ENHANCING LAND REGISTRATION SYSTEMS USING BLOCKCHAIN TECHNOLOGY: A CASE STUDY OF ADAMA CITY

Dagnie Arega

Thesis submitted to the Department of Architecture

College of Civil Engineering and Architecture (CoCEA),

Office of Graduate Studies
Adama Science and Technology University

June, 2025

Adama, Ethiopia

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DECLARATION

I hereby declare that this research entitled "**Enhancing Land Registration Systems Using Blockchain Technology: A Case Study of Adama City"** is my original work. That is, it has not been submitted to any other university. All materials used for this thesis have been duly acknowledged through citation.

Dagnie Arega	________________________	________________
Name of student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read this thesis entitled "**Enhancing Land Registration Systems Using Blockchain Technology: A Case Study of Adama City"** prepared under my guidance by Dagnie Arega. Therefore, I recommend the submission to the department following the applicable procedures.

Roba Gemechu (PhD)	__________________	__________________
Name of Major Advisor	Signature	Date

ACKNOWLEDGMENT

First and foremost, I would like to thank the Almighty God for granting me the strength, patience, and perseverance to complete this thesis successfully.

I am deeply grateful to my advisor, Roba Gemechu (PhD), for his invaluable guidance, constructive feedback, and unwavering support throughout the course of this research. His insightful comments and encouragement greatly enriched the quality of this work.

My sincere thanks go to the faculty and staff of the Department of Architecture, College of Civil Engineering and Architecture (CoCEA) at Adama Science and Technology University, for providing a conducive academic environment and essential resources for the completion of this study.

I would also like to express my heartfelt appreciation to the officials and staff members at the Adama City Land Administration Office, whose cooperation and provision of critical data made this case study possible.

Special thanks to my family and friends for their continuous love, support, and encouragement throughout my academic journey. Their belief in me kept me motivated during challenging times.

Finally, I acknowledge all individuals and institutions, whether mentioned or unnamed, who directly or indirectly contributed to the successful completion of this thesis.

APPROVAL PAGE OF THE THESIS

I, the advisor of this thesis entitled "**Enhancing Land Registration Systems Using Blockchain Technology: A Case Study of Adama City"** and developed by Dagnie Arega hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis proposal by Dagnie Arega have read and evaluated the thesis entitled "**Enhancing Land Registration Systems Using Blockchain Technology: A Case Study of Adama City"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for future thesis work.

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ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Full Form
GIS	Geographic Information System
ICT	Information and Communication Technology
DBMS	Database Management System
E-Government	Electronic Government
DLT	Distributed Ledger Technology
BTC	Blockchain Technology
KYC	Know Your Customer
API	Application Programming Interface
IPFS	InterPlanetary File System
POS	Proof of Stake
PoW	Proof of Work
CIP	Cadastral Information Platform
LRS	Land Registration System
LRA	Land Registration Authority
LLC	Land Lease Certificate
NFT	Non-Fungible Token
TLD	Top-Level Domain
P2P	Peer-to-Peer
SLA	Service Level Agreement
UAV	Unmanned Aerial Vehicle (for land surveying)

Abstract

Efficient and transparent land registration systems are critical for secure land tenure. This study aims to investigate the potential of blockchain technology to improve the land registration system in Adama City. Data were gathered from both primary and secondary sources. Primary data included semi-structured interviews with government officials, land administrators, real estate agents, and blockchain experts, as well as focus group discussions with local residents and landowners. The study employed a structured data processing and analysis method to ensure accurate integration of land registry data into a blockchain system. Initial preprocessing involved cleaning, verifying, and standardizing data from multiple sources to meet blockchain compatibility standards. The study demonstrated the effectiveness of blockchain technology in ensuring transparent, traceable, and immutable land registry transactions. Ownership analysis across 19 parcels revealed dynamic participation, with parcels like 42, 47, 49, and 60 each undergoing three ownership changes the highest in the dataset. Network analysis identified central actors such as Hanna, Jemila, and Girma, who engaged in over five transactions each, indicating strong market influence. Spatial analysis showed that parcels in the central region experienced the highest transaction density, with up to three transactions per parcel. The blockchain audit, covering 6 blocks and recording 24 transactions, confirmed the integrity and chronological traceability of all changes. These findings underscore blockchain's potential to enhance land governance by improving accountability, reducing fraud risk, and providing a secure, auditable framework for land administration. The study revealed that blockchain technology significantly enhances public trust and access to land information in Adama City by providing a transparent, immutable, and decentralized system that reduces corruption and enables real-time, user-friendly access to land records. The system demonstrated efficient recording of ownership changes, prevention of tampering, and clear visualization of land transfer patterns, supporting fair and accountable land administration.

