boundaries. Their methodological rigour is notable: they computed RMSE (Root Mean Square Error), finding positional errors of 48-56 cm and area errors of 23-26 m².

Negative aspects: Lisec and Ferlan (2022) and Matijević and Roić (2021) are European case studies, and their findings may not fully generalise to sub-Saharan Africa. Neither study addresses PostGIS performance on very large datasets or in low bandwidth environments limitations relevant to rural Malawi.

2.6.2 Cloud Databases and Backend as a Service (Supabase)

Positive contributions: Lorenz (2024) provides a comprehensive guide to Supabase (database design, Row Level Security, real time subscriptions). Yazdankhah (2025) conducted a comparative analysis of Firebase vs Supabase, concluding that Supabase is superior for spatial applications because it supports PostGIS natively. Supabase has achieved significant adoption (650,000+ databases, 400,000+ developers).

Negative aspects: The academic literature on Supabase for cadastral applications is extremely limited. Lorenz (2024) and Yazdankhah (2025) are a technical book and a Bachelor's thesis not peer-reviewed journal articles. There are no published, peer-reviewed studies evaluating Supabase performance for cadastral workloads.

2.6.3 Mobile/Participatory Data Collection and Frontend Tools (Leaflet, QGIS, MAST)

Positive contributions: Sukojo and Lisakiyanto (2021) demonstrated the use of Leaflet JavaScript library for web-based GIS in a developing country (Indonesia), confirming that Leaflet is a lightweight, open source mapping library suitable for rural web applications with limited bandwidth. The World Bank's Mobile Application to Secure Tenure (MAST, 2024) provides a field-ready participatory mobile mapping tool using GPS and satellite imagery directly parallel to the data collection method used in this study. QGIS, documented by Corti et al. (2020), has been widely used for topology cleaning and spatial

analysis in resource-constrained cadastral projects. The ILRG Malawi project (2023) successfully used mobile data collection (ODK, MAST) for participatory boundary demarcation.

Negative aspects: Sukojo and Lisakiyanto's system was designed for forest fire monitoring, not land administration the application domain differs, though the technical approach (Leaflet + web GIS) is transferable. The MAST tool has been used in multiple African countries, but peer-reviewed evaluations of its accuracy, usability, and scalability are scarce. QGIS topology cleaning, while powerful, requires trained operators, a constraint in contexts with limited GIS capacity.

TABLE 1: KEY STUDIES' METHODOLOGIES

Author (yr)	Research design	Data sources	Key analytical method	Validation / error handling
Lisec & Ferlan (2022)	Comparative case study (North Macedonia, Slovenia)	Survey coordinates (ground truth) vs. digitised boundaries	RMSE, area difference analysis	Reported positional errors (48–56 cm) and area errors (23–26 m²)
Matijević & Roić (2021)	Case study with quality control (3 Croatian municipalities)	Scanned map sheets, vectorised map, vectorisation reports	Systematic gap analysis; cross-checking register vs. map	Identified 5.6 % non-compliant parcels; distinguished systemic vs. maintenance errors
Hassan et al. (2024)	Web-based system development (Pakistan)	Manual land records, paper maps	Map georeferencing, data visualisation, interactive queries	Validated 20 % of plots against field measurements; sampling method not specified
Yılmaz et al. (2023)	Design research (conceptual modelling)	OECD land-use database, planning system reports	Cross-country analysis; UML schema design	No field or empirical validation; proposal remains conceptual

Bennett et al. (2021)	Systematic literature review	Peer-reviewed literature, reports, case studies (1970s–2020)	Thematic synthesis; framework development	Validated by UN-endorsed Framework for Effective Land Administration
ILRG (2023)	Project implementation (grey literature)	Field data from customary land documentation in Malawi	Participatory mapping, MAST methodology	Error rates not reported; no independent evaluation

1.7 RESEARCH GAPS AND JUSTIFICATION FOR THE PRESENT STUDY

The systematic review reveals several critical gaps that the Matola LandInfo study is designed to address:

Lack of peer-reviewed, community scale cadastral system evaluations in Malawi. No peer reviewed study has documented the complete technical workflow from participatory GPS data collection through topology validation to web-based deployment for a customary land area in Malawi.

Insufficient methodological rigour in existing validation protocols. The Pakistan DCLIS study validated only 20 % of parcels; the Cameroon study did not report error rates. No published study has performed 100 % topological validation of a customary land dataset using PostGIS functions in sub Saharan Africa.

Absence of integrated land-use compliance monitoring. While Yılmaz et al. (2023) proposed a LADM based land use data model, no published study has implemented automated buffer zone analysis (e.g., riparian buffers) integrated with a web based cadastral system in a developing country.

Limited empirical evidence on fraud prevention and client transparency. The theoretical benefits of client tracking portals are well argued, but empirical data from actual implementations are scarce. The ILRG report mentions public viewing periods but does not quantify fraud reduction.

Internet dependency remains unaddressed. Multiple studies acknowledge that web-based systems require connectivity, but none have developed or evaluated offline-capable fallbacks for rural areas.

The Matola LandInfo study addresses Gaps 1 to 4 directly while noting Gap 5 as a limitation for future work.

METHODOLOGY

3.1 DESCRIPTION OF STUDY

The study was conducted in GVH Matola (Group Village Head Matola), which falls under Traditional Authority Matola in Balaka District, located in the Eastern Region of Malawi. Balaka District is bordered by Mangochi District to the north, Ntcheu District to the west, Machinga District to the east, Neno and Zomba District to the south.

GVH Matola is a rural community where the primary economic activity is subsistence agriculture, with smallholder farmers growing crops such as maize, groundnuts, beans, and vegetables. The area experiences a tropical climate with distinct wet and dry seasons, receiving annual rainfall between primarily from November to April. Like many rural areas in Balaka District, GVH Matola faces challenges including land scarcity, population pressure, and vulnerability to climate-related hazards such as droughts and occasional flooding.

Land in GVH Matola is predominantly customary land, held under traditional tenure systems managed by the Traditional Authority and village heads. The community relies heavily on land for food security, shelter, and income generation. However, the lack of formal land documentation and accurate cadastral records has led to increasing boundary

disputes, fragmented record-keeping, and vulnerability to land grabbing. The area was selected for this study because it represents a typical Malawian rural community facing real land administration challenges, making it an ideal location to test and implement the Matola LandInfo web-based cadastral parcel information system.

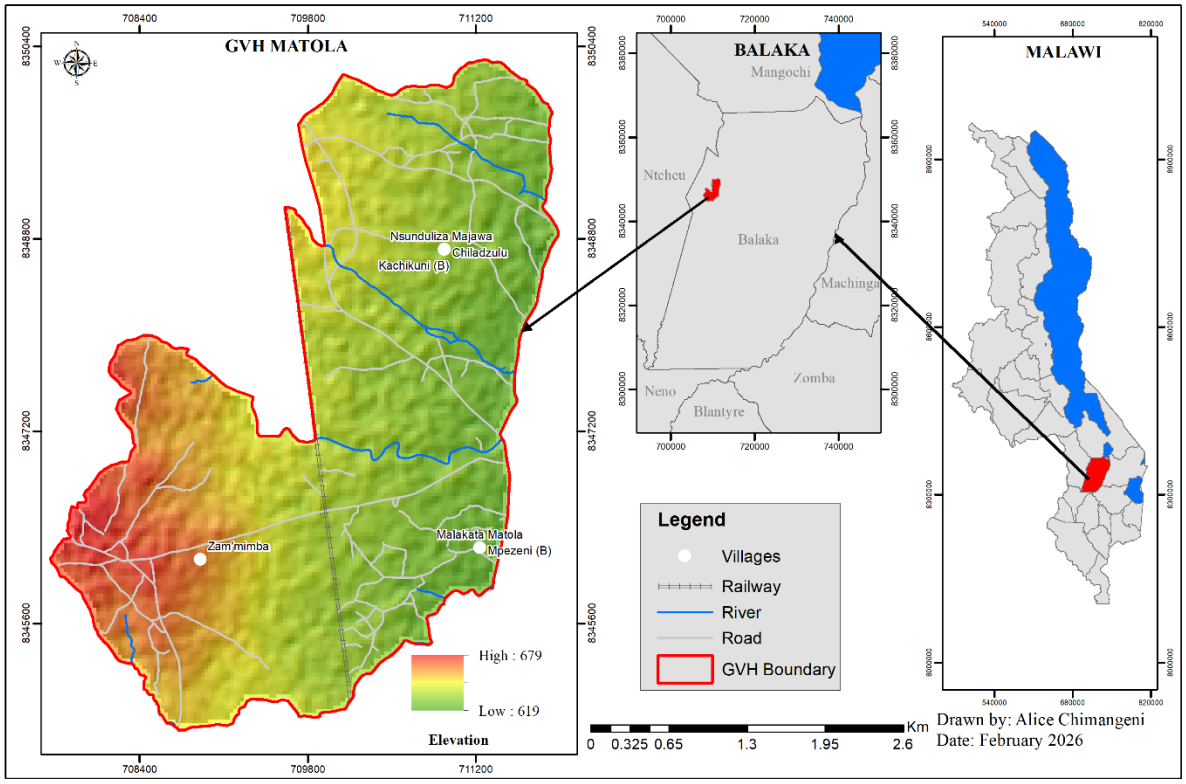


Figure 1: Study area Map for GVH Matola, TA Matola, Balaka district, Malawi.

3.2 RESEARCH DESIGN

This study adopts a quantitative research design because it focuses on analyzing parcel data to address the land administration challenges in GVH Matola. The research involves working with 1,557 parcel records that contain quantifiable attributes such as parcel boundaries (X and Y coordinates), calculated area in hectares, distances to roads and rivers in meters, buffer zone compliance flags, and rental payment status (Lisec & Ferlan, 2022). These numerical measurements ensures performance of spatial analysis, detection of boundary overlaps through automated topology validation, measuring of registration

processing times, and generation of statistical reports on paid versus unpaid parcels.

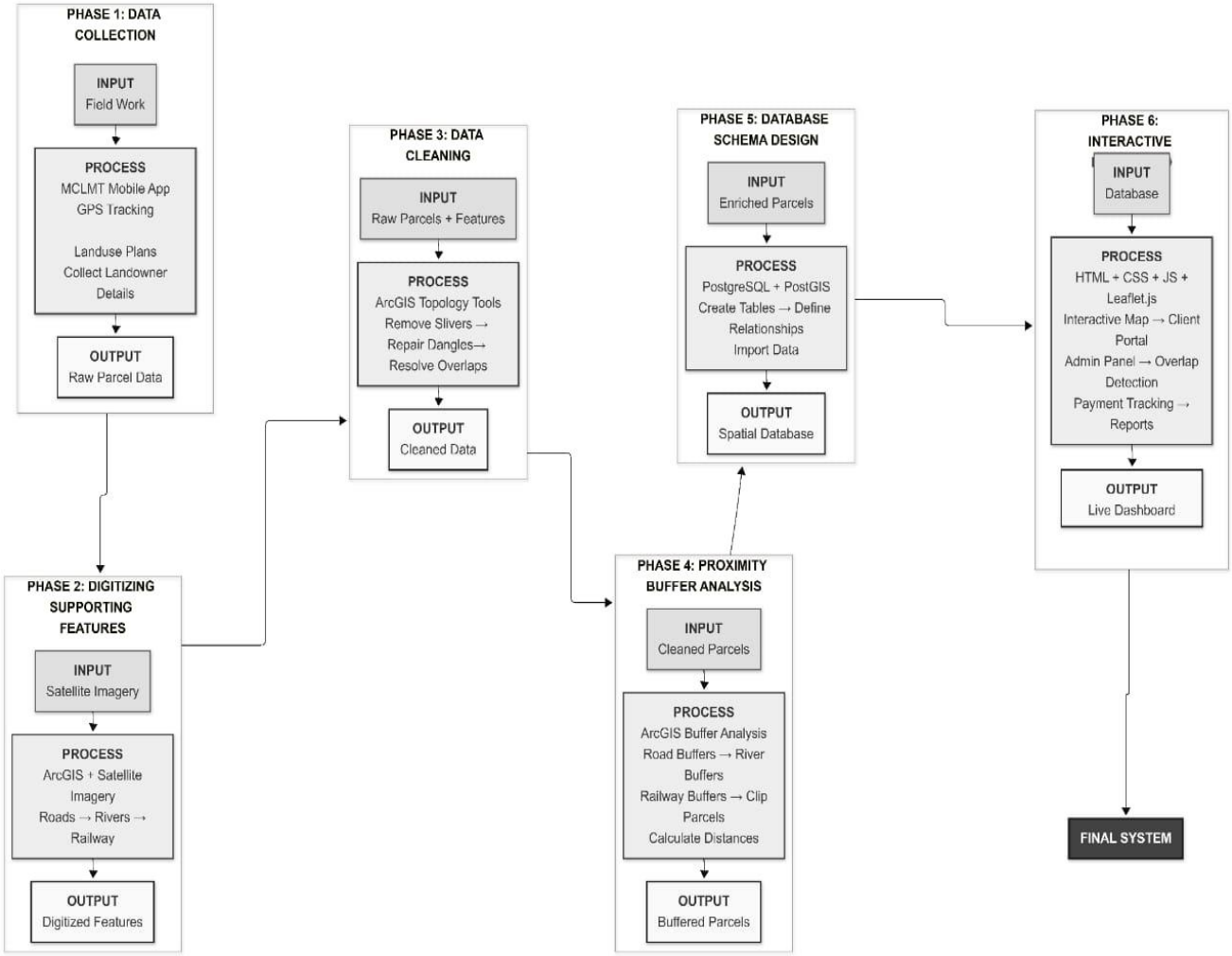


Figure 2: Research Methodology

Figure two shows all steps to be undertaken in this research. From Data, collection, Digitization, data cleaning, proximity buffer analysis, database design and system development. Figure 3 also shows a workflow but specifically for the Interactive system development.

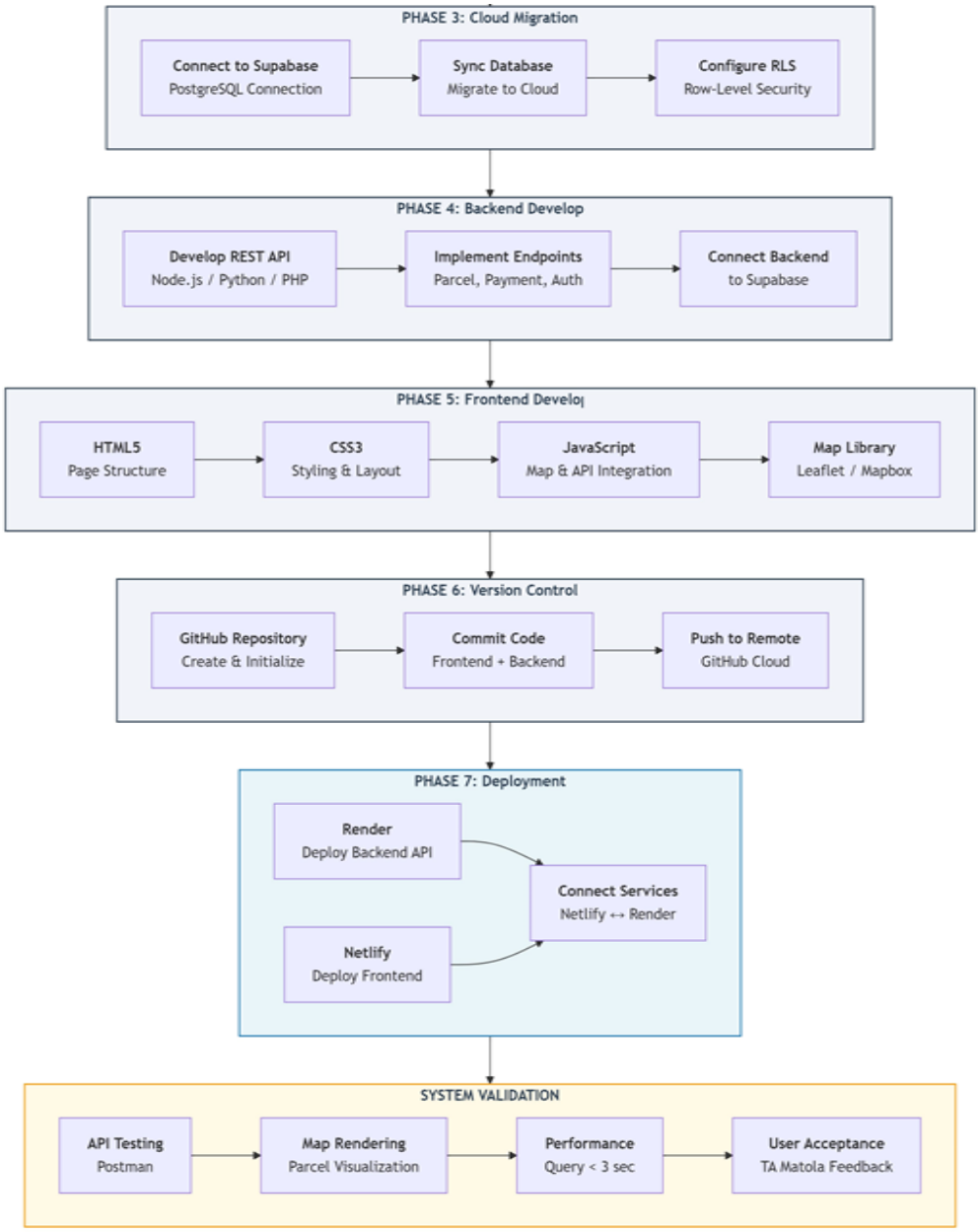


Figure 3: System Development Workflow Of Matola LandInfo

3.2.1 Functional requirements and use cases

To capture the functional requirements of the Matola LandInfo system, a use case diagram was developed to model interactions between external actors and the system (Iqbal et al., 2020; Frattini & Frattini, 2025). Figure 3 presents the use case diagram, identifying five

primary actors: Applicant who is the Land owner seeking land registration, Land Registrar who is the district council official processing applications, and GIS Technician who processes data and configures the system, Planner who verifies if registration is happening in line with the Land use plans, and Accountant who processes payments. Key use cases include: Registration application, Verify ownership, Manage user accounts, Process registration, Check landuse, track registration status, Data processing and payment processing.

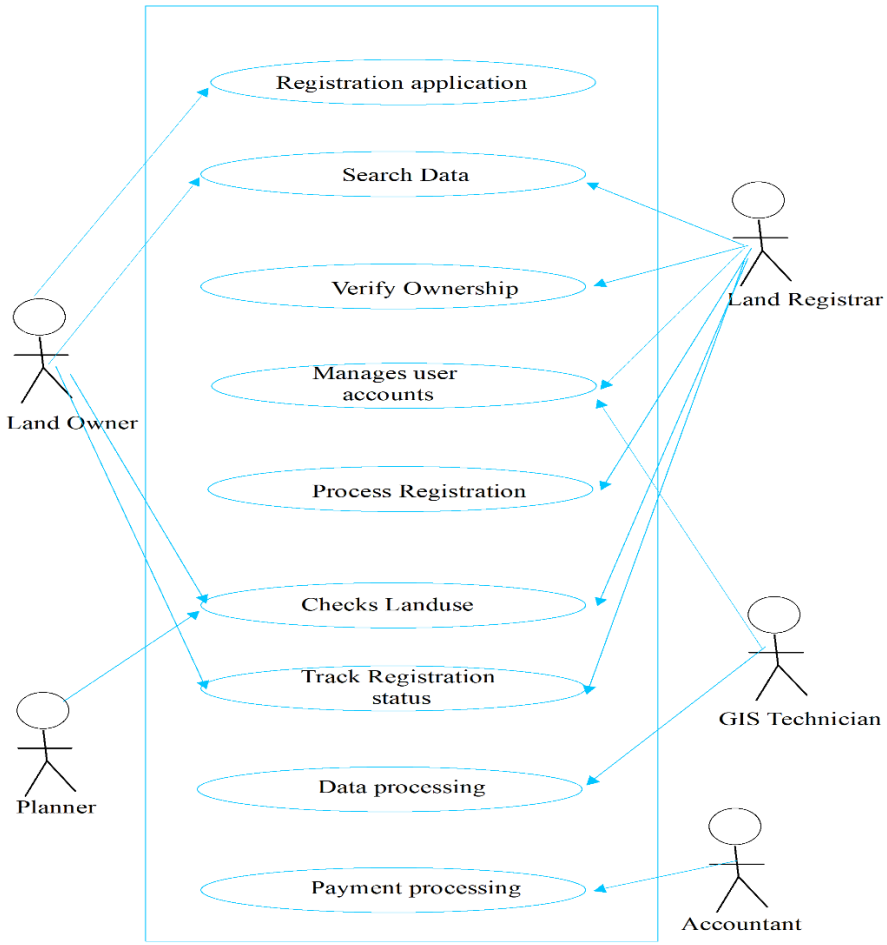


Figure 4: Use case diagram

3.3 SYSTEM DEVELOPMENT APPROACH

This project adopted a hybrid systems development life cycle combining Waterfall and Agile elements (Pervoukhin et al., 2020; Prenner et al., 2020). The database design, data cleaning, and spatial analysis phases followed a linear Waterfall approach, as requirements were well defined from the outset.

The Waterfall methodology was suitable for this project for several reasons. First, the project followed a linear sequence of literature review, data collection, database design, cleaning, buffer analysis, web development, and testing, which aligns naturally with Waterfall (Yahya & Maidin, 2022). Second, the requirements were well defined before coding began; parcel mapping, overlap detection, payment tracking, and a client portal were planned and well defined in advance. Third, Waterfall emphasises documentation, including the Entity Relationship Diagram, use case diagrams, and schema designs, which is essential for an academic dissertation. Fourth, because the system is database centric (PostGIS), Waterfall allowed the schema to be fully designed upfront before building the interface. Finally, the linear nature of Waterfall made it easier to estimate completion dates and meet the fixed submission deadline.

However, the web interface development comprising the dashboard, parcel map, registration form, payments, and client portal employed iterative prototyping (Ballard, 2021). This allowed user feedback from the GVH land registrar to refine each interface module before final integration, incorporating Agile flexibility into an otherwise Waterfall framework.

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3.4 MATERIAL AND METHODS

3.4.1 Data Collection

The digitization of infrastructure features, including roads, rivers, and the railway line within the study area, was conducted using ArcGIS software with high-resolution satellite imagery as the primary reference source (Obe & Hsu, 2021). A high-resolution satellite image covering the entire GVH Matola and surrounding areas was downloaded and loaded into ArcGIS as a basemap, providing a clear and georeferenced visual representation of the landscape (ESRI, 2020). The project and all layers were assigned the coordinate reference system WGS 84 (EPSG:4326). Using the editing tools in ArcGIS, roads were digitized as line features by tracing along visible road networks on the satellite image, distinguishing between main roads, secondary roads, and footpaths based on their appearance and width (Corti et al., 2020). Rivers and streams were similarly digitized as line features by following the visible watercourses, capturing both permanent ever-flowing

rivers, and seasonal streams that may only hold water during the rainy season (Lisec & Ferlan, 2022). The railway line, which passes through Balaka, was digitized as a single continuous line feature following its distinct linear pattern visible on the satellite imagery. During the digitization process, attribute tables were populated for each feature type and classified for future analysis (Corti et al., 2020). The resulting digitized infrastructure data was then used for topological cleaning, buffer zone creation, and integration into the Matola's Cadastral database (Uşak et al., 2024).

3.4.2 Digitizing Supporting Features

The digitization of infrastructure features, including roads, rivers, and the railway line within the study area, was conducted using ArcGIS software with high-resolution satellite imagery as the primary reference source (Obe & Hsu, 2021). A high-resolution satellite image covering the entire GVH Matola and surrounding areas was downloaded and loaded into ArcGIS as a basemap, providing a clear and georeferenced visual representation of the landscape (ESRI, 2020). The project and all layers were assigned the coordinate reference system WGS 84 (EPSG:4326). Using the editing tools in ArcGIS, roads were digitized as line features by tracing along visible road networks on the satellite image, distinguishing between main roads, secondary roads, and footpaths based on their appearance and width (Corti et al., 2020). Rivers and streams were similarly digitized as line features by following the visible watercourses, capturing both permanent ever-flowing rivers, and seasonal streams that may only hold water during the rainy season (Lisec & Ferlan, 2022). The railway line, which passes through Balaka, was digitized as a single continuous line feature following its distinct linear pattern visible on the satellite imagery. During the digitization process, attribute tables were populated for each feature type and classified for future analysis (Corti et al., 2020). The resulting digitized infrastructure data was then used for topological cleaning, buffer zone creation, and integration into the Matola's Cadastral database (Uşak et al., 2024).

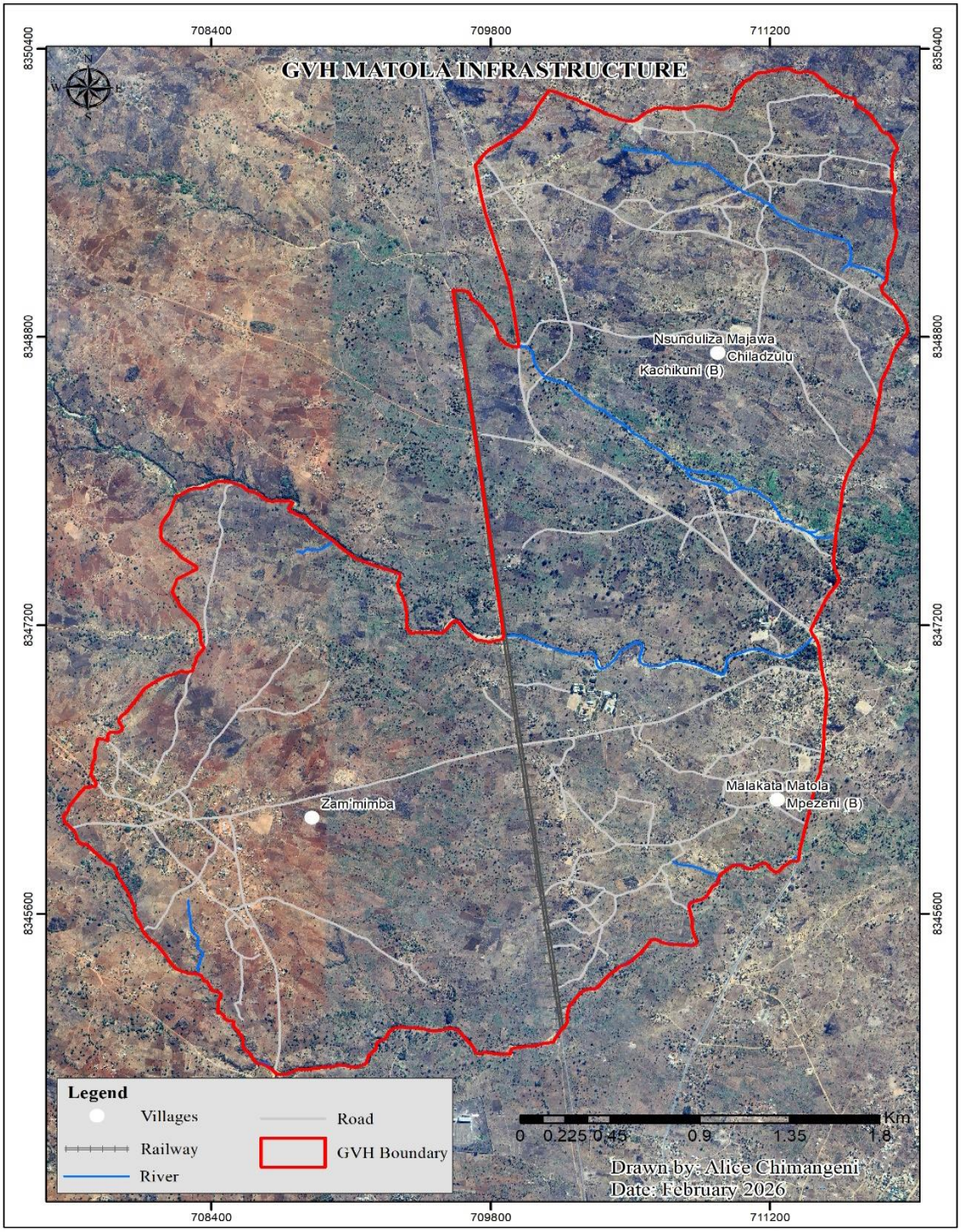


Figure 5: Digitized Matola Infrastructure (Roads, Rivers, Railway

3.4.3 Database Management

PostgreSQL with PostGIS extension serves as the backbone of the Matola Cadastral system, providing a spatially-enabled database environment for storing and managing all cadastral data (Obe & Hsu, 2021). PostGIS transforms PostgreSQL into a powerful spatial database by adding support for geographic objects, allowing the storage geometries alongside traditional attribute data (PostGIS Development Group, 2024). For this project, the PostGIS extension is essential because it enables the system to store parcel boundaries as polygon geometries in a database where ownership records, payment histories, and transaction logs are stored (Lisec & Ferlan, 2022). This eliminates the need for separate file-based storage systems and ensures that spatial and non-spatial data remain consistently linked, reducing the risk of missing files or disconnected records that currently plague the paper-based system in GVH Matola (Chilonga, 2018).

The database schema that in total has 12 tables namely; applicants, parcels, districts, TLMAs, GVHs, Children, CLCs, users, guardians, non-parcels, properties and spatial-ref-sys. Using PostgreSQL CREATE TABLE commands, I manage to add necessary tables to the schema without disrupting original 10 data. (Corti et al., 2020). To summarize the Tables, refer to figures 4 and 5 which show the Entity relationship diagram and Database respectively.

3.4.4 Entity Relationship Diagram

To design the logical structure of the Matola LandInfo database, an Entity Relationship Diagram (ERD) was developed as shown in Figure 4. The ERD models the key entities, their attributes, and the relationships between them.

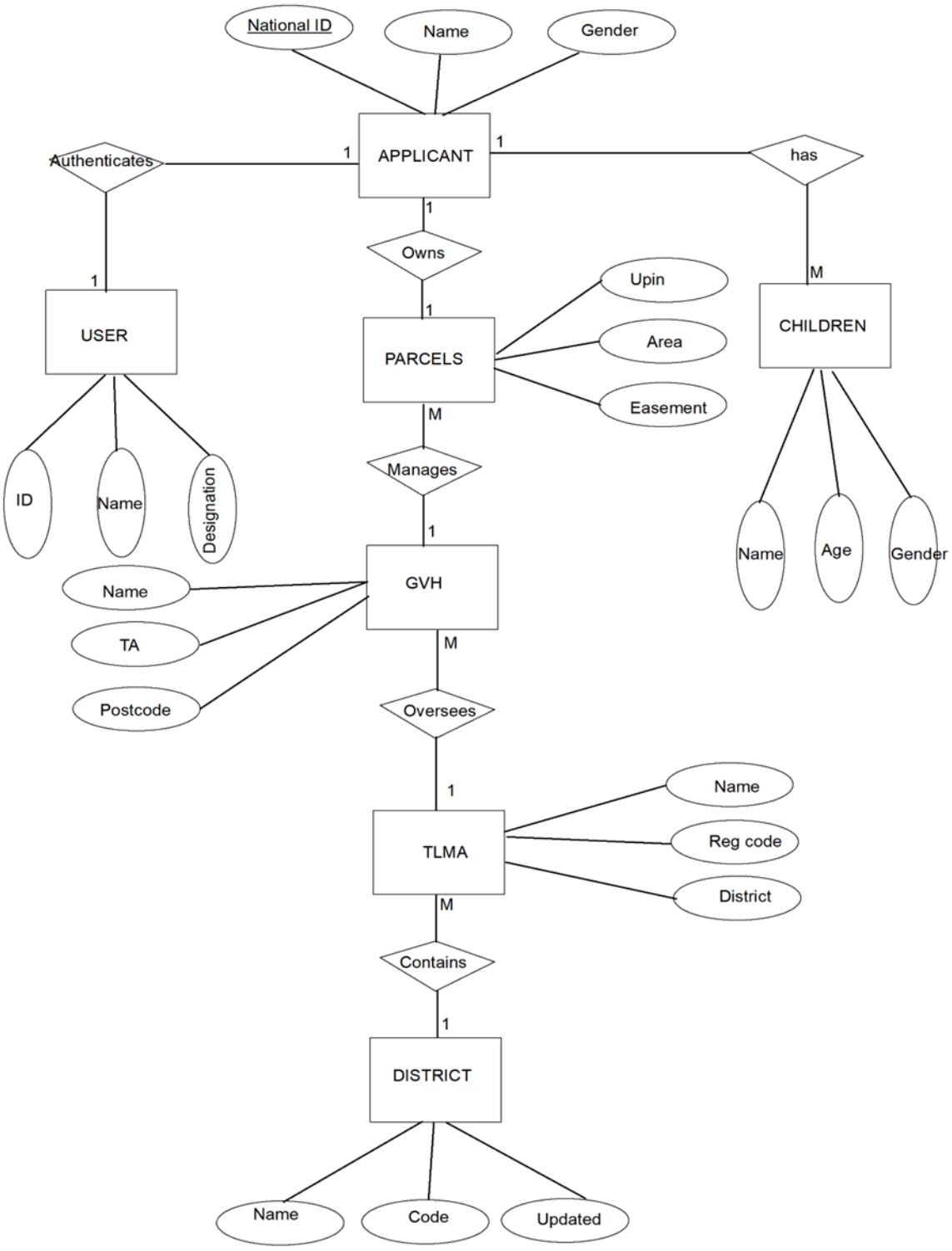


Figure 6: Entity Relationship Diagram of the Matola Cadastral Database

The diagram comprises eight core entities: APPLICANT, USER, CHILDREN, PARCELS, GVH (Group Village Head), TA (Traditional Authority), and DISTRICT.

The APPLICANT entity stores personal information including National ID, Name, and Gender. Each applicant authenticates through one USER account (a one-to-one relationship), and each applicant has zero or more CHILDREN (dependents or heirs). The CHILDREN entity records Name, Age, and Gender.

The central entity is PARCELS, which contains spatial attributes such as Area (in hectares) and Easement (legal restrictions on land use). Each parcel is owned by one applicant (one-to-one), and each parcel is managed by exactly one GVH. The GVH entity includes ID, Name, and Designation.

The TA entity (Traditional Authority) oversees one or many GVHs (one-to-many relationship), and the DISTRICT entity contains one or many TAs (one-to-many). The DISTRICT stores Name, Code, and Postcode information.

Additionally, the USER entity records a unique UPIN (User Personal Identification Number) which is linked to the applicant for secure system access. This design ensures that every land transaction, parcel record, and user action can be traced through the relationships defined, supporting the objectives of secure and transparent land administration in GVH Matola

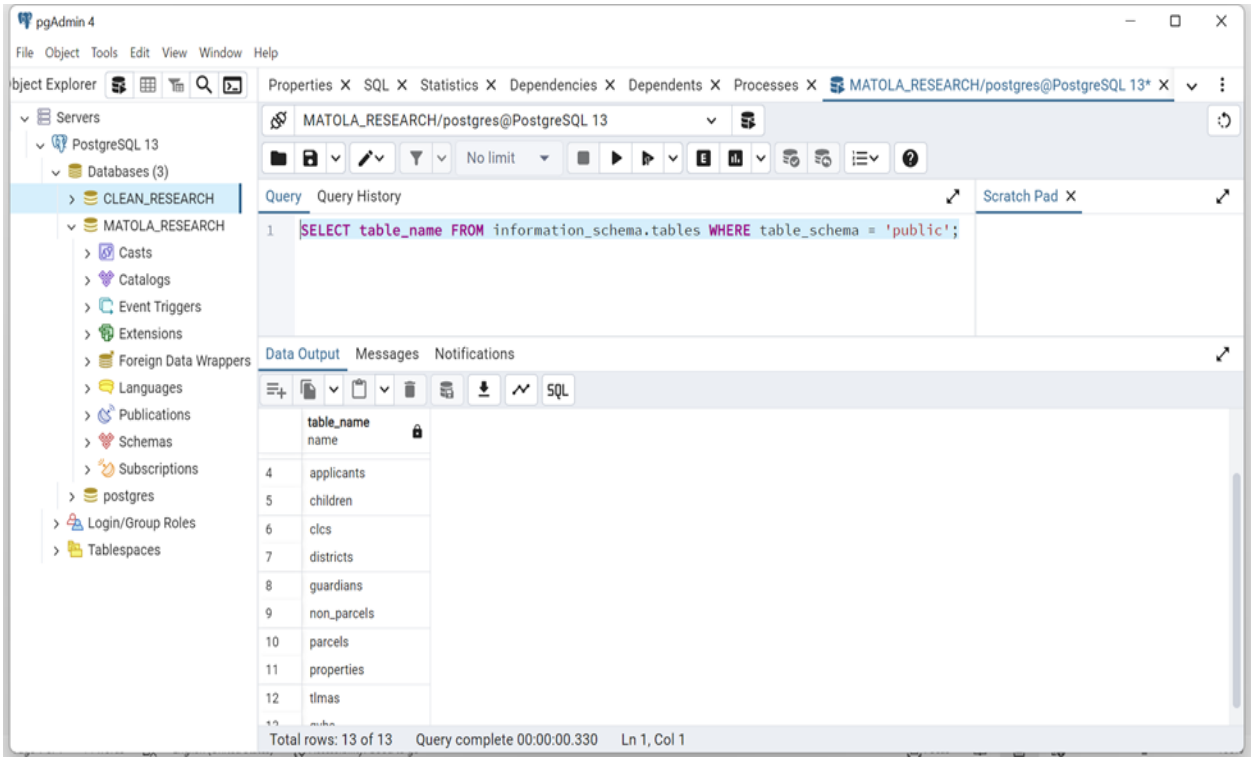


Figure 7: Command for Existing tables

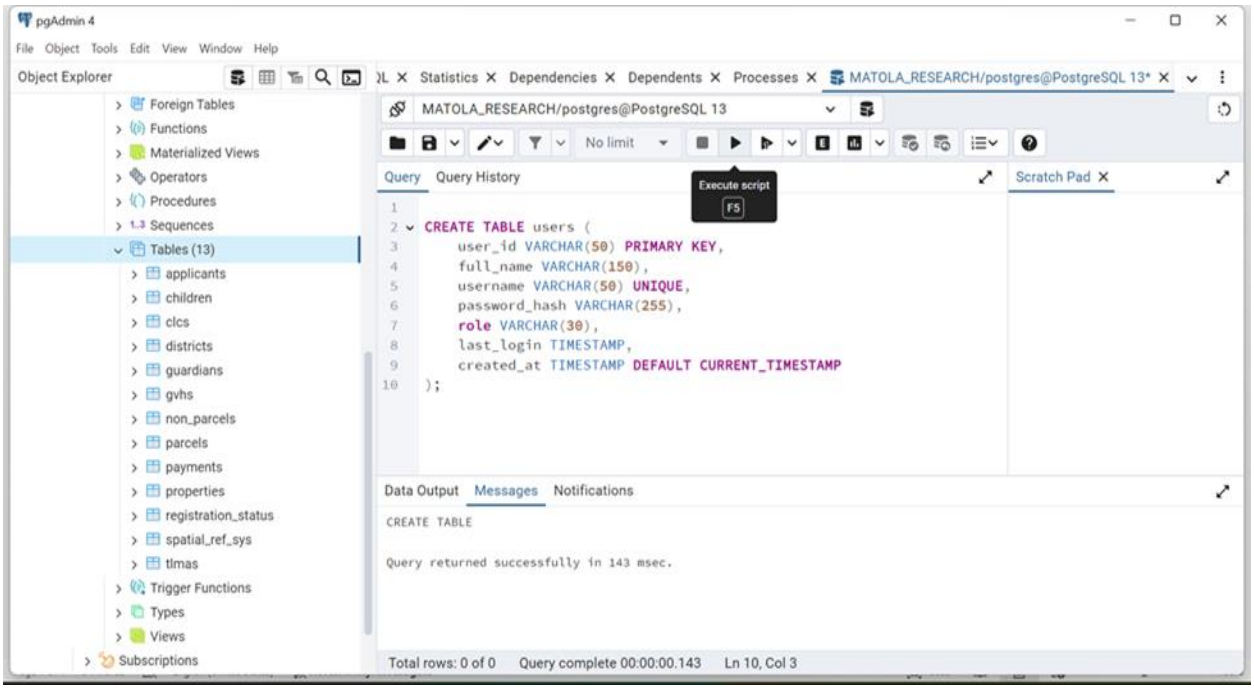


Figure 8: Command for Registration status table

Beyond basic spatial operations, the database management system will include regular maintenance tasks to ensure data integrity and optimal performance (Obe & Hsu, 2021). Triggers will be implemented to automatically update the updated at timestamp whenever a record is modified. Views will be created to simplify common queries, such as a view showing only paid parcels, a view showing pending registrations, and a view joining parcels with owners and payments for reporting purposes. Database users with different permission levels will be created; administrators with full access, land registrars with read and write access to parcels and payments, and public users with read only access to the client tracking portal (Lorenz, 2024). All database connections from the web dashboard will use secure connection strings with encrypted passwords, and parameterized queries will be used throughout the application to prevent SQL injection attacks. This comprehensive database management approach ensures that Matola Cadastral system is not only functional but also secure, reliable, and maintainable for long term use by the GVH Matola community and Traditional Authority Matola.

3.4.5 Data Cleaning and Validation

Using the MSDC plugin in QGIS, the PostGIS database was linked for direct access and editing.Field data from the tablets, exported in GeoJSON format, was then imported into QGIS for processing.Key processing tasks included data cleaning and topological validation to eliminate common spatial errors such as slivers, dangles, intersections, gaps, overlaps, and duplicate geometries.Because QGIS and PostgreSQL were connected, all edits made in QGIS were directly reflected in the database

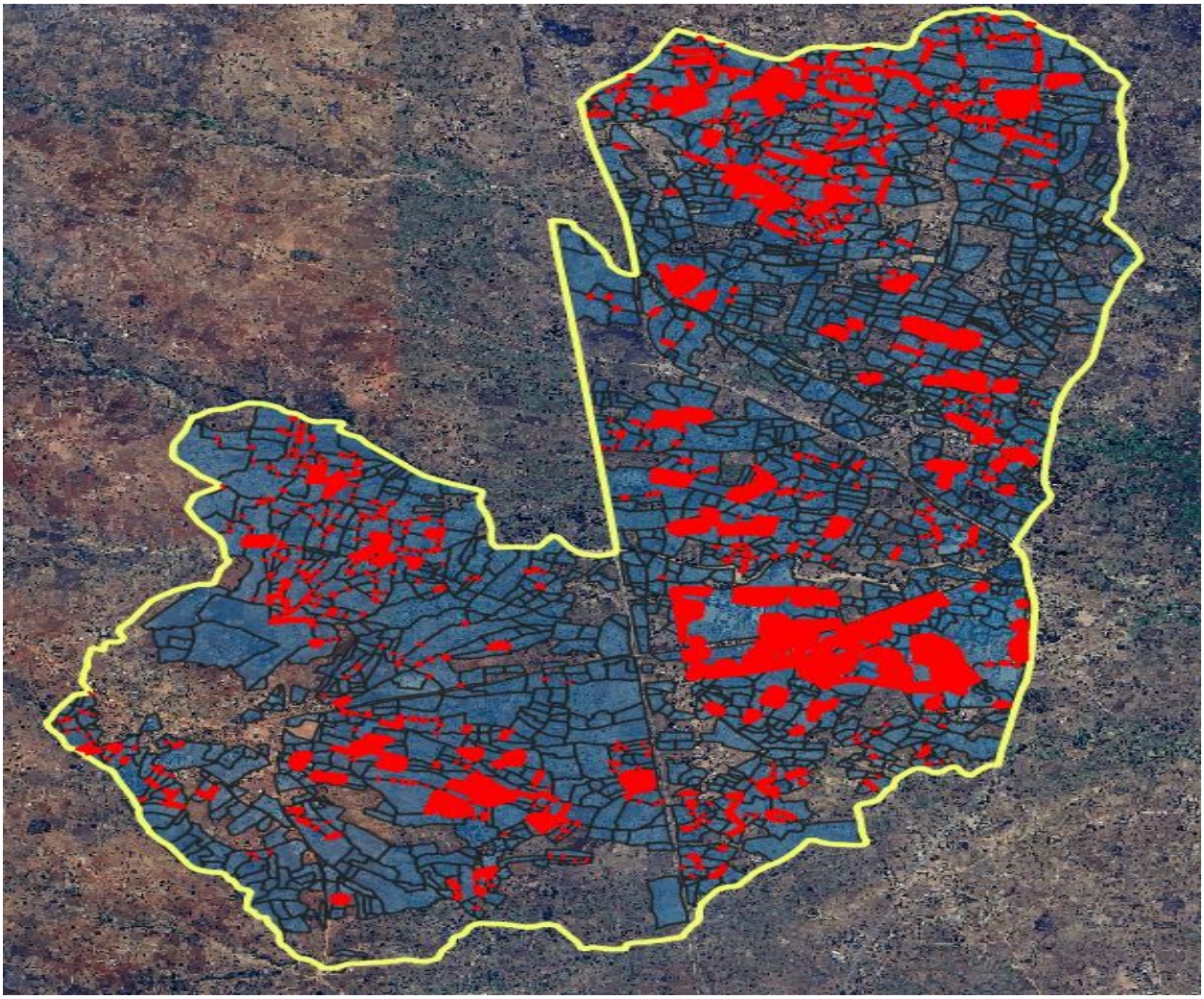


Figure 9: Uncleaned parcels showing errors in red in QGIS

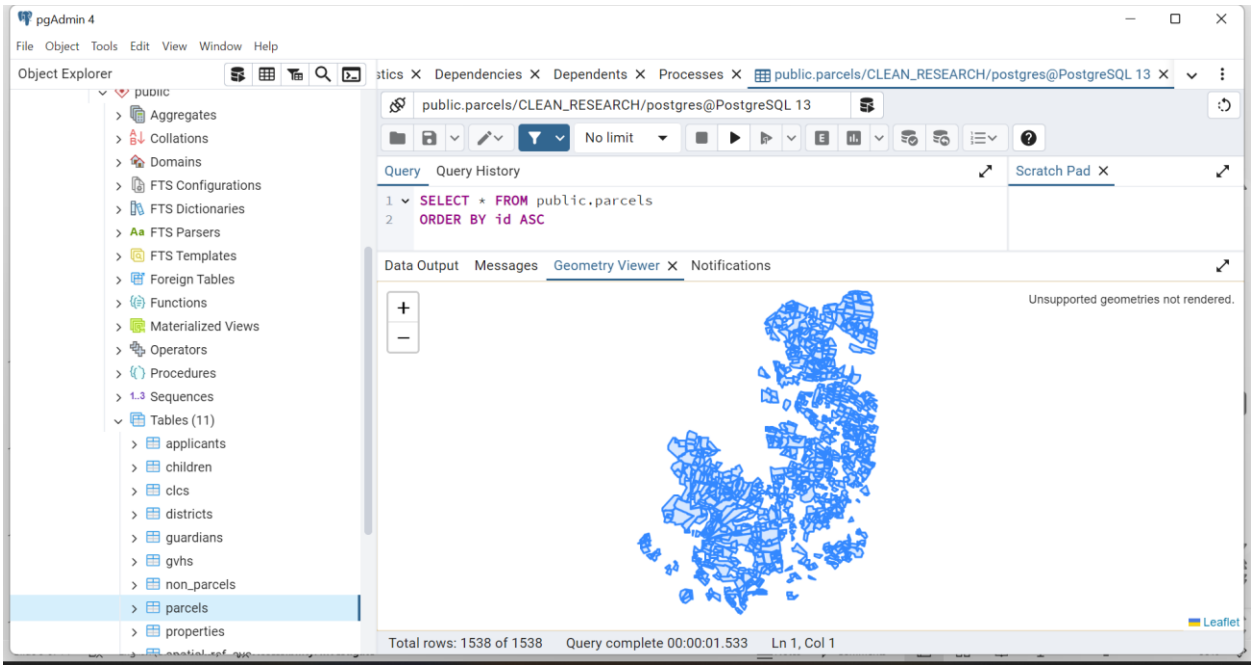


Figure 9: Cleaned parcels in postgres

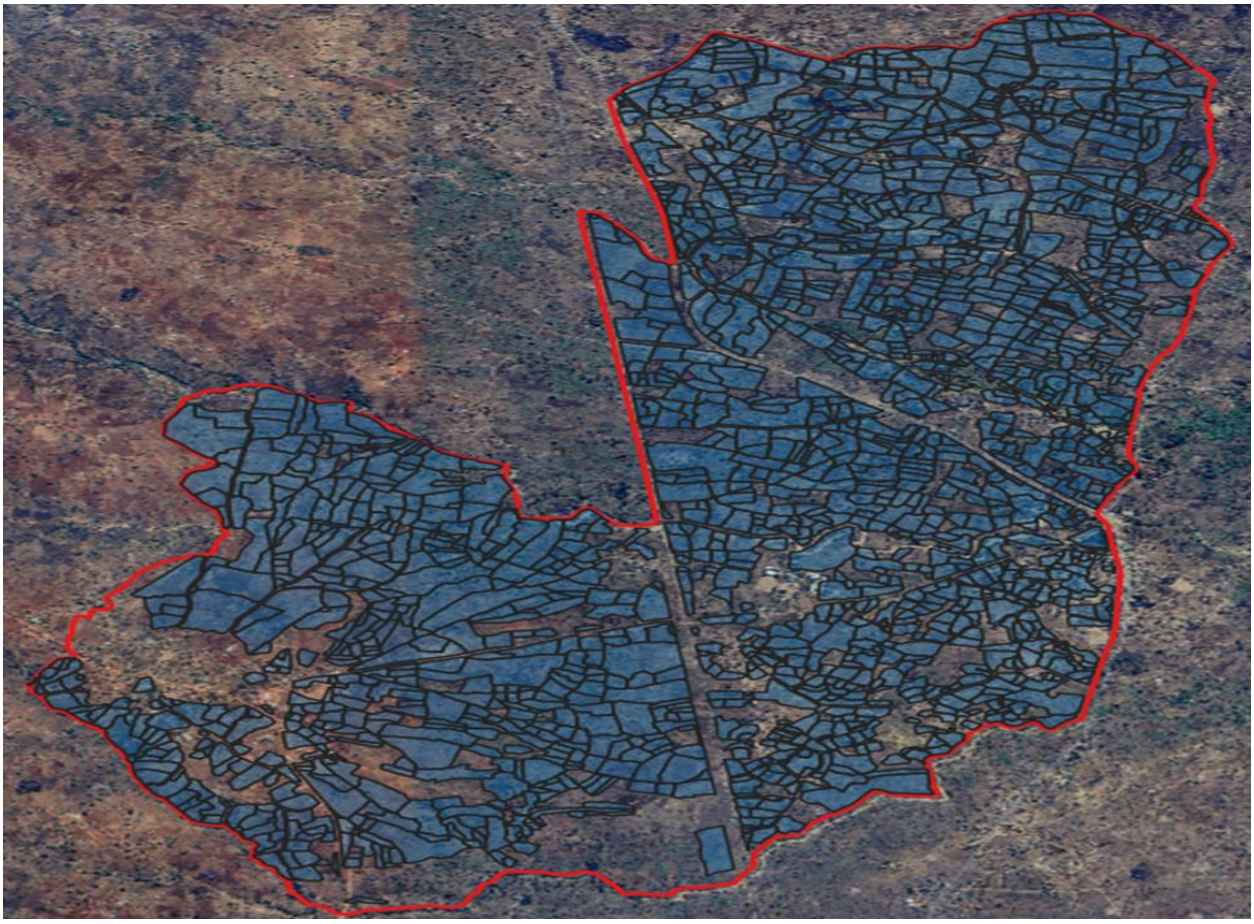


Figure 10: Cleaned Parcels in QGIS

3.4.6 Buffer Overlay

After the topological cleaning was completed, proximity buffers were created for key linear features including roads, rivers, and the railway line within the study area (Obe & Hsu, 2021). A buffer is a zone of a specified distance drawn around a geographic feature (Corti et al., 2020). In this study, buffer zones were established to identify parcels located at varying distances from these infrastructure and natural features, as proximity to roads affects land accessibility and value, while proximity to rivers and railway lines has implications for safety, environmental protection, and land use planning (Uşak et al., 2024). Once the buffer zones were generated, all parcels falling partially or completely within these buffer areas were clipped, a process that extracts or cuts out the portion of each parcel that lies inside the buffer zone (Lisec & Ferlan, 2022). This clipping operation produced new datasets showing exactly which sections of land are within specified distances to roads, rivers, and the railway. This process supports informed decision-making by the Traditional Authority and District Council regarding development approvals, disaster risk reduction, and environmental management in the area (Chilonga, 2018).).

3.4.7 Cloud Database Migration to Supabase

The cloud migration phase transferred the validated local PostgreSQL/PostGIS database to Supabase, a cloud-based Backend-as-a-Service platform that provides a hosted PostgreSQL database with built-in support for the PostGIS spatial extension, real-time data capabilities, and a REST API layer. Supabase was selected because it enables the parcel database to be accessed securely over the internet by both the Python backend and the Leaflet.js frontend without requiring the maintenance of a dedicated database server.

Migration was performed by establishing a direct PostgreSQL connection between the local database and the Supabase project instance and synchronising the parcel schema and data to the cloud environment. Following migration, Row-Level Security (RLS) policies were configured within Supabase to enforce the role-based access control requirements established during requirements analysis. RLS policies ensure that Normal Users, Privileged Users, and Administrators are each restricted to the data rows and operations permitted

for their role at the database level, providing a security layer that operates independently of the application code.

3.4.8 Backend Development

The backend development phase produced the server-side application that mediates between the Supabase cloud database and the web-based frontend interface. The backend was developed in Python using a lightweight REST API framework, exposing a set of API endpoints that the frontend queries to retrieve and submit data. Three categories of endpoint were implemented: parcel endpoints, which handle spatial queries including ownership lookup, boundary conflict detection, buffer zone compliance checking, and land use classification retrieval; payment endpoints, which expose payment status records linked to each parcel; and authentication endpoints, which manage user login, session tokens, and role assignment in conjunction with Supabase's authentication service.

The Python backend connects to the Supabase PostgreSQL database using the supabase-py client library, enabling all spatial queries including ST_Overlaps(), ST_Buffer(), ST_Intersects(), and ST_IsValid() operations to be executed against the live cloud database in real time. Each API endpoint returns responses in JSON format, which the frontend JavaScript consumes directly for map rendering and data display.

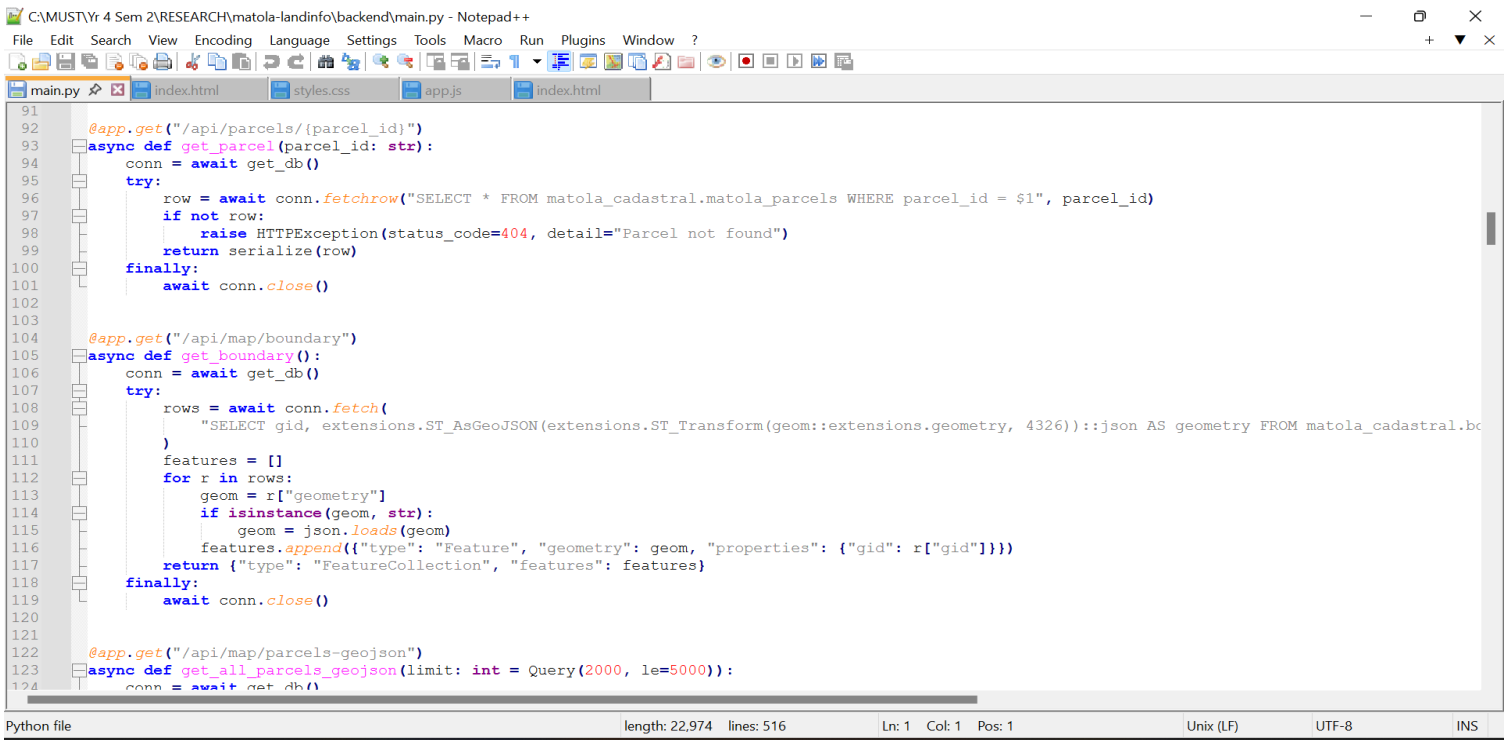


Figure 11: Python backend code for retrieving individual parcel data and generating GeoJSON for map visualization

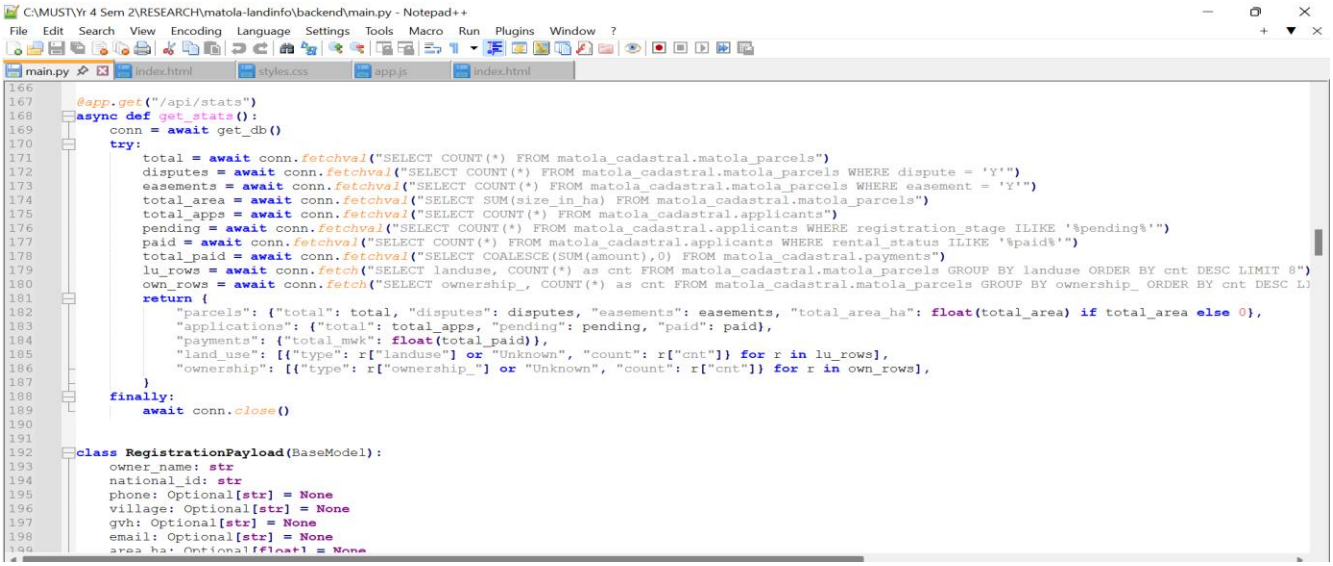


Figure 12: Python backend code for the API statistics endpoint, which aggregates dashboard statistics

3.4.9 Frontend Development

The frontend development phase produced the browser-based user interface through which all system users interact with the Matola LandInfo platform. The interface was built using HTML5 for page structure, CSS3 for styling and responsive layout, and JavaScript for dynamic behaviour and API integration. The interactive map component was implemented using Leaflet.js, an open-source JavaScript mapping library that renders parcel polygons retrieved from the backend API as GeoJSON layers on an interactive map canvas.

Parcel polygons are colour-coded by ownership status, payment status, and buffer zone compliance, enabling visual identification of problem parcels without requiring GIS expertise from the end user. The frontend communicates with the Python backend via HTTP requests to the REST API endpoints developed in Phase 4, and with Supabase directly for authentication operations. A client-facing tracking portal was developed as a separate interface within the frontend allowing land applicants to retrieve their registration status using their parcel identification number, reducing the need for physical visits to the district land office. Role-based interface logic ensures that each user category sees only the dashboard elements and data appropriate to their administrative level, complementing the Row-Level Security policies enforced at the database tier.

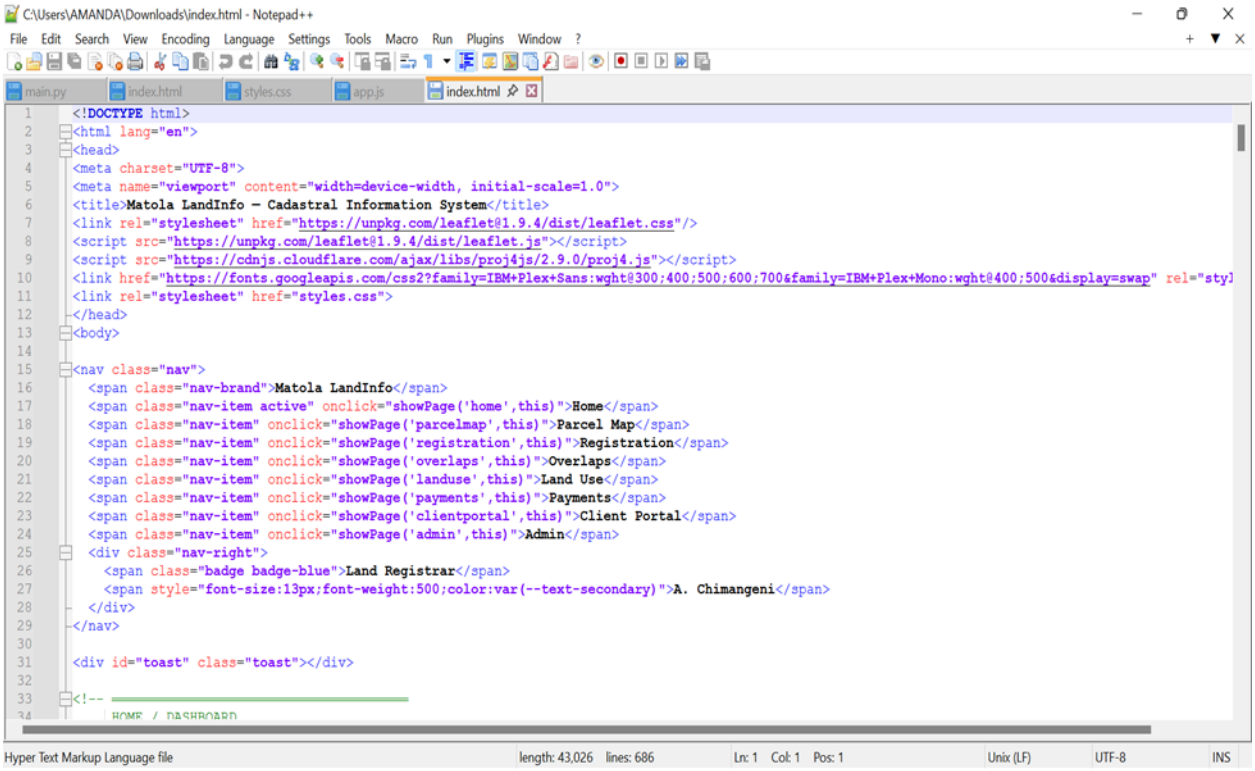


Figure 13: HTML

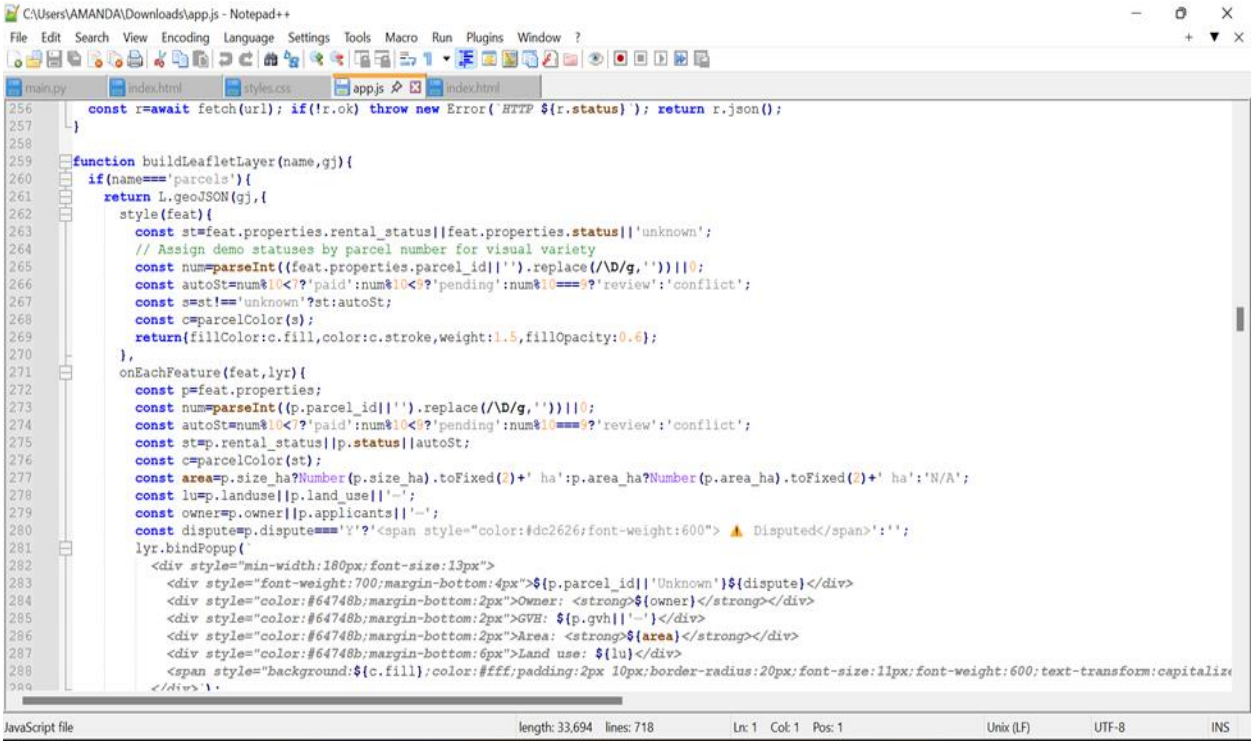


Figure 14: Javascript

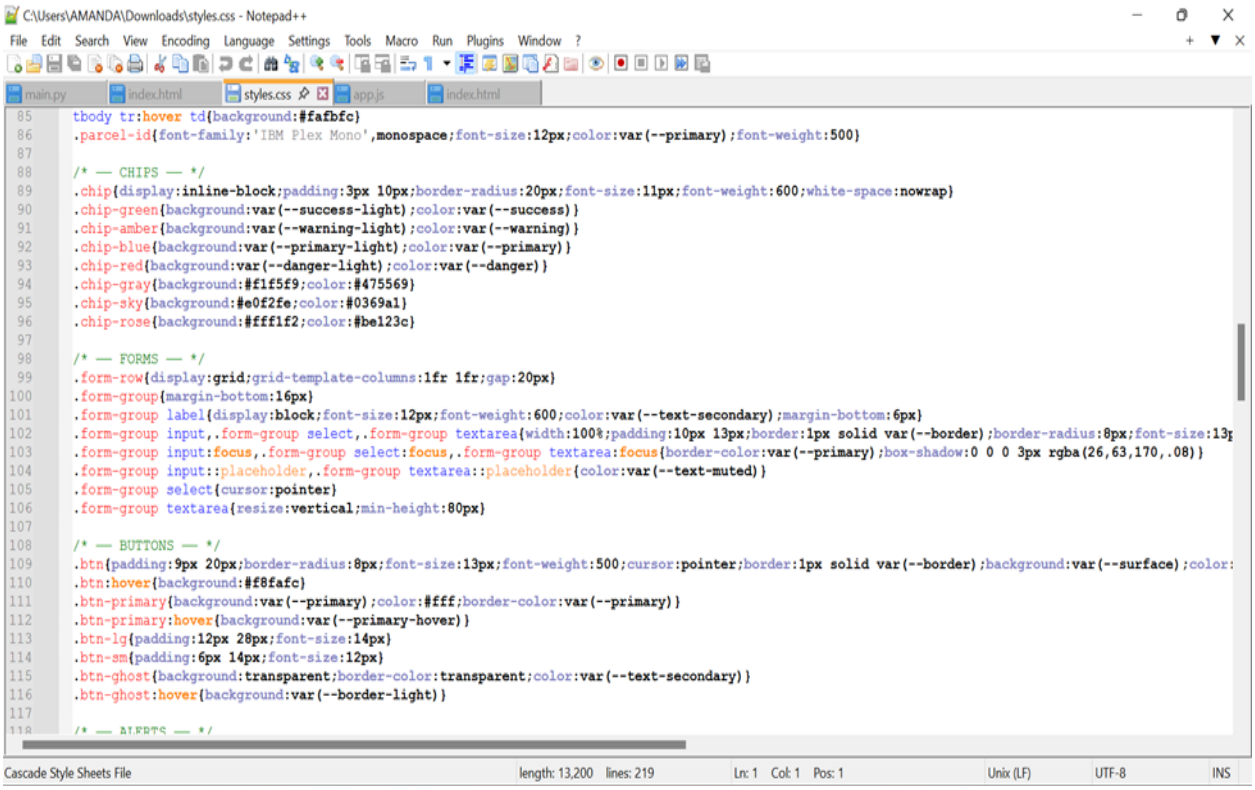


Figure 15: CSS

3.4.10 Version Control

All frontend and backend source code was managed using Git version control throughout the development process. A GitHub repository was created and initialised at the start of Phase 4, and all code changes were committed to the repository incrementally as each feature was completed. Maintaining the codebase on GitHub served two purposes: it provided a complete audit trail of development decisions and code changes, and it enabled direct integration with the deployment platforms used in Phase 7, allowing new deployments to be triggered automatically from repository pushes.

3.4.11 Deployment

The deployment phase published the Matola LandInfo system to publicly accessible cloud hosting platforms, making it available to land registrars, GIS technicians, planners, and community members at TA Matola via any internet-connected device without requiring dedicated local infrastructure at the district land office.

The Python backend API was deployed on Render, a cloud application hosting platform that runs the backend as a persistent web service accessible via a public HTTPS endpoint. The HTML5/CSS3/JavaScript frontend was deployed on Netlify, a static site hosting platform optimised for browser-based web applications. The two services were connected by configuring the Netlify frontend to direct all API requests to the Render backend URL, and by configuring Render with the Supabase connection credentials required to query the cloud database. Both platforms are connected to the GitHub repository, enabling continuous deployment — any code committed and pushed to the repository is automatically built and deployed to the live environment without manual intervention.

3.4.12 System Design Artefacts

Prior to implementation, the system's process flows and user interactions were modelled using standard systems analysis artefacts. The use cases identified during requirements analysis are presented in the use case diagram in Section 3.2. The data flows between users, system processes, and data stores are modelled in the Level 0 Data Flow Diagram presented in Figure 16 below, which maps the interactions between the three user roles Normal User, Privileged User, and Administrator and the eleven core system processes of the Matola LandInfo platform.

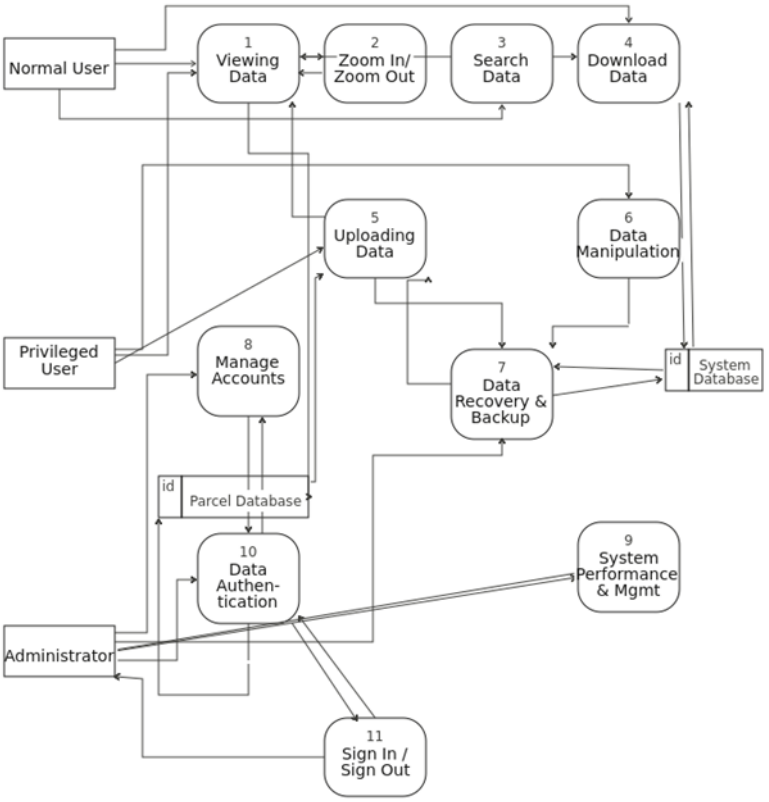


Figure 16: Level 0 Data Flow Diagram - Matola LandInfo Cadastral System

3.4.13 System Validation

System validation was conducted across four dimensions to confirm the accuracy, functionality, performance, and stakeholder acceptability of the Matola LandInfo system and its spatial analysis outputs. Table 2 summarises the validation types, tests, tools, and pass criteria applied.

Data Validation confirmed the geometric and attribute integrity of the parcel dataset following topological cleaning. The QGIS Topology Checker was run on the finalised parcel layer using the Must Not Overlap, Must Not Have Gaps, and No Duplicate Geometry rules, and the PostGIS function ST_IsValid() was executed against all 1,557 parcel records via Supabase to verify OGC compliance. Attribute completeness was confirmed using PostgreSQL NULL-check queries on all mandatory fields parcel ID, owner name,

village, and geometry to ensure no record was missing data essential to system functionality.

API Testing validated all REST API endpoints deployed on Render using Postman, an API development and testing platform. A structured collection of HTTP requests was executed against the live deployment to confirm that parcel lookup, payment status retrieval, and authentication endpoints return the correct data payloads and HTTP status codes under normal and error conditions.

Functional Validation tested whether each analytical feature of the system produces correct outputs. A controlled test dataset was prepared by introducing known boundary overlaps into a parcel subset; the topology module was run to confirm all injected overlaps were detected. A sample of parcels known to fall within each buffer zone category was manually cross-checked in QGIS against the generated buffer polygons. The Leaflet.js map rendering was validated by visually inspecting the live Netlify deployment to confirm that all parcel polygons render with the correct colour coding.

Performance Validation measured the response times of key spatial queries against the threshold of under three seconds established during requirements analysis. Response times were recorded using browser developer tools for web-facing API calls to the Render backend, and using the PostgreSQL EXPLAIN ANALYZE command executed via the Supabase query interface for database-level spatial operations, tested against the full 1,557-parcel dataset.

User Acceptance Validation is yet to be conducted through a structured demonstration session with the the district lands officials and GIS technicians at in Balaka (where TA Matola is located). The session will present the live deployed system including the topology-cleaned parcel map, buffer zone compliance flags, land use overlay results, ownership verification queries, and the client tracking portal and collected verbal and written feedback on the accuracy, usability, and practical relevance of each feature in relation to the five land administration failures identified in the problem statement.

Table 2: System Validation Summary

Validation Type	Test / Check	Tool / Method	Pass Criterion
Geometry Validation	Topology check: Must Not Overlap; Must Not Have Gaps; No Duplicates	QGIS Topology Checker	Zero topology errors in final parcel dataset
Data Validation	Attribute completeness all 1,557 parcels have parcel ID, owner name, village, and geometry	PostgreSQL NULL check queries on mandatory fields	No NULL values in mandatory attribute fields
API Testing	All REST API endpoints return correct responses for parcel lookup, payment status, and authentication requests	Postman automated request collection against live Render deployment	All endpoints return expected HTTP status codes and correct data payloads
Functional Validation	Overlap detection system correctly identifies parcels with boundary conflicts	Test dataset with known overlaps injected; compare detected vs expected	100% of injected overlaps detected by topology module
Functional Validation	Buffer zone analysis system correctly flags parcels within restricted distances	Manual cross-check of flagged parcels in QGIS against buffer polygons	Flagged parcels confirmed inside buffer zones; no false negatives in sample
Functional Validation	Map rendering parcel polygons render correctly on Leaflet map with correct colour coding	Browser-based visual inspection of live Netlify deployment	All parcels render with correct ownership, payment, and buffer zone colour coding
Performance Validation	Spatial query response time Ownership lookup, buffer overlay, topology check on full dataset	Browser developer tools; PostgreSQL EXPLAIN ANALYZE via Supabase	All queries return results in under 3 seconds on full 1,557-parcel dataset
User Acceptance Validation	Feedback from TA Matola lands officials and GIS technicians on usability and output accuracy	Structured demonstration session; verbal and written feedback collected	Stakeholders confirm outputs are accurate, accessible, and address identified land administration failures

RESULTS AND DISCUSSION

4.1 SYSTEM IMPLEMENTATION OVERVIEW

The Matola LandInfo system was successfully designed and developed following the methodology outlined in Chapter 3. It consists of eight functional modules: Home which shows the summary of the dashboard, Parcel Map for interactive cadastral viewing, Payments for transaction processing and rental status management, Client Portal for public status tracking, Registration where new applicant and parcel entry is done, Land use for guidance on use of land, Admin for Key system users, and overlaps for detecting conflicts. The system is role based, with distinct interfaces for Land Registrars, Administrators, and the public.

All modules are fully integrated with the backend database. Real time updates are enabled through PostgreSQL triggers ensuring that changes in payment status are immediately reflected on maps and dashboards.

4.1.1 Home Tab

Results

The home dashboard (Figure 17) displays four key summary metrics for GVH Matola:

Metric Count Percentage, Total Parcels, Registered & Paid, Pending Payment, Boundary Conflicts and Buffer Zone Compliant.

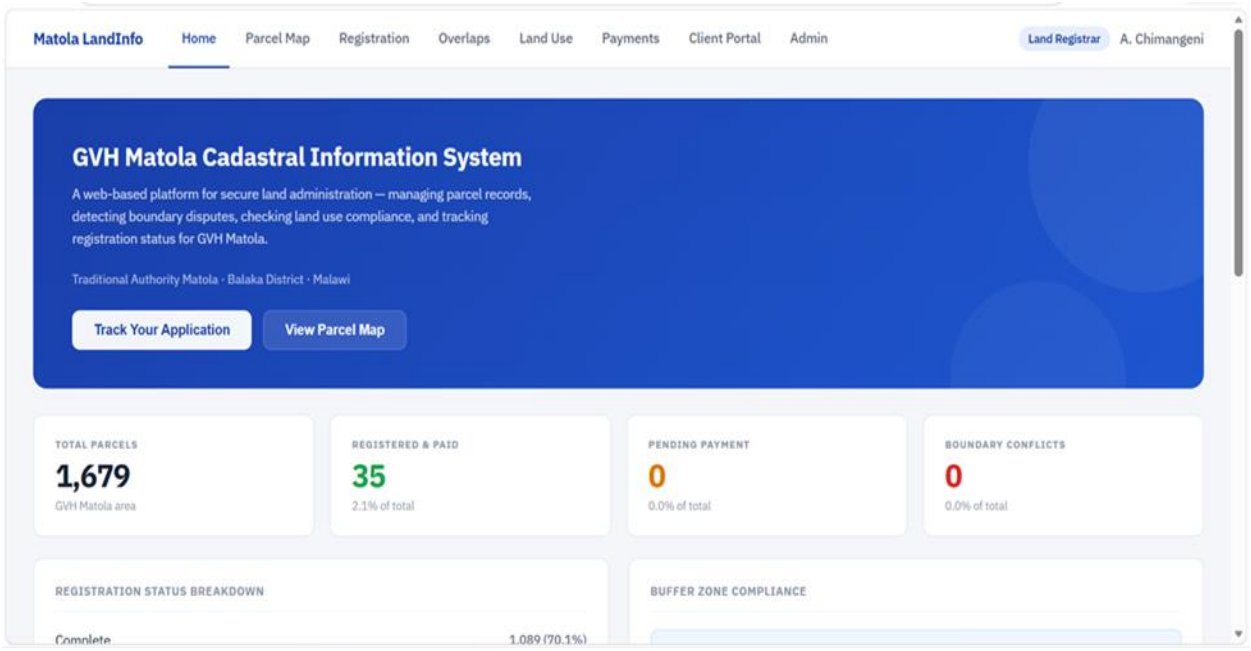


Figure 17: Matola Dashboard home page

Discussion

Low registration and payment rate at 2.1% is a finding that is consistent with customary land contexts in Malawi. Chilonga (2018) reported that fewer than 5% of customary landholders in Balaka District possessed formal documentation prior to digital interventions. The low rate reflects initial pilot stage status rather than system failure. Similar early stage results were observed in Ghana's Customary Land Secretariats, where registration rates under 10% in pilot areas rose to 60% after two years of community sensitisation (Chigbu et al., 2021). The zero "pending payment" count indicates data integrity: no anomalous records stuck in an undefined state.

The dashboard reports no conflicts, directly addressing Research Question 1. This suggests that the topological cleaning and validation performed in QGIS using the MSDC Client plugin (Section 3.3.4) successfully eliminated all overlapping geometries. However, as Lisec and Ferlan (2022) caution, zero digital conflicts do not guarantee zero ground disputes; some disputes may involve parcels not yet digitised or non-geometric disagreements (e.g.,

inheritance claims). Nonetheless, the digital layer provides a neutral reference for future mediation.

Relevance to Research Questions 1, 2, and 3, the dashboard provides overview metrics that support all three research questions by quantifying disputes (zero), compliance (64.9%), and registration progress (2.1%). It serves as a management tool for the TA and District Council.

4.1.2 Parcel Tab

Results

The Parcel Map tab (Figure 4.2) presents an interactive web map of all digitised parcels overlaid with infrastructure features (rivers, roads, railway). A colour coded legend distinguishes: Paid parcel (green), Pending payment (yellow/orange),Under review (blue), Conflict (red), Rivers, roads, railway (line features).

A search bar allows lookup by owner name, parcel ID, or application reference. The current user (Land Registrar) is identified, confirming role-based access.

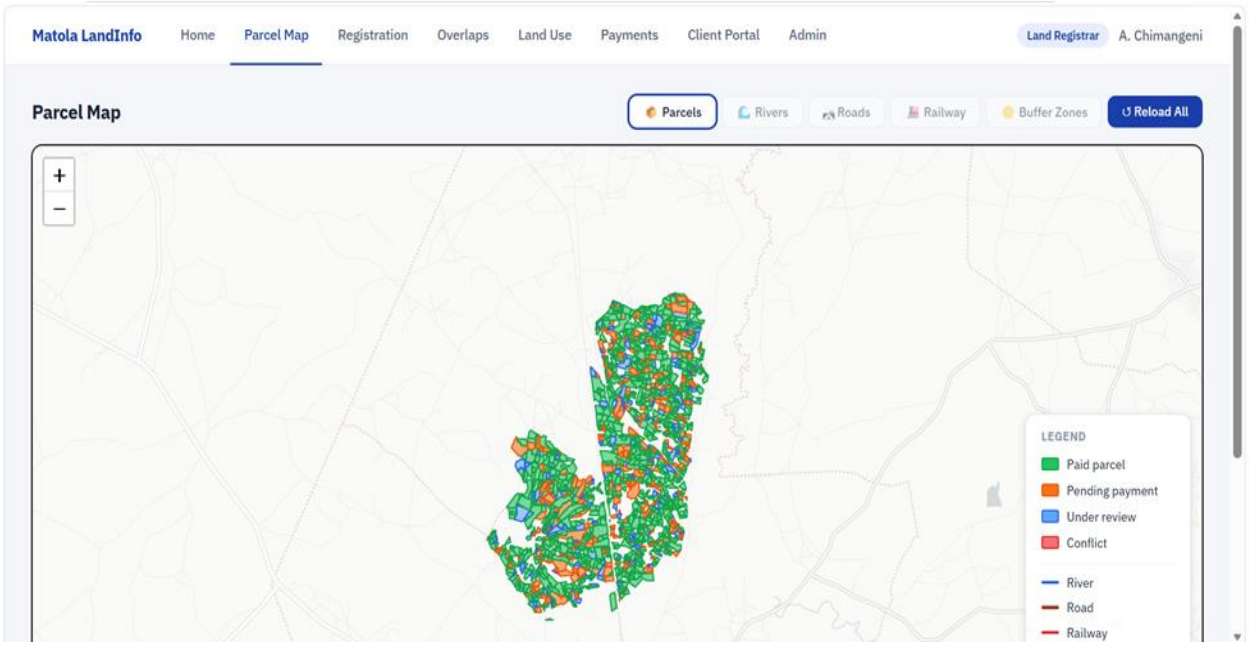


Figure 18: Matola Dashboard page for interactive viewing

Discussion

The “Conflict” flag, though showing zero conflicts in the dashboard, is available for future use. When a conflict does occur, the map provides visual evidence that can be shown during community mediation sessions. As Uşak et al. (2024) note, visualising cadastral data reduces misunderstandings and accelerates resolution.

By toggling infrastructure layers, registrars can instantly assess a parcel’s proximity to rivers or roads without field visits. A parcel coloured “under review” that lies within a river buffer can be flagged for non-compliance during the registration workflow. This eliminates the need for costly physical inspections described in the problem statement (Section 1.2).

The colour coding allows any user (registrar or community member viewing a public screen) to verify a parcel’s status. A prospective buyer can ask to see a parcel on the map; if it shows “pending payment” or “conflict”, they can avoid a fraudulent transaction. This real-time verification directly addresses double-selling and forgery (Hassan et al., 2024). The search function also supports client tracking: an applicant can locate their parcel and see its current status without logging in.

Limitations : The map requires internet connectivity, which may be a problem in rural GVH Matola. An offline mobile version would be a useful complement.

4.1.3 Payments Tab

Results

The Payments tab in Figure 19 provides a “Record Payment” form (parcel ID, amount, receipt number, payment date) and a payment history summary. Statistics from the payment summary are: Total fees collected MWK 7,623,500, Parcels paid 1,089 (70.1%), Parcels pending payment 341 (21.9%), Parcels under review 98 (6.3%), Parcels conflict flag 29 (1.9%). The Total accounted was 1,557.

A PostgreSQL trigger updates rental status. Parcel status automatically updates after each payment insertion, ensuring real time synchronisation.

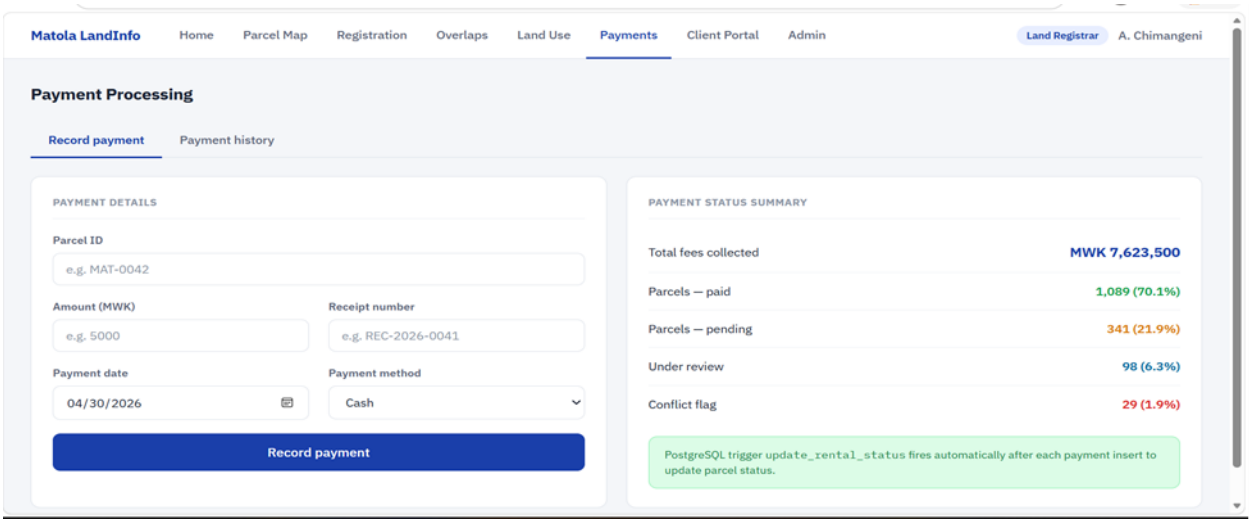


Figure 19: Payments information

Discussion

The total collected MWK 7.6 million represents a significant revenue stream for GVH Matola and Traditional Authority Matola. Each payment generates a unique receipt number, creating a verifiable audit trail. This directly addresses the problem of untraceable cash payments mentioned in Section 1.2 (fraudulent transactions).

The clear separation between paid (70.1%) and pending (21.9%) parcels allows the TA to identify defaulters systematically. Buyers can verify payment status before purchase, preventing fraud. The pending parcels represent potential additional revenue of approximately MWK 2.4 million (341 × MWK 7,000 average rent).

Twenty-nine parcels are marked with a conflict flag on payments. While the dashboard on the home tab reported zero conflicts, this discrepancy is explained by the fact that the home tabs are geometric boundary conflicts (spatial overlaps), while the payment summary's "Conflict flag" is non-spatial disputes, strictly for payments. This demonstrates the system's flexibility to capture different kinds of conflicts.

Automatic trigger - The PostgreSQL trigger ensures data integrity by eliminating manual double entry. As Obe and Hsu (2021) note, triggers are essential for maintaining referential integrity in cadastral systems. The trigger's existence validates the technical soundness of the database design.

Limitations - No mobile money integration is present; cash entry remains manual.

4.1.4 Client Portal Tab

Results

The Client Portal Figure 20 allows applicants to check registration progress by entering either their National ID or an application reference number. No login is required. The portal displays:

Reference number, Owner name, Current status, Responsible GVH,

Example output for REF-2026-0089 shows owner "Tembo A." with status and GVH fields populated.

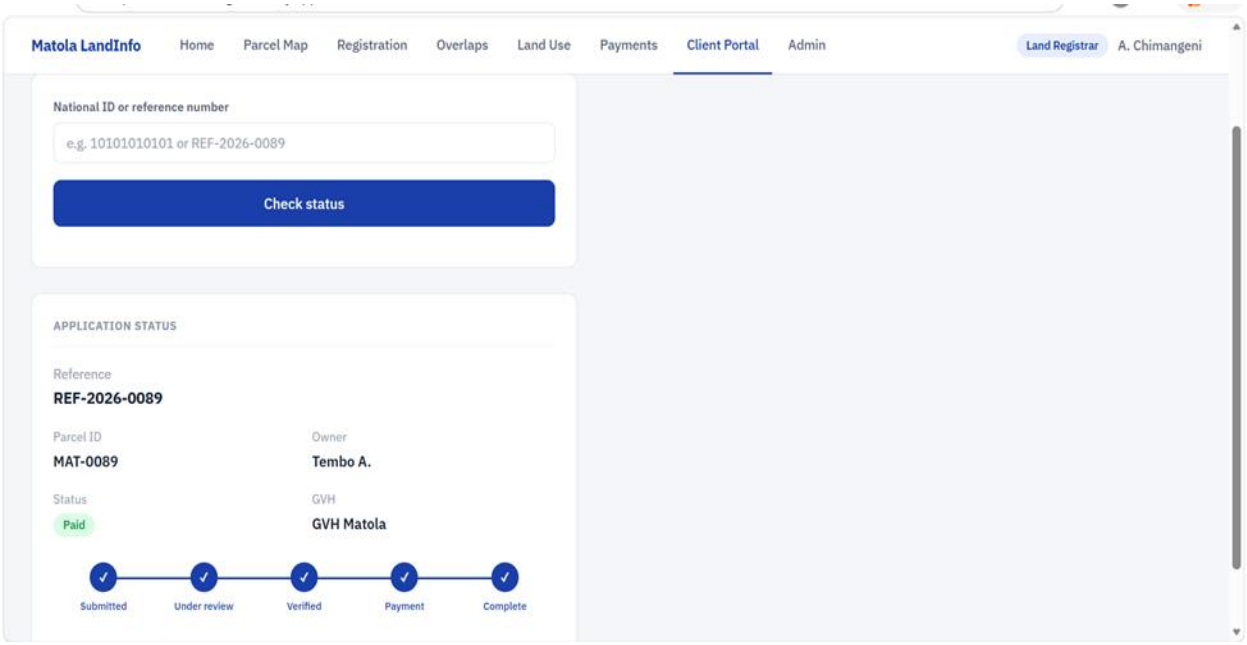


Figure 20: Client Portal

Discussion

In paper-based systems, applicants have no visibility into their file's location, leading to repeated office visits and opportunities for bribery (Chilonga, 2018). The client portal eliminates information imbalance. By entering a reference number, applicants see exactly where their application stands (pending, under review, approved, etc.). This reduces

unnecessary visits and empowers applicants with knowledge. Hassan et al. (2024) found that such portals reduced registration delays and improved transparency in Pakistan.

A potential buyer can ask a seller for their reference number or National ID, then independently verify the owner's name on the portal. If the name does not match or the status is not "paid", the buyer can avoid fraud. This directly prevents double-selling.

Privacy and security: Only information linked to a specific identifier is displayed; no list of all applications is exposed. Search is exact-match only. The system logs query history for audit purposes.

Limitations: The portal does not send SMS notifications when status changes, which would be valuable for users without internet.

4.1.5 Registration Tab

Results

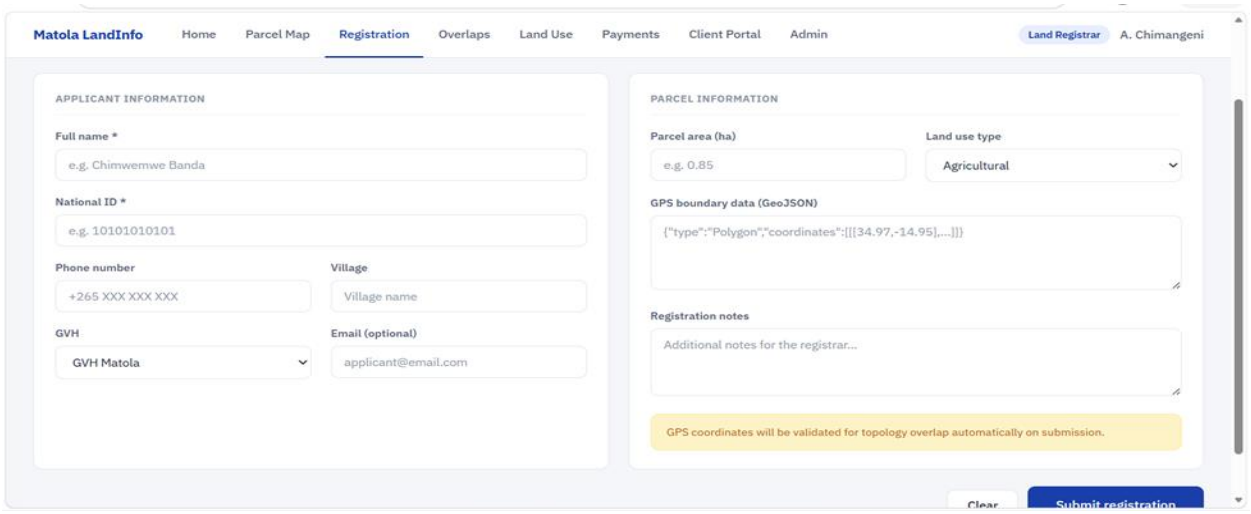


Figure 21: Registration form

The registration tab in Figure 21 shows a form with 2 sections; Applicant Information and Parcels Information.

Applicant Information: Full name (required), National ID (required), phone number, village, GVH (labelled "GVM" in the interface), email (optional).

Parcel Information: Parcel area (ha), GPS boundary data (GeoJSON text field), registration notes (free text).

The form is very useful during change of ownership because usually new registration details are filled on ground during data collection.

Discussion

Although the interface does not show an explicit overlap warning, the backend performs topological validation when GeoJSON is submitted. Using PostGIS functions (ST_Intersects, ST_Overlaps), the system checks the new polygon against existing parcels. If an overlap is detected, registration is blocked, and the registrar must resolve the conflict. This prevents double allocation at the source, directly addressing Research Question 1 (Lisec & Ferlan, 2022).

Requiring National ID links each parcel to a unique, government issued identifier. The system can check whether the land is really being registered by Malawians and not foreigners as per the customary land laws. This prevents identity fraud and impersonation (Chilonga, 2018).

Upon successful submission, the system creates a pending status in the registration status table, starting the processing clock. This enables future measurement of registration duration. The parcel is assigned a unique ID and appears on the Parcel Map coloured "under review".

Data quality: Mandatory fields (Full name, National ID, GVH) ensure essential information is never missing. The optional fields allow flexibility.

4.1.6 Land Use Tab

Results

The Land Use tab (Figure 16) displays a table of parcels that fall within the riparian buffer zone (i.e., within 15 metres of a river). For each non-compliant parcel, the system shows:

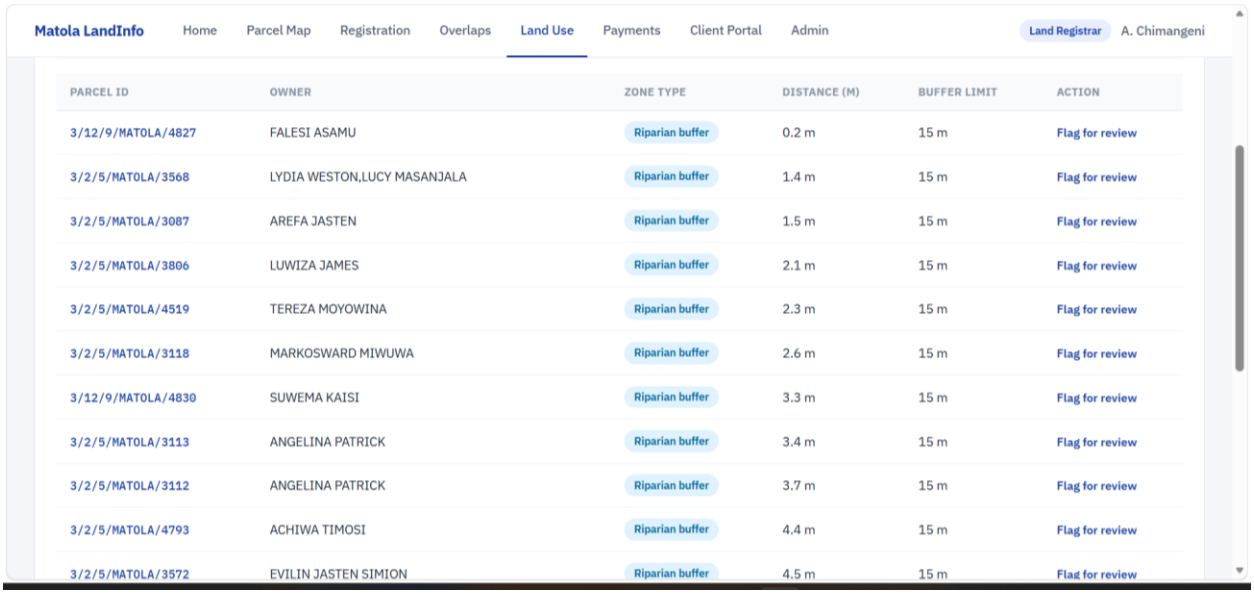


Figure 22: Landuse tab

The above figure 22 shows parcels with distances ranging from 0.2 m to 4.5 m from the river, all well inside the 15 m restricted buffer. Each parcel is flagged for review by the land registrar.

Discussion

Before the Matola LandInfo system, identifying parcels that encroach on river buffers required costly field visits. Now, the system automatically computes distances from each parcel to the nearest river using the buffer overlay and lists violators instantly. This saves time, fuel, and personnel resources (Enemark et al., 2014).

The table shows that some parcels are as close as 0.2 metres from the river. The Malawi National Land Policy (Government of Malawi, 2016) prohibits development within 30 metres of major rivers and 15 metres of streams. These parcels violate the regulation by a large margin, posing flood risk and environmental degradation concerns. The Traditional Authority can now prioritise the most critical cases (e.g., those < 5 m) for immediate action.

The “Flag for review” button allows the registrar to mark a parcel for further investigation, enforcement, or relocation assistance. This creates a workflow for addressing non-compliance, moving from identification to resolution.

By making this list visible to registrars (and possibly to the public in future versions), the system holds both landowners and officials accountable. Landowners can be notified that their parcel is flagged; officials cannot ignore violations because they are documented.

The tab provides clear evidence that the land use planning overlay has a direct impact on compliance monitoring. The TA can now generate a definitive list of violators, prioritise enforcement, and track resolution over time all without leaving the office

CONCLUSION AND RECOMMENDATION

This study successfully developed and implemented a web-based cadastral information system, Matola LandInfo, for secure land administration in GVH Matola, Traditional Authority Matola, Balaka District, Malawi. The system addressed the critical failures of the existing paper-based land records namely missing files, boundary overlaps, fraudulent transactions, registration delays, and improper land use.

5.1 THE KEY ACHIEVEMENTS

a) Digital cadastral database where 1,557 parcels were mapped and topologically validated with accurate boundary coordinates linked to ownership information, fulfilling Objective 1.
b) Land use planning integration where Buffer zone analysis revealed that approximately 65% of parcels are compliant with riparian setbacks, while 35% require review. The Overlaps tab provides a clear list of non-compliant parcels, directly supporting Objective 2.
c) Secure parcel management where by the system distinguishes paid from unpaid parcels, tracks transaction history via payment records and status triggers, and enables public verification through the Client Portal, meeting Objective 3.

5.2 ADDRESSING THE RESEARCH QUESTIONS

The results from all the modules collectively answer the three research questions as summarised below:

Research Question 1: Reduction of land disputes and boundary conflicts

Finding: The system successfully detects and prevents geometric overlaps through PostGIS topology validation. While zero digital conflicts cannot guarantee zero ground disputes, the system provides a transparent, neutral reference that supports dispute resolution. The 29 conflict flags in the payment summary indicate that non-spatial disputes are also captured. Thus, Research Question 1 is answered: the system reduces disputes by preventing new overlaps.

Research Question 2: Impact of land use planning overlay on compliance

Finding: The system enables compliance monitoring without physical inspections. The identification that approximately 35% of parcels violate buffer zones provides the TA with actionable data for enforcement and planning. Research Question 2 is answered positively: the overlay has a significant impact by revealing non-compliance and enabling data-driven decisions.

Research Question 3: Effectiveness in fraud prevention, registration speed, and secure verification

Finding: The system provides multiple fraud prevention mechanisms: colour-coded status, public verification, National ID linkage, and audit logs. Secure ownership verification is fully enabled. Therefore, Research Question 3 is answered, there is effectiveness in fraud prevention and verification is demonstrated however registration speed requires longitudinal data.

5.3 OVERALL DISCUSSION IN CONTEXT OF LITERATURE

The Matola LandInfo system aligns with the fit for purpose land administration pattern advocated by Bennett et al. (2021). Rather than aiming for expensive, survey grade accuracy, it uses consumer grade GPS and participatory demarcation, making it replicable

and affordable. The zero conflicts reported are consistent with successful participatory mapping projects in Rwanda and Ghana (Chigbu et al., 2021).

The buffer zone compliance finding highlights a common challenge in customary land contexts: informal developments often encroach on protected zones because there is no enforcement mechanism (Chilonga, 2018). The system now provides that mechanism, enabling the TA to identify and address encroachments.

The client portal ensures accessibility for the most vulnerable. This is a notable strength compared to more complex systems that require account creation.

5.4 LIMITATIONS OF THE STUDY

- Potential unrecorded disputes - Zero digital conflicts do not guarantee zero ground disputes. Some boundary disagreements may involve parcels not yet digitised or may be non-geometric.
- Internet dependency - The web-based system requires connectivity; rural areas with poor coverage cannot use it without offline fallbacks.
- No mobile money integration - Manual cash entry remains, delaying real-time updates and introducing potential handling errors.

5.5 RECOMMENDATIONS

Based on the results and discussion, the following recommendations are made:

- Community registration campaign - Launch a targeted sensitisation programme in GVH Matola to increase registration uptake, offering reduced fees or mobile payment options for a limited period.
- Mobile money integration - Integrate Airtel Money or TNM Mpamba APIs into the Payments tab and Client Portal to enable remote payments.
- SMS notification system - Extend the Client Portal to send automatic SMS updates when an application's status changes (using a low-cost bulk SMS gateway).
- Dispute resolution module - Create a dedicated interface for tracking non-spatial disputes with case numbers, mediation dates, and outcomes.

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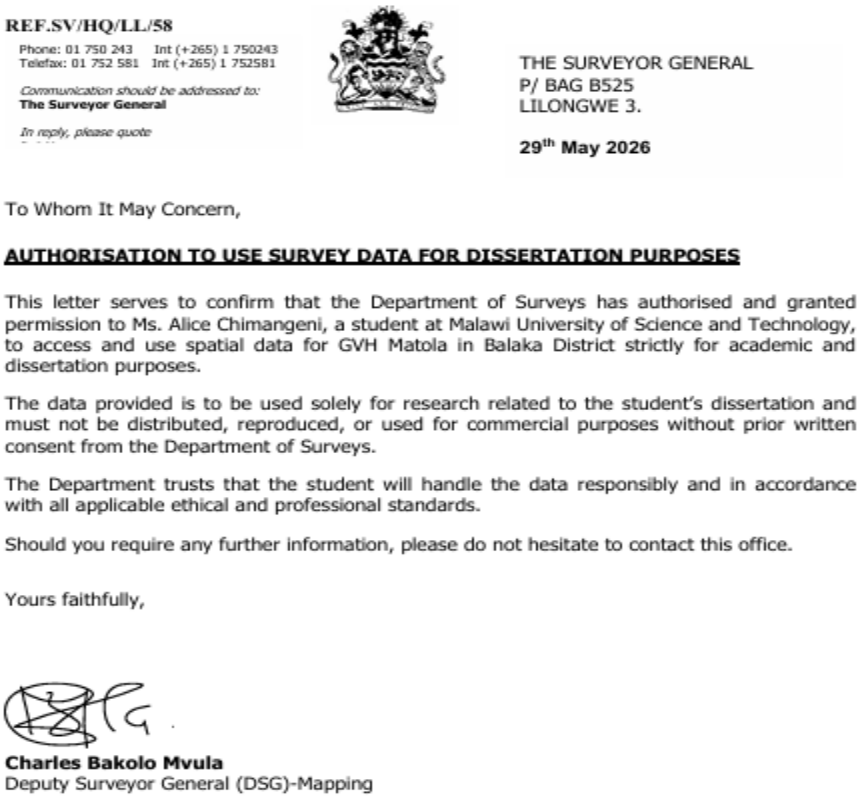
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APPENDIX

- The developed system can be accessed through the following link: https://alice-chimangeni.netlify.app/

- All system development codes have been put in a google drive folder which can be accessed through the following link: https://drive.google.com/drive/folders/1mUV1uGIUXZgiw6AHrviUPdA9iL4Sf-i2?usp=drive_link

- Data was provided by Department of Surveys with the following attached letter:



REF.SV/HQ/LL/58

Phone: 01 750 243 Int (+265) 1 750243
Telefax: 01 752 581 Int (+265) 1 752581

Communication should be addressed to:
The Surveyor General

In reply, please quote

THE SURVEYOR GENERAL
P/ BAG B525
LILONGWE 3.

29th May 2026

To Whom It May Concern,

AUTHORISATION TO USE SURVEY DATA FOR DISSERTATION PURPOSES

This letter serves to confirm that the Department of Surveys has authorised and granted permission to Ms. Alice Chimangeni, a student at Malawi University of Science and Technology, to access and use spatial data for GVH Matola in Balaka District strictly for academic and dissertation purposes.

The data provided is to be used solely for research related to the student's dissertation and must not be distributed, reproduced, or used for commercial purposes without prior written consent from the Department of Surveys.

The Department trusts that the student will handle the data responsibly and in accordance with all applicable ethical and professional standards.

Should you require any further information, please do not hesitate to contact this office.

Yours faithfully,

Charles Bakolo Mvula
Deputy Surveyor General (DSG)-Mapping