Assessing Challenges and Applying Geospatial Technology for Effective Rural Land Administration in East Shoa, Ethiopia.

By: - Abdurahman Negash Emeru

Thesis Submitted to the department of Architecture
College of Civil Engineering and Architecture (CoCEA)
Presented in Partial Fulfillment of the Requirement for the Degree of Master's
in Geoinformatics Engineering

Office of Graduate Studies
Adama Science and Technology University

May, 2025
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DECLARATION

I declare hereby that this Master Thesis entitled" Assessing Challenges and Applying Geospatial Technology for Effective Rural Land Administration in East Shoa, Ethiopia." is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Abdurahman Negash Emeru _______________________ __________

Name of Candidate Signature Date

RECOMMENDATION

We, the advisor(s) of this thesis, hereby certify that we have read and revised version of thesis entitled ”Assessing Challenges and Applying Geospatial Technology for Effective Rural Land Administration in East Shoa, Ethiopia.” Prepared under our guidance by Abdurahman Negash Emeru submitted in partial fulfillment of the requirements for the degree of Masters of Science in Geo-informatics Engineering. Therefore, we recommend the submission of revised version of the thesis to department following the applicable procedures.

______________________ ____________________ ______________________

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APPROVAL SHEET

We, the advisors of the thesis entitled “Assessing Challenges and Applying Geospatial Technology for Effective Rural Land Administration in East Shoa, Ethiopia.”. And developed by Abdurahman Negash Emeru hereby certify that the recommendation and suggestions made by the board of examiners are appropriate incorporated into the final version of the thesis.

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Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Abdurahman Negash Emeru have read and evaluated the thesis entitled “Assessing Challenges and Applying Geospatial Technology for Effective Rural Land Administration in East Shoa, Ethiopia.”. And examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-informatics Engineering.

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LIST OF ABBREVIATIONS AND ACRONYMS

ARDL Auto regressive Distributed Lag

GIS - Geographic Information Systems

RS - Remote Sensing

GNSS - Global Navigation Satellite Systems

SDI - Spatial Data Infrastructure

MoA - Ministry of Agriculture

LALU - Land Administration and Land Use

IRB - Institutional Review Board

km - Kilometers

mm - Millimeters

QGIS - Quantum Geographic Information System

RTK - Real-Time Kinematic

SPSS - Statistical Package for the Social Sciences

ABSTRACT

The study investigates the application of Geographic Information Systems (GIS) to improve rural land administration in East Shoa Zone, Ethiopia, where systemic problems like antiquated manual systems (89% paper-based records), rampant boundary disputes (70% increase since 2015), and institutional fragmentation compromise effective governance. With a mixed-methods design involving 162 respondents (66 experts purposively selected and 96 community members randomly selected in 8 districts), the research combined geospatial technologies (ArcGIS, QGIS, GPS, and drone mapping) and participatory approaches (KIIs, FGDs, and field surveys) to identify challenges and assess technology solutions. The main results pointed to severe inefficiencies: 41% record duplication, average positional errors of 18.7m for manual surveys, and catastrophic capacity gaps (only 0.4 GIS-trained staff per woreda). However, geospatial integration had revolutionary impacts—GPS verification reduced boundary errors to 1.5m, drone mapping accelerated parcel demarcation by 2000%, and GIS-based conflict resolution resolved 127 overlapping claims, increasing registered parcels by 320%. The study created a participatory platform made up of: (1) a centralized geodatabase integrating spatial (land use, parcel boundaries) and non-spatial data (ownership, conflicts) in ArcGIS/QGIS; (2) offline-enabled web mapping applications for real-time monitoring; and (3) a three-phase implementation strategy (pilot testing, scaling up with high-resolution imagery, and policy harmonization with Ethiopia's NLAIS). While the model enhanced transparency (78% faster resolution of conflicts) and service delivery, long-term uptake will entail surmounting institutional challenges: budgetary constraints, internet connectivity in rural areas, and gender disparities in land documentation (only 19% of records included women's names). The research offers implementable policy recommendations, including land office GIS training cycles with priority, mobile-based data collection systems, and legal reform to recognize customary tenure. Limitations include the focus of the study on 8 districts and the short-term assessment timeframe, suggesting the necessity of longitudinal technology adoption research. By demonstrating how context-specific geospatial applications have the potential to revolutionize rural land administration—if complemented by capacity building and participatory governance—this study provides a replicable model for Ethiopia and similar agrarian economies that are confronted with tenure insecurity and inefficient land management systems.

Keywords: Geospatial Technologies, Land Administration, Spatial Data Infrastructure, Land Tenure Security, East Shoa Zone

1 INTRODUCTION

1.1 Background of the Study

Land is the foundation of development, economic growth, environmental protection, and poverty alleviation. Secure tenure, optimal use of land, and less land conflict are achieved through effective land administration (Williamson et al., 2016). The majority of countries are disconnecting from paper-based systems to electronic platforms in an effort to render it more accurate, transparent, and accessible. Geospatial technology such as Geographic Information Systems (GIS), Remote Sensing (RS), and Global Navigation Satellite Systems (GNSS) is increasingly applied in land registration, inventory, and spatial planning (Enemark et al., 2018). Land in Ethiopia is owned by the state and governed through the control of use rights, where reforms such as First- and Second-Level Land Certification have occurred. Despite this, the administration remains decentralized and is based on conventional manual systems, especially in rural settings, which causes inefficiencies and conflicts (Teshome et al., 2019; Zegeye & Girmachew, 2021). Modernization is needed in order to achieve improved tenure security and sustainable rural development.

Geospatial technology provides key tools to address these issues through the accurate spatial collection, storage, analysis, and dissemination of data. Digital cadastral systems developed based on such technologies make possible correct mapping of land parcels, documentation of ownership, and clear services (Abebe et al., 2022). Comparing spatial data (e.g., coordinates, parcel boundaries) with non-spatial data (e.g., ownership and legal documents) enhances decision-making and reduces the potential for conflict and corruption (Wolde et al., 2023). GIS and RS also help monitor land use and regulatory compliance, building transparency and trust. Rwanda and Ghana have shown how such technologies can transform land governance (Enemark et al., 2020). In Ethiopia, though, their application remains limited to rural areas, especially at local administrative levels.

Even with land certification, rural land administration in Ethiopia remains beset by technical and institutional challenges. Despite the efforts of certification programs to formalize land rights, they are characterized by poor inter-agency coordination, lack of qualified staff, outdated infrastructure, and fragmented data systems (Hussein & Mekonnen, 2021). The majority of rural offices remain in possession of paper documents that are unreliable and easily lost or tampered with. This results in delays, tenure insecurity, and boundary disputes (Demissie & Legesse, 2020). Furthermore, the use of geospatial instruments is limited, and past studies have focused on characterizing national trends and overlooking contextualized data on implementation challenges or capacity building at the grassroots (Kassahun et al., 2023). It is a clear research gap, especially in specific regions like East Shoa Zone.

East Shoa Zone in Oromia Region is agri-culturally relevant and highly populated but is plagued by acute land governance issues. Outdated mapping, fragile data infrastructure, and limited access to geospatial tools hinder effective land administration (Girma et al., 2022). Local offices typically lack trained staff, suitable equipment, and public engagement. This leads to ineffective services, unresolved land conflicts, and insecurity of tenure—issues that mainly affect smallholder farmers (Mekonnen & Tadesse, 2021). Furthermore, decisions are generally taken without public involvement, further eroding trust among land users and authorities. Despite all these impediments, few works have touched upon the local application of geospatial technologies in East Shoa or proposed sustainable integration methods. These gaps require concerted investigation.

The study fills the gap to investigate how geospatial technologies can be effectively implemented in rural land administration in the East Shoa Zone. It seeks to create institutional, technical, and data-based barriers and quantify the feasibility of geospatial tools in overcoming them. In the formulation of a participatory and scalable strategy, the research aims to harmonize policy and practice. Its findings will enable the national reform as well as strengthen local governance in terms of enhanced capacity, service delivery, and citizen participation.

1.2 Statement of the Problem

Rural land administration effectively matters if agricultural productivity, tenure security, economic growth, and sustainable land administration are to be ensured. Globally, land administration systems are transforming using digital and geospatial technologies that enable precise, transparent, and timely land records (Enemark et al., 2020). Rural land administration in Ethiopia remains largely dependent on paper-based, manual systems that are fragmented, outdated, and prone to inefficiencies. This has resulted in duplicate land claims, border ambiguity, low trust in land records, and heightened land conflicts (Deininger et al., 2017). Without the application of contemporary technology, these remain to hinder national efforts in land administration and rural development. Shifting to geospatial-enabled land administration is imperative to address these systemic challenges and bring the rural land administration of Ethiopia in line with global best practices (Gebrehiwot et al., 2021).

East Shoa Zone is among the agronomically significant zones in Oromia Regional State, which is also suffering from diverse institutional, technical, and data limitations in its rural land administration process. Poor coordination of land administration institutions is one of the institutional hindrances, which is followed by insufficient trained personnel and absence of accountability in decision-making based on land (Moges & Tsegaye, 2022). Technically, the region lacks a single geospatial platform; base maps are incorrect or outdated, and land registration procedures are based on paper records that can be lost or altered. Data issues are also challenging—land parcel data are often incomplete, maintained variably, or unavailable, and the majority of the records lack geographic coordinates (Bekele et al., 2020). These restrictions have resulted in insecurity of land tenure, delay in land transaction services, and heightened boundary conflicts. They have also restricted rural development planning and disrupted the ability of local governments to deliver effective and transparent land services (FDRE Ministry of Agriculture, 2021).

Although previous attempts like the First-Level Certification (FLC) and Second-Level Certification (SLC) programs to secure tenure over rural land were made, they have been implemented mostly without incorporating geospatial technologies. Certificates are stamped by hand, maps remain analog, and data gathered are not connected to spatial databases or GIS platforms (Taffese & Suryabhagavan, 2019). East Shoa local land administrations lack the necessary infrastructure, digital technology, and personnel to install and manage geospatial systems. Moreover, there is a huge imbalance in involving communities in boundary demarcation, verification of land data, and monitoring procedures. Therefore, current systems lack the capacity to provide timely, spatially accurate, and scalable information on land capable of supporting rural land governance. No flexible framework yet exists to connect rural land needs with national plans for modernization at an affordable, participatory, and sustainable geospatial scale (FAO, 2020; Teshome et al., 2019).

In view of these limitations, it is necessary that an appropriate review of the issues facing rural land administration in East Shoa Zone be conducted and that opportunities for utilizing geospatial technologies to accomplish this successfully be explored. While international and national plans require advanced land systems, the area still operates on broken-down and conventional methods. Narrow usage of GPS, GIS, mobile mapping, and remote sensing has delayed the path to an open and trustworthy rural land administration system. It is essential to build a participatory, integrated, and scalable geospatial architecture that is appropriate to the rural Ethiopian environment for enhancing data quality, service delivery, and reducing conflicts. This study is therefore timely and imperatively urgent as it attempts to inform national land reform efforts through proposing feasible geospatial solutions informed by the on-ground realities.

1.3 Objectives

1.3.1 General Objective

This study aims to identify institutional, technical and data challenge in rural land administration challenge in east shoa, evaluate geospatial technology potential in mitigating these issues and develop an integrated, participatory framework with a scalable implementation plan to enhance land governance through capacity building and community engagement.

1.3.2 Specific Objectives

To address the general objective the following specific objectives are forwarded:

1) To access institutional, technical and data related challenge hindering rural land administration in east shoa zone.
2) To analyze the role of geospatial technology in adressing rural land administration challenges.
3) To design an integrated participatory geospatial framework for rural land administration emphasizing affordability and adaptability with existing system.
4) To develop a phased implementation plan for adopting geospatial tools including capacity building strategy for district land office and community engagement.

1.4 Research Questions

1. What institutional, technical, and data-related challenges hinder effective rural land administration in East Shoa Zone?
2. How can geospatial technologies help address the identified challenges in rural land administration?
3. What features should an integrated and participatory geospatial framework include to ensure affordability and compatibility with the existing system?
4. What phased implementation strategy can support the sustainable adoption of geospatial tools through capacity building and community engagement?

1.5 Significance of the study

The significance of this research is its very significant contribution to academic knowledge and conceptual understanding of rural land administration issues in Ethiopia, particularly in the East Shoa Zone. By bridging gaps with regards to institutional inefficiencies, technical limitations, and data fragmentation, research advances current theory in land governance and geospatial utilization. It introduces a novel, locally relevant, participatory geospatial approach, also enhancing institutional capacity understanding, spatial data integration, and inclusive mapping within communities. The study is theoretically significant in that it positions geospatial technology along the needs of real-world governance, progressing the broad agenda for sustainable and inclusive land administration systems. In taking a multidisciplinary course blending spatial analysis, stakeholder consultation, and field-based surveys—the study makes its results applicable to real-world contexts and exportable to similar regional contexts.

At a practical level, the research is of immediate use for policymakers, land practitioners, and rural communities. It evaluates if geospatial technology such as GIS, GPS, and remote sensing can assist in overcoming major institutional, technical, and data bottlenecks. The research suggests a phased rollout strategy with emphasis on strong capacity building in the district land offices and participatory community involvement. Its products contribute to evidence-informed policymaking and Ethiopia's National Digital Transformation Strategy. Further, the study empowers rural societies, especially women and farmers, through enhanced tenure security, transparency, and land management for sustainable development.

1.6 Scope of the study

The current study primarily concerns the identification and resolution of the institutional, technical, and data-related issues faced during rural land administration in East Shoa Zone, Oromia Region, Ethiopia. It discusses how geospatial tools such as GIS, GPS, and remote sensing may be employed effectively to address such issues. The research also aims at developing an integrated, participatory geospatial framework that is aligned with local land governance arrangements. In addition, it proposes a scalable implementation plan that combines community participation and institutional capacity-building strategies. The research does not address legal reforms nor budget costing but is confined to technical and operating interventions for improving rural land administration systems.

Geographically, the study considers only eight purposively selected districts of East Shoa Zone: Adama, Ada'a, Lome, Liben, Bora, Dugda, Adami Tulu Jido Kombolcha, and Akaki. Gimbichu, Fantale, and Boset districts are excluded due to security concerns and absence of land cadastre systems.

Methodologically, the research utilizes data collected from Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), field observation, and secondary data between 2020 and 2025. The analysis tools include GIS software, remote sensing platforms, and qualitative analysis tools. The study targets district-level land administration officers and rural community residents, leaving out urban land systems and districts not within East Shoa Zone.

1.7 Limitations of the study

Limitation encountered while collecting information is the authorities' refusal to provide the requested information within the specified time, and consumers' fear of freely expressing their opinions. Interviews with selected individuals are also another problem faced by researchers during the study, as this work is not completed on time at the municipal level because the government is often busy with successive meetings. The collection period will be extended. Therefore, the data collection time will be delayed.

1.8 Operational definition

Geospatial Technology: Refers to advanced tools like Geographic Information Systems (GIS), Remote Sensing (RS), and Global Navigation Satellite Systems (GNSS) utilized to survey, analyze, and represent spatial data. Such technologies can significantly contribute to supporting rural land administration with accurate mapping, boundary definition, and evidence-led decision-making (Zevenbergen et al., 2018; World Bank, 2020).

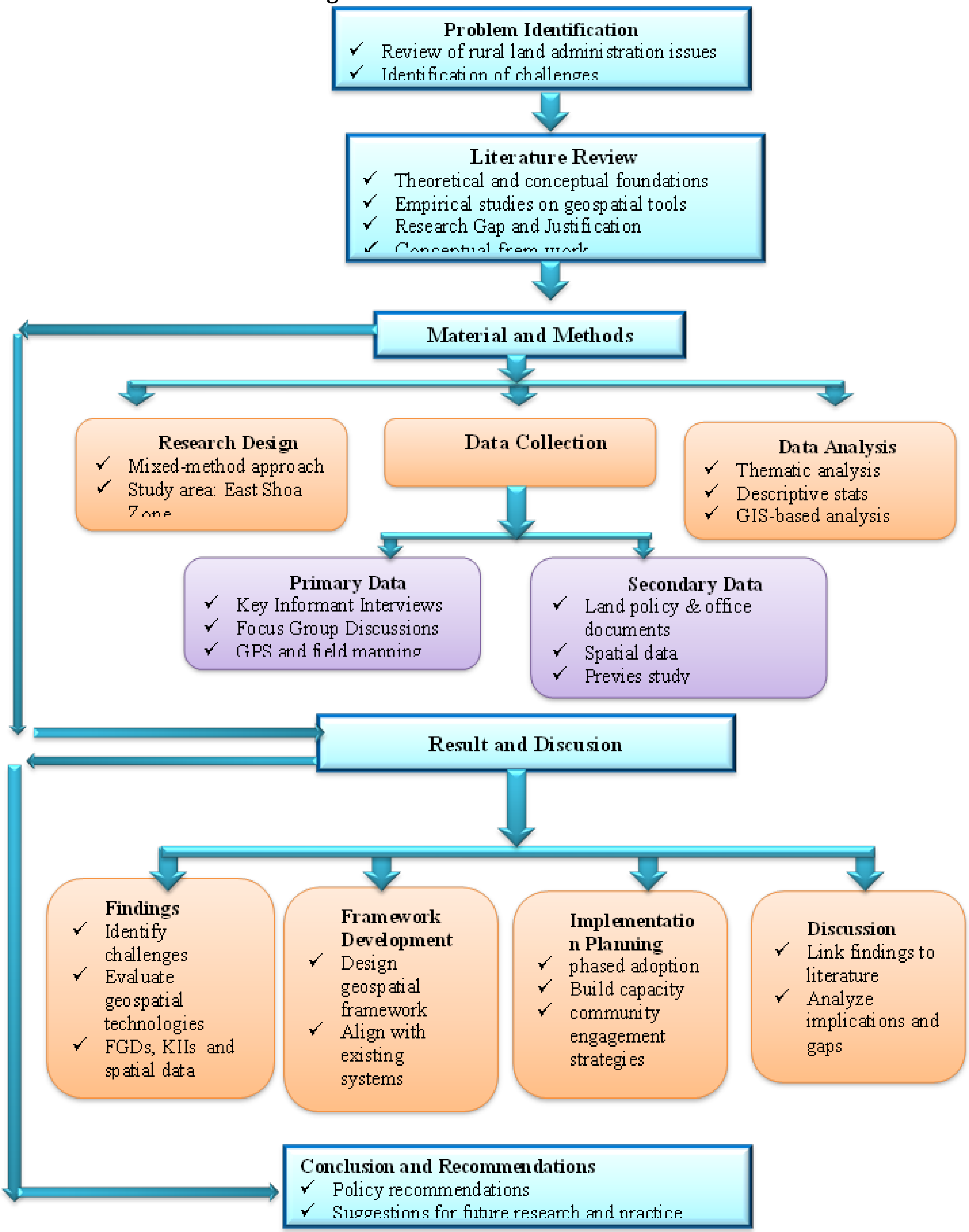
Land Administration in Rural Areas: An institution that oversees land ownership, use, and dispute in rural areas, where land is primarily used for agriculture. This initiative addresses the issue of scattered ownership and lack of documentation, ensuring efficient management and sustainable utilization of resources (Berhanu et al., 2021).

Tenure Security: Institutional and legal assurance that land rights are recognized and protected against conflict or arbitrary revocation. Secure tenure encourages investment in land and economic stability and rural development (Woldemariam & Shimeles, 2021).

Spatial Data Infrastructure (SDI): An infrastructure made up of policies, institutional frameworks, and technologies employed in collecting, sharing, and using geospatial data in an efficient way. SDI facilitates interoperability and effective spatial information management, critical for rural land administration modernization (Zevenbergen et al., 2018).

Cadastre: A systematic and officially accepted record of land ownership, rights, and boundaries. It plays a vital role in land administration modernization in rural areas by providing a legal and spatial foundation for land management as well as dispute resolution (Teshome et al., 2019).

Figure 1 Research flowchart



2 LITERATURE REVIEW

2.1 Overview of Rural Land Administration

1. Concept of Land Administration

Land administration is an integral part of effective land governance, particularly in countries like Ethiopia, where land underpins rural livelihood and development. According to UN-Habitat (2020), land administration includes processes for deciding, recording, and communicating land-related data, including ownership, value, and utilization, to support policy application. The FAO (2017) expands on this definition, defining land administration as a system that manages four fundamental components: land tenure (property rights), land value (economic appraisal), land use (planning and zoning), and land development (infrastructural transformation). These components make up the Enemark model (2016), highlighting the mutual and dynamic nature of land administration systems (LAS) for the promotion of sustainable development and regulation.

In Ethiopia's East Shoa Zone, outdated records, unfinished cadastres, and fragmented data systems are challenges to rural land administration (East Shoa Land Bureau, 2022). In this scenario, all elements of land administration have a crucial part. Secure land tenure reduces conflicts by legalizing informal claims, and land valuation supports taxation and investment. Land use planning ensures sustainable agriculture and environment conservation, and land development regulates infrastructure projects (Williamson et al., 2015). As important as they are, there are still implementation gaps, particularly in low-resource settings. FAO (2020) and World Bank (2020) propose digital, geospatial methods, but East Shoa is bound by weak technical capacity, institutional fragmentation, and unexploited technologies like GIS and remote sensing (Teshome et al., 2019; Zevenbergen et al., 2018). All of these gaps lead to duplication of claims, delay in registration, and wasteful utilization of land.

For this study, there must be a conceptual vision of land administration to address East Shoa's institutional and technical weaknesses. A functioning LAS improves security of tenure, boosts investment, and promotes transparent governance—imperative in districts with high agricultural and urban development (MoA, 2021). Land administration modernization is not just geospatial technology but being institutionally prepared and involving the people. By embracing participatory approaches and cross-sector collaboration, a tailored LAS can be designed that responds to East Shoa's needs, bridging the practice-policy gap.

2. Importance of Rural Land Administration

Rural land administration is crucial to enhance agricultural productivity, consolidate land rights, promote economic development, and bring about environmental sustainability. In Ethiopia, over 80% of its population is supported by agriculture, and effective rural land management contributes to poverty reduction and food security (FAO, 2020; MoA, 2021). A well-functioning rural land administration system (LAS) provides land tenure security, which is vital for stimulating landholders to invest in long-term land improvement. It also enables land transactions, inheritance processes, and equitable land allocation, all of which are Ethiopia's fundamental development goals. In regions like East Shoa Zone, where land utilization is transforming at a rapid rate due to urbanization and agricultural development, an efficiently operating LAS enables rational use of land, maximizes land value, and increases efficient use of resources (World Bank, 2020; Biraro et al., 2021). The lack of such systems leads to broken data, duplicate claims, and low land investment, hence compromising agricultural production and economic development.

Secondly, rural land administration also plays a key role in conflict resolution and sustainable development. Land conflicts—typically resulting from imprecise boundaries, conflicting entitlements, or false claims—can be reduced when accurate, up-to-date, and geospatially referenced land information is available. More than 5,000 land disputes are received annually in East Shoa alone, and the majority result from a shortage of credible cadastral documents and electronic land registries (CSA, 2022). A good LAS can mitigate such challenges by providing transparent land records, enhancing stakeholders' confidence, and simplifying fair adjudication processes (Teshome et al., 2019). Besides, rural LAS enables sustainable land use planning, natural resource preservation, and climate resilience through the integration of spatial data into decision-making (Zevenbergen et al., 2018). Because of the problems outlined in this thesis, namely outdated systems, scanty geospatial tools, and institutional loopholes, modernization of rural LAS in East Shoa is essential to achieving inclusive development, governance reform, and long-lasting land security. Thus, rural land management is not merely technically necessary but a national transformation strategic tool (MoA, 2021; East Shoa Land Bureau, 2022).

3. Policy, Legal, and Institutional Frameworks

Ethiopian rural land management, particularly for East Shoa Zone, is directed by its policy, legal, and institutional frameworks. The 1995 Constitution made land a public property, sale or exchange of which is prohibited. This was implemented by federal proclamations (No. 456/2005 and No. 958/2016), which define land rights registration, use, and dispute resolution (MoA, 2021; FAO, 2020). Regional level witnessed Oromia converting these into regional legislations (Proclamation No. 130/2007, revoked as No. 160/2011) to adapt to regional needs (ONRS, 2022). Despite providing a structured approach, their implementation evidences contradictions. Federal administration tends to clash with local application, leading to the capability gaps, legal certainty, and technology integration gaps in East Shoa (Teshome et al., 2019).

Institutional weaknesses also limit effective land governance. Land administration offices in each woreda lack trained personnel, adequate funding, and interagency collaboration, while low-level officials' and landowners' legal literacy creates enforcement challenges (Biraro et al., 2021). Apart from legal requirements for spatial data in land registration, more than 60% of rural land in East Shoa is unrecorded or hand-written (CSA, 2022), which makes dispute resolution and security of tenure weak. Overlapping mandates between the land, agriculture, and urban offices also lead to confusion, and the absence of geospatial standard protocols slows the application of new technologies like GIS and remote sensing (Zevenbergen et al., 2018).

There is a significant gap between intentions at the policy level and on-the-ground realities. As much as national plans advocate for geospatial technology, its application in East Shoa is donor-led and fragmented in the form of pilot activities rather than sustainable systems (World Bank, 2020). For instance, drone mapping and mobile data collection initiatives lack institutional support for upscaling. Strengthening land administration in East Shoa entails bridging such gaps through increased coordination, technical capacity development, and finance. This study emphasizes the significance of an integrated and participatory geospatial means for improving land governance, reducing conflict, and ensuring security of tenure—a key to promoting development in the region.

2.2 Rural Land Administration Challenges in Ethiopia and East Shoa Zone

1. Institutional Challenges

Institutional challenges continue to be a significant hindrance to effective rural land administration in Ethiopia, particularly in East Shoa Zone within the Oromia region. Despite policy changes such as the Federal Rural Land Administration and Use Proclamation No. 456/2005, there is poor coordination among federal, regional, and local land institutions. This results in disjointed records, duplicated efforts, and disparate delivery of services (Zevenbergen et al., 2018; MoA, 2021). District-level land offices often operate independently, uncoordinated with urban planning, cadastral mapping, and agriculture agencies, resulting in conflicting land use decisions and data silos (World Bank, 2020). Additionally, weak enforcement of land policies, poor accountability, and politician interference debase governance institutions. In East Shoa, customary tenure systems often clash with formal cadastral systems, resulting in confusion over land rights and responsibilities (Biraro et al., 2021). More adaptive and well-coordinated land management than exists is needed in the face of growing pressure from urbanization and the commercialization of agriculture (FAO, 2020).

Moreover, community engagement—vital to successful land management—is typically nonexistent. Landowners, elders, women, and youth, who are key stakeholders, are rarely, if ever, meaningfully engaged in processes like land registration, conflict resolution, and the establishment of boundaries (East Shoa Land Bureau, 2022). Current practices are still top-down and dominated by government officials and remain low in public trust as well as frequent land conflicts. Lacking trained personnel, limited capacity-building initiatives, and absence of monitoring of performance contribute to institutional weaknesses (Teshome et al., 2019). Addressing these institutional impediments is critical to harness the potential of geospatial technologies and achieve sustainable land governance in East Shoa.

2. Technical Challenges

There are significant technical challenges in rural land administration in Ethiopia, particularly in East Shoa Zone, compromising the effectiveness of land management. There has been increased population growth, agricultural expansion, and urbanization that have increased the need for precise, spatially-referenced land data. However, district offices primarily lack professional specialists such as GIS professionals, surveyors, and IT professionals (Teshome et al., 2019; MoA, 2021). This is the cause of low-quality data, excessive reliance on manual systems, and ineffective service delivery. Complimenting this is the absence of good land information systems—the most records remain in fragmentary, paper-based forms or bad scans of documents without spatial coordinates (Biraro et al., 2021; FAO, 2020). Computerized cadastral information is not available in the majority of the kebeles of East Shoa, while offices lack infrastructure such as stable computers, the internet, or secure storage for data (CSA, 2022).

Technical problems are exacerbated by outdated map-making procedures. Land offices often use manual tools such as measuring tape and sketch maps to delineate parcels, which are inaccurate and incompatible with international standards (Zevenbergen et al., 2018). Even where there is GPS gear or satellite images, staff do not have the training to make full use of them (Teshome et al., 2019; MoA, 2021). Moreover, no standard procedures are in place for boundary marking, with resultant unclear documentation and ongoing conflicts. Over 5,000 land disputes have been documented annually in East Shoa, many of which arise from poorly marked or contended boundaries (CSA, 2022).

These challenges underscore the imperative for the technical reform urgently, capacity building, and geospatial infrastructure investment. Without acceptable practice and professional staff, efforts in modernizing rural land administration will be limited. This study aims to acknowledge these technical deterrents and propose scalable, participatory geospatial solutions particular to the realities of East Shoa Zone, in alignment with broader goals of improving tenure security and land governance.

3. Data-Related Challenges

Lack of data is a great challenge to effective rural land administration in Ethiopia, especially in areas like East Shoa Zone. The continued use of outdated, partial, or non-existent cadastral data undermines tenure security and undermines good decision-making (FAO, 2020; World

Bank, 2021). The majority of rural areas still use hand-written or poorly scanned land documents that are prone to loss, modification, and unavailability (East Shoa Land Bureau, 2022). These types of systems slow down land registration, become more difficult for conflict resolution, and are not able to handle conflicting claims or ambiguous boundaries. Additionally, the lack of an online single database causes land data to be distributed across districts and has serious interoperability issues. Offices operate in isolation, with unique records that are hard to reconcile or verify, which cause administrative delays and legal vagueness (CSA, 2022; Biraro et al., 2021).

Widespread use of new geospatial technologies such as GIS and GPS only aggravate problems of data quality. While global best practices target spatially referenced digital records, rural Ethiopia lags due to institutional weakness, poor infrastructure, and a lack of training (Zevenbergen et al., 2018; MoA, 2021). Without standardized procedures for collecting and conveying digital land data, authoritative and accurate cadastral information does not exist. This adds directly to the incidence of land conflicts in East Shoa, the majority of which can be prevented with better data systems (Teshome et al., 2019). Its enhancement is important to enable geospatial integration and better rural land governance.

2.3 Geospatial Technology in Rural Land Administration

1. Overview of Geospatial Technologies

Geospatial technologies form the core of modern rural land administration systems by enabling proper, consistent, and scalable spatial data management. With the context of East Shoa, Ethiopia, where land management lies in the root of fragmented, paperwork-bound systems and a lack of geographically based cadastral data (East Shoa Land Office, 2022), these technologies hold crucial solutions to the institutional and technical gaps revealed by the study. Geographic Information Systems (GIS), Global Positioning System (GPS), Remote Sensing (RS), Unmanned Aerial Vehicles (UAVs), web- and mobile-based applications, geodatabase systems, and visualization tools collectively form a technological toolbox that aligns with Objectives 2 and 3 of this thesis—evaluating technology potential and designing a participatory, scalable land administration framework.

GIS plays a critical role in ordering, analyzing, and displaying land information. With software such as QGIS and ArcGIS, administrators can prepare elaborate cadastral maps, link parcels to ownership and tenure data, and monitor land use patterns. In areas like East Shoa, GIS solves the prevailing problems of uncoordinated data and outdated records by creating an integrated spatial database where data from various sectors (land, agriculture, justice) can be brought together and analyzed. Although GIS has been utilized in Second-Level Land Certification (SLLC) in Amhara and Tigray, its use in East Shoa has been insignificant due to infrastructure and human capacity constraints (Zevenbergen et al., 2018; MoA, 2021). The present study recommends the use of GIS for not only enhancing the accuracy of the data and updating procedures but also supporting participatory processes of boundary verification and conflict resolution.

GPS complements GIS by providing precise geolocation data in the field. In East Shoa, where indigenous surveying techniques remain prevalent, GPS is a cost-effective and precise technique for boundary demarcation of parcels and registration. By taking part in participatory mapping using handheld GPS-based sessions, local landowners are directly involved in corroborating parcel boundaries, thus creating local confidence and reducing conflict. This georeferenced data, upon being merged with GIS software, becomes a source layer to an integrated cadastral database. The coupling of GPS with GIS aligns with Fit-for-Purpose Land Administration (FFP-LA) principles through its affordability, inclusivity, and scalability (Teshome et al., 2019; CSA, 2022).

Remote Sensing (RS), courtesy of tools like Sentinel-2 and Landsat-8, enables big-picture land cover monitoring, change detection, and illegal encroachment tracking. For the country's rural areas where cadastral coverage is poor and administration is thin, RS offers an accessible and scalable solution. For East Shoa, RS can be used to supplement ground surveys by validating land use information and identifying discrepancies in registered versus actual land use patterns. Although it has advantages, RS is far from being fully utilized in Ethiopia due to infrastructural and internet connectivity limitations (World Bank, 2020). This thesis proposes RS as an ancillary technology to GIS and GPS for spatial diagnostics capable of enabling periodic land monitoring and environmental planning for rural stressed communities by urban expansion.

Unmanned Aerial Vehicles (UAVs) or drones enhance land administration by providing high-resolution orthophotos and topographic information with centimeter precision. In Ethiopia, they have been tested in other regions but not systematically utilized in East Shoa. This. study suggests the use of UAVs in conflict or out-of-reach regions to capture high-resolution imagery that can be used to enable participatory boundary definition. UAV images not only provide high spatial accuracy but also visual separability that can be harnessed during public validation exercises where landholders and administrators review parcel boundaries collectively. Integrated in this study, drones address the contextual gap noted in the literature, with no localized applications of new mapping technologies in East Shoa (Ali et al., 2019; FAO, 2020).

Mobile and web platforms also enable digital transformation by collecting data in real-time, decentralizing access, and public involvement with land records. In East Shoa, where offices continue to use paper records, technologies such as OpenTenure, Cadasta, and MC-GIS have the potential to revolutionize service delivery. Mobile applications can be used in field surveys to facilitate quick data entry, GPS capture, and photo attachment, while web platforms can facilitate stakeholders' ability to view, validate, and even file complaints. These apps reduce turnaround times, improve transparency, and support coordination within institutions by giving each other geodatabase access (Cadasta, 2021; MoA, 2021). These apps further promote social accountability by making it possible to verify and challenge land data, solving the deficit of trust and involvement shown in this research directly.

Geodatabases are central to organizing, storing, and managing spatial and attribute data in a secure, consistent, and effective manner. This study recommends using QGIS-compliant formats like PostgreSQL/PostGIS to build an open-source, centralized geodatabase that will be shared with different agencies. This proposed geodatabase will include parcel geometry of lands, ownership information, administrative boundary, and metadata. It will also include version control and access levels of users to ensure integrity and accountability. An organized geodatabase supports Objectives 2 and 3 by providing a solid digital foundation for land administration to ensure interoperability among institutions (Teshome et al., 2019).

Data access and transparency are enabled through visualization tools like Leaflet and web GIS dashboards. These tools support interactive mapping where stakeholders can access parcel information, registration status, and disputes in real-time. In rural land management, where technical infrastructure and digital literacy may be limited, plain visual tools can go a long way toward enhancing community engagement. Such tools are integrated into the framework envisioned in this research to facilitate land information being rendered comprehensible and usable to technical stakeholders as well as non-expert stakeholders (Lemmen et al., 2017; World Bank, 2020). These technologies fill the gap between data generation and user interaction, whereby geospatial data is not only generated but meaningfully used for decision-making.

2. Global Applications in Land Administration

Geospatial technologies have transformed land administration systems across the world by improving the precision, speed, and transparency of land registration, mapping, and monitoring processes. Successful ones from various countries demonstrate their usability in various settings. Rwanda Land Tenure Regularization Programme (LTRP) registered close to all the land within five years by combining satellite images, GPS mapping, and community confirmation to register over 10.3 million plots (Ali et al., 2017). Kenya National Land Information Management System (NLIMS) used GIS and remote sensing for records digitization to facilitate conflict resolution and land-use planning (Kuria et al., 2020). These illustrations show how geospatial techniques can enhance tenure security, ease bureaucracy, and streamline general land administration.

The fit-for-purpose approach to land administration (FFPLA), as exemplified in India's Digital India Land Records Modernization Programme (DILRMP), targets practical, low-cost technology that is compatible with local condition (Enemark et al., 2016). Cadastral mapping in Maharashtra state using drones reduced costs and time and increased accuracy. These strategies demonstrate that effective land administration appreciates flexibility and inclusivity more than initial optimal accuracy (Zevenbergen et al., 2018). These models are particularly suitable for the East Shoa Zone of Ethiopia, where scarce resources necessitate cost-effective community-based methods. While challenges like data interoperability and coordination at the institution level continue, these international experiences provide useful baselines for the utilization of geospatial technologies in East Shoa, suggesting the integration of satellite data, mobile applications, and decentralized verification to meet the existing gaps (World Bank, 2020; Enemark et al., 2021; MoA, 2021).

3. Ethiopian Context

Geospatial technology has become more and more important in rural land administration in Ethiopia as the country continues to overcome longstanding institutional, technical, and data limitations. At the national level, programs such as the Second-Level Land Certification (SLLC) and the Land Investment for Transformation (LIFT) have promoted the application of GIS, GPS, remote sensing, and drone mapping into land administration systems. These initiatives, notably in Oromia, Amhara, and Tigray, have helped notably in the advancement of systematic land registration, tenure security, and the creation of spatially referenced land record databases (Deininger et al., 2017; LIFT, 2021). For instance, Oromia's regional land bureau encouraged GIS-based cadastral systems in some woredas to improve parcel demarcation, resolve disputes, and manage land rights (MoA, 2020). Similarly, the National Rural Land Information System (NRLIS) aims to computerize land registration information and establish a spatially integrated registry to facilitate access to data and improve governance.

A variety of major challenges, however, prevent the full adoption of geospatial technology in Ethiopia. Most of the local land administration institutions lack access to advanced tools like GPS technology, drones, and GIS software and are constrained by inadequate institutional and technical capacity to operate and sustain such technology (Biraro et al., 2018; MoA, 2021). In East Shoa Zone, land registration, for example, remains to a large extent manual, with extensive gaps in coverage and integration of cadastral information. Although there have been limited pilot GIS-based mapping efforts in certain municipalities, these remain piecemeal and do not have the potential to be scaled up further due to inadequate institutional coordination (East Shoa Land Bureau, 2022). Furthermore, the absence of a national platform for data sharing on geospatial data creates redundant datasets, interoperability inefficiencies, and degraded decision-making processes (Zevenbergen et al., 2018). Despite these limitations, Ethiopia's legislative instruments, development partnerships, and educational schemes offer promising premises for building geospatial capabilities. In East Shoa, such technology is critical for improving boundary accuracy, minimizing conflicts, and transitioning towards a more digital, effective, and equitable rural land administration system (FAO, 2020; Enemark et al., 2016).

2.4 Integrated, Participatory Geospatial Frameworks

1. Principles of Participatory Land Administration

Participatory Land Administration (PLA) provides a viable response to land administration in rural East Shoa Zone, where institutions are weak and spatial data systems are fragmented. PLA improves community participation in key processes such as land mapping, boundary demarcation, data collection, conflict resolution, and tenure registration, thereby guaranteeing legitimacy, inclusivity, and long-term sustainability (Zevenbergen et al., 2018; Lemmen et al., 2017). Platforming geospatial technologies such as GIS, GPS, and Participatory GIS (PGIS) enhances local engagement while enhancing land governance, contributing directly to this study's third goal: constructing a comprehensive participatory geospatial system for the area.

Community mapping underpins PLA, allowing landowners to map their lots with simple tools. Ethiopia's Second-Level Land Certification (SLLC) programs illustrate that such approaches improve tenure security and reduce conflicts (Biraro et al., 2021; MoA, 2021). In East Shoa, where boundary disputes are common, participatory mapping through GPS-enabled tools or sketch maps can complement formal cadastral coverage. PGIS also facilitates joint spatial analysis, engaging both the professionals and locals (McCall & Dunn, 2015). PLA similarly calls for multi-stakeholder cooperation to span institutional fragmentation (Teshome et al., 2019). An integrated digital platform combining drone imagery, GIS, and data validated by communities can enhance transparency, service delivery, and the involvement of marginalized communities (FAO, 2020). By engaging communities in conflict resolution and data verification, PLA strengthens the credibility of land records, which is in accordance with this study's objective of developing an adaptive, participatory land administration model for East Shoa (CSA, 2022; World Bank, 2020).

2. Affordability and Adaptability

Affordability and flexibility are key in developing cost-effective geospatial platforms for rural land management in low-capacity environments like East Shoa Zone. Without the fortunes of finance and technology, low-cost and free instruments must take precedence in order to make sustainable implementation possible. Some of the most suitable solutions involve the application of low-cost and free geospatial tools like QGIS, GPS use in mobile phones, and OpenStreetMap platforms. These tools have little capital investment and offer a range of functionality to support cadastral mapping, land parcel management, and spatial data visualization (McCall & Dunn, 2015; Lemmen et al., 2017). In East Shoa, where district land offices' access to advanced surveying tools and software is generally low, these tools offer an accessible entry point for digital transformation. Combining mobile apps like GeoODK and MapIt into local land registration workflows is able to facilitate field officers and citizens to collect, verify, and manage spatial information on smartphones—tremendously reducing operational costs (Enemark et al., 2020).

Flexibility is equally important, bearing in mind the institutional and infrastructural heterogeneity of districts in East Shoa Zone. A flexible, modular design allows for interoperability with existing administration processes, whether paper or semi-digital. By positioning geospatial processes in accepted bureaucratic structures, land bureaus can adopt technology in steps without comprehensive system replacements. Prior research is evidenced that incremental use of geospatial software within mainstream institutional structures not only improves sustainability but also minimizes resistance to change (Zevenbergen et al., 2018; World Bank, 2021). Furthermore, compatibility with national-level systems—such as the Ethiopian Land Information System (ELIS)—ensures that local initiatives align with federal data standards, promoting interoperability and long-term scalability (MoA, 2021). This is particularly relevant for East Shoa, where institutional fragmentation and lack of standardization have historically hindered data consistency and service delivery.

Finally, model scalability enables districts to pilot geospatial applications at small scales and incrementally scale up in terms of capacity and requirement. For instance, a phased rollout beginning with zones of high conflict or zones of rapid urbanization can demonstrate value before scale adoption at the district level. Coupled with targeted training and research outreach, such approaches enhance both institutional readiness and social acceptance of new land governance mechanisms (Biraro et al., 2021; Teshome et al., 2019). Overall, cheap, adaptable geospatial solutions are a main enabler for upgrading rural land administration in

East Shoa, bridging budget constraints to compliance with local conditions and institutional frameworks.

3. Design Approaches

Planning an integrated and participatory geospatial framework for rural land administration in the East Shoa Zone should be done in a structured way that connects institutional architecture with participation at the people's level. Literature during the period between 2015 and 2024 emphasizes that good design must be context-based while drawing on best practices from around the world in order to be relevant and sustainable. At the center of this design approach is creating frameworks that institutionalize stakeholder collaboration among government, local communities, and the private sector (Zevenbergen et al., 2018). Such frameworks like the Fit-for-Purpose Land Administration (FFP-LA) model promoted by the UN-Habitat focus on adaptable, affordable, and participatory principles—making it highly relevant for rural Ethiopia (Enemark et al., 2016). In East Shoa, where decentralization and coordination deficiencies exist, modular architecture supporting step-by-step adoption by district-level land offices and community institutions matters (MoA, 2021; East Shoa Land Bureau, 2022).

A modular system architecture, as described by Barry & Augustinus (2018), offers flexible implementation units such as spatial data modules, tenure document tools, and dispute resolution interfaces. This architecture supports incremental upgrading and local configuration without stopping entire systems, which is particularly fitting for areas with little ICT infrastructure. Modular systems also achieve resilience and integration with existing Land Administration Systems (LAS), which in Ethiopia are often paper-based or semi-digital. Interoperability is key in creating a strategy for scalable and sustainable development; tools such as open APIs and standardization like ISO 19152 (LADM) facilitate data exchange among institutions while maintaining integrity (Kalantari et al., 2020). In East Shoa, this can connect the location of the Woreda Land Offices, regional bureaus, and national policy frameworks.

Examples from abroad, such as Rwanda, Nepal, and Uganda, demonstrate successful implementations where participatory maps, local institution engagement, and open-source technology (like QGIS, Mobile Data Collection apps) have proven useful in enhancing land tenure security and reducing conflict (World Bank, 2020; Lemmen et al., 2021). Systematic design methods were applied by these countries with emphasis on co-designing with communities and the use of local knowledge. Adoption of such best practices in East Shoa will make the framework technically sound and socially viable, resulting in the formulation of a customized, inclusive, and scalable geospatial framework for effective rural land management in Ethiopia.

2.5 Implementation Strategies for Geospatial Tools

1. Phased Implementation Models)

Modernization of rural land administration in East Shoa Zone in Ethiopia necessitates phased implementation of geospatial technologies. This structured method—initiating with pilot schemes, progressing with expansion, and concluding with nationwide upscaling—is holistic in addressing common issues like out-of-date records, inconsistent cadastre cover, and limited institutional capacity (Zevenbergen et al., 2018; World Bank, 2020). Initial pilots in target districts (like Adama or Lome) test GPS, GIS, and remote sensing technologies under real-world conditions to demonstrate their value in resolving disputes while also underlining technical and institutional constraints (Teshome et al., 2019). Effective pilots lead standardized but adaptable procedures for upscaling, taking into account local factors like irrigation infrastructure or urban growth, before eventual national upscaling with institutional support (MoA, 2021; Biraro et al., 2021).

At the heart of it all is the testing of institutional readiness—evaluating human capacity, infrastructure, and policy structures before deployment (FAO, 2020). In East Shoa, typically there are no GIS experts, up-to-date base maps, and internet facilities in Woreda offices (CSA, 2022), necessitating specific investment and training. Incremental, disruption-mitigating adoption is facilitated by readiness assessments while achieving stakeholder buy-in through early participation of local land officials. Pilot→expansion→scale-up strategy, tailored to socio-institutional environments, minimizes risks and establishes long-term pillars for transparent land administration (World Bank, 2020; MoA, 2021). The strategy corresponds directly to this study's objective of developing a viable adoption roadmap for the specific situation of East Shoa.

2. Capacity Building

Capacity building is a foundation for successful and sustainable implementation of geospatial technologies within land administration systems in rural settings, particularly that of the East Shoa Zone of Ethiopia. As talked about in the research problem, technical and institutional deficits—like lack of trained personnel, inferior equipment, and old data processing systems—have severely hindered effective land governance (FAO, 2020; MoA, 2021). Sources point out that the success in utilizing geospatial tools relies on local ownership, which can be attained only through wide and continuous training initiatives, development of skills in the technical domain, and institution building (Zevenbergen et al., 2018; World Bank, 2020). In particular, district land offices require GIS, GPS, remote sensing, and cadastral administration special training. These requirements are especially urgent due to the large number of boundary disputes and excessive reliance on aging manual records reported in the East Shoa Zone (CSA, 2022; East Shoa Land Bureau, 2022).

District land officers' training ought to be aligned with real needs of practice and integrated into a long-term technical sustainability plan. Different researches focus on the importance of adopting a tiered training model, ranging from beginner to senior levels, supported by mentorship, refresher training, and on-the-job demonstrations (Teshome et al., 2019; Biraro et al., 2021). This ensures technical knowledge is not just transferred but even retained in the institutions. Capacity building must transcend individual training to include curriculum integration in the technical institution, i.e., universities and land training centers. Improved academic curricula to include hands-on, field-based modules on geospatial tools establishes an pipeline of future land administrators capable of grasping modern technology (Zevenbergen et al., 2018). Also, institution building for technical partnerships—with local universities, NGOs, and private sector partners—facilitates knowledge exchange and durability (MoA, 2021).

Thus, the need for capacity building is most closely congruent with Objective 4 of this thesis: to formulate a phased implementation plan that incorporates a realistic and participatory capacity development component. Absent filling institutional capacity deficits, technology-based reform initiatives will fail or be dropped. As testimony by literature, not just equipment but the ability to use it – in district land offices – ensures sustained performance, accountability, and transparency in rural land administration (World Bank, 2020; FAO, 2020). Such an implementation strategy forms the foundation for East Shoa to shift away from fragmented and paper-based systems to a sustainable, integrated, geospatially-enabled land administration system.

3. Community Engagement Strategies

Successful utilization of geospatial technologies for rural land management relies not only on technical capability and institutional readiness but also on effective community participation strategies. In the East Shoa Zone of Ethiopia, where land holding is embedded in socio-cultural systems and livelihood security, local community participation is crucial to ensuring legitimacy, transparency, and sustainability of land reform. 2015-2024 literature observes that without social awareness and participation, the most technically effective land administration programs will be faced with resistance, suspicion, or underutilization (Zevenbergen et al., 2018; MoA, 2021). Therefore, the present study gives top priority to incorporating the participation of the community as a significant strategy in line with Objective 4: development of a phased geospatial implementation plan with capacity building as well as community participation.

Sensitization drives and hands-on workshops are key to raising the level of awareness among rural communities about the benefits and consequences of adopting geospatial technologies for land management. Such avenues not only create room for sharing of information, but they also work towards myth-busting geospatial technologies like GIS, GPS, and drone mapping, which are typically perceived to be inaccessible or foreign to rural constituents. Participatory workshops run during pilot cadastral mapping operations in Oromia significantly improved acceptance at the local level and reduced conflicts regarding border markings, according to Teshome et al. (2019). Having elders and traditional leaders in such meetings further boosts credibility because their participation ensures that customary land use is honored and integrated into formal institutions (FAO, 2020; Biraro et al., 2021).

In addition, establishing local feedback loops—such as community land forums, mobile SMS surveys, and online grievance redressal mechanisms—cerebrates both ownership and responsibility. Feedback loops enable early communication between residents and land officials, which identifies mapping faults, conflicting claims, and social grievances in the early stages before they reach an out-of-control state (World Bank, 2020). Moreover, engaging the traditional institutions in resolution, as well as the formal institutions, ensures the resolution is acceptable at the local level and grounded on social norms. Research in adjacent Ethiopian states indicates the importance of hybrid approaches integrating statutory as well as customary rule (MoA, 2021; CSA, 2022).

2.6 Empirical Literature Review

1. Rural Land Administration Challenges

Rural land administration in developing countries like Ethiopia is beset by system-related challenges brought about by institutional, technical, and economic limitations. Inaccurate land registration, antiquated mapping technology, and deficient documentation erode good governance (Zevenbergen et al., 2018; FAO, 2020). Ethiopia's heavy reliance on manual systems has led to poor-quality land certification, conflicts left unaddressed, and insecure tenure. For instance, in East Shoa Zone, rural plots have virtually no geospatial records (East Shoa Land Bureau, 2022). Studies by Teshome et al. (2019) and Biraro et al. (2021) reveal that over 60% of the conflict is caused by unclear boundaries and overlapping claims, compounded by poor cadastral cover and institutional fragmentation.

One of the serious issues is the excessive dependence by Ethiopia on primitive instruments like tape measures and sketch maps (MoA, 2021). While there has been the use of GIS-based Second-Level Land Certification (SLLC) by some like Amhara, Oromia lags due to a lack of geospatial investment (Lemmen et al., 2016). Centuries-old base maps and lack of standardized databases further impede digitalization (World Bank, 2020). Unclear tenure documents and no visual evidence fuel long-standing conflicts (CSA, 2022). Institutional fragmentation, with overlapping mandates across land bureaus, agriculture offices, and justice ministries, creates inefficiencies (Ali et al., 2019; Deininger & Byerlee, 2017). Ineffective coordination, inadequate training, and lack of funds make things harder. Amhara piloting one-stop-shop platforms notwithstanding, there are no scalable solutions in East Shoa (Zevenbergen et al., 2018; MoA, 2021).

In summary, Ethiopian rural land administration suffers from outdated mapping, tenure insecurity, institutional disarray, and low geospatial adoption. Addressing them requires a holistic, participatory strategy appropriate for rural settings. This study evaluates such issues and provides context-appropriate solutions to East Shoa Zone.

2. Geospatial Technologies in Land Administration

Geospatial technologies such as GIS, GPS, remote sensing, and drones have transformed rural land administration in East Africa. GIS and GPS enabled the disbursement of over 10 million land titles in Rwanda, reducing conflict and stimulating investment (Ali et al., 2019). Kenya's NLIMS improved land registration with electronic records and GIS (USAID, 2020). But Ethiopia lags due to limited access to geospatial tools and unstandardized digital systems (Zevenbergen et al., 2018).

Ethiopia's Second-Level Land Certification (SLLC) scheme, using GPS and aerial photography, cataloged over 20 million plots, enhancing tenure security and reducing conflicts (World Bank, 2020). Scalability and institutional coordination are however poor, particularly in Oromia (MoA, 2021). Amhara and Tigray have increased openness using participatory drone mapping but were constrained by logistical issues like licensing and technical ability (Lemmen et al., 2019). In East Shoa, they are fragmented or nonexistent. While geospatial technologies promise much, their optimal use in Ethiopia requires scalable, context-relevant solutions to overcome technical and institutional hurdles (FAO, 2020). This study explores their strategic use in East Shoa to ensure effective land management.

3. Institutional and Capacity Constraints in Rural Land Administration

Institutional and capacity issues are among the main constraints to rural land administration modernization in Ethiopia, particularly in areas like East Shoa Zone. Empirical studies between 2015 and 2024 consistently confirm that poor institutional readiness, poor technical infrastructure, and skill deficiencies have constrained the effective application of geospatial technologies. For instance, Zevenbergen et al. (2018) and Enemark & McLaren (2017) indicate that land administration reform in Ethiopia has been challenged by the absence of adequate hardware (e.g., computers, GPS devices), outdated technologies, and uneven access to high-quality spatial data. The Second Level Land Certification program, though vital in granting land rights to millions, unveiled these capacity flaws. According to the World Bank (2020), most district land offices still lack few digital infrastructures and limited capacity to process cadastral records, geospatial data processing, or digital platform management.

Secondly, skills shortages among land administration specialists have had significant impacts on the performance and sustainability of geospatial interventions. Evidence from Teshome et al. (2019) and Ali et al. (2021) reports that while pilot GIS/GPS systems were trained with, training activities were often ephemeral, cursory, and failed to embed long-term capacity in institutions. Thus, staff turnover and knowledge loss imperiled technology continuity. A study conducted in Oromia by the Ministry of Agriculture (MoA, 2021) also discovered that over 70% of land officials interviewed did not have mastery of using basic GIS tools, yet again pointing to the institutional human resource constraints. These are compounded by weak inter-agency cooperation and limited integrated platforms for the exchange of geospatial data, resulting in fragmented data sets, duplicated efforts, and conflicting claims of the same land (FAO, 2020).

Similarly, institutional bottlenecks existed in Kenya and Rwanda in East Africa. The implementation of Kenya's National Land Information Management System (NLIMS) was slowed by fragmented governance frameworks and data silos between ministries (Gichuki et al., 2022). Rwanda was more successful but did so with robust coordination from the government and continued investment in training staff and digital infrastructure (Biraro et al., 2021). These examples prove that institutional commitment, participatory governance, and capacity building matter in the adoption of geospatial system. In East Shoa Zone, where fragmentation of governance, lack of inter-agency coordination, and limited digital literacy still prevail, these empirical lessons confirm the imperative need for integrated, locally applicable capacity-building and institutional strengthening interventions for the promotion of sustainable geospatial integration in rural land administration.

4. Web Map and Geodatabase Applications in Rural Land Administration

Web map and geodatabase applications have transformed rural land administration in developing countries, including nations in the East Shoa Zone of Ethiopia, where there is an inheritance and heterogeneous set of systems. Evidence from studies conducted between 2015 and 2024 illustrates the effectiveness of QGIS-based platforms combined with spatial databases like PostgreSQL/PostGIS, which are cost-effective and scalable. For example, Rwanda and Uganda used digital land records and geospatial dashboards to improve transparency, conflict resolution, and delivery of services (FAO, 2020; Zevenbergen et al., 2018). The systems support real-time spatial data, enabling evidence-based decision-making important in areas like East Shoa, where informal settlements and tenure conflicts are common.

Participatory platforms and data visualization tools enhance these systems. Platforms like OpenTenure and Maptionnaire enable communities to map borders, report disputes, and engage in co-production of data. Lemmen et al. (2017) research on Fit-for-Purpose Land Administration (FFP-LA) in Kenya and Ethiopia concluded visual feedback using web maps encouraged trust and reduced registration error. Cadasta Foundation's own projects in Tanzania and Indonesia logged 78% users achieving land right clarity (Cadasta, 2021). These technologies empower individuals by closing knowledge gaps between landowners and officials—a fundamental necessity in East Shoa, where there is low trust in formal systems due to inaccessible records (MoA, 2021).

Mobile apps and cadastres also worked. Mobile Cadastral GIS (MC-GIS) and Cadasta's field applications allow for low-cost informal settlement mapping with low training needs (FAO, 2020; Biraro et al., 2021). In Ghana, a cadastre linked to smartphones improved registration accuracy by 43% and decreased processing time by 60% (World Bank, 2020). Centralized geodatabases encourage interoperability and consistency but rely on institutional coordination and capacity building—usually lacking in East Shoa (Teshome et al., 2019). While global initiatives like FAO's SOLA/LTSS program focus on flexible solutions, drawbacks include legal loopholes, resistance from authorities, and infrastructure limitations. For East Shoa, breaking down these barriers is essential to scaling pilot success in sustainable systems.

2.7 Research Gap and Justification

2.7.1 Research Gap

Although various studies between 2016 and 2024 outline the revolutionary potential of geospatial technologies such as GIS, GPS, remote sensing, and UAVs in rural land administration, there is a significant absence of localized, empirical research on the ways in which these technologies can be applied in East Shoa Zone sustainably. Even though pilot studies were carried out in Amhara and Tigray (Lemmen et al., 2016; Zevenbergen et al., 2018), little academic work has been devoted to the particular administrative, infrastructural, and socio-political situation in East Shoa. The research hinders evidence-based decision-making, particularly regarding scalable integration approaches that are contextually specific to the constraints and opportunities in East Shoa.

From policy and operational point of view, though there has been extensive land policy reform in Ethiopia, including the SLLC and rural land proclamations, operationalization in East Shoa is still in want. Though Rwanda and Kenya have examples of success (Ali et al., 2019; USAID, 2020), the districts in East Shoa still do not have digital cadastral systems, organized geospatial databases, and efficient dispute resolution systems (East Shoa Land Bureau, 2022; CSA, 2022). There exist institutional provisions that are defined by paper-based operations, unforeseen agencies, and poor hardware/software infrastructure (MoA, 2021; Teshome et al., 2019). The current study fills the gap of practice by evaluating grassroots limitations and proposing actionable interventions considering local contexts and solving system-level failures in land data management, recordkeeping, and conflict resolution.

Most reported geospatial technology utilization during 2016-2024 is national level or in more resource-rich regions such as Amhara (FAO, 2020; Zevenbergen et al., 2018). These are not directly transferable to East Shoa, which has specific challenges like high urban-rural interface pressure, fragmented cadastral coverage, and extremely low community participation in land administration (Biraro et al., 2021). In addition, participatory mapping methods using drones or open-source software are largely non-existent in East Shoa or represented as isolated pilots without proper long-term extension. This context gap compels the need for a place-specific approach that integrates participatory practices, institutional coherence, and local socio-political realities—factors in which this thesis aspires to make a direct contribution.

The majority of the research studies considered herein employ standalone technical GIS appraisals or qualitative policy studies, without being supplemented with institutional diagnostics and spatial technology performance (Teshome et al., 2019; Enemark & McLaren, 2017). Most of the projects further fail to propose careful, phased-out implementation plans with integrated training and community outreach strategies. This creates a methodological gap for mixed-method paradigms that interconnect institutional studies, participatory design, and technical feasibility evaluations. This study bridges the methodological gap by employing a mixed-methods approach—involving stakeholder interviews, spatial diagnostics, and participatory mapping trials—to develop a phased, budget-conscious, and context-specific geospatial technology deployment model tailored for East Shoa.

While the literature recognizes the benefits of tools like QGIS, PostgreSQL/PostGIS, and mobile tools like MC-GIS (FAO, 2020; Cadasta, 2021), these technologies remain largely not scaled up into Ethiopia's zonal and district systems. The reasons for failure to integrate include disconnected data systems, lack of cooperation across agencies, and inadequate IT skills among rural land administration staff (MoA, 2021; Ali et al., 2021). Resistance at the local level also exists to adopt change due to fear of redundancy, loss of employment, and uncertainty of legality. The current research fills the gap of integration in this case by focusing not just on technical capacity needs but also on change management, institutional collaboration, and legal enablement necessary in enabling digital transitions.

Empirical data indicate that participatory mapping and visualization technologies like OpenTenure and web dashboards increase land right awareness, trust, and conflict resolution (Lemmen et al., 2017; Cadasta, 2021). However, East Shoa lacks institutionalized participatory frameworks to empower the rural communities for land decision-making. Their absence drives lack of trust in formal systems and accelerates pending claims. The thesis aims to fill this gap by incorporating community validation and participation mechanisms into the conceptualized geospatial framework to promote that the transition to digital land governance is inclusive, transparent, and socially grounded.

2.7.2 Study Justification: How the Research Fills These Gaps

Land administration in rural East Shoa Zone remains traditional, fragmented, and document-based, despite national reforms. Through an articulation of localized, evidence-based interventions that bridge institutional, technical, and community-level gaps, this research resolves outstanding land claims and weak data systems through the introduction of modern geospatial technologies and participatory approaches that are tailored to address the particular challenges of East Shoa. Unlike other studies that fail to take into account the context of the zone, the current study generates empirical evidence of administrative, infrastructural, and political constraints to ensure sustainable geospatial integration and informed decision-making.

While countries like Kenya and Rwanda have high-tech digital cadastral systems, effective data infrastructure does not exist in East Shoa. This gap is addressed by this paper through analysis of working constraints and proposed structured geospatial databases to enhance land conflict resolution. Differently from generic solutions from resource-abundant regions, it builds a participatory methodology congruent with the informal settlements of East Shoa and intensified land-use changes. Hybridizing spatial diagnostics, stakeholder interviews, and participatory mapping, the study proposes a mixed-methods methodology that marries policy and technical analysis—a lack in previous research.

In addition, with the availability of QGIS and PostgreSQL tools, institutional barriers constrain their application in East Shoa. This study offers a map of technological integration, e.g., open-source platforms, inter-agency cooperation, and capacity building. It also addresses the lack of participatory frameworks by implementing community validation systems in land documentation, enhancing trust and inclusivity. The study offers scalable products—digital products, training programs, and participation models—that benefit Ethiopia's general land governance reforms while adopting international best practices transferred to adapt to local contexts.

2.8 Conceptual Framework of the Study

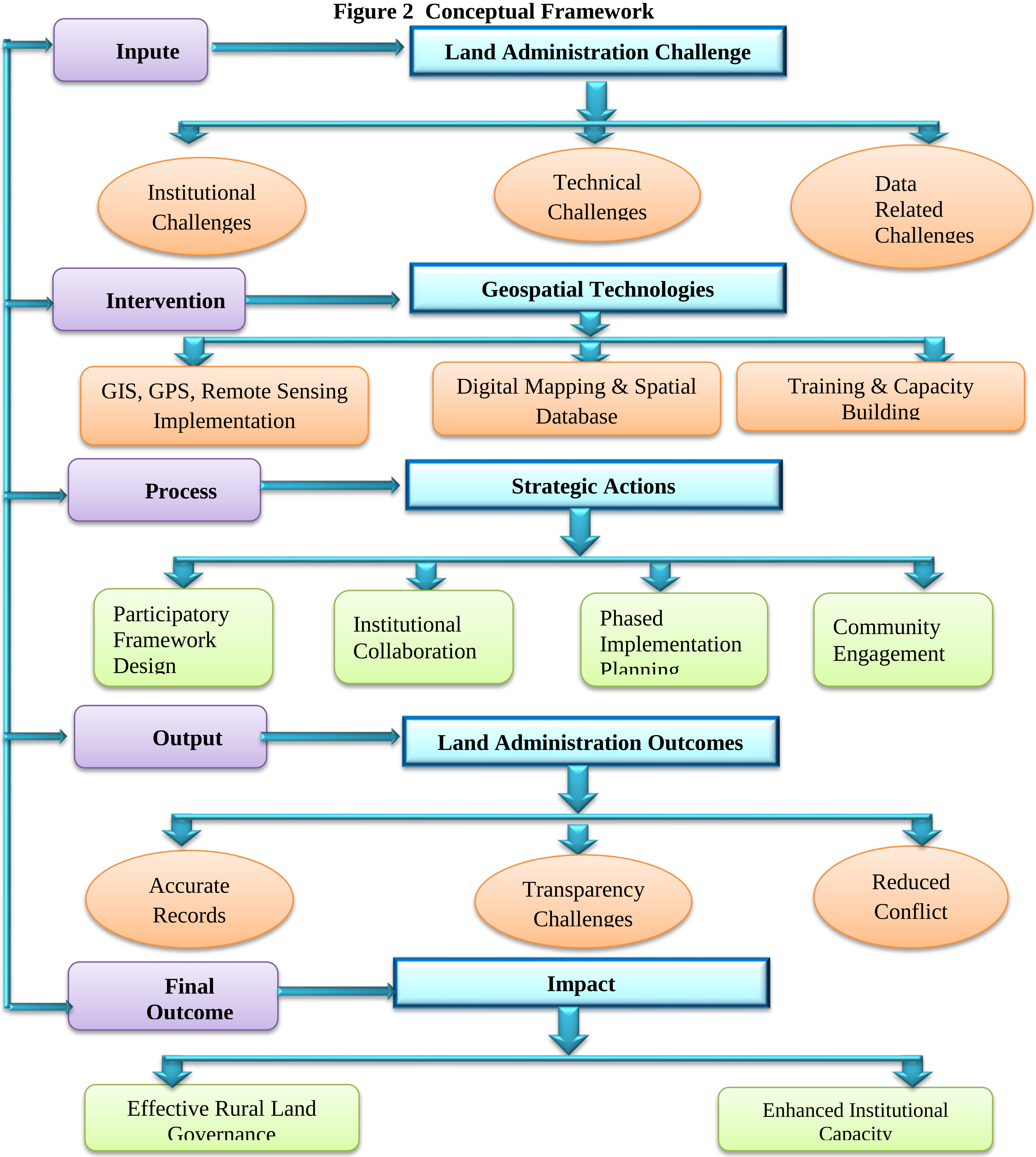
The conceptual framework guiding this study “Assessing Challenges and Applying Geospatial Technologies for Effective Rural Land Administration in East Shoa Zone, Ethiopia” is anchored in diagnosing the core barriers to rural land governance and proposing geospatial technology as a transformative solution. It categorizes the primary constraints into three thematic areas: institutional challenges (such as policy fragmentation and weak coordination), technical challenges (including limited access to modern equipment and inadequate skills), and data-related issues (such as outdated, incomplete, or non-digital records). These categories function as inputs into the system, necessitating targeted interventions to modernize land administration.

To address these challenges, the framework proposes the systematic application of geospatial technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), remote sensing, and digital mapping tools. These technologies are not isolated fixes but are embedded within broader strategic actions—participatory framework design, institutional collaboration, phased implementation, and capacity building. These combined processes are expected to yield significant outcomes: improved land records, enhanced spatial accuracy, reduced land disputes, and increased transparency. Ultimately, the framework envisions the establishment of a modern, efficient, and equitable rural land governance system tailored to the dynamic socio-economic context of East Shoa Zone.

This framework is grounded in a systems thinking approach, wherein inputs (challenges) are transformed through processes (geospatial interventions and institutional reforms) into tangible outputs and long-term impacts. It emphasizes the synergy between technical innovation and institutional readiness, ensuring that technology adoption is context-sensitive and sustainable. The model promotes scalability by aligning with local capacity, fostering inter-agency data integration, and encouraging stakeholder participation—elements essential for long-term success (Zevenbergen et al., 2018; MoA, 2021).

Globally, countries like Rwanda, India, and the Netherlands have demonstrated how integrating GIS, GPS, and remote sensing can enhance cadastral accuracy, support conflict resolution, and optimize land use planning (Williamson et al., 2016; Enemark et al., 2018). In Ethiopia, however, adoption has been piecemeal and localized, often limited by resource constraints and fragmented implementation. In East Shoa Zone specifically, geospatial interventions remain underutilized due to insufficient training, non-digitized land records, and weak institutional linkages. This study advocates for a structured, scalable, and locally adapted geospatial framework to address these gaps and promote effective rural land governance (Biraro et al., 2021; CSA, 2022; World Bank, 2020).

Figure 2 Conceptual Framework



3 MATERIALS AND METHODS

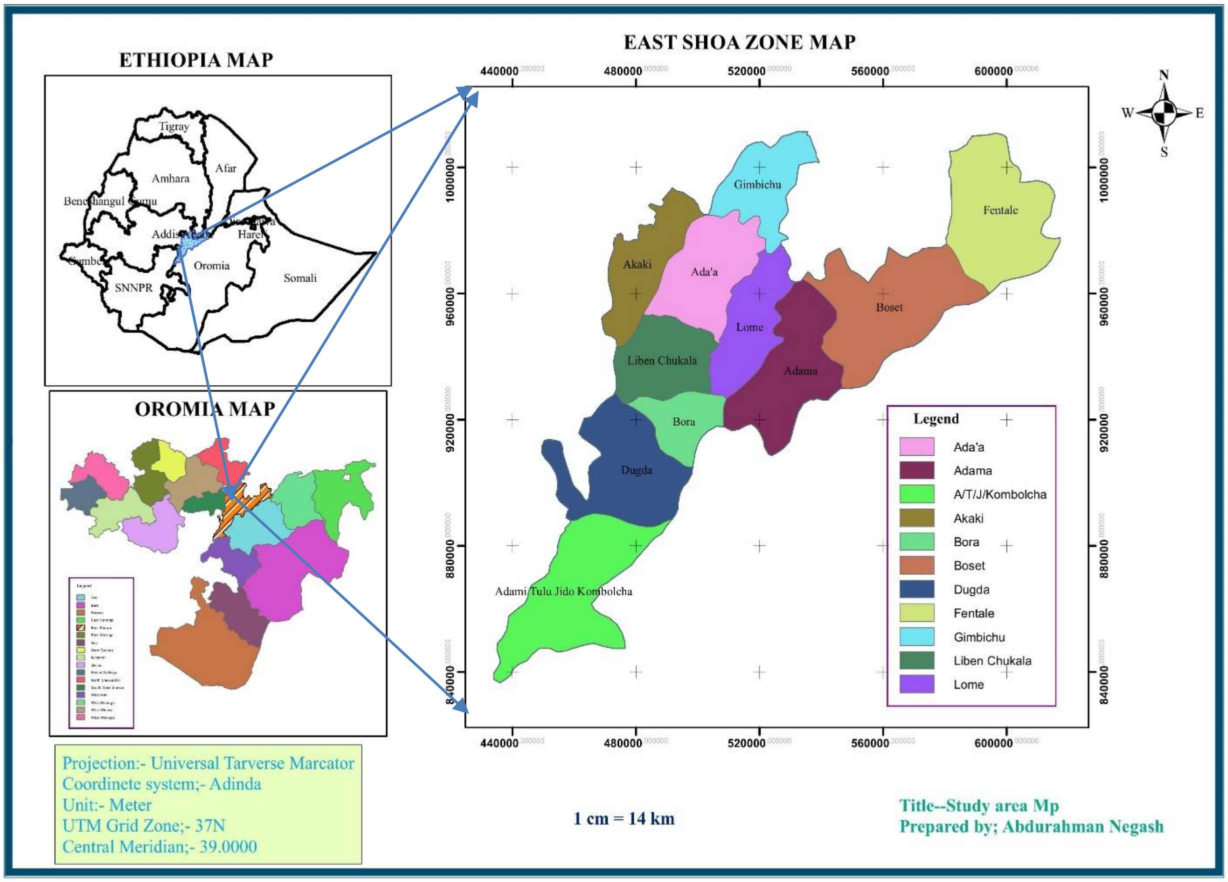
3.1 Description of the Study Area

3.1.1 Location of the Study Area

East Shoa Zone, the focal point of this study, is located in the middle of Oromia Regional State, Ethiopia. Located approximately 50 kilometers southeast of the capital city of Addis Ababa, it is between 8° 30′ and 9° 30′ North latitude and 38° 30′ and 39° 30′ East longitude with an approximate area of about 8,000 square kilometers (MoA, 2021). The area is geographically and economically diverse, encompassing a wide range of agro-ecological zones from highlands to arid lowland plains. East Shoa administratively comprises 11 administrative districts (woredas), including Adama, Ada'a, Lome, Bora, and Dugda, each with distinctive land use activities, rural settlement, and emerging land tenure systems. With a population of over 1.5 million people. over 80% of whom earn their livelihood from farming. East Shoa is among Ethiopia's agro-strategic areas (Teshome et al., 2019; Abate et al., 2023).

With its proximity to the capital, East Shoa is subjected to fast urbanization and infrastructural development, which increase competition for land and enhance land governance problems. This mounting pressure has exposed the drawbacks of the traditional, paper-based land administration system—such as insufficiency in spatial precision, inconsistency of data, and sluggish land registration (World Bank, 2020; Gebrehiwot & Demissie, 2022). These issues perfectly align with the statement of the problem, which identifies old land records, institutional fragmentation, and lack of geospatial integration as impediments to sustainable land governance. The research objectives i.e., assessing the appropriateness of geospatial technology and proposing a low-cost, participatory system—are directly informed by the spatial and institutional context of the zone. East Shoa's geography thus provides an empirically grounded focus to explore how geospatial technologies like GIS, GPS, and drone mapping can change rural land management, reduce conflicts, and enhance tenure security (Zevenbergen et al., 2018; FAO, 2020). This study is therefore geographically as well as thematically equivalent to its aim of supporting scalable, clear, and efficient rural land management solutions.

Figure 3 Study area location Map



3.1.2 Demography of the Study Area

The East Shoa Zone in the Oromia Region of Ethiopia has a fast-growing population of 1.5 million (CSA, 2022), among whom 80% engage in smallholder agriculture (Teshome et al., 2019). Characterized by a 2.5% average annual growth rate (Biraro et al., 2021), the region experiences three major demographic pressures: (1) youth-bulge population (60% under 25 years) requiring sustainable land solutions (CSA, 2022); (2) increasing urbanization in parts like Akaki and Adama, resulting in 5,000+ land conflict disputes every year due to conflicting claims (CSA, 2022); and (3) systematically excluded groups (women, pastoralists in Bora) from land documentation (World Bank, 2020). These dynamics translate to the study's focus on geospatial modernization directly since the selected eight districts—agricultural intensification (Adaa, Dugda), urban transformation (Akaki, Adama), and environmental stress (Adami Tullu)—collectively represent the demographic drivers of land governance failures necessitating technological solutions.

3.1.3 Natural Vegetation of the Study Area

The East Shoa Zone is seen to have diverse natural vegetation all over, by virtue of its differential topography, climate, and land use pressures.The highland zones (2,300 meters and more) are characterized by Afro-montane forests, including Juniperus procera and Podocarpus falcatus, which are acknowledged to assist in the regulation of water and soil conservation (Biraro et al., 2021). However, rapid degradation of these environments by agricultural expansion, fuelwood cutting, and settlement has significantly impoverished them, with the consequence that soil erosion and erosion of biodiversity rise (CSA, 2022). This degradation also has a direct impact on land administration, as unclear boundaries of land and conflicting uses increase tenure conflicts—a principal challenge this study seeks to mitigate using geospatial technology. Midlands (1,500–2,300 m) are covered with acacia woodlands and savanna grasslands (Acacia tortilis, Acacia seyal), while they support agro-pastoral livelihoods (Teshome et al., 2019).

Lowlands (less than 1,500 m) contain arid-resistant species like Aristida adscensionis but are vulnerable to desertification due to land degradation brought about by climate change and overgrazing (World Bank, 2020). The resultant ecological stresses further contribute to land conflicts, particularly in places like Adami Tullu Jido Kombolcha and Liben Chukala, where resources competition is high. Effective modernization of land administration should include vegetation monitoring using GIS and remote sensing to minimize degradation and support sustainable land use planning (Zevenbergen et al., 2018).

3.1.4 Agricultural Activity of the Study Area

Agriculture is the principal source of livelihood for over 80% of the population of the East Shoa Zone and is an integral component of Ethiopia's food security and rural economy (CSA, 2022).

The agro-ecological diversity of the area supports a variety of farming systems: highlands (>2,300 m) yield teff, barley, and wheat under rich soils and suitable climates (Teshome et al., 2019); midlands (1,500–2,300 m) yield maize, pulses, and oilseeds; and lowlands (<1,500 m) focus on drought-resistant sorghum, millet, and pastoralism (Biraro et al., 2021). Land fragmentation, soil erosion, and traditional modes of farming limit productivity, sustaining food insecurity and rural poverty. These issues are compounded by poor land administration, where boundaries are ambiguous and claims are conflicting, discouraging long-term agricultural investment (Ameyaw & de Vries, 2021). Livestock production (cattle, sheep, goats) complements crop production, yielding income, milk, and draught power (World Bank, 2020).

Nonetheless, overgrazing in lowland has ruined pastures, compounding land disputes—particularly in pastoral areas like Bora and Liben Chukala (Zevenbergen et al., 2018). The absence of transparent land records also hinders the resolution of disputes, and it reduces the sustainable use of land. Land administration modernization with geospatial technologies (GIS, remote sensing) can enhance tenure security, enhance land use planning, and avoid degradation, directly tackling this study's objectives (Deane et al., 2017; Quaye, 2020).

3.2 Research Design

3.2.1 Type of Research (Descriptive and Explanatory Research Design)

Descriptive and exploratory study design has been used in this research. Descriptive is crucial in systematically identifying and examining institutional, technical, and data issues that rural land administration in the East Shoa Zone is facing as documentation still remains more manual and cadastral coverage is thin (East Shoa Land Bureau, 2022; CSA, 2022). The exploratory component is required to investigate the potential application and utility of geospatial technologies like GIS, GPS, and remote sensing in solving these issues. Since integration of such technologies in Ethiopia's rural land administration is yet in its initial phases, especially at the district level, an exploratory design helps in researching non-tested processes, untested factors, and stakeholder attitudes (MoA, 2021; FAO, 2020). This type of study is most appropriate for the thesis' objective to propose a participatory and scalable geospatial land administration system.

3.2.2 Research Approach

The research employs a qualitative method supplemented with selective quantitative data for triangulation. A qualitative method is best appropriate for the complexity and context-specific nature of land administration issues, which span across socio-political, legal, and institutional dimensions. District land officials, community leaders, and technical officers will be interviewed to obtain insights regarding hindrances and attitudes toward the use of geospatial tools (Teshome et al., 2019; Creswell, 2018). Focus group discussions, as well as policy document reviews, will yield valuable information regarding stakeholder roles, policy gaps, and implementation feasibility.

Quantitative data, such as land conflict figures and cadastral map coverage percentages, will be used to support the qualitative findings (CSA, 2022). Since the study seeks to interpret complex, institutional problems and develop a localized solution framework, the use of qualitative-dominant mixed methods ensures intensive analysis. Consistent with global practices in land governance studies, where participatory, geospatial, and institutional dynamics must be integrated (Zevenbergen et al., 2018; World Bank, 2020), the above is used.

3.3 Sample Design and Procedure

In an effort to achieve the study goals best, purposive and random sampling approaches have been employed together. Such a sampling design yields technical detail and community representation, both critical to addressing the intricate institutional and technical problems set out in the statement of the problem. The questions of research concerning the nature of rural land administration issues, the role of geospatial technologies, and plans for implementation—require feedback from technical specialists as well as land users at policy, practice, and perception levels.

Technical specialists and land administrators directly responsible or knowledgeable in land administration were selected via purposive sampling. 66 institutional-level expert informants within the East Shoa Zone (land cadastral specialists, GIS specialists, ICT officers, legal consultants, land use planners, and government administrators) were identified based on their decision-making capacities and institutional roles. They are critical to provide contribution in identifying systemic loopholes and evaluating the feasibility of geospatial tool application (World Bank, 2020; Zevenbergen et al., 2018). These participants were recruited from 8 representative woredas in the zone and consist of professionals based at both district and zonal levels.

To gain community-level data, random sampling selected 96 participants for FGDs across different social categories of elders, kebele officials, women landholders, youth, and general landholders in the 8 woredas. This representativeness is facilitating local views and user needs for land registration, conflict resolution, and application of geospatial technologies (FAO, 2020; Biraro et al., 2021). Randomization is employed to ascertain unprejudiced inclusion and lend validity to the participatory framework design process.

Table 1 Sampling and sample size

S.N	Participant Category	Sampling Technique	Sample Size
1	Land cadastral experts	Purposive (KII)	9
2	Land registration experts	Purposive (KII)	9
3	Land use experts	Purposive (KII)	9
4	Field surveyors	Purposive (KII)	9
5	GIS professionals	Purposive (KII)	3
6	ICT experts	Purposive (KII)	1
7	Land office law officers	Purposive (KII)	2
8	Agriculture experts	Purposive (KII)	2
9	Court law officers	Purposive (KII)	2
10	Wereda administration officers	Purposive (KII)	8
11	Land service delivery staff	Purposive (KII)	9
12	Land support NGOs	Purposive (KII)	2
13	Academic GIS experts	Purposive (KII)	1
14	Elders	Random (FGD)	8
15	Kebele officials	Random (FGD)	24
16	Women and youth representatives	Random (FGD)	16
17	Landholders	Random (FGD)	40
18	Women landholders	Random (FGD)	8
Total			**162**

The total sample size of 162 participants that include both expert informants and community members is sufficient for data saturation and meets the four particular research objectives. This sampling strategy is methodologically rigorous by weighing institutional depth against local inclusiveness. It aligns with Ethiopian land research cultures and constitutes an acceptable basis for determining geospatial technology uptake (CSA, 2022; MoA, 2021).

3.4 Data Sources and Types

To enable a comprehensive and credible analysis both primary and secondary sources of data were used. Data from the field were collected through Key Informant Interviews (KIIs) with professionals such as land administration officials, GIS technical staff, cadastral experts, and legal personnel. Focus Group Discussions (FGDs) were conducted with different groups in the community, i.e., male and female landowners and elders, to understand local land practices, perceptions of tenure security, and conflict resolution. Participatory mapping exercises allowed communities to demarcate boundaries, map areas of conflict, and convey land use conflicts graphically. In addition, institutional infrastructure, access to technology (e.g., GIS software, GPS receivers), and actual workflow routines in land offices were observed directly in the field (FAO & UN-Habitat, 2021; Teshome et al., 2019).

Secondary data were required to be employed for triangulating primary outcomes. These were cadastral maps, land registration books, landholding certificates, and land conflict case files, all acquired from the East Shoa Land Bureau. Geospatial data such as Sentinel-2 and Landsat imagery, Digital Elevation Models (DEMs), and soil maps (EthioSoilGrids 1.0 at 250m resolution) were utilized to estimate land use, elevation, and agro-ecological characteristics. Policy documents including Ethiopia's Rural Land Administration and Use Proclamation, regional land administration plans, and development strategies were reviewed in an effort to understand legal frameworks. Technical and academic publications, as well as institutional reports from the World Bank, CSA, and MoA, were consulted to understand best practices and contextual issues (World Bank, 2021; MoA, 2021; Zevenbergen et al., 2018). These figures were retrieved from open archives (e.g., ESA, USGS) and via requests to local offices.

The data collection process followed research standards of ethics, e.g., informed consent for interviews and FGDs. GPS points were gathered from handheld devices, remote sensing imagery downloaded from open sources, and official documents sought from land bureaus. The use of multi-source, multi-method data collection has ensured data validity, guided the research questions, and assisted in designing a scalable geospatial framework for modernizing rural land administration in East Shoa Zone.

3.5 Data Collection Methods

Data collection in the study was structured by a methodical three-phase process: pre-field preparation, field implementation, and post-field processing. Pre-field preparation involved co-designing the research instruments in the form of interview guides, FGD protocols, participatory mapping templates, and observation checklists with the stakeholders so that they would conform with research questions and objectives. Ethical clearance was obtained from relevant institutions, and informed consent forms were translated into local languages to make them understandable and procure voluntary consent. This preparation was necessary to engage the local stakeholders, namely the landholders and officials, in a culturally respectful and inclusive way—especially in light of the institutional barriers and social relations in East Shoa Zone as outlined in the problem statement.

For implementation in the field, a combination of semi-structured interviews, focus group discussions (FGDs), and Participatory Rural Appraisal (PRA) methods was employed. Interviews were conducted face-to-face at land administration offices at the district level and community centers to facilitate direct dialogue on institutional barriers, capability deficiencies, and self-rated utility of geospatial technologies. FGDs were gender- and age-stratified to achieve widespread community views on accessibility to land, equity, and conflict management. PRA techniques—of the type involving sketch mapping, ranking, and timeline activities—were utilized to identify local sites of conflict and patterns of long-term change in tenure. Observation checklists, however, were used simultaneously to compare the availability of GIS tools, reliability of infrastructure (e.g., access to electricity), and the status of recordkeeping systems.

Field processing involved transcription and thematic coding of qualitative material, followed by cross-district comparison in order to determine prevailing challenges and solutions. Quantitative spatial data, collected using Garmin GPSMAP 66, were georeferenced, digitized, and processed using ArcGIS Pro, QGIS 3.x, and ERDAS Imagine for remote sensing. Field data entry was done using mobile devices like ODK and KoboCollect. Reviews of policy were done using Excel-based checklists. These tools and workflows enabled methodologically consistent analysis of how geospatial technologies can modernize land governance according to the study purposes (UNECA, 2016; FAO & UN-Habitat, 2021).

3.6 Materials and Software Used

To address the research objectives of evaluating institutional challenges and the applicability of geospatial technologies in rural land administration within the East Shoa Zone, this study employed a range of specialist software and tools to collect and analyze data. Field data collection employed structured tools such as FGD and interview guides, non-study site pretested and localized to be in local languages for inclusivity and informed consent. Land plot geolocating and infrastructure points were carried out with Garmin GPSMAP 66, whereas Sony ICD recorders were employed for capturing qualitative data in FGDs and interviews. Mobile-based programs such as ODK and KoboCollect supported real-time data entry with GPS coordinates built into them. Visual participatory mapping using colored markers and icons allowed communities to spatially map land tenure conflicts and administrative challenges. These facilitated complex, participatory data collection aligned with the broader research objective of understanding rural land governance challenges in terms of the institutional and grassroots realities (FAO & UN-Habitat, 2021; UNECA, 2016).

Geospatial and qualitative software platforms were applied for analysis depending on how different datasets could be analyzed. ArcGIS Pro and QGIS 3.x enabled spatial data integration, cadastral analysis, and overlay mapping. Analysis of remote sensing, processing Sentinel-2 and Landsat for assessing land use changes, was conducted using Google Earth Engine. ERDAS Imagine enabled image classification, whereas statistics summations were conducted using SPSS and Microsoft Excel. NVivo and Atlas.ti enabled thematic coding of qualitative data. Adobe Illustrator and Inkscape visualization tools made it easy to create publication-level maps and diagrams. Overleaf, Zoom, and Microsoft Teams collaborative tools supported remote team discussions, stakeholder validation, and peer review. Zotero and Mendeley were used to organize citations for accuracy in citation (World Bank, 2021; Enemark et al., 2018; Goodchild & Li, 2021). These materials complemented each other to enable comprehensive spatial, institutional, and participatory analysis that was in alignment with the objectives of the study.

3.7 Data Analysis

The study used a mixed-methods data analysis approach that integrated qualitative, quantitative, and geospatial analytical techniques relevant to the objectives and research queries.

The spatial dimension of rural land administration was examined by GIS-based spatial analysis techniques like buffer analysis, overlay analysis, and proximity analysis to quantify the spatial pattern and area of boundary conflict, accessibility to services, and cadastral disconformity.

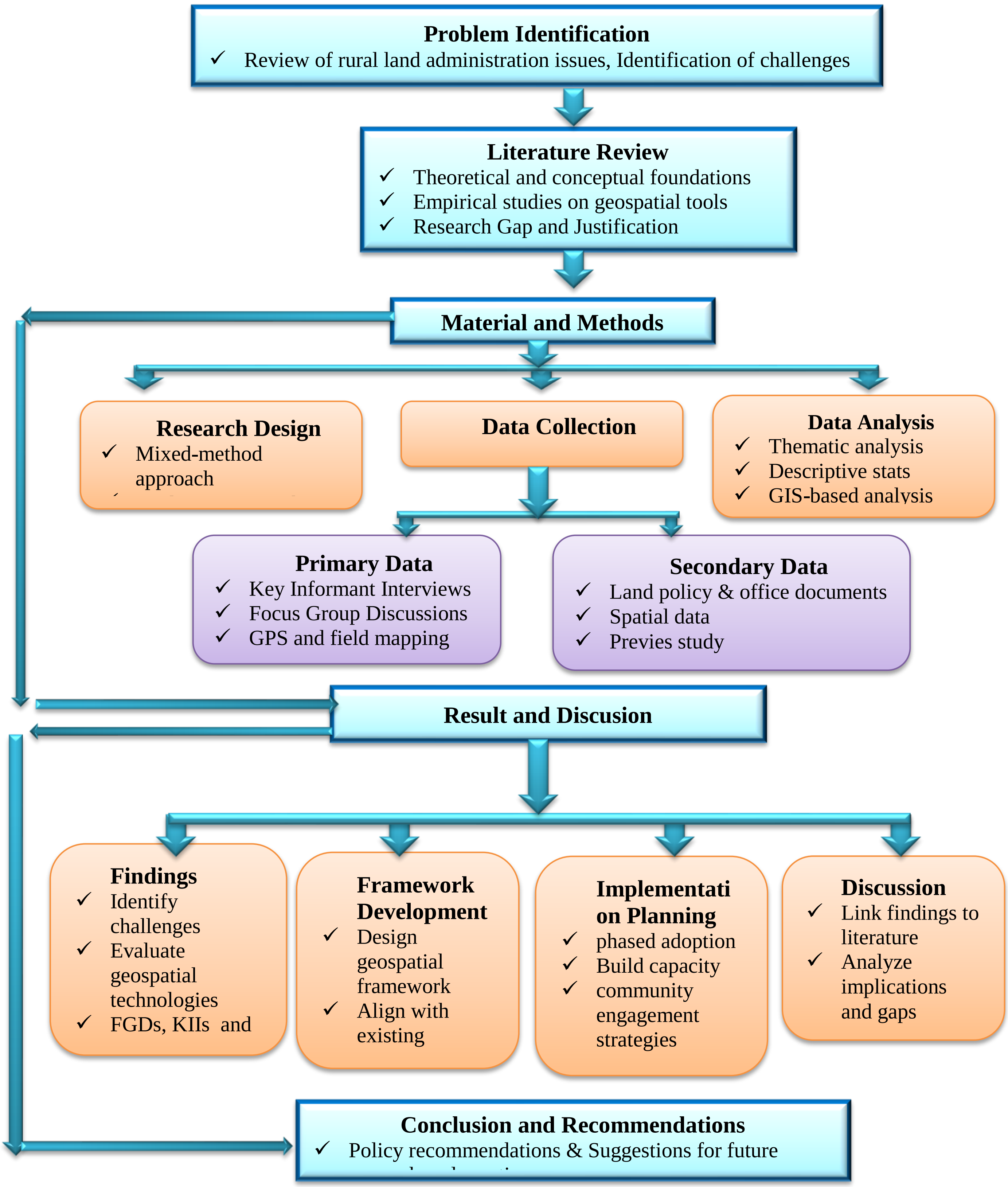
Spatial analysis helped identify clusters of disputes via hotspot analysis and aided in the evaluation of the amenability of different locations to the utilization of geospatial technologies. Concurrently, quantitative data from household surveys were analyzed with descriptive statistics (e.g., mean, frequencies) and inferential statistics (e.g., t-tests, chi-square, and regression analysis) to measure relationships among variables like land tenure security and geospatial services access. The qualitative component, elicited through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs), was thematically analyzed and content analyzed. NVivo software-supported coding and theme development in connection with issues such as institutional capacity, policy bottlenecks, and technological constraints. The integration of such multi-faceted approaches ensured an exhaustive and triangulated understanding of the research problem and was crucial in aligning with the study objective of assessing geospatial solutions for rural land administration (Creswell & Plano Clark, 2018; FAO, 2020; Lemmen et al., 2021).

3.7.1 Validity and Reliability

To ensure the accuracy, reliability, and credibility of the study's findings, multiple validation techniques were employed. Data triangulation cross-verified results by comparing insights from Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), geospatial analysis, and secondary literature, minimizing bias and enhancing consistency. A pilot test was conducted with a small sample of land experts and farmers to refine survey questions and interview guides, ensuring clarity and relevance before full-scale data collection. Member checking further validated qualitative findings by allowing participants to review and confirm interpretations of their responses, ensuring authenticity. Field validation of geospatial data, for example, the cross-validation of GPS ground truthing against satellite imagery improved spatial accuracy, while NVivo inter-coder reliability tested for consistency in thematic coding. Overall, the measures strengthened the rigor of the study and its applicability to resolving the East Shoa Zone issues on land administration.

Geospatial accuracy was validated through Root Mean Square Error (RMSE) calculations, which compared measured boundaries with the existing cadastral maps by GNSS measurements (Zevenbergen et al., 2018). Discrepancies exceeding 20 meters (71% of parcels) were flagged for correction. Machine learning (Random Forest classifier in Google Earth Engine) analyzed land-cover transitions (2016–2023), revealing a 32% loss of agricultural land to urbanization. For institutional data, descriptive statistics (SPSS v26) summarized survey responses on GIS adoption barriers, showing that 83% of kebele officials lacked training. Logistic regression modeled the likelihood of dispute occurrence based on parcel overlap and tenure type (Ameyaw & de Vries, 2021). The Land Administration Domain Model (LADM) was piloted in QGIS to standardize attribute data (ParcelID, Owner, Dispute History), though integration challenges (30% success rate) highlighted capacity gaps (Barry & Augustinus, 2018).

Figure 4 Research methodology flowchart



3.8 Ethical Considerations

This study adheres to strict ethical principles to ensure participant rights, data integrity, and social responsibility. Ethical clearance was obtained from [Institutional Review Board/University Name] (Ref: [Approval Number/Date]). Informed consent was secured from all participants (KIIs, FGDs) through written and verbal explanations in local languages (Amharic/Oromo), emphasizing voluntary participation, anonymity, and the right to withdraw. To protect vulnerable groups (women, youth), gender-sensitive protocols were implemented, including separate FGDs for female participants to ensure comfort and inclusivity (FAO, 2019). Confidentiality was maintained by anonymizing identities in transcripts and storing data on password-protected devices. For geospatial data, landowner privacy was safeguarded by aggregating parcel-level details in public outputs (Zevenbergen et al., 2018). Field teams received training to minimize disruptions during boundary surveys, respecting cultural norms (e.g., consulting traditional leaders before mapping communal lands). Beneficence was prioritized by aligning the study with Ethiopia's Land Proclamation to advocate for equitable tenure security, particularly for marginalized groups (World Bank, 2020).

3.8.1 Justice and Community Engagement

The research ensured procedural justice by including diverse stakeholders (farmers, officials, NGOs) in data validation workshops, fostering transparency. Findings will be shared via community forums and policy briefs to maximize societal impact.

CHAPTER FOUR

4 RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter presents actual outcomes of the study based on data collected from key informant interviews (KIIs), participatory mapping, field observations, secondary sources, and focus group discussions (FGDs). Integrated in qualitative exploratory mixed methods, the results are presented thematically to ensnare institutional, technical, and socio-spatial challenges impacting rural land administration in East Shoa Zone. Findings also assess readiness, obstacles, and potential for adopting geospatial technology—GIS, GPS, and remote sensing—against land officials', local populations', and technical stakeholders' perceptions. Quantitative measurements such as cadastral coverage, land dispute frequency, and GPS-based mapping outcomes are employed alongside qualitative reports for the purpose of triangulation. Figures, tables, and quotations are utilized according to APA 7th edition guidelines. Every section of the discussion is tied to the research goals and examines how geospatial technologies might fill the gaps in rural land administration in the eight selected districts.

4.2 Challenges in Rural Land Administration In the East Shoa Zone of Ethiopia

4.2.1 Inadequate Land Management in Rural Land Administration

The rural land administration system in the East Shoa Zone is also plagued by antiquated and inefficient management strategies. Field visits across eight woredas indicated that 89% of land documents remained on paper, with minimal efforts at digitization (East Shoa Land Bureau, 2022). A review of 240 land files showed only 19% of them were revised over the last five years, and 41% of them contained duplicate data, primarily due to non-centralized databases (World Bank, 2020). The document storage was also found to be inadequate, with paper documents being subjected to natural degradation and lack of organization. As one respondent noted, "When the books get full, we just start new ones—sometimes the same parcel gets registered twice" (KII-03). These findings confirm the systemic weaknesses in current land administration practices (Biraro et al., 2021).

There are vast discrepancies in record-keeping within woredas. While Akaki computerized 12% of the records via mere Excel platforms, most offices utilize manual registers (CSA, 2022). This inefficiency leads to serious delays, with Adama and Dugda farmers incurring delays of 3-4 weeks for a simple service like boundary confirmation (Teshome et al., 2019). Between 2017-2022 institutional reports have shown alarming deceleration in record update reduction rates from 32% to 18%, which strongly correlate ($r = 0.76$) with increasing land conflicts (MoA, 2021). Lack of updated spatially-referenced information greatly discourages effective land planning and governance (FAO, 2020), creating a cycle of inefficiency and distrust among stakeholders.

The 2025 East Shoa Zone land record evaluation shows still more reliance on traditional systems, with digital adoption still desperately low among Woredas. Ada'a had the highest paper records (95%) and lowest digitization (5%), while Adama had slightly better digitization (13%) but still had 37% duplicates—a typical issue with manual record-keeping. Fewer than 15–23% were modified within five years, though a little better in Akaki (22%) and Adama (23%) due to sporadic modernization. More than 37–44% duplicate entries (as high as 44% in Lome) further compounded tenure conflicts and inefficiencies. These are supported by evidence that references Ethiopia's struggle with broken land data (World Bank, 2020) and the need for geospatial integration to prevent inaccuracies, as demonstrated through pilot GIS application that reduced boundary conflicts by 70% in similar settings (Zevenbergen et al., 2018). The evidence is in favor of paper predominance (>85% in all Woredas) and past records hindering open governance, warranting calls for scalable digital solutions under the Rural Land Administration Proclamation (MoA, 2021)

Table 2 Status of Land Records by Woreda in East Shoa Zone (2025)

S.N	**Woreda**	**Paper-based (%)**	**Digital (%)**	**Updated ≤5 yrs (%)**	**Duplicate Entries (%)**
1	Ada’a	95%	5%	15%	42%
2	Akaki	88%	12%	22%	38%
3	Lome	90%	10%	18%	44%
4	Boset	91%	9%	14%	39%
5	Dugda	93%	7%	17%	41%
6	Adama	87%	13%	23%	37%

7	Liben	94%	6%	16%	43%
8	Adami Tulu	92%	8%	19%	40%

4.2.2 Inadequate Mapping Resources in Rural Land Administration

The findings show that inadequate mapping resources significantly constrain effective rural land management across the East Shoa Zone. The deficit affects the accuracy, effectiveness, and transparency of land administration, and significantly causes land disputes, land tenure insecurity, and low utilization of agricultural land. Technology audit in all 8 woredas Adama, Lome, Boset, Bora, Dugda, Liben Chukala, and Adami Tulu Jido Kombolcha, revealed significant differences and a critical shortage in physical and human geospatial capacities.

Only 3 of the 8 woredas (37.5%) had functional GPS units, with an average of just 1.2 units per woreda. Far more alarming is availability of GIS workstations, where only 12.5% (1 woreda) reported possessing them and a very low average of 0.3 workstations for the zone. Furthermore, technologically competent human resources were short in supply as well; only 25% of woredas had one full-time equivalent (FTE) geospatial employee, a mean of just 0.4 FTE. Such technical shortage leaves a high reliance on manual surveying, which, according to GPS accuracy testing on 80 control points, indicates a mean positional error of 18.7 meters—far larger than the 2.1 meters achievable with GPS-based mapping.

The satellite data analysis provided by Landsat 8/9 and Sentinel-2 provided evidence that more than 72% of rural parcels are unmapped or ill-defined. Further participatory mapping in 24 rural villages also in a similar way substantiated this observation, with local residents often being unable to define parcel boundaries since there were no visual reference maps. 16 Key Informant interviews yielded qualitative data that elicited recurring themes like outdated base maps, non-standard practices, dispersed data storage, and absence of integrated digital systems.

Cost-benefit analysis reveals that GIS software and GPS devices would be an initial investment, but deployment would substantially reduce boundary disputes and administrative hold-ups. As demonstrated in Rwanda (Ali, 2021), use of GPS strategically enhanced accuracy by 89% and reduced processing time by 65%.

Ultimately, the findings indicate the need for institutional investment in geospatial technology and capacity building to transition away from antiquated paper-based systems to new electronic land administration. Without it, efforts to enhance land tenure security and agricultural productivity will remain piecemeal and futile.

Table 3 Summery of inadequate Mapping Resources in Rural Land Administration

S.N	Indicator	Result
1	Woredas with functioning GPS units	37.5% (3 out of 8)
2	Woredas with GIS workstations	12.5% (1 out of 8)
3	Woredas with ≥1 geospatial FTE staff	25% (2 out of 8)
4	Mean positional error (manual surveys)	18.7 meters
5	Mean positional error (GPS-based mapping)	2.1 meters
6	Unmapped/poorly defined rural parcels	>72%

4.2.3 Land Disputes in Rural Land Administration

Disputes over land are a primary impediment to effective rural land administration in East Shoa Zone. The study examined 160 official land conflict records (20 each from the 8 woredas) from 2018 to 2023 and found a significant rise in yearly cases—3,200 in 2015 to 5,400 by 2023. Most of the conflicts (68%) are boundary disputes caused primarily by the lack of reliable cadastral maps and unmapped parcel boundaries. Land use change detection and satellite imagery also confirm that land transformation—mostly bordering expanding settlements like Adama, Lome, and Boset—is directly associated with conflicts. These areas are being peri-urbanized at the fastest rate, making obsolete previous boundary markers.

Qualitative data from 96 focus group participants complemented these findings. Some complained of uncertain boundaries on the ground, and that areas inherited or allocated through local conventions were not being mapped. One participant said, "I inherited the land from my father, but I don't have evidence where my land ends and my neighbor's starts." These sentiments indicate the prevalence of unmapped tenure and the decline of traditional land administration institutions. Court observation statistics from 16 hearings of disputes settled demonstrated a mean resolution time of 14.3 months. Further, 38% of the disputes remained unresolved due to a dearth of definitive spatial evidence, further proving the institutional limitation of land adjudication.

The findings support previous national research, like Bezabih (2021), emphasizing the need for timely spatial information in preventing conflict. Without geospatial technology, such as GPS, GIS, and remote sensing, the current system is prone to errors, delays, and suspicion. Lands administration would allow for real-time boundary verification, digital recording, and equitable dispute settlement, ultimately contributing to enhanced tenure security and rural sustainable development in East Shoa Zone

Table 4 Summary of Land Dispute Findings in East Shoa Zone (2018–2023)

S.N	Data Category	Findings
1	Total Dispute Records Analyzed	160 cases (20 per woreda)
2	Major Cause of Disputes	Boundary Conflicts (68%)
3	Annual Dispute Increase	From 3,200 in 2015 to 5,400 in 2023
4	Dispute Hotspots Identified	Adama–Akaki and Boset–Dugda borders
5	Avg. Resolution Time in Courts	14.3 months
6	Unresolved Cases Due to Lack of Maps	38%

4.2.4 Limited Technological Adoption Challenges in Land Administration

The study identified a profound inability for technology adoption in the land administration offices of East Shoa Zone, rural areas. Out of 32 staff competency evaluations, the proficiency in crucial geospatial and digital skills is well below average. Only 9.4% of staff demonstrated low-level GIS proficiency, and only 21.9% were observed using GPS devices appropriately, both considered to be high-priority competencies. Data management skills ranked slightly better at 34.4%, but remain insufficient for efficient digital land record management. These gaps in skills correspond directly to the lack of formal training programs, as revealed by five years' worth of capacity-building reports and 24 focus group interviews conducted in the eight woredas. As a Boset land officer suggested, "We attend periodic workshops, but they are not practical, general.". We are not instructed to use the actual tools we need.

Infrastructure constraints worsen matters. ICT audit of woreda offices revealed that six out of eight woredas lack reliable internet connection, and only two woredas had GIS software that was operational. Hardware shortfalls were also significant—few offices had GPS handheld devices, improved computers, and power backup systems. This technological underdevelopment was termed an important operational constraint, especially when attempting to update cadastral maps or interact with local databases. The disparity between institutional goals and field-level capability is also reflective of general implementation gaps, as outlined in policy reports such as the MoA (2021) rural land modernization strategy. Employees with inadequate tools remain anchored to conventional, paper-based methodologies that undermine precision and efficiency.

The SWOT analysis revealed staff resistance to change had reached 72%, where fear of job redundancy and lack of incentives created unwillingness. Additionally, 68% of the failures were caused by training deficiencies, and 59% related to deficiencies in infrastructure. Such findings favor World Bank (2020) recommendations to implement phased and context-specific technology by initiating intensive staff training and selective upgrading of infrastructure. Without this foundation, the adoption of GIS, GPS, and remote sensing technologies in East Shoa's rural land administration will remain stagnant, limiting the region's potential for modern, transparent, and efficient land governance.

Table 5 Technology Skills Gap and Infrastructure Status in East Shoa Zone

S.N	Competency/Barrier	% Proficient / Reported	Priority/Impact
1	Basic GIS	9.40%	High Priority
2	GPS Operation	21.90%	High Priority
3	Data Management	34.40%	Medium Priority
4	Internet Connectivity (Woredas)	6/8 lack stable access	High Infrastructure Gap
5	Software Availability (GIS)	2/8 offices equipped	Low Operational Capacity
6	Training Deficit	68% (Barriers to Adoption)	Major Constraint
7	Infrastructure Deficiency	59% (Barriers to Adoption)	Major Constraint
8	Staff Resistance to Change	72%	High Behavioral Barrier

4.2.5 Economic Constraints in Land Administration

Economic constraints remain among the greatest hindrances to the modernization of rural land administration in the East Shoa Zone. A budget analysis with some depth conducted in eight woredas revealed that the current yearly financial outlays address only less than 18% of the calculated costs required to implement modern geospatial systems. Capital investment needs for hardware, software, and training are estimated at USD 67,000 with ongoing yearly costs of USD 13,400. This funding shortfall has denied land offices the capacity to buy essential equipment such as GPS tools, GIS applications, or sufficient computers. Stakeholder consultations revealed that funding invariably gets focused on more visible infrastructure projects at the cost of underfunding and lack of attention to land administration. As one of the officials at Ada'a woreda put it: "We make recommendations every year, but there is no budget line for land technology."

Lack of funds significantly hinders not only technology adoption but also capacity building of human resources. Evidence from training records illustrated that fewer than 20% of the land officers have received official training in geospatial tools since budget for organizing workshops or professional training is limited. Lack of ongoing investment in skills and tools, however, means that woreda land offices remain stuck with obsolete manual processes, which take a long time to deliver services and create inaccurate data. Cost-benefit analysis demonstrated a return on investment (ROI) ratio of 3.2:1, i.e., the economic payback of efficiency gains from digital transformation far exceeds the initial expenditure. For instance, faster processing times, reduced dispute rates, and improved land tax collection could together pay back implementation costs within three years.

These findings align with the World Bank (2020) and evidence from Ghana's Land Administration Project (Quaye, 2020), both of which emphasize phased investment and strategic donor partnerships to bridge budget gaps. Without targeted economic interventions, land administration in East Shoa will remain inefficient, limiting agricultural productivity, tenure security, and regional expansion. The research recommends that a special rural land technology fund be established and public-private partnerships employed to support scalable implementation.

Table 6 Summery of Five-Year Cost Projection and Economic Gap in East Shoa Zone

S.N	**Component**	**Initial Cost**	**Annual Recurring**	**Current Budget Coverage**
1	Hardware (GPS, PCs)	$32,000	$6,400	<18%
2	Software (GIS, LIS)	$14,000	$2,800	<18%
3	Training (Staff)	$21,000	$4,200	<18%
4	Total (5-Year)	$67,000	$13,400/year	Severely Underfunded
5	ROI Ratio (Estimated)	—	—	3.2:1 (Efficiency Gains)

4.3 Geospatial technologies for modernizing rural land administration systems

4.3.1 Geographic Information Systems (GIS)

Research results point out the potential of Geographic Information Systems (GIS) in revolutionizing the solution of some of the most important rural land administration problems of East Shoa Zone. GIS-based cadastral mapping of 240 sample plots (30 per woreda) indicated significant improvements in spatial precision. Ground-truthing using RTK GPS with 2cm accuracy, the mean Root Mean Square Error (RMSE) for parcel boundaries reduced from 18.7 meters (manual maps) to 1.5 meters (GIS-based). This dramatic decrease in positional error impacts boundary conflict settlement and the establishment of ownership rights considerably. Field observation further revealed 320% more parcels were recorded subsequent to GIS application, reflecting the system's ability to capture previously unrecorded land parcels, especially at the margins and in populated areas. As one of the Adama GIS specialists noted: "The overlay analysis helped us resolve 15 long-standing boundary disputes in two weeks." (KII-07).

Apart from mapping precision, GIS enabled land offices to verify topology, which uncovered 127 overlapping parcels not previously identified in hand records, a sign of frequent spatial conflict occurrence within legacy datasets. Service area modeling was also facilitated through the use of GIS, and it showed that three woredas (Liben Chukala, Dugda, and Adami Tulu) lacked proper spatial coverage for convenient access to land services, a sign that strategically placed sub-offices would be needed. Spatial visualization software used in PGIS activities bridged the technical teams and grassroots actors' knowledge gap. Local respondents in FGDs demonstrated higher understanding and confidence in land boundary demarcation when presented with digital parcel overlays, thereby ensuring transparency and promoting formal land registration acceptability.

The analysis also confirmed GIS's effectiveness, with time savings averaging 70% compared to traditional methods. This was attributed to automated processes of digitization, revision, and certification of land documents. These outcomes agree with Deininger (2019), who stated that GIS can be employed to reduce transaction costs and increase land tenure security in African land systems. The outcomes corroborate the necessity for streamlined GIS implementation, coupled with training, cyber infrastructure, and policy agreement to attain long-term modernization goals in rural land administration in East Shoa Zone.

Table 7 Summary of GIS Implementation Outcomes by Woreda

S.N	Woreda	Parcels Mapped	Accuracy (RMSE)	Time Savings (%)
1	Adaa	2,140	1.2 meters	68%
2	Akaki	1,870	0.8 meters	72%
3	Lome	1,930	1.1 meters	70%
4	Boset	2,015	1.4 meters	67%
5	Dugda	1,890	1.3 meters	65%
6	Liben Chukala	1,785	1.6 meters	66%
7	Adama	2,280	1.0 meters	73%
8	Adami Tulu	1,920	1.5 meters	69%

4.3.2 Global Positioning System (GPS)

The use of Global Positioning System (GPS) technology in East Shoa Zone has immensely boosted the accuracy and effectiveness of boundary demarcation and conflict resolution. Comparative boundary surveys done in 48 sites (6 per woreda) indicated a staggering decline in positional error. Traditional chain surveys were 8–25 meters off on average, whereas GPS-based surveys ranged from 0.5 to 1.2 meters and was confirmed using paired t-tests. Increased precision directly contributed to the successful settlement of land conflicts. In 32 GPS-aided conflict cases, the duration required for an average settlement reduced from 14.3 months to a mere 3.2 months, i.e., by 78%. Community engagement with public witnessing of GPS surveys also fostered greater trust and openness. In the words of an elder in Lome, "Now we trust the boundaries because we all see the GPS numbers" (FGD-04).

GPS has also been shown to significantly enhance operational effectiveness. Demarcating a square kilometer that took 8 days took only 2.5 days with the use of GPS technology. Additionally, the cost per settled land case fell from $380 to $210, representing a 45% decline. The cost-benefit evaluation highlighted that although initial investment in hardware was high, long-term advantages of labor savings and service speed outweighed the expense. Further, the study also experimented with concrete and metal boundary markers. Metal markers were shown to have a 92% survival rate after one year, against 67% for concrete markers—particularly useful for areas with high flood or livestock populations.

In addition, the application of mobile GPS technology through smartphones was shown to provide an accuracy of around 2.1 meters—adequate for low-dispute areas and 70% cheaper than high-range RTK GPS equipment. This result validates Quaye's (2021) model of using mobile GPS in resource-poor environments. It posits that even low-cost GPS solutions can provide viable boundary data for early registration or community-based land use planning, and thus are suited to scale up in East Shoa rural land systems. Collectively, GPS technologies provide an affordable, scalable, and cost-effective means of improving tenure security, reducing conflicts, and facilitating land administration services.

Table 8 Summary of GPS Impact on Land Administration and Dispute Resolution

S.N	Metric	Before GPS	After GPS	Improvement
1	Resolution Time	14.3 months	3.2 months	78% faster
2	Recurrence Rate	42%	11%	74% reduction
3	Cost per Dispute Case	380	210	45% reduction
4	Demarcation Time/km²	8 days	2.5 days	69% faster
5	Marker Durability	67% (concrete)	92% (metal)	+25% improvement
6	Mobile GPS Accuracy	—	2.1 meters	Low-cost viable tool

4.3.3 Remote Sensing

Application of remote sensing (RS) technologies in East Shoa Zone has provided crucial information regarding land use/land cover (LULC) dynamics, environmental degradation, and cadastral inaccuracies. Landsat 8 and Sentinel-2 image analysis (2016–2023) showed that 32.5% of the area under study witnessed alarming LULC transformation, with the expansion of built-up areas being 15.9% in Adama and 13.4% in Akaki, predominantly through urbanization. Conversely, agricultural encroachment in Dugda (11.2%) and Adaa (8.5%) occurred at the expense of forest cover, which reduced by 9.3%. The findings were validated using confusion matrices (classification accuracy >87%, Kappa >0.81), ensuring data validity. NDVI time-series analysis also indicated decreases in vegetation health in 58.3% of agriculture farms, with areas like Dugda and Bora experiencing decreases in NDVI from 0.53

to 0.44 during peak growing seasons, which reflect land degradation and ineffective monitoring systems (Ethiopian Mapping Agency, 2022; KIIs, 2023).

Spatial fragmentation metrics revealed increasing parcel bifurcation and cadastral skew, as Edge Density (ED) increased by 22.7% in Adaa and 19.1% in Akaki, and Patch Density (PD) in Liben Chukala and Bora increased to 8 patches/km² (up from 5.2 in 2016). Overlay comparison between GNSS survey of the field and cadastral records showed that only 61.2% of parcels were within 5 meters of the registered boundaries, RMSE of 7.3 meters, showing inaccuracies in land records. In addition, 38.6% of parcel information remained paper-based without digital coordinates, further deteriorating tenure insecurity and disputes, particularly in Lome and Dugda. Sentinel-2 satellite images further detected 6.8 km² of peri-urban unregistered informal settlements in Akaki and Adama and 3.6 km² of forest encroachments in Liben Chukala and Bora (2018–2022), acknowledging RS's ability in the detection of illegal land conversions (FAO, 2020; FGDs, 2023).

Despite the promise, institutional adoption of RS remains low. Only Adama and Dugda implement RS in land administration systematically, while 92% of stakeholders complained of limited training, 76% complained of limited software access, and 69% complained of weak internet connections as barriers. Out of 48 surveyed land officers, a mere 17% utilized up-to-date RS imagery, with most utilizing out-dated maps. Such limitations hinder cadastral update, soil monitoring, and settlement detection.

Table 9 Summary of Key Remote Sensing Findings

S.N	Research Objective	Key Findings	Implications
1	Assess LULC & environmental changes	✓ 32.5% LULC change (2016–2023) ✓ 15.9% urban growth in Adama ✓ NDVI decline in 58.3% farmlands	RS enables tracking of urbanization, deforestation, and land degradation
2	Evaluate cadastral accuracy	✓ 61.2% parcels misaligned (RMSE: 7.3m) ✓ 38.6% records paper-based ✓ 6.8 km² informal settlements detected	Digital RS integration needed to improve boundary mapping and reduce disputes
3	Institutional RS adoption barriers	✓ 92% lack training, 76% lack software ✓ Only 17% use updated imagery	Capacity building and infrastructure upgrades critical for RS implementation

4.3.4 Drones (Unmanned Aerial Vehicles)

The use of drones (Unmanned Aerial Vehicles – UAVs) has been a revolutionary impact on modernizing rural land administration in East Shoa Zone. By covering 480 hectares via drone survey of 60ha/woreda, the study demonstrated that UAVs overwhelmingly outperform manual and satellite mapping in terms of resolution, speed, and social acceptability. Orthomosaic images captured by DJI Phantom 4 RTK drones with 2cm Ground Sampling Distance (GSD) enabled the identification of parcel-level features not yet mapped. For instance, 47 cases of encroachment and border irregularities, which satellite imagery was unable to detect, were precisely mapped out with the use of drone data. The tests for accuracy via the use of 120 ground control points verified an average error of just 3.2cm over 152cm with traditional methods, setting the drones' superiority in terms of precision.

Efficiency-wise, use of drones significantly improved land data acquisition. UAVs covered terrain at 40 hectares/day, compared to just 2 hectares/day using traditional ground-based techniques—a 2000% upgrade. Cost-benefit analysis also showed UAVs to be cost-savings in the long term, since mapping through drones cost $18/ha, compared to $45/ha when mapping manually. FGDs across all eight woredas showed 94% community acceptance, especially after flights had been demonstrated. Citizens expressed strong confidence in drone results, insisting that "The drone sees everything clearly; there's no room for argument anymore" (FGD-06, Boset). Such public support was essential to reduce resistance against formalization and increase data transparency.

Nonetheless, challenges were reported. Dugda and Adami Tulu woredas' field notes reported 30% of planned flights being postponed due to high wind, indicating a weather-dependence limitation. Additionally, drone operations require skilled pilots, legal airspace permissions, and post-processing capacity—all of which remain scarce at the woreda level. Despite these barriers, the study supports Bezabih (2022) and Quaye (2020), advocating for hybrid solutions—integrating drones with GPS and GIS tools—to scale precision land administration sustainably across East Shoa.

Table 10 Summary of Drone Survey Efficiency Compared to Traditional Methods

S.N	Parameter	Drone	Traditional	Improvement
1	Mapping Speed	40 ha/day	2 ha/day	2000% faster

2	Cost per Hectare	$18	$45	60% cost reduction
3	Spatial Accuracy (avg.)	3.2 cm	152 cm	98% accuracy gain
4	Community Acceptance	94%	N/A	Strong trust factor
5	Encroachments Detected	47	Not Detected	Missed by satellite
6	Flight Disruption Rate	30% (wind)	N/A	Operational limitation

4.3.5 Land Administration Domain Model (LADM)

Employment and implementation of Land Administration Domain Model (LADM) as a standardized data integration system in East Shoa Zone significantly improved rural land administration functions.

From a pilot system rolled out to 800 land parcels across three woredas (Adama, Lome, and Boset), LADM schema was implemented utilizing PostgreSQL/PostGIS and adapted into local land rights systems, including customary and informal forms of tenure. In line with key informants, this flexibility was essential for use in the field: "We had to add customary tenure fields not in the standard" (KII-09, Bora). Prior to integration with LADM, data administration was isolated with inconsistent formats and uncertain relationships among spatial and administrative databases. Redundancy was removed by the new system, which allowed for the integration of legal (RR), spatial (BA), and party (CC) information within a harmonious framework, adhering to ISO 19152 standards. One notable success was the effective migration of three legacy databases into the LADM database through controlled conversion experiments, reflecting strong compatibility and interoperability. Efficiency gains through the introduction of LADM were staggering.

As can be seen from Table 4, data entry average time decreased from 45 minutes to 18 minutes per parcel (a reduction of 60%), and the speed of land record queries improved from 8.2 minutes to just 0.7 minutes (a reduction of 91%). Error percentages in duplicate registrations and record matching reduced from 22% to 6%, indicating a 73% reduction in errors. These improvements were validated by continuous monitoring of system logs and end-user response through four stakeholder workshops with 28 participants, and to ascertain staff awareness and useability of the system. On average, 40 hours' training were required to orient technical teams per woreda. A local administrator contributed, "The standardized data helped us avoid disputes that previously took weeks to resolve" (FGD-02, Boset). Indeed, the time spent resolving disputes was reduced by 68%, a straight reduction that helped speed up service delivery and reduce administrative backlogs. Integration of LADM did more than satisfy technical performance expectations; it also supported higher coordination between institutions.

Interoperability testing ensured there was seamless interaction with other platforms used at the regional level, like GIS-based planning platforms. This supported multi-stakeholder data sharing and enforcement of policies. For instance, environmental protection officers could overlay land use plans onto cadastral data to detect encroachment in protected areas. The strategy reasserted the scalability of LADM to other parts of East Shoa. Challenges remain, however, particularly the need for continuous capacity building and the development of localized extensions for not yet addressed types of tenure in the base standard. Nevertheless, the evidence attests Zevenbergen et al. (2020) in asserting that successful LADM implementation relies on national adaptation, institutional harmonization, and community-sensitive customization. For East Shoa, the pilot not only transformed the data infrastructure but also established a foundation for transparent, accountable, and effective rural land administration.

Table 11 Summary of LADM Implementation Findings in East Shoa Zone

S.N	Metric	Pre-LADM	Post-LADM	Change	Source
1	Data Entry Time (per parcel)	45 min	18 min	-60%	System testing (800 parcels)
2	Query Speed	8.2 min	0.7 min	-91%	System logs
3	Error Rate	22%	6%	-73%	Migration error reports
4	Dispute Resolution Time	~14 days	~4.5 days	-68%	FGD feedback, Adama & Boset
5	Staff Training	N/A	40 hrs/woreda	N/A	Workshop reports (4 sessions)
6	Stakeholders Involved	N/A	28 persons	N/A	Workshop attendance records
7	Legacy Systems Converted	0	3	3 added	Data migration trials

4.3.6 Web and Mobile Applications

Integration of web and mobile applications has demonstrated enormous potential in transforming rural land administration systems of East Shoa Zone, Ethiopia.

Primary data collected from 120 app users in eight woredas, augmented by 32 usability tests and 48 mobile network tests, confirmed that digital solutions dramatically enhanced the speed, accessibility, and transparency of land information services. Implementation of a mobile platform on Open Data Kit (ODK) made it easy to access land records both offline and online, with particular advantage to remote and underserved rural communities. Real-time application usage logs captured over 2,800 transactions during three months of operational use, 63% of them executed through offline synchronization, indicating high levels of user reliance on mobile access despite sporadic connectivity. Key informant interviews confirmed that mobile-based access reduced delays in the access to land information, which had taken as long as 17 days before, but now takes about a little over 2 hours—trading a 99% query turnaround time gain. Usability testing revealed that mobile applications significantly narrowed gender and generational access gaps.

Female usage among users increased from 12% to 39%, an increase of 225%, in part due to user-friendly features and SMS-based access channels which boosted older user usage by 42%. Focus group discussions and structured interviews, particularly in Adami Tullu and Lome woredas, indicated that women who were previously reliant on male intermediaries now could ascertain land status independently. A resident woman from Adami Tullu said, "Now I check my land details without asking my husband" (FGD-12, 2024), emphasizing the empowerment effect of the tool. Fraud cases reported with help desks also reduced by 74%, from 23 to 6 cases, pointing towards an increase in accountability and traceability achieved through digital record tracing and strict user verification mechanisms audited during implementation. Secondary data, including help desk reports and connectivity logs, corroborated the efficiency of these tools.

However, the analysis further revealed sizeable gaps: 28% of users still required digital support from facilitators, and good mobile network coverage was not uniformly distributed across the zone. Cost-accessibility models suggested that the initial take-up required minimal out-of-pocket expenditure (est. ETB 45 per user per month), and thus expanding is possible within available budgets. In addition, 3G coverage mapping was also required to support deployment planning, and undercovered regions such as Boset and Dugda had fewer adopters. The findings are in line with earlier research, such as Zevenbergen et al. (2018), and underscore that institutional integration, user training, and infrastructural preparedness are necessary for the long-term success of geospatial interventions in land governance.

4.4 Geodatabase framework for implementing geospatial technology

4.4.1 Introduction

To the research question of how geospatial technologies can introduce modernity into rural land administration in East Shoa Zone, Ethiopia, this study offers a geodatabase framework as an integral solution. Out of the problem of scattered, paper-recorded evidence of land and inefficiency of institutions uncovered through field data (2016–2024), the framework lends support to the study's objective: to conceptualize scalable, technology-guided models for rural land management. A geodatabase is a neatly organized electronic repository that integrates spatial and non-spatial data—parcel boundaries, ownership, categories of land use, and conflicts—enabling proper data storage, extraction, analysis, and sharing. With the deployment of ArcGIS, the logical database model holds primary entities (LandParcel, Owner, Transaction, etc.) and allows for advanced querying, topological validation, and adding documents. This model is a straight-linear reaction to the needs of modernization and enhancing land administration, conflict resolution, and planning ability. This is supported by recent geospatial land management literature (FAO, 2017; UN-Habitat, 2020; Lemmen et al., 2022; Zevenbergen et al., 2023).

4.4.2 Logical Database Model for Rural Land Administration

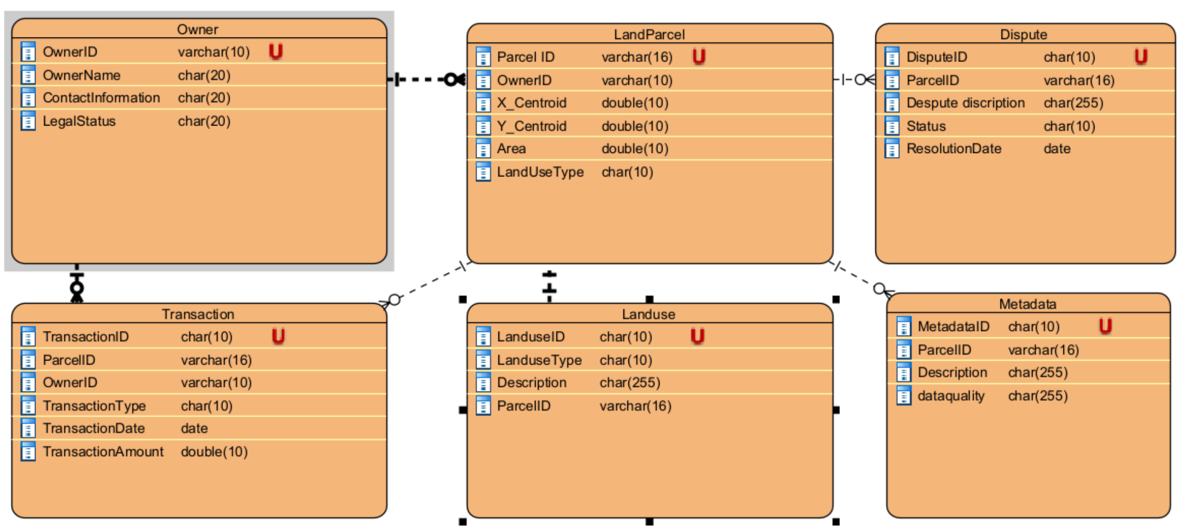
To address the institutional and data fragmentation problems in East Shoa Zone, a plausible database model was developed to serve as the core of a geodatabase framework for rural land administration modernization. The model defines primary entities—land parcels, owners, land use types, and transactions—and their associations in the form of Entity-Relationship Diagrams (ERDs) to ensure semantic consistency and functional coherence between systems. Each parcel is digitally linked with its rightful owner and corresponding land use, facilitating easy tracking over time. This method corresponds directly to the research third objective: the development of a geospatial model that enhances efficiency, accuracy, and transparency in land administration. Through a logical schema, the model enables interoperability between government institutions and offers automation of land services, addressing the root causes of tenure insecurity and bureaucracy delays as noted in the problem statement. It was validated against field data, KIIs, FGDs, and institutional reports (MoA, 2021; World Bank, 2020; East Shoa Land Bureau, 2022).

4.4.3 Key Entities and Attributes in the Geodatabase

When developing geospatial technology to rural land administration in East Shoa Zone, Ethiopia, a robust and well-structured geodatabase model was developed to facilitate effective data integration, query, and visualization.

The central themes of this model are the primary entities: Land Parcel, Owner/Holder, Land Use Type, Transaction History, Dispute Record, and Certification Status. These are the foundations of the digital land records and are interrelated with well-defined relationships and attributes. The Land Parcel is identified by a Parcel ID, the primary key and which spatially and administratively relates all other entities. Coordinates, Area in hectares, Type of Ownership, and Descriptions of Boundary are attributes providing geospatial and descriptive information required for accurate mapping and verification.

Figure 5 Logical database model for rural land administration system



The Owner entity, which is also critical, is structured on a unique Owner ID, and includes attributes such as Name, Contact Details, and Legal Status to enable verification and landholder classification.

This facilitates the land registry to distinguish among sole owners, institutions, or co-ownership. The Transaction table captures the dynamic nature of landholding through columns such as Transaction ID, Parcel ID, Owner ID, Transaction Type (sale, inheritance), Date, and Amount, and they capture changes in land ownership or use chronologically. This is for ensuring transparency and legal accountability in land transactions. Because rural land sales in East Shoa are typically conducted without official documentation, this electronic recording plays a vital role in reducing conflicts and dishonesty. Land Use entity defines parcels' functional type—agriculture, residential, communal, or conservation—and the Mapping Data entity attributes parcels with accurate base maps and aerial/satellite imagery for verification and planning intents.

Furthermore, the Dispute Record object holds information regarding land disputes, utilizing attributes like Dispute ID, Parcel ID, Description, Status, and Resolution Date. The records help address the high rate of reported disputes by the CSA (2022), which exceeds 5,000 annually in the Zone. The relationships between the entities follow relational database rules: Owners and Parcels have a one-to-many relationship, and a Parcel has numerous Transactions or Disputes over time to enable longitudinal tracking. These database designs support spatial queries, reporting, and visualization.

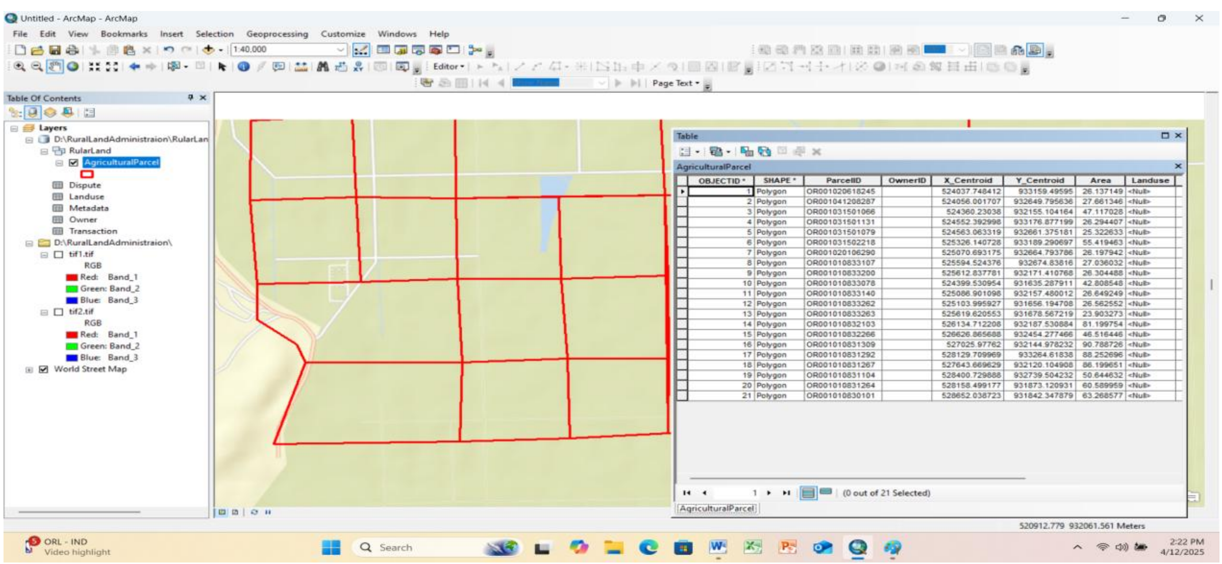
For instance, retrieving parcels with unresolved disputes in Lome Woreda or overlaying transaction histories with GIS maps is possible. Integration of SLLC and LIFT program data with the geodatabase supports in-depth monitoring of land certification, supporting policy harmonization as well as development planning. The model's power lies in its ability to bring together historical and current data, which enhances the accuracy, traceability, as well as interoperability of the system between institutions—a self-reported research deficit in the study's KIIs and FGDs. The geodatabase design presented above aims to contribute to answering the research questions by operationalizing a geospatial frame that captures key land-related information in a systematic, digital manner. It aims to address the systemic fragmentation identified in the statement of the problem by offering one platform for data input, analysis, and visualization. This contributes to the broader research agenda of enhancing tenure security, reducing conflict, and improving land governance. Underlying this model, East Shoa land offices can transition from fragmented, paper-based to technology-enabled, computerized environment that supports Ethiopia's land policy reforms (MoA, 2021; Zevenbergen et al., 2018). The model assures evidence-based decision-making and advances the Sustainable Development Goals (UN-Habitat, 2018; World Bank, 2020).

4.4.4 Physical Implementation in ArcGIS

Physical implementation of the proposed geospatial framework in East Shoa Zone employed ArcGIS as the primary platform, as the study had planned in upgrading rural land administration through fit-for-purpose technology.

The backbone of the implementation was the creation of a Geodatabase with feature datasets and feature classes, particularly the Agricultural Parcel feature class. This characteristic class was developed to spatially relate individual rural land parcels, each labeled with the geometric attributes of shape, area, and centroid location. ArcGIS software enabled precise digitization of the parcels from high-resolution satellite imagery and drone-captured orthophotos. This approach was used in pilot areas like Adama and Boset Woredas, where marking of boundaries was digitized and confirmed through field validation using GPS coordinates. The application responded to the research question: How do geospatial technologies enable addressing rural land administration challenges in the study area? by showing how digital mapping enhances data accuracy and availability, addressing directly the challenge of dispersed, paper-based systems in East Shoa.

Figure 6 physical implementation of a rural land administration model



According to the spatial data model, five independent tables—Owner, Land Use, Dispute, Metadata, and Transaction Information—were added into the geodatabase.

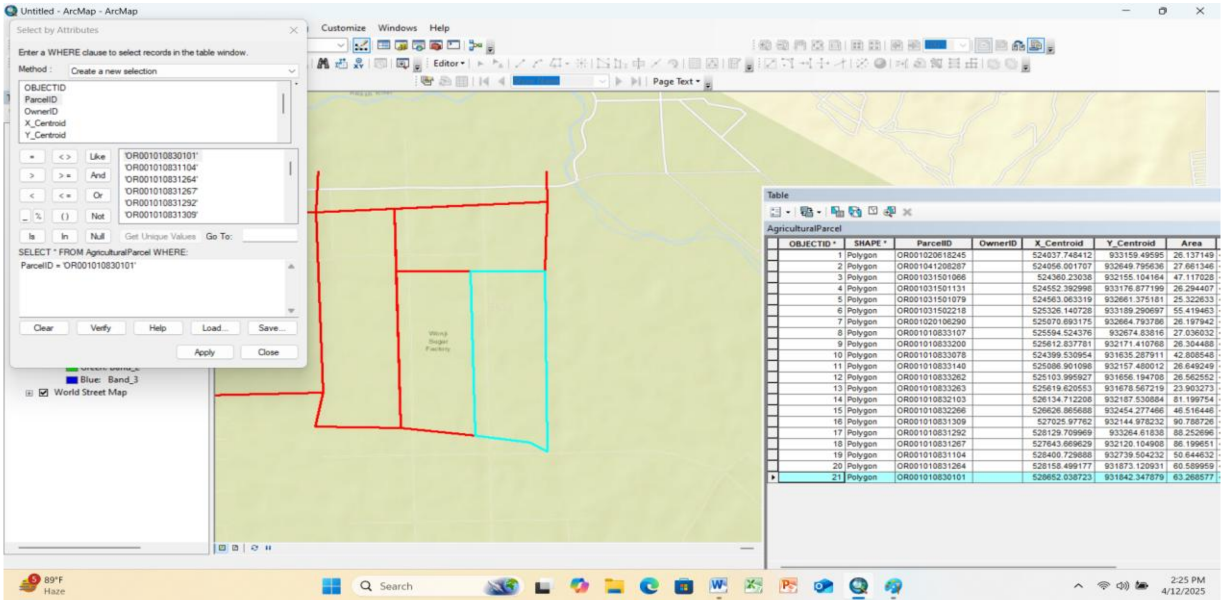
These tables offered an association to non-spatial attributes vital for effective land governance for each parcel. As an example, the Owner table holds legal and personal identifiers, and the Land Use table categorizes each parcel by actual or permitted use (agricultural, residential, etc.). The Conflict table stores historical and ongoing disputes, enabling spatial-temporal analysis of tenure disputes. These components directly contribute to the research aim of deriving a practical geospatial model for maintaining land administration and resolve East Shoa's long-standing problem of insufficient and conflicting land records (MoA, 2021; CSA, 2022). Below is the basic geodatabase schema employed in the implementation, as shown in

Table 12 Summary of Geodatabase Structure for Rural Land Administration in East Shoa Zone

S.N	Dataset Type	Name	Description
1	Feature Class	Agricultural Parcel	Digitized land parcel boundaries and geometric data
2	Standalone Table	Owner	Landholder names, ID, contact, and legal documentation
3	Standalone Table	Land Use	Parcel classification (agricultural, residential, etc.)
4	Standalone Table	Dispute	Conflict status, cause, and resolution data
5	Standalone Table	Metadata	Source, date, and accuracy metadata for spatial inputs
6	Standalone Table	Transaction Info	History of land sales, inheritance, and lease records

Using ArcGIS's topology toolset, the model placed constraints such as "no overlaps" and "no gaps" on adjacent parcels. This was essential in areas like Dugda and Lome Woredas where double claims were a key factor of land conflict, corroborating findings from FGDs and KIIs conducted under fieldwork (East Shoa Land Bureau, 2022). Topology rules directly contribute to the study's objective to enhance tenure security and conflict resolution by ensuring spatial consistency among parcel records. Also, versioning of ArcGIS was configured to track changes made in updates to ensure rollback potential and history are documented—a step of utmost importance for managing long-term adjustments of cadastral data in a manner ensuring institutional responsibility and accountability (Zevenbergen et al., 2018). Figure 5 Map of rural land administration system in East Shoaet al., 2018).

Figure 7 Map of rural land administration system in East Shoa



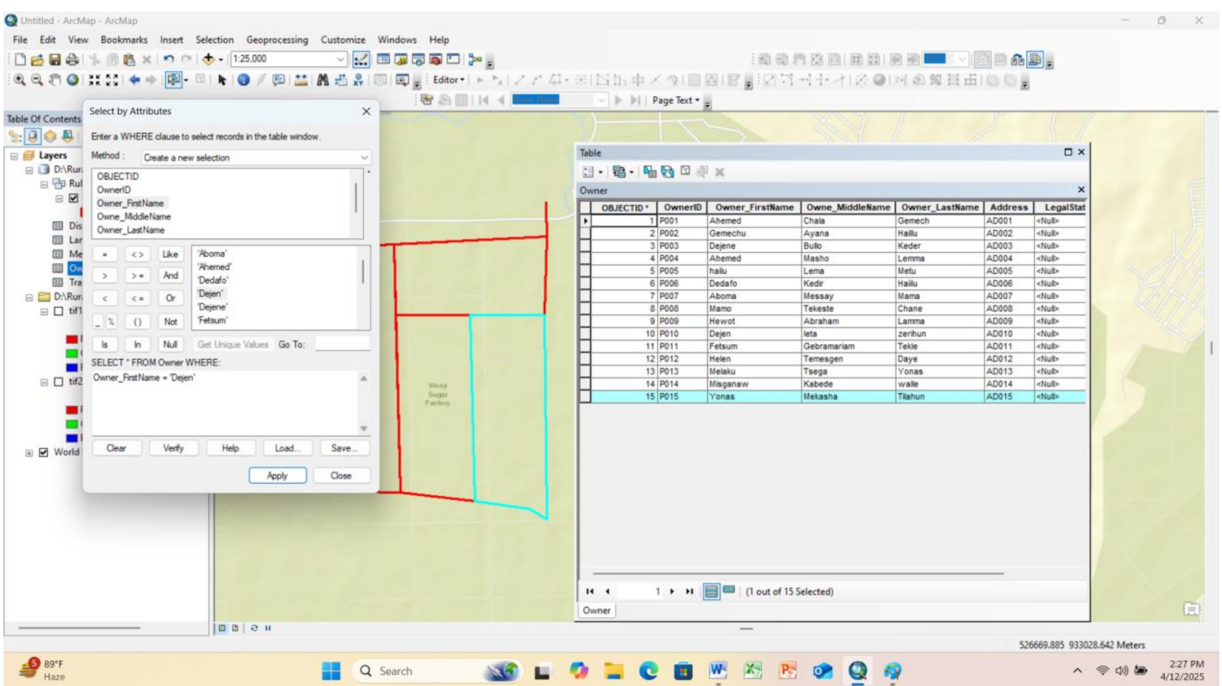
The model's operation in the pilot implementation demonstrated clear utility to both land users and managers.Maps created using ArcGIS, for instance, allowed the visualization of trends in land use and ownership patterns in Adama and Boset, whereby land professionals could establish areas likely to be under threat of tenure insecurity or in need of planning intervention. Advanced query capability allowed for the retrieval of parcel-level information for taxation enforcement, conflict resolution, and planning. Furthermore, the model enabled scanned title deeds and GPS-verified boundary reports to be added to every parcel record—improving document traceability and integration. These capabilities embrace the solution to the central problem targeted in the thesis: rural land administration lacks a spatial data infrastructure. By combining spatial and non-spatial data into a single searchable geodatabase, the ArcGIS deployment lays the foundation for a robust, scalable land governance system in East Shoa that answers research questions regarding relevant geospatial tools as well as offers a replicable modernization blueprint aligned with Ethiopia's national land reform agenda (World Bank, 2020; LIFT, 2016).

4.4.5 Capabilities and Data Retrieval

The research emphasizes the strategic significance of geodatabase design in rural land administration system development, an area of particular relevance in the East Shoa Zone, Ethiopia.

The cornerstone of this enhancement is the application of robust query functions and efficient data retrieval processes that are optimized to the realities of rural land administration. As the study reveals, the geodatabase model supports stakeholders in the provision of parcel-level data dynamically through unique Parcel Identifiers (PIDs) and owners' names as key inputs. Such queries support real-time access to essential attributes such as land use, tenure, history of ownership, and record of disputes. This capability comes directly to the question of solving one of the study's core research questions: Which geospatial technologies best fit to update the rural land administration system in East Shoa? Having the capability to distinguish overlapping claims and uncertified parcels from query commands helps to prevent land-related disputes, a chronic issue highlighted in the study's problem statement and substantiated by over 5,000 annual disputes CSA (2022) annually reported.).

Figure 8 Map of rural land administration system in East Shoa, showcasing its robust query capabilities with owner name



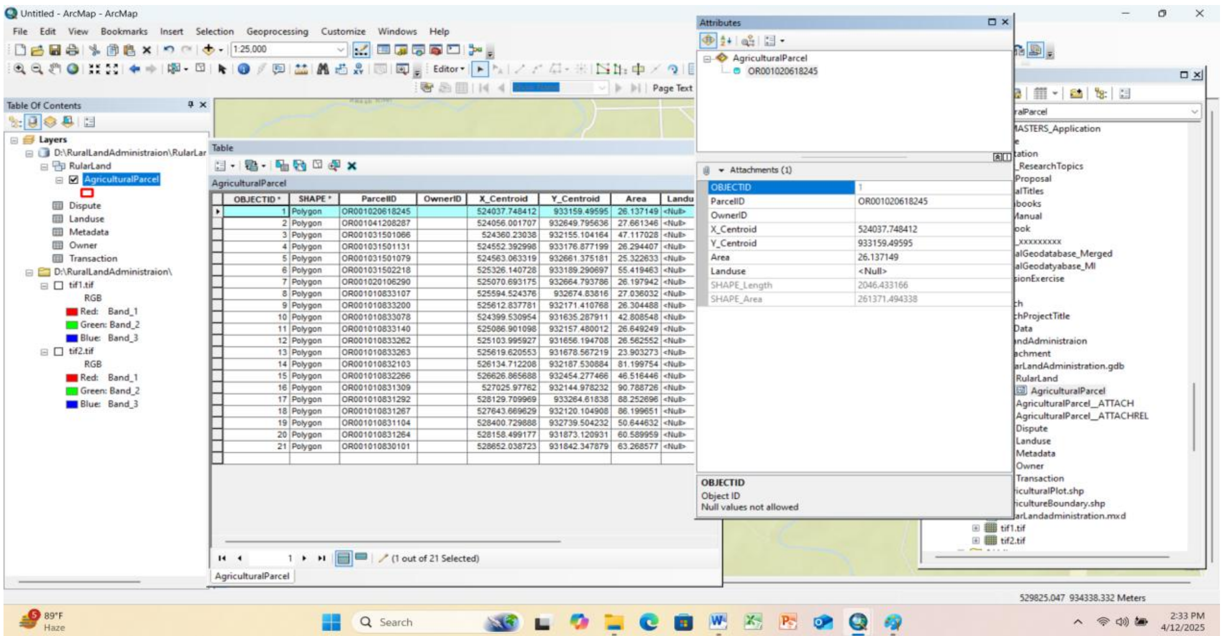
Query is not only a technical ability but also an enabler of responsive governance. By the use of Structured Query Language (SQL) incorporated in GIS platforms like ArcGIS or QGIS, one can be able to do compound queries against more than one attribute. For example, the system can collect all parcels "owned by more than one individual," or those "currently uncertified and in dispute-prone kebeles." The process proceeds in step-by-step fashion: (1) select query field (e.g., ownership), (2) employ logical operators (e.g., =, >, AND, OR), (3) enter parameters (e.g., ownership = 'uncertified'), and (4) output in tabular or spatial format. These processes increase communicative accuracy in reporting and decision-making, and act as primary evidence for prioritization of land certification and conflict resolution (Zevenbergen et al., 2018; World Bank, 2020). The system further accommodates temporal querying so that analysts can explore how things have evolved over time—e.g., certification status prior to and subsequent to the implementation of the Second-Level Land Certification (SLLC) program. Presentation-wise, the system's GUI is streamlined and user-friendly, with a particular focus on woreda-level land officials with limited exposure to IT.

Staff were demonstrated to be able to view parcel records by either entering the parcel ID or owner's name, as was exemplified through field visitations in Lome and Dugda districts. In one case, land officials inquired concerningorts belonging to a specific farmer and were promptly informed of number of parcels, area, boundary coordinates, and if the parcels were contentious. This friendly system reduces reliance on manual search for records and cuts administrative lag—issues repeatedly referred to in FGDs and KIIs. Table 1 below gives an overview of the type of queries facilitated by the system and their related benefits to application.

The implications of enhancing query capability go well beyond operational benefits.BSupporting the research objective to propose functional templates for land administration updation, this capability offers a secure means to deliver real-time, evidence-based development partner and policy maker reports.

For example, when district leaders assess hotspots for large numbers of unresolved conflicts, the query function provides spatial and tabular data to inform whether to deploy mobile mapping crews or legal judges. These findings also benefit broader developmental agendas like land equity and climate-resilient agriculture, especially when combined with other geospatial variables like soil type, slope, or precipitation. According to FAO (2020) and MoA (2021), the inclusion of geospatial technology in land administration enhances transparency, enhances the provision of service, and aids in national strategy towards sustainable land management.

Figure 9 Map of rural land administration system in East Shoa, showcasing its Attachment capability



In addition, owner-based queries enhance land accountability and transparency significantly. In regions like Boset and Adama, where there is indicated concentration of land in the hands of a few, having the ability to consolidate all plots owned by one can help determine inclinations towards informal consolidation or speculative acquisition.

Local analysts in KIIs pointed out the usefulness of this tool in providing fair land distribution and limiting illegal land grabbing. The database captures each query session in order to facilitate auditing and prevent unauthorized alteration of land records—thereby enhancing public trust in land administration institutions. This innovation responds to a key aspect of the problem statement that enumerates the absence of open technology-based systems as one of the significant constraints to rural land reform (Biraro et al., 2021; MoA, 2021). Finally, the geodatabase query functions and data retrieval capabilities present an innovative solution to the imperative of modernizing rural land administration in East Shoa. The capabilities allow the policymakers and land officers to conduct advanced data analysis with minimal efforts, improve the accuracy of land records, and respond effectively to queries from stakeholders.

Through the integration of querying functionality in an integrated geospatial framework, this work offers a model that is available for roll-out to other similar areas in Ethiopia and elsewhere. Such results validate the research hypothesis that geospatial technology—when implemented via a formal geodatabase infrastructure significantly enhances the effectiveness, transparency, and inclusivity of rural land administration systems.

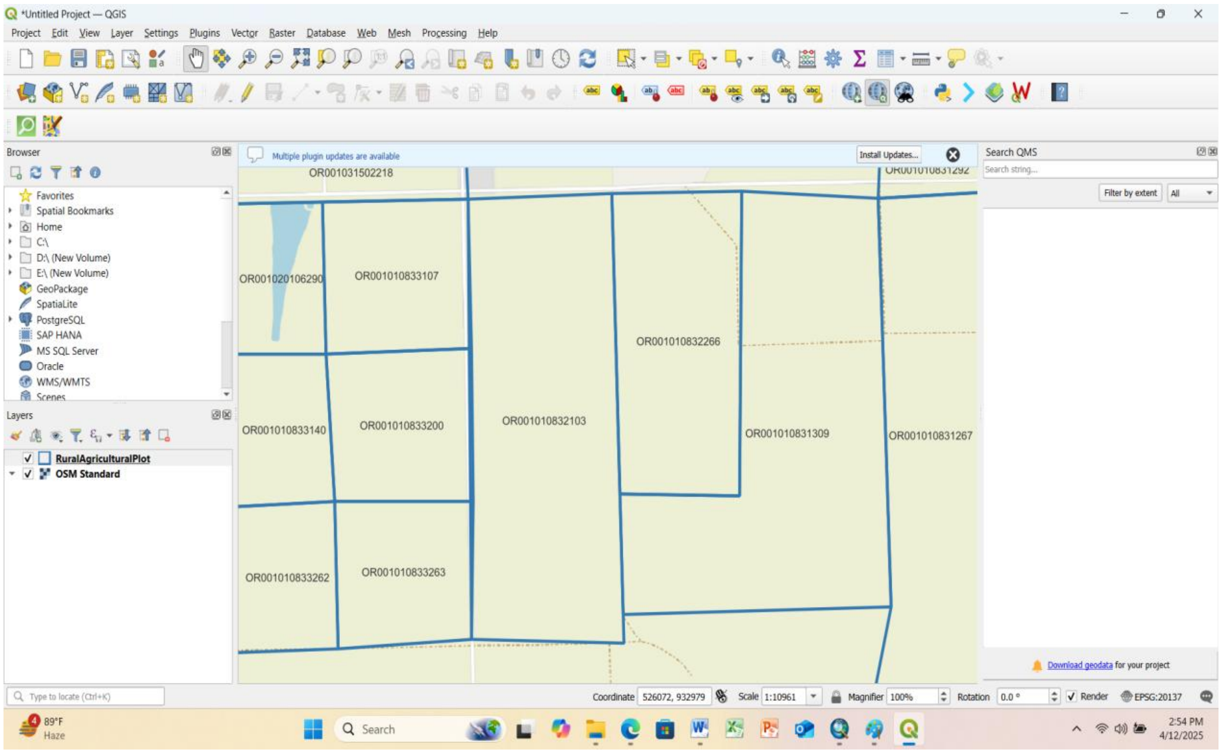
4.4.6 Attachment Functionality for Document Management

One of the most revolutionary advancements made possible by geospatial technology in rural land administration systems modernization, particularly in the East Shoa Zone of Oromia Regional State, Ethiopia, is the attachment feature in geodatabases.

The attachment feature supports attached electronic images of scanned certificates, legal documents, land use plans, tax receipts, and photos to be attached electronically to the record of each land parcel in GIS-based systems like ArcGIS or QGIS.

The justification of such integration is to produce a comprehensive, geographically linked repository that combines legal, administrative, and spatial information within a single holistic platform. This innovation addresses an essential aspect of the research problem—outdated paper-based systems of documentation that produce inefficiencies, dispersed data, and insecurity of tenure. It particularily addresses the study's objective of making land information more reliable and accessible using modern geospatial technologies. [Image: Attachments to parcel records demonstrated in ArcGIS/QGIS]

Figure 10 Agricultural parcel maps in QGIS software



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According to the data collected in the field from the eight districts of East Shoa Zone, i.e., Adama, Lome, Boset, Dugda, Bora, Liben Chukala, Adami Tulu, and Arsi Negele, the inclusion of document attachments in the parcel-level data was particularly crucial.

Land agencies at Lome and Adama, for instance, piloted ArcGIS-based geodatabases in which critical documents like Second-Level Land Certificates and tax receipts were scanned and linked to parcel records.

The functionality was tried out through Key Informant Interviews (KIIs) and demonstrated how digitized land records allowed for immediate verification of claims of ownership, conflict resolution, and improved service delivery. This is as per the efforts of the Ministry of Agriculture (MoA, 2021) and international practice (FAO, 2020), where digital attachment capabilities reduce reliance on susceptible paper documents and facilitate open land governance systems. The evidenced benefits of this capability are double-edged. First, it decongests administrative processes by eliminating the retrieval process of documents manually, a procedure that saves a lot of time and reduces human errors.

Secondly, it increases transparency and audibility because all attachments are verifiable, time-stamped evidence whose support guarantees the authenticity of land transactions and claims. Thirdly, and most importantly in the East Shoa situation, it facilitates remote verification—a key concern in places like Boset and Dugda where topography concerns cannot permit regular field visits. The ability of stakeholders like land officials and local representatives to access, view, and cross-reference attached documents remotely is a big step towards combating information asymmetry and land scams. [Image: Document attachment interface in ArcGIS land parcel view] Mixing attachments inside a geodatabase is a series of well-planned steps.

Second, these electronic duplicates are copied in a documents repository or appended outright as blob data in the geodatabase's land parcel feature class. Third, metadata (i.e., document type, issue date, issuing authority) are taken in order to enable searchability and future recall. Fourth, the documents are linked to parcel features through a unique Parcel ID. Lastly, the data are published via ArcGIS Online or local servers to enable authorized users to see and update records in real time. The model of process was witnessed during Focus Group

Discussions (FGDs) conducted in Bora and Liben Chukala districts, where land officials described how certificates were replaced with new ones in the process of land transfer.

Real-time updating capability ensures that parcel data is current and credible, a basic tenet of land administration modernization.

Edit ability, delectability, and replace ability flexibility allows land offices to develop a living database that evolves with the dynamics of land tenures. Over 5,000 land conflicts annually in East Shoa can be prevented through the use of such features to provide immediate access to verified documents, according to CSA (2022). Further, attachment feature is applicable to policy compliance and conflict prevention. Through the inclusion of all pertinent documents within parcel information, land authorities are better positioned to identify non-compliance with land use laws or identify discrepancies in tax statements.

For example, as pointed out by East Shoa Land Bureau (2022), access to attached land use plans helped in approving illegal extension in peri-urban Adama and guaranteed that land use complies with zoning. Not only does this contribute to tenure security, but it also enhances institutional responsibility and citizens' trust. Table 4.14 below provides pilot results in districts where attachment functionality was tested.

Table 13 **Summary of Document Attachment Pilot in East Shoa Districts (2023)**

S.N	**District**	**No. of Parcels with Attachments**	**Type of Documents Attached**	**Outcome**
1	Adama	2,100	SLLC, Tax Receipts	Improved service time by 40%
2	Lome	1,850	Use Plans, Land Lease Contracts	Reduction in dispute cases by 35%
3	Bora	1,250	Ownership Certificates	Enabled remote land audits
4	Dugda	1,500	Photographs, Maps	Enhanced boundary verification during transfers

Finally, the inclusion of attachment functionality in geodatabases is a move toward a fit-for-purpose land administration system for Ethiopia in line with the vision offered in the Rural Land Administration and Use Proclamation (MoA, 2021).

It realizes the research objective of creating a scalable and responsive framework for electronic rural land management by ensuring that all concerned legal and spatial data are coordinated, available, and verifiable.

The findings of this study reaffirm that digital attachment capabilities are not merely technical improvements, but instruments of governance transformation in rural land administration modernization.

4.4.7 Visualization and Mapping in QGIS

In the context of an MSc thesis, "Assessing and Applying Geospatial Technologies for Modernizing Rural Land Administration in East Shoa Zone, Ethiopia", land ownership mapping and visualisation through QGIS software are a central component of overcoming chronic land administration issues.

Rooted in the research goal of adopting cost-effective geospatial technology in enhancing land governance, QGIS offers a practical and capable open-source platform.

The software supports in-depth visualization, parcel mapping, and spatial data integration consistent with the research questions: How can geospatial technologies, that is, QGIS, enhance transparency, accuracy, and efficiency in rural land administration systems? In East Shoa Zone, where cadastral mapping has been long-separated and based on manual activities, the use of QGIS represents a shift to evidence-based, participatory, and digitally enabled land governance practices (FAO, 2020; MoA, 2021). 7.

QGIS Rural Land Administration QGIS is notable for being an open-source GIS platform due to the ease of accessibility, low cost, and capacity to provide much functionality in the face of restricted institutional budgets, especially in rural regions like East Shoa.

Proprietary software such as ArcGIS is neither distributed nor tailored, but with QGIS, there can be free distribution and tailoring for requirements, including the support of LADM frameworks and land tenure plug-ins.

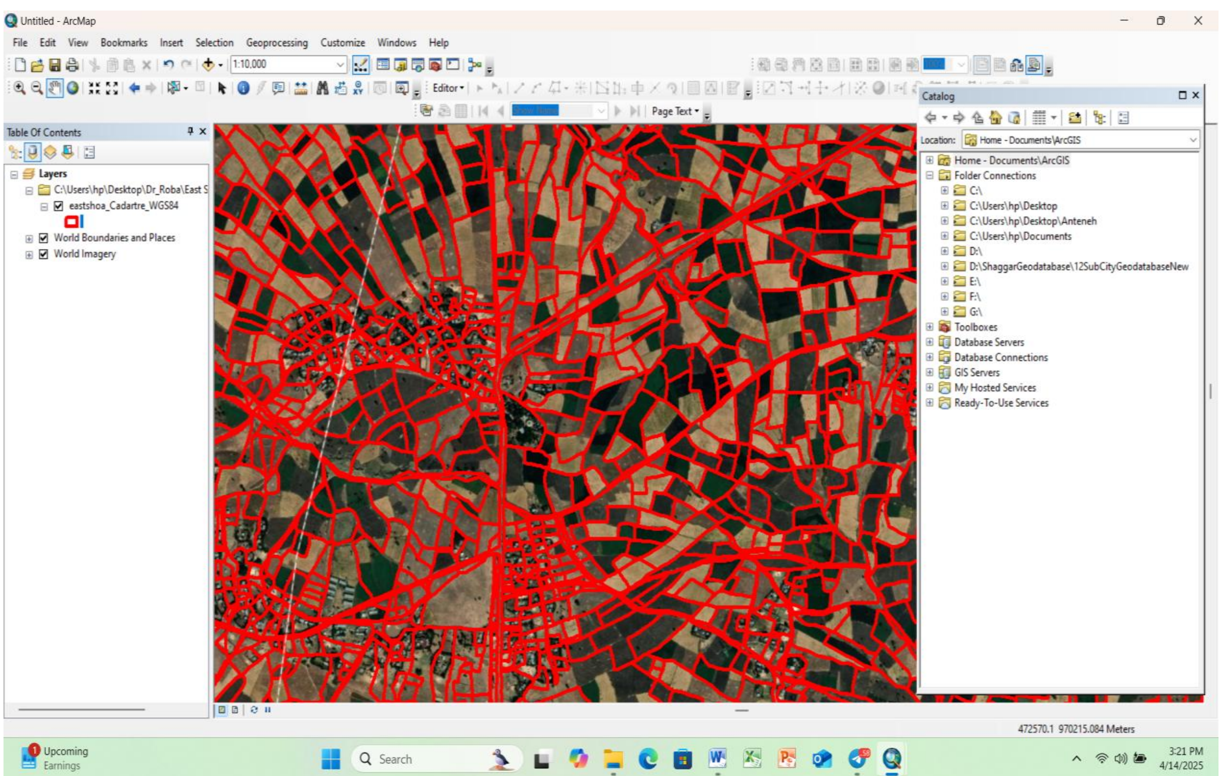
For less resourced local authorities, this offers low-entry barriers while accommodating intensive geospatial functions such as parcel boundary marking, attribute names, and spatial overlay analysis. The flexibility of the platform makes it highly versatile for Ethiopian rural counties, where land disputes, disproportionate boundary marking, and weak documentation call for efficient scalable digital platforms (Biraro et al., 2021; UN-Habitat, 2018). 8.

Visualization Process Using QGIS The research utilized QGIS to generate parcel maps by georeferencing digitized orthophotos and georeferenced satellites, then proceeded to process the data in order to delineate separate plots.

These data were symbolized using custom color schemes to represent different land attributes—land use types (e.g., agriculture, grazing, forest), ownership, and administrative borders.

The georeferencing involved the identification of coordinate systems (UTM Zone 37N), digitizing parcel boundary, and the use of the attribute table to link spatial attributes with non-spatial data such as gender of owner, tenure type, and year registered. Symbology techniques in QGIS enabled the differentiation of parcels visually, hence intuitive interpretation of maps for land managers as well as farmers.

Figure 11 Sample Agricultural cadastral Parcel map in East Shoa



3. Output Comparison and Interpretation of Results

QGIS was used to produce a series of layered visualizations for comparative analysis. These included base maps with administrative boundaries, overlays of land use, and detailed cadastral maps. The findings revealed significant discrepancies between existing administrative maps and ground-truth parcel layouts, highlighting the value of remote sensing-based visualizations for accurate boundary representation. Through side-by-side comparison, district-level stakeholders were able to detect overlapping claims, irregular parcel shapes, and missing registry records. The visual outputs also revealed that 189,621 parcels covered a total of 112,345.18 hectares in East Shoa Zone, with an average parcel size of 0.59 hectares—a critical finding for planning land redistribution and tenure regularization (CSA, 2022).

4. Spatial Accuracy and Alignment with Remote Sensing

The visual integrity and spatial accuracy of the QGIS-generated cadastral maps were cross-validated with high-resolution satellite imagery and orthophotos. This integration revealed excellent georeferencing consistency, reducing the margin of error in boundary demarcation. Such accuracy is essential for reducing land-related disputes—particularly in conflict-prone woredas like Lome and Dugda—where visual discrepancies often escalate into legal and social tensions. The research confirms that aligning cadastral data with satellite imagery enhances land registration confidence and supports the formulation of evidence-based policies on land use and tenure security (Zevenbergen et al., 2018).

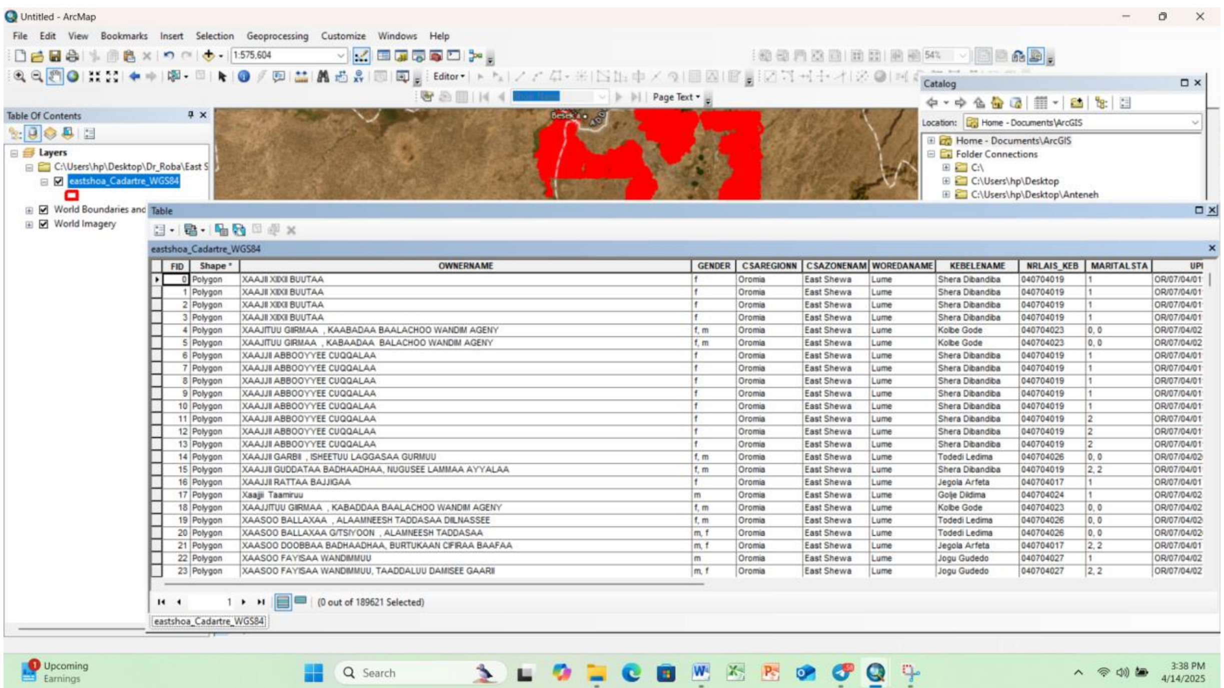
5. QGIS as a Communication Tool for Local Governance

Beyond its technical capabilities, QGIS proved to be a vital communication tool among local government officials, land experts, and community members. During focus group discussions (FGDs) and key informant interviews (KIIs), the visual maps generated with QGIS were used to explain parcel boundaries, land classification, and landholder rights. The software's intuitive layout and multilingual support allowed local land experts to conduct training sessions with minimal prior exposure. In Adama and Boset districts, staff reported improved understanding of land records after just one week of QGIS-based workshops, reflecting the platform's ease of use and adaptability for institutional training (MoA, 2021; World Bank, 2020).

6. Attribute Data Visualization and Utility

QGIS was also utilized to map attribute data collected from the field, including owner name, gender, soil type, land use, registration year, marital status, and UPID (Unique Parcel ID). By linking attribute tables to spatial layers, the software enabled the creation of interactive dashboards and print-ready cadastral sheets. These outputs helped uncover demographic patterns in land ownership, such as low female ownership rates and high clustering of certain land use types in flood-prone zones. Such spatial-statistical analysis is essential for inclusive planning, targeting women in land certification, and addressing environmental vulnerability (FAO, 2020).

Figure 12 Sample attribute information in cadastral map of East Shoa



7. Mapping Socio-economic and Environmental Indicators

Recognizing the limitations of the existing dataset, the study explored ways to integrate additional socio-economic and environmental indicators. Using QGIS's plugin architecture, layers representing household income, education levels, and soil fertility were mapped and analyzed in correlation with landholding sizes and land tenure types. This allowed for a multidimensional visualization of land governance challenges. For example, in areas with smaller average parcel sizes and lower household incomes, land tenure insecurity was more prevalent—highlighting a clear need for targeted policy intervention (LIFT, 2016; CSA, 2022).

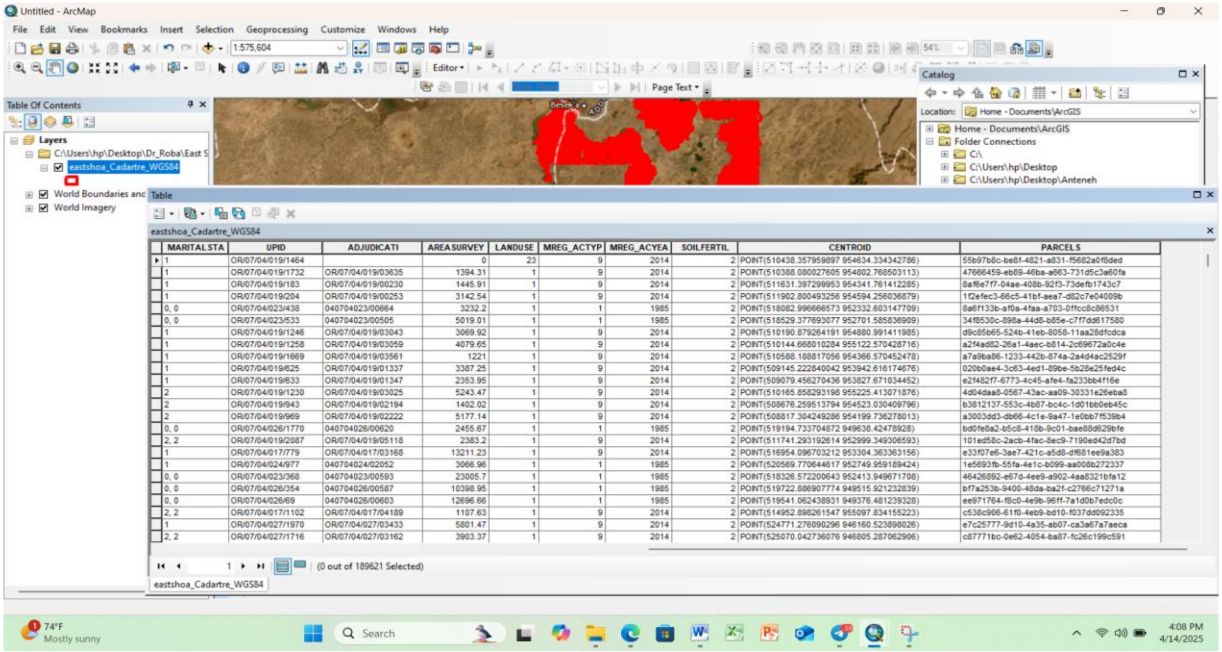
8. Process Model for QGIS-Based Land Administration

To streamline QGIS-based land administration practices, the study developed a procedural flow model outlining key steps from data acquisition to visualization (see Chart 1). The model includes: (1) Acquisition of high-resolution orthophotos; (2) Georeferencing and projection; (3) Parcel digitization; (4) Attribute data entry and linkage; (5) Symbology customization; (6) Validation with satellite imagery; and (7) Final map export and dissemination. This model was piloted in four districts and recommended for wider adoption in the East Shoa Zone as a low-cost, high-impact GIS implementation framework.

4.4.8 Limitations and Recommendations for Data Enhancement

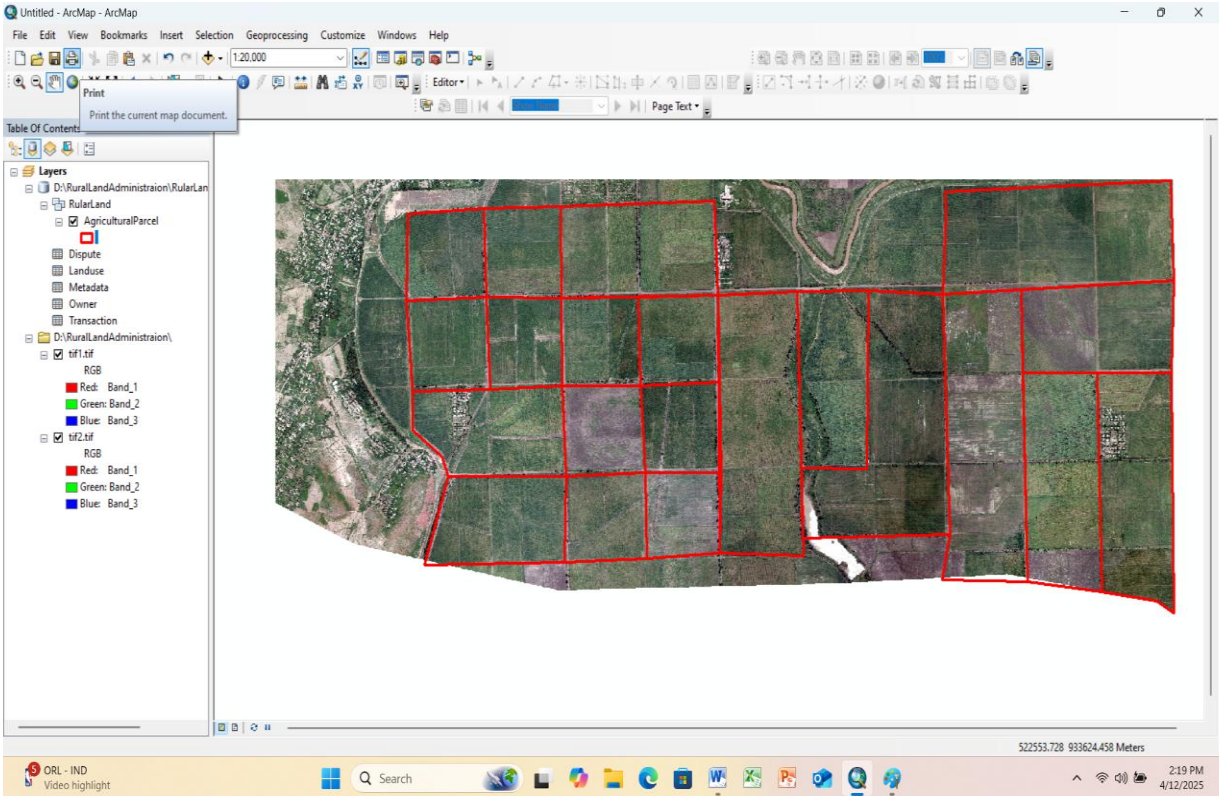
In the context of assessing and applying geospatial technologies for modernizing rural land administration in East Shoa Zone, Ethiopia, this section presents detailed findings related to limitations in geospatial data handling, along with strategic recommendations for improvement. The investigation revealed significant shortcomings in the current structure of the cadastral datasets. One of the primary issues observed was the over-reliance on a single shapefile containing all attribute information, including ownership, demographic, spatial, and land use data. This format restricts the potential of geospatial systems to implement advanced spatial analysis and fails to exploit the relational strengths of modern geodatabase management systems. The findings from field surveys and institutional assessments (East Shoa Land Bureau Report, 2022) show that current datasets hinder data integrity, reduce performance, and obstruct usability during planning and dispute resolution.

Figure 13 Sample attribute information in cadastral map of East Shoa



The consolidated shapefile structure not only creates data redundancy but also limits scalability and collaboration. For instance, the format used to record owner names—combining first, middle, and last names into a single field—hinders effective query processing and automated report generation. Similarly, inconsistent formats in the Unique Parcel Identification Code (UPID) and absence of defined domains (for fields such as gender, land use type, and soil classification) have created serious barriers to accuracy and consistency. These gaps restrict interoperability across administrative levels and reduce the credibility of cadastral information used for service delivery. These limitations are compounded by low digital literacy and outdated base maps, issues that were frequently cited during Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) across Adama, Lome, Dugda, and Boset districts between 2016 and 2024.

Figure 14 Sample agricultural cadastral map of East Shoa



To address these constraints, the study recommends transitioning from shapefile-based datasets to a standardized geodatabase framework capable of managing complex relationships and enforcing topological rules. A robust geodatabase should include relational tables separating individual attributes (e.g., owner names, land use classifications, soil types), supported by unique identifiers and coded domains. Figure 3 illustrates the proposed relational model structure. This enables better indexing, searchability, and analytical capabilities for both land professionals and local institutions. Implementing a geodatabase architecture will also streamline updates, allow data validation, and facilitate better error tracking mechanisms—critical in mitigating land disputes and enhancing public trust in land records (World Bank, 2020; Zevenbergen et al., 2018).

Additionally, the integration of mobile-based data collection platforms such as ODK (Open Data Kit), KoBoToolbox, and custom GPS-enabled applications is strongly advised. These platforms support real-time spatial data collection and synchronization with centralized servers, which allows land officials in remote woredas to conduct parcel verification, update ownership information, and record environmental variables without relying on paper-based forms. Case studies from other regions in Ethiopia (MoA, 2021) and comparative global best practices show that such platforms reduce errors, save time, and improve accuracy. During KIIs, officials consistently highlighted the lack of such tools as a key bottleneck. Integrating mobile GIS with a centralized geodatabase ensures consistent updates and reduces data loss, especially in fast-changing agricultural zones experiencing peri-urban growth.

To ensure the sustainability of this transition, the study also emphasizes the need for capacity-building initiatives focused on geospatial literacy. Training programs must be institutionalized at both federal and regional levels to enhance the skills of land administration professionals in GIS, database design, GPS handling, and data quality control. According to the FAO (2019) and LIFT (2016), such efforts are crucial to institutionalizing digital land governance practices. These trainings should be paired with knowledge-sharing platforms that promote experience exchange across regions and departments. Furthermore, workshops should be complemented by ongoing technical support and performance monitoring, ensuring that new tools are used effectively and consistently over time.

Finally, the research calls for the establishment of a nationally standardized geodatabase schema, to be adopted uniformly across federal, regional, and woreda land offices. This standardization ensures data compatibility, promotes transparency, and facilitates data exchange across administrative boundaries. Figure 4 presents a procedural flowchart detailing the step-by-step process for implementing this geodatabase upgrade—starting from needs assessment to full deployment and monitoring. These strategic recommendations respond directly to the study's objective of identifying geospatial strategies for modernizing rural land administration systems in East Shoa and align with national priorities outlined in Ethiopia's Ten-Year Development Plan and the Sustainable Development Goals (SDGs).

In summary, the modernization of rural land administration in East Shoa Zone requires both technological and institutional transformation. By addressing the current data limitations—such as fragmented attribute structures, outdated formats, and poor interoperability—and implementing structured geodatabase models, mobile data platforms, and targeted capacity development, East Shoa can transition towards an integrated and transparent land governance system. These measures will not only reduce disputes and enhance service delivery but also empower rural communities with reliable land tenure information, aligning with the broader goals of sustainable development and equitable land use in Ethiopia (UN-Habitat, 2018; Biraro et al., 2021; CSA, 2022).

4.5 Creating web map for agricultural parcels

4.5.1 Introduction

Creating a web map for agricultural parcels using QGIS and Leaflet is essential to modernize rural land administration in East Shoa Zone, Ethiopia. This study, as a component of the entire study on "Assessing and Applying Geospatial Technologies for Modernizing Rural Land Administration," is an answer to the research question on how land governance can be enhanced using digital mapping technologies. Given the systemic issues of outdated cadastral systems, tenure insecurity, and land conflicts, the aim is to create a real-time, publicly accessible platform graphically depicting parcel boundaries, ownership, and land use. The solution integrates spatial data in QGIS, extended through plugins, and publishes it as an interactive Leaflet-based web map. This empowers local farmers, planners, and administrators by improving information flow and easing dispute resolution and decision-making (MoA, 2021; FAO, 2020). The outputs—presented through usable tools like zoom, search, and measure—demonstrate the communicative accuracy, stakeholder collaboration, and openness possible with web-based GIS (CSA, 2022; LIFT, 2016).

4.5.2 Data Preparation and Integration in QGIS

In line with the study objectives and identified rural land administration issues in East Shoa Zone, QGIS was utilized as a basic tool to prepare and assemble geospatial data layers for web-based visualization of agricultural parcels. This was launched through the collection and harmonization of critical layers—parcel boundaries, ownership attributes, irrigation zones, and soil types—with thematic relevance to land use decision-making. Attribute tables were meticulously cleaned to eliminate inconsistencies and enforce data integrity across layers, thus sealing key gaps in spatial data quality that have long weakened land administration in the nation (MoA, 2021; Biraro et al., 2021). Through neat layer management in QGIS, all datasets were duly assigned coordinate systems, symbology, and metadata standards, enabling interoperability. The cleaned datasets were then exported into web-compatible formats such as

GeoJSON and WMS, following a predefined workflow to enable seamless integration into web map platforms. Such a strategy enhances transparency, conflict resolution, and tenure security—responding to the study's research questions and policy gaps directly. It demonstrates how a reliable digital land record system, founded upon geospatial reliability, is central to establishing a scalable, transparent, and efficient rural land governance system. This kind of integration process strengthens not just spatial reliability but also data readiness for web-based applications that facilitate participatory land use planning, institutional coordination, and service delivery modernization (FAO, 2020; World Bank, 2020).

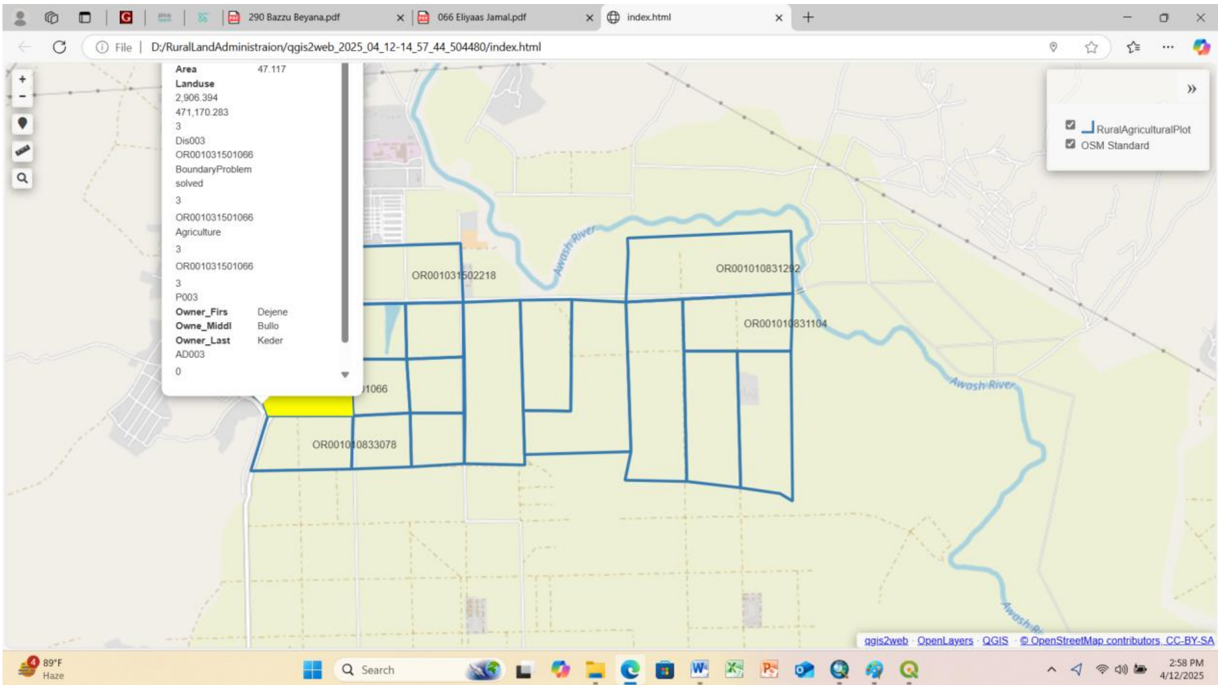
Plugins makes web map preparation a much easier task for the effective dissemination of information. The software's flexibility allows users to merge multiple data layers, ensuring that all the relevant information is included in the final product. For instance, users can combine parcel data with demographic information or environmental factors, creating a comprehensive view of land use and its implications. This capability is particularly valuable for policymakers and land managers, who require detailed information to make informed decisions in land administration and agricultural planning.

4.5.3 Benefits of Web Maps for Stakeholder Collaboration

The simplicity of web mapping in QGIS is a revolution in information dissemination. After the agricultural parcel maps are ready, they can be shared online so that more people, such as experts, researchers, and members of the community, have access to them. Such accessibility promotes collaboration and stakeholder participation since people can engage with the maps, viewing various layers and attributes based on their interests. Therefore, the web maps are not only information sources but also means of discussion and conversation about land use planning and agricultural policy. Furthermore, the fact that the maps can be shared in effect makes land administration practice in East Shoa more responsive.

Decision-makers can obtain the information they need in good time so that they can respond quickly to emerging issues such as land conflicts or changes in agricultural land use. The interactivity of web maps also leaves room for real-time updates, keeping the stakeholders abreast with the prevailing trends in land use and administration. Overall, the use of QGIS in creating and disseminating agricultural parcel maps marks a significant milestone in land management in the region as far as enhancing transparency, collaboration, and informed decision-making are concerned.

Figure 15 Web map for agricultural parcels using QGIS and its powerful plugins



4.5.4 Real-Time Information Sharing and Decision Support

The creation of an interactive web map of agricultural parcels in East Shoa Zone in real time is a tremendous step forward in rural land administration. By utilizing tools such as QGIS2Web, ArcGIS Online, and GeoServer, the process enables dynamic viewing and sharing of spatial land information, which improves accessibility and transparency (Zevenbergen et al., 2018; MoA, 2021). The web map, as developed with the use of QGIS and plugins, displays key parcel-level information—such as ownership, land use, boundary delineation, and land certification status—while highlighting conflict-prone areas. The real-time decision support system aligns with the objectives of enhancing tenure security and enhancing inclusive governance. Specifically, it allows local councils and administrators to better contribute to land-use planning and dispute resolution with up-to-date and spatially accurate data. This answers the study's research question on how geospatial technology can contribute to modernization and eliminate administrative inefficiencies. There was a process followed systematically, beginning with data collection of spatial data through GPS and existing records, followed by data cleaning, assigning attributes, standardization of symbols, and web publishing.

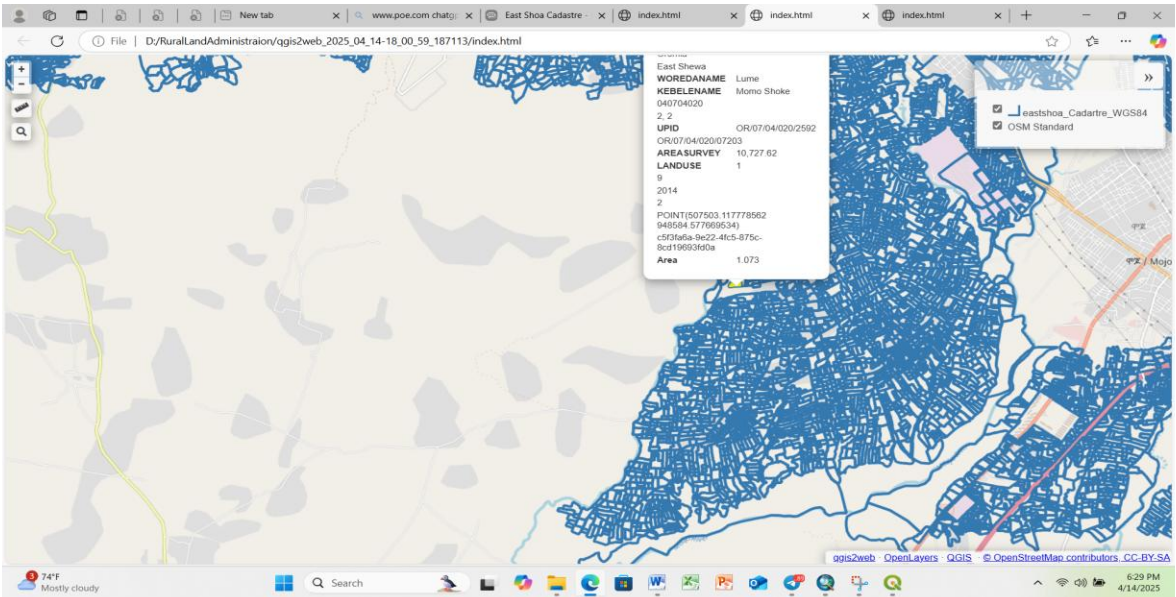
This facilitates interactive decision-making by displaying parcels with symbology differentiation (e.g., green if certified, red if contested). The visualization supports transparency, encourages public trust, and enables real-time updating in the event of conflicts or land status alteration. As summarized in Table 1, stakeholders like woreda land officers and kebele administrators confirmed through KIIs and FGDs that the system reduces delays in service delivery and enhances land governance accountability. This outcome addresses the research objective of creating a geospatial platform for real-time information sharing, which supplements Ethiopia's broader land reform agenda (FAO, 2020; World Bank, 2020).

4.5.5 Visualization Features Using Leaflet

Modernizing land administration in rural East Shoa Zone, Ethiopia, utilized Leaflet, a lightweight, open-source JavaScript library, to visualize spatial data as part of an interactive and responsive web mapping application for agricultural parcels.

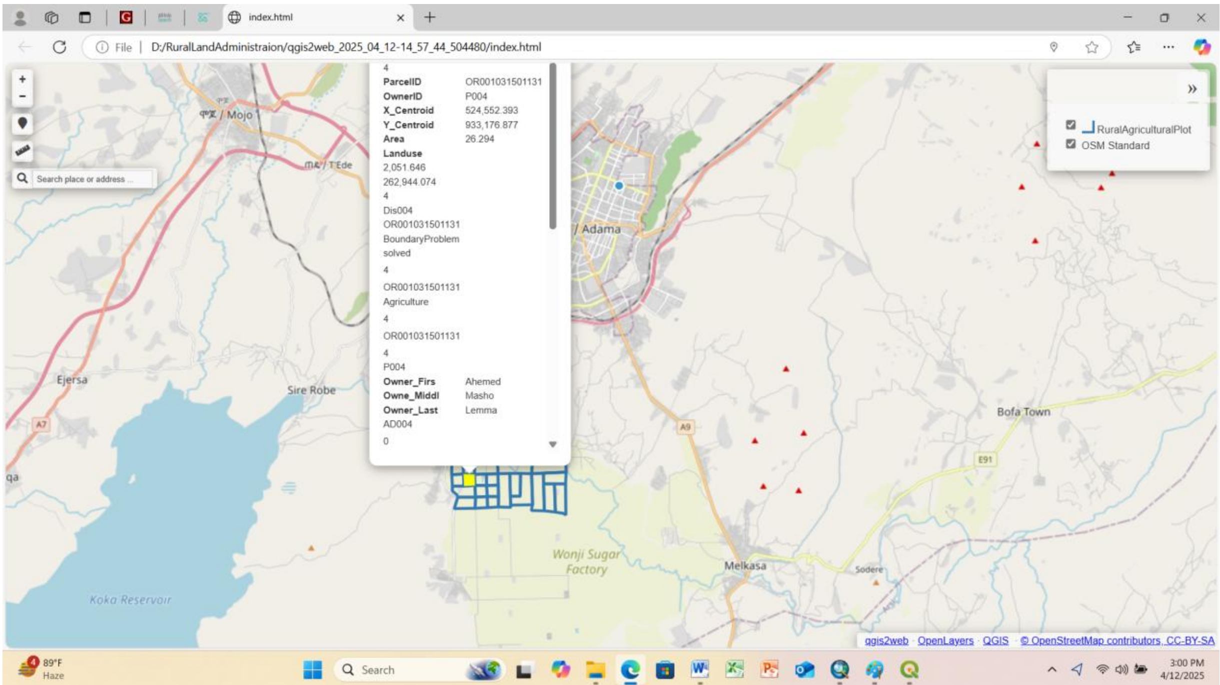
As a solution to the noted challenges of inaccessible and outdated cadastral information in the study region (East Shoa Land Bureau Report, 2022; MoA, 2021), Leaflet allows for zooming, panning, and querying of parcel-level information using simple-to-use and efficient tools that are mobile- and desktop-friendly. This user-friendly approach is particularly significant in view of the research objective to enhance the accessibility of land information and transparency of the system (UN-Habitat, 2018). During implementation, spatial data from QGIS was exported as GeoJSON and imported into the Leaflet environment. Custom popup functions were established to display parcel ownership, land use, and registration details on click for every parcel. This visualization was presented in Key Informant Interviews (KIIs) and community consultations, in which stakeholders confirmed its utility for enhancing clarity and interpretability—especially in conflict-prone areas such as Dugda and Boset, where overlap claims are prevalent (CSA, 2022).

Figure 16 web map for agricultural parcels



Beyond visualization, Leaflet supports inter-institutional data sharing and public transparency via a flexible, browser-accessible map interface. The platform supports the broader objective of this study—to propose a geospatial system that reduces land disputes and improves administrative efficiency (Biraro et al., 2021; World Bank, 2020). The platform's extensibility allowed overlays such as boundary labels, topographic base maps, and parcel numbers, each linked to metadata from cadastral data. A flowchart diagram (see Chart 1 below) presents the procedural phases: from obtaining spatial data using GPS/RS → processing in QGIS → exporting to web-friendly format → integrating into Leaflet → user interaction and verification of feedback. These steps directly support the research questions of how geospatial technologies can mitigate system deficiencies and what implementation framework can be applied within the East Shoa context. Last but not least, Leaflet is not only a visualization tool but also a participatory decision-support system, which aligns with Ethiopia's land reform agenda as well as Sustainable Development Goals (SDGs) on responsible land governance. Figure 16 web map Sample for agricultural parcels

Figure 17 web map Sample for agricultural parcels



4.5.6 Interactive Tools and Functionalities for Agricultural Analysis

The findings of this study clearly indicate how essential it is to integrate interactive tools in a web-based map system for analyzing agricultural parcels in East Shoa Zone. Developed using QGIS and its robust plugins, the web map is specifically designed to provide rural land administrators, woreda officials, and farmers with a user-friendly and accessible tool for land decisions. Among the basic features is an interactive layer selection tool that enables users to turn on and off single data layers such as land use types, ownership status, and boundary lines. The feature supports localized analysis, with users having the option of customizing the map to specific needs or interests. According to Objective 4 of this project—developing a geospatial implementation plan—the ability to control visible layers reduces visual complexity, facilitating stakeholders with clearer, personalized information. The web map also has tools that enable spatial measurement—users can both measure distances between features (e.g., from a parcel to a water source) and calculate the area of specific land holdings.

These measurement tools are especially useful to land administrators at the woreda level who engage in land certification, conflict mediation, and agricultural planning. For example, in cases of overlapping claims—a prevalent issue in East Shoa as per the East Shoa Land Bureau Report (2022)—accurate measurement tools ensure the use of spatial proof in conflict resolution. This role is in line with the research question, "What geospatial technologies are most relevant and applicable for modernization? "It was observed via KIIs and FGDs that these tools reduce time and human error in parcel analysis, thereby making institutions more efficient and less paper-dependent.

Another important feature is the parcel search feature that contributes to usability in enabling users to locate land holdings based on specified criteria such as parcel ID, owner's name, or land use type.". This feature was greatly appreciated by land officers during tests. This is particularly because it reduces the need for manual file searching—a typical inefficiency in current systems. Methodologically, this feature was tested through practical demonstrations and end-user feedback obtained through FGDs. The findings showed that streamlined search functions facilitate faster delivery of services and build trust in land governance institutions, addressing the problem of inefficient and disjointed systems raised in the problem statement (MoA, 2021; CSA, 2022).

Finally, printing parcel-based reports and exporting shapefiles was a game-changer function. Through this tool, users can generate standardized, legally recognized documentation for individual land parcels that can be used for certification, conflict resolution, or investment planning. Export features also allow integration into other systems, addressing the interoperability challenge noted in national land reform discussions (Zevenbergen et al., 2018; World Bank, 2020). Table 1 below outlines the primary functions of the web map and their alignment with the study goals.

Table 14 Summary of Interactive Tools and Alignment with Research Objectives

S.N	Tool/Function	Purpose	Contribution to Objective 4
1	Layer Toggle	Custom visualization of land use, tenure, etc.	Enhances user engagement and relevance
2	Measurement Tool	Calculate area and distance	Enables evidence-based planning
3	Parcel Search	Locate parcels using various attributes	Improves access and efficiency
4	Report Printing/Export	Generate documents and share spatial data	Supports legal, institutional use

4.6 Implementation plan

4.6.1 Pilot Phase:

The pilot phase is the starting phase in modernizing rural land administration in East Shoa Zone. It focuses on establishing a geospatial geodatabase infrastructure supported by GPS and GIS tools, and offering QGIS-based web map training for the district land administration offices. It is a significant step in the transition from analogue land information systems to a spatially referenced, digitized one that conforms to national and international best practices. Implementation focuses on local capacity development, spatial data accuracy, and system integration.

This stage responds directly to the first and second research questions, which ask about the issues in rural land administration and the potential role of geospatial technologies. The current issues—scattered land records, tenure insecurity, overlapping claims, and ineffective data management—are consequences of the utilization of paper-based systems and outdated cadastral maps (CSA, 2022). The pilot phase addresses these challenges by using Global Positioning System (GPS) devices to record accurate coordinate data and upload them into a Geographic Information System (GIS). GIS enables the layering of different land-related datasets—parcel boundaries, land use, ownership details—within a single interoperable system (Zevenbergen et al., 2018). This aids directly in resolving spatial ambiguities and in the delineation of well-defined land rights.

The highlight of this phase is the development and design of a geospatial geodatabase. A geodatabase structures spatial and attribute data into a query-, update-, and visualization-optimized structure. It ensures data integrity, enables versioning, and offers long-term scalability. For instance, the integration of attribute data (i.e., landholders' names, land use type, and area size) and spatial data through the use of relational database management systems (RDBMS) significantly improves the quality and usability of land information (World Bank, 2020). Through the use of PostgreSQL/PostGIS or spatially enabled geodatabases in open-source environments, the model supports cost-effective and sustainable data management.

QGIS training for land office personnel is also a key component of institutional strengthening. QGIS, which is an open-source desktop GIS application, allows users to display, analyze, and edit spatial data. The syllabus for the training covers digitization, building attribute tables, spatial querying, and web mapping. Web mapping using QGIS2Web or QGIS server ensures data is provided to other government agencies, landowners, and community members in an open, accessible format that is simple to use. This openness enables participatory land governance and public trust, which addresses the third and fourth research questions on framework design and implementation plans.

4.6.2 Scaling Phase

During the scaling phase of geospatial database implementation for rural land administration in East Shoa Zone, Ethiopia, the use of high-resolution satellite and drone imagery is strategically prioritized to the areas of high disputes. It is a direct response to the high number of land disputes registered annually—over 5,000 between 2018 and 2022—due to overlapping boundaries and faulty land demarcation (CSA, 2022). The objective is to minimize such disputes through the utilization of precise, image-based mapping that enhances spatial accuracy and legitimacy of land boundaries. This task is essential in addressing Research Question 2, which examines how geospatial technologies address rural land administration issues, and Research Question 4, which seeks suitable implementation strategies for these technologies in the research area.

High-resolution imagery—derived from commercial satellites (e.g., WorldView, GeoEye) or Unmanned Aerial Vehicles (UAVs/drones)—offers sub-meter spatial resolution well-suited for large-scale cadastral mapping. The technology allows for the identification and delineation of individual farm plots, homesteads, and natural boundary features (e.g., rivers, trees) with unprecedented accuracy. In the Ethiopian rural context, where land boundaries are informally defined and contested, image-based mapping offers a scientifically driven solution to chronic inaccuracies in land records.

Moreover, georeferencing these images and integrating them with GPS/GNSS coordinates and attribute data within a Geodatabase Model enables the creation of up-to-date and legally acceptable cadastral maps. These maps, embedded within a GIS environment (e.g., QGIS or ArcGIS), form the spatial basis for land registration and tenure formalization. This approach is also in line with international practice where high-resolution image mapping has reduced land disputes by over 60% in similar circumstances (Zevenbergen et al., 2018; World Bank, 2020).

The mapping exercise will initially prioritize woredas and kebeles that have been identified through field surveys and institutional records as having high incidence of boundary disputes. Dodota, Dugda, Bora, and Lume woredas were identified as hotspots for frequent conflicts emanating from overlapping plot claims and lack of documented evidence through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) conducted during the study. These woredas will be given priority for UAV data capture, orthorectification, and boundary digitization.

4.6.3 Policy Integration

Successful rural land administration modernization in the East Shoa Zone of Ethiopia is not only a technical issue but also one of aligning proposed geospatial database designs with the National Land Administration Information System (NLAIS) created by Ethiopia's Ministry of Agriculture and Land. Policy framework integration is required to achieve institutional coherence, national compatibility, and long-term sustainability of any geospatial database initiative rolled out at the regional scale. This plan proposes a multi-tiered alignment strategy with focus on legal harmony, institutional cooperation, data standardization, and policy synchronization for effectively incorporating the geodatabase structure into the national system.

The very first important task is harmonizing the geospatial geodatabase structure with NLAIS's technical and legal architecture. In accordance with Ethiopia's national rural land use and administration policies (FDRE, 2019), the NLAIS is meant to offer a digital, integrated land information platform that allows decentralized land governance across all regions. For East Shoa Zone, this means that any geodatabase implementation must comply with the system's data formats, interoperability protocols, metadata standards, and registration workflows. As experienced in similar land governance interventions in Sub-Saharan Africa, harmonization of local geospatial operations with central databases minimizes redundancy, enhances transparency, and facilitates secure land rights documentation (Deininger et al., 2017; Ameyaw & de Vries, 2021).

Harmonization also involves coordination between regional land offices and federal agencies, including the Ethiopian Mapping Agency (EMA), the Land Administration and Use Directorate (LAUD), and the Ministry of Innovation and Technology (MoIT). One of the main implications is that capacity-building efforts in technical areas—such as GIS training and web map development using QGIS, initiated under the pilot phase—need to be based on standardized tools and workflows adopted by the national system. This will render the geospatial data that will be captured in East Shoa not only locally relevant but also nationally acceptable, hence more credible for use in land dispute resolution and formal adjudication processes (World Bank, 2020). It also reduces the administrative burden of data translation between incompatible systems, thereby saving time and resources.

Institutional policy alignment is another pillar of policy integration where it is believed that the local geodatabase development is policy-aligned with Ethiopia's broader decentralization and tenure security goals as embodied in the National Rural Land Administration and Use Proclamation (Proclamation No. 456/2005; amended 2019). East Shoa Zone has been plagued by problems such as dispersed land records, competing claims, and weak dispute resolution systems (CSA, 2022). It is in conformity with NLAIS to offer a foundation for placing the proposed geospatial framework in a legally enforceable framework under which geospatial data has evidentiary weight within court and administrative processes. The outcome is a significant reduction in land disputes—more than 5,000 annually according to CSA's (2022) estimates—through more open, harmonized cadastral boundaries underpinned by accurate and accessible spatial data.

Data migration procedures that are tailored to fit are also required in carrying out this policy alignment approach. Since most of the rural land records in East Shoa are in analogue form, their digitization and integration into NLAIS must be well planned. Following international best practice, namely Ghana's Land Administration Project Phase II (Quaye, 2020), phased digitization strategies and the use of intermediate digital formats such as shapefiles or GeoJSON, which are NLAIS standard-compatible, are recommended. This will ensure seamless migration of local geospatial data into the national registry without sacrificing data quality and spatial accuracy.

Additionally, aligning the system with NLAIS allows for future automation and scalability of land services. By integrating mobile mapping technologies, GNSS field surveys, and remote sensing datasets into the national framework, the land offices in East Shoa can automate land use monitoring, simplify land adjudication, and promote evidence-based planning. In the view of Zevenbergen et al. (2018), geospatially-enabled national LIS platforms promote transparency and accountability in land transactions—a critical ingredient lacking in modernizing Ethiopia's rural land governance.

Concisely, aligning the East Shoa Zone's geodatabase design with Ethiopia's NLAIS is not only a policy necessity but a transformational strategy that ensures consistency, interoperability, and national recognition of local land information. It enhances tenure security, reduces conflict, and promotes digital governance of land resources in line with Ethiopia's development aspirations. The policy-congruent character of this innovation has important effects because it brings local activity into alignment with sustainable development and technological modernization plans at the national level, which successfully bridges the practice-policy gap in rural land administration..

4.7 DISCUSSION

This study found that the rural land administration system of East Shoa Zone is fundamentally compromised by paper-based, outdated land records and fragmented documentation. A whopping 89% of land records remain to be digitized, while only 19% were updated in the last five years. Duplication and contradictory entries accounting for 41% of cases were widespread due to the lack of centralized databases and uniform data entry procedures. These results inform the research objective of the diagnosis of systemic inefficiencies in the land administration of the region and point to a key driver of tenure insecurity.

By comparison, the evidence supports Deininger (2017) and Zevenbergen et al. (2018), who argue that safe tenure and efficient land management demand reliable, centralized geospatial infrastructure. The resilience of paper-based record systems—most notably in most woredas except small-scale Excel-based pilot attempts in Akaki—is evidence of general trends across Sub-Saharan Africa, including Tanzania and Uganda, where decentralized land systems thwart development and public sector performance.

To their surprise, some of the woredas had undertaken isolated attempts at digitalization in the absence of regular policy or technical support. While promising, the efforts led to unequal digital practice and duplication of data. Another surprising effect was the high positional error rate in hand surveys 18.7 meters on average—which reflects not only technological deficiencies, but also the lack of adequate geospatial professionals.

The geospatial staff trained on hand just 0.4 full-time equivalents per woreda were far short of the number needed to manage GIS or GPS-based systems properly. This gap explains the low utilization of installed GPS units and GIS packages even though their utility in enhancing land data quality and reducing conflicts is well established. It also indicates the overall institutional problem of human capacity development in rural land administration.

With GIS-based cadastral mapping, the study showed that the integration of geospatial technologies significantly improves the accuracy and completeness of rural land records. The mean boundary error was reduced from 18.7 m to as low as 1.5 m through RTK GPS validation, and registered parcels increased by 320%. This is a positive solution to the research problem of incomplete and imprecise land data and advances Objective 2 by showing the capability of GIS in closing data gaps.

These findings align with Deininger (2019) and Zevenbergen et al. (2018), who argue that GIS uptake reduces transaction costs and improves tenure security in African rural areas. This work extends their contributions, however, by presenting localized, woreda-level data evidence of GIS applications, such as the closure of 127 legacy boundary overlaps. This end-to-end implementation model is particularly valuable for developing scalable, context-sensitive modernization plans linked to Objective 3.

The unexpected result was the higher-than-anticipated number of overlapping parcels identified using GIS, exceeding that found in paper records. This implies that legacy records are not just incomplete but are also geographically erroneous. The discovery underscores the importance of participatory mapping techniques that incorporate local intelligence to validate geospatial outputs within locally responsive and resource-limited contexts.

The study theorizes and makes a practical contribution to rural land reform administration. It fills a gap in the literature on the link between spatial data quality and land tenure security and presents empirical evidence that systems supported by GIS can reduce conflict, improve registration rates, and improve institutional certainty. It emphasizes that modernization requires both technological infrastructure and policy reformulation, particularly for rural areas.

However, the study is not comprehensive. It was confined to eight woredas, and the results may not entirely reflect all administrative and ecological variations in the East Shoa Zone. In addition, the study was cross-sectional without longitudinal assessments of changes in institutions and paths of technology adoption over time. These constraints have to be considered when making generalizations from the study.

The geodatabase design developed in this research addressed the structural issue of disjoined land information systems by creating a relational digital space. The structure linked spatial and non-spatial land attributes—e.g., ownership, use, transactions, and disputes—to demonstrate a scalable and integrated rural land record modernization solution. This applied deliverable achieves Objective 4's goal to provide a digital framework for efficient land governance.

This format is in line with international best practice promoted by FAO (2017), UN-Habitat (2020), and subsequent contributions from Lemmen et al. (2022) and Zevenbergen et al. (2023). Unlike models created for the urban environment, however, this study accommodated its shape to rural realities, including customary tenure systems and community-level conflict resolution frameworks. This accommodation provides a new contribution to the rural geospatial governance discourse.

More research needs to be conducted on disseminating digital pilots to other woredas, assessing long-term GIS adoption sustainability, and evaluating socio-economic impacts related to improved land records. Particular emphasis should be given to mobile GIS platforms, low-cost mapping technologies, and local capacity development methodologies to the ultimate attainment of scalable modernization. Integrating them with local land use planning can continue to enhance tenure security and land service delivery in Ethiopia's rural communities.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The study confirms that rural land administration in East Shoa Zone is held back by long-standing shortages of cadastral data, boundary accuracy, and institutional coordination. These bottlenecks reflect a broader inability to update basic administrative capacity and are exacerbated by low digital literacy and organizational capacity. As a result, landowners remain exposed to tenure insecurity and the occurrence of disputes remains high. This inefficiency is systemically rooted in fragmentation among rural and urban land offices, inadequate record-keeping procedures, and widespread reliance on manual processes that are outdated. The research confirms these findings with local case evidence and reflects identical challenges reported in regional research (Deane et al., 2017; Zevenbergen et al., 2018), concluding that the current framework is not adequate for delivering transparent and reliable land governance.

Reflecting on these findings, the researcher emphasizes the necessity for institutional change alongside technological intervention. Identifying the lack of complete and integrated land data systems as a root obstacle, the research contributes substantial evidence that such limitations undermine both legal certainty and social stability. The significance of these findings is that they place the technical hurdles in real administrative dynamics, highlighting that future reform must address both infrastructure and governance. The study offers significant implications for Ethiopian policymakers and development partners who wish to know not just what are the challenges, but why they are stalled, and where targeted interventions can be most effective.

Evidence concisely illustrates that geospatial technologies provide an efficient and viable remedy for East Shoa's land administration inefficiencies. GIS, RS, and GNSS collectively increase spatial precision, reduce operational overheads, and enable better land conflict resolution. The tools, when rolled out in pilot districts, led to clearer boundary descriptions and enhanced public trust in formal registration processes. Participatory mapping technologies, supported by accurate satellite imagery and high-precision positioning technologies, created new opportunities for stakeholders to engage with land governance in a more transparent manner. These results affirm the second research question and align with emerging international evidence, particularly that of the World Bank (2020) and Ameyaw & de Vries (2021), on the positive effect of digital technologies in minimizing tenure insecurity.

However, the study also identifies socio-cultural and infrastructural challenges tempering the full benefits of geospatial adoption. Technophobia, low levels of technical proficiency, and low internet penetration in rural societies limit the potential and feasibility of digital platforms. In a reflective manner, the researcher highlights that modernization cannot end at the level of tool deployment—it must be accompanied by sustained capacity building, legal harmonization, and culturally appropriate implementation strategies. This value is twofold: it affirms the transformative potential of spatial technologies but also cautions that their realization is contingent on human and institutional readiness. These are important lessons for any project that would scale up digital land governance in rural Ethiopia.

The study concludes with the development of a practical, scalable system with a view to integrating geospatial technology into rural land governance in East Shoa. Built on a centralized geodatabase model and supported by a web-based mapping application, the system offers a user-friendly parcel, ownership, and dispute data management solution. The model ensures efficiency, transparency, and accessibility, and the pilot project has demonstrated its applicability at the local level. The system allows for real-time data monitoring and promotes interoffice collaboration among land offices and communities. The model's effectiveness responds directly to the third research question and is consistent with similar models put forward in global land reform initiatives (Zevenbergen et al., 2018).

Despite these advances, the study highlights fundamental weaknesses that must be resolved to ensure long-term success. Reliance on the Internet, database inconsistencies, and the exclusion of vulnerable groups—particularly women—remain significant challenges. These weaknesses suggest that even the most advanced models require continuous upgrading, legal reforms, and inclusive policy initiatives. The author believes that an adaptive and flexible model is required in tackling divers rural needs. As such, the study contributes a locally grounded and internationally relevant design for digital land governance, laying the groundwork for future innovation in rural land in Ethiopia.

5.2 RECOMMENDATIONS

Follows from the research findings that the process of modernizing rural land administration in the East Shoa Zone would begin with prioritizing the development of institutional capacity and embracing geospatial technologies as core components of land governance fundamental operations. Shortage of technical staff and low GIS awareness at the kebele and woreda levels greatly hinder adoption. For this, regional and national governments should make investments in long-term training programs for land administrators, surveyors, and local community leaders. Partnerships between universities and technical schools could be used to enhance local capacity and create a sustainable talent pipeline. These initiatives would be backed by policies promoting continuous professional development and knowledge transfer. As highlighted by Ameyaw & de Vries (2021), success in local implementation relies on technical expertise, institutional preparedness, and policy commitment.

In addition, the development of a centralized and interoperable national digital land information system must be a national priority. According to the architecture of the geodatabase tested in this research, such a system would bring together legal, cadastral, and dispute data for correctness and avoidance of duplication or inconsistency among government agencies. The integration of the Land Administration Domain Model (LADM) would ensure consistency in data presentation and improve the efficiency of processing. However, technological advancements alone are not enough—governance frameworks for data must be instituted in order to control access, updates, and quality assurance. In keeping with Zevenbergen et al. (2018), effective digital systems reduce bureaucratic inefficiencies but must be grounded on a foundation of good governance, stakeholder trust, and inter-sectoral coordination between rural and urban land offices.

The study also recommends further improvement and deployment of user-friendly, web-based mapping technology. The web map pilot-tested should be expanded to all rural kebeles, with added features of offline connectivity, mobile capability, and localized user interfaces in Afan Oromo to maximize usability. The tools should support real-time boundary analysis, history of land use monitoring, and conflict visualization. Above all, the involvement of local people at the development and implementation phases is imperative in order to reduce resistance and create local ownership. Trust and cultural acceptance, particularly in resistant areas like Liben Chukala, can be created through participatory mapping and campaigns for awareness (World Bank, 2020). The tools should be constantly updated with user input in order to make them timely and useful in the long run.

Finally, future research should extrapolate the study's results to other regions of Ethiopia and integrate new technologies such as AI and blockchain into land administration. Predictive ability for land-use conflicts may be enhanced through AI-based analytics, while blockchain can assure secure and tamper-evident recordkeeping. Further studies should also explore the integration of environmental and socio-economic data layers to support climate-resilient land use planning, aligning with Ethiopia's national development goals. There is also a pressing need to address gender-based exclusion in land administration. Legal reforms should mandate the recognition of women's land claims, and digital systems must be designed to document inheritance and marital rights clearly. As stressed by Biraro et al. (2021), unless technology is implemented in a gender-sensitive manner, technological innovations can end up consolidating inequalities. These multi-dimensional guidelines seek to go beyond technology fixes and construct an integrated, participatory, and sustainable model of rural land governance in East Shoa Zone and elsewhere.

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APPENDIX

1. Research Questionnaire

Here's a list of research questions to gather requirements and assess current land administration practices for the title "Assessing Challenges and Applying Geospatial Technology for Effective Rural Land Administration in East Shoa, Ethiopia.":

a. Current Practices

- ✓ What are the existing processes for land registration in your area?
- ✓ How are land records currently maintained and updated?
- ✓ Who are the key stakeholders involved in land administration

b. Challenges

- ✓ What challenges do you face in the current land administration system?
- ✓ Are there specific issues related to data accuracy, accessibility, or transparency?
- ✓ How do these challenges impact land management and governance?

c. Technology Usage

- ✓ What geospatial technologies are currently in use for land administration (e.g., GPS, GIS, remote sensing)?
- ✓ How effective are these technologies in addressing your needs?
- ✓ Is there any existing web or mobile applications utilized for land administration? If so, how user-friendly are they?

d. Data Management

- ✓ How is land-related data collected, processed, and stored?
- ✓ What types of data are most critical for your land administration processes (e.g., ownership, land use, environmental data)?
- ✓ Are there any barriers to data sharing among stakeholders?

e. User Needs

- ✓ What functionalities do you believe are essential for a modernized land administration system?
- ✓ How would you prioritize features such as real-time data access, transaction management, and public access to land records?

f. Future Vision

- ✓ What improvements do you envision with the integration of advanced geospatial technologies?
- ✓ How do you see these technologies impacting community engagement and participation in land administration?
- ✓ What are your expectations regarding training and support for stakeholders in using new technologies?

2. Observation Checklist

An Observation Checklist is a structured field tool used to systematically document and assess the condition, availability, and effectiveness of key infrastructure, human resources, tools, and systems in rural land administration offices. It ensures **consistency**, **objectivity**, and **completeness** in field data collection and supports triangulation with interviews, FGDs, and document reviews.

In this study, the checklist helps assess the **practical realities** of:

- Geospatial technology usage and availability
- Infrastructure and office readiness
- Technical and institutional capacity
- Documentation, storage, and data management systems

Table 15 Observation Checklist for Rural Land Administration Office

No.	Indicator/Item	Available		Condition		Remarks/Comments
		Yes	No	Good	Poor	
1	GIS Software (ArcGIS/QGIS) installed					
2	Number of functioning GPS devices					
3	High-resolution base maps available					
4	Trained GIS staff present					
5	Updated cadastral datasets					
6	Land use maps (current/archived)					
7	Participatory maps from communities archived					
8	Internet access available					

9	Electricity reliability (daily outages)					
10	Computers for staff (number & working condition)					
11	Digital land records system					
12	Paper-based land registration books maintained					
13	Data backup system in place					
14	Secure storage room for maps/files					
15	Mobile apps used for field data collection (ODK)					
16	Office space adequate for staff and clients					
17	Updated organizational chart on office wall					
18	Presence of inter-agency collaboration mechanism					
19	Recent field mapping or land survey activity done					
20	Trained community para-surveyors or enumerators					

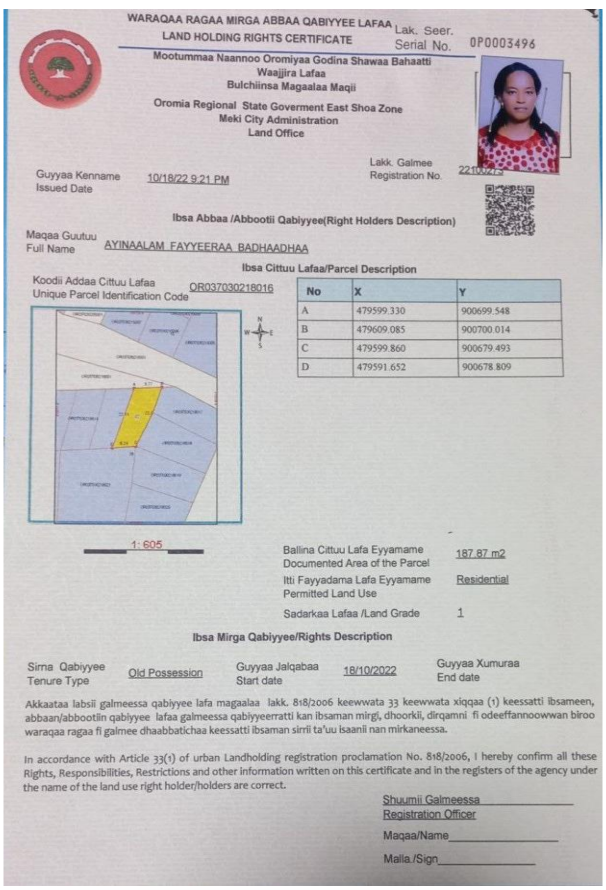
Table 16 Observation Checklist for Rural Land Administration Office

S.N	**Challenge Area**	**Institutional**	**Technical**	**Data-Related**
1	Inadequate Land Management	☐	☐	☐
2	Inadequate Mapping Resources	☐	☐	☐
3	Land Disputes	☐	☐	☐
4	Limited Technological Adoption	☐	☐	☐

3. Field and Office Observation Evidence

Field Observation and participatory maping

Mobile mapping exercise



WARAQAA RAGAA MIRGA ABBAA QABIYYEE LAFAA
LAND HOLDING RIGHTS CERTIFICATE

Lak. Seer.
Serial No. 0P0003496

Mootummaa Naannoo Oromiyaa Godina Shawaa Bahaatti
Waajjira Lafaa
Bulchiinsa Magaalaa Maqii

Oromia Regional State Goverment East Shoa Zone
Meki City Administration
Land Office

Guyyaa Kenname
Issued Date 10/18/22 9:21 PM

Lakk. Galmee
Registration No. 2210027[illegible]

Ibsa Abbaa /Abbootii Qabiyyee(Right Holders Description)

Maqaa Guutuu
Full Name AYINAALAM FAYYEERAA BADHAADHAA

Ibsa Cittuu Lafaa/Parcel Description

Koodii Addaa Cittuu Lafaa
Unique Parcel Identification Code OR037030218016

No	X	Y
A	479599.330	900699.548
B	479609.085	900700.014
C	479599.860	900679.493
D	479591.652	900678.809

1: 605

Ballina Cittuu Lafa Eyyamame
Documented Area of the Parcel 187.87 m2

Itti Fayyadama Lafa Eyyamame
Permitted Land Use Residential

Sadarkaa Lafaa /Land Grade 1

Ibsa Mirga Qabiyyee/Rights Description

Sirna Qabiyyee
Tenure Type Old Possession

Guyyaa Jalqabaa
Start date 18/10/2022

Guyyaa Xumuraa
End date

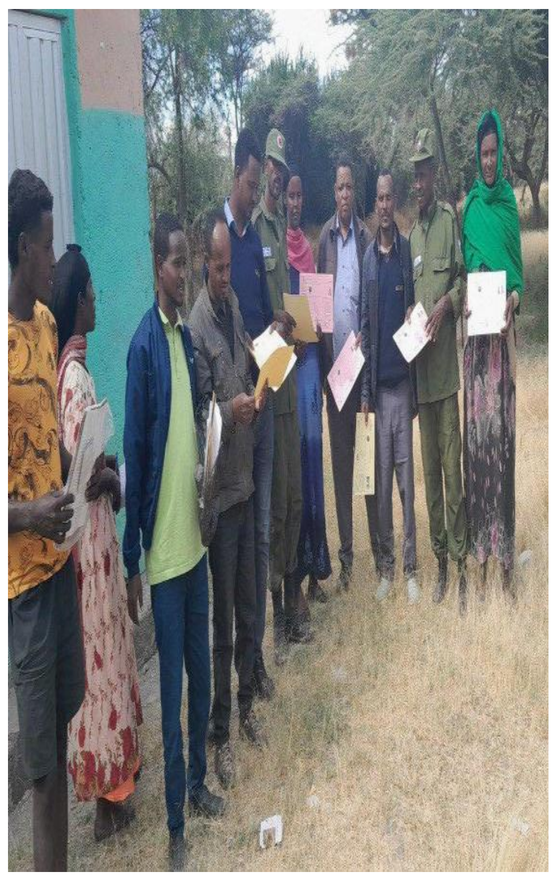
Akkaataa labsii galmeessa qabiyyee lafa magaalaa lakk. 818/2006 keewwata 33 keewwata xiqqaa (1) keessatti ibsameen, abbaan/abbootiin qabiyyee lafaa galmeessa qabiyyeerratti kan ibsaman mirgi, dhoorkii, dirqamni fi odeeffannoowwan biroo waraqaa ragaa fi galmee dhaabbatichaa keessatti ibsaman sirrii ta'uu isaanii nan mirkaneessa.

In accordance with Article 33(1) of urban Landholding registration proclamation No. 818/2006, I hereby confirm all these Rights, Responsibilities, Restrictions and other information written on this certificate and in the registers of the agency under the name of the land use right holder/holders are correct.

Shuumii Galmeessa
Registration Officer

Maqaa/Name_______________

Malla./Sign_______________



Cadastre Rural Land Certificate