Keywords: Blockchain, Land Registry, Land Transactions, Transparency, Ownership Traceability

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Land registration systems are integral to urban planning, securing property rights, and fostering economic development (Abab et al., 2021). A robust land registry facilitates clear ownership records, which are essential for legal transactions, property development, and land-based investments (Amin et al., 2020). In urban settings, where rapid population growth and land demand are frequent, an effective land registration system supports sustainable land use, proper taxation, and efficient allocation of resources (Baker et al., 2017). The security of land tenure is particularly important for economic activities as it enables individuals and businesses to invest in property with confidence, contributing to broader economic growth (Mohammad et al., 2019). In Ethiopia and other developing nations, land registration is crucial for fostering secure property ownership, which in turn strengthens the formal land market and stimulates local economies.

However, traditional land registration systems in many urban areas face significant challenges, including inefficiency, corruption, data inaccuracy, and limited accessibility. Paper-based registries are susceptible to errors, loss of data, and fraudulent activities (Jensen & Lema, 2018). As cities expand and populations increase, these systems often struggle to keep up with the growing demand for land transactions, leading to delays, disputes, and lack of transparency (Williamson et al., 2017). This inefficiency not only undermines public trust but also restricts economic development, as investors and residents are hesitant to engage in transactions within a system prone to errors and corruption (Deininger et al., 2016). Furthermore, slow and cumbersome processes in land registration create barriers to formal property markets and hinder the ease of doing business (Malombe et al., 2020).

Blockchain technology offers a transformative solution for these challenges. Blockchain is a decentralized digital ledger that ensures the secure and transparent recording of transactions. Each transaction is validated by multiple nodes in the network, making the system resistant to fraud and tampering (Narayanan et al., 2016). The immutable nature of blockchain guarantees that once a record is added, it cannot be altered or deleted without detection, enhancing the trustworthiness of land transactions (Tapscott & Tapscott, 2016). Furthermore, blockchain technology enables real-time updates, reducing delays in registering land transactions and improving the overall efficiency of land administration systems (Zohar, 2015). By eliminating intermediaries and central authorities, blockchain also reduces the cost and complexity of transactions, making land registration more accessible and efficient (Catalini & Gans, 2016).

Studying the application of blockchain technology in Adama City's land registration system is highly relevant, particularly given the challenges faced by traditional land administration systems in Ethiopia and other urban centers in developing countries. Adama City, like many other rapidly urbanizing regions, faces significant issues with land registration, such as inefficiency, fraud, and the lack of real-time updates, all of which hinder urban development and investment (Jensen & Lema, 2018). Blockchain technology offers a promising solution to these problems by enhancing the transparency, security, and efficiency of the land registration process (Williamson et al., 2017).

The potential benefits of blockchain technology in land registration systems are numerous. First, blockchain can significantly improve transparency by creating an immutable and publicly verifiable record of land transactions. This transparency can reduce opportunities for fraud and corruption, thereby increasing public trust in the system (Narayanan et al., 2016). Additionally, blockchain's ability to streamline processes, such as reducing the need for intermediaries and eliminating paper-based records, can lower transaction costs and expedite land transactions (Catalini & Gans, 2016). This efficiency is particularly important in rapidly growing cities like Adama, where land demand often outpaces the capacity of traditional land administration systems. Furthermore, blockchain technology can enhance land tenure security by providing a reliable, digital proof of ownership that is difficult to tamper with, thus reducing the risk of land disputes (Tapscott & Tapscott, 2016).

Exploring the impact of blockchain on land tenure security and economic development in Adama City is crucial because secure property rights are foundational to economic growth. With a more transparent and efficient land registration system, individuals and businesses can engage more confidently in land transactions, leading to increased investments, improved access to credit, and a more stable property market (Deininger et al., 2016). Additionally, secure land tenure can empower residents and ensure that urban growth is managed sustainably, contributing to long-term economic development in the city.

1.2.Statement of the problem

Land registration systems in Adama City, like in many rapidly urbanizing areas in Ethiopia, face significant challenges that hinder the effective management of land and property rights. Currently, the system relies heavily on manual record-keeping, with land ownership and transaction records maintained in physical documents. This traditional approach is prone to errors, inconsistencies, and loss of data, which often leads to legal disputes and confusion over property ownership (Jensen & Lema, 2018). Moreover, the process of land registration is slow and inefficient, with applicants often facing lengthy delays in processing and registering property transactions (Malombe et al., 2020). A lack of transparency in the system exacerbates these issues, as there are no easily accessible public records that can confirm ownership or transaction histories, making it difficult for landowners and investors to verify land titles and ownership rights.

Land disputes are common in Adama City, often arising from ambiguous or incomplete records, as well as fraudulent activities such as the sale of the same land to multiple buyers (Deininger et al., 2016). These issues not only affect individuals but also lead to broader inefficiencies in land administration, with legal battles consuming time and resources that could be better allocated to urban development and infrastructure. The inefficiency of the current land registration system undermines the growth of formal land markets and discourages potential investors, ultimately hindering economic development in the city (Williamson et al., 2017). According to recent studies, the average time for land registration in Adama City exceeds several months, with an increasing backlog of cases (Jensen & Lema, 2018). Additionally, instances of land fraud continue to increase, undermining public trust in the system.

The inefficiencies and challenges in Adama City's land registration system have far-reaching consequences for residents, businesses, and local governance. For residents, unclear property rights and prolonged registration processes create significant barriers to securing loans, investing in property, or making informed decisions about land use. These challenges not only affect individuals but also contribute to an unstable property market, reducing confidence in the formal land transaction system and deterring potential investors (Mohammad et al., 2019). In many cases, the lack of clear and accessible land records forces individuals to rely on informal or illegal methods to settle land disputes, further complicating the problem.

For businesses, the slow and cumbersome land registration processes increase transaction costs and introduce uncertainty into property transactions, affecting the ease of doing business and overall economic activity (Malombe et al., 2020). This uncertainty is especially harmful for sectors that rely on land, such as real estate development, agriculture, and infrastructure, where timely and secure land transfers are essential for investment and growth (Baker et al., 2017). Local governments, too, face challenges in urban planning and land use management due to inaccurate or incomplete data on land ownership and use, making it difficult to allocate resources efficiently and plan for sustainable development. These systemic issues lead to poor urban governance, stunted economic development, and increased inequality in access to land and resources.

The existing land registration system in Adama City clearly highlights the urgent need for modernization. Technological solutions, particularly blockchain technology, offer a promising avenue to address the issues of inefficiency, fraud, and data inaccuracies that plague traditional systems. Blockchain technology is characterized by its decentralized nature, which eliminates the need for a central authority to manage and verify transactions, reducing the risk of corruption and manipulation (Narayanan et al., 2016). The immutability of blockchain ensures that once a land transaction is recorded, it cannot be altered or deleted without detection, which greatly enhances the transparency and trustworthiness of land records (Tapscott & Tapscott, 2016). Moreover, blockchain allows for real-time updates to land records, improving the speed and efficiency of land transactions and reducing the delays currently experienced in Adama City (Catalini & Gans, 2016). With these advantages, blockchain technology could significantly transform the land registration system, making it more secure, transparent, and efficient.

The exploration of blockchain as a solution for land registration is timely and relevant, as it aligns with global trends toward digital innovation in land governance. Blockchain could streamline processes, enhance accountability, and reduce costs associated with land transactions in Adama City. It could also improve public access to land information, enabling residents and businesses to verify ownership records instantly and securely, fostering trust in the system (Williamson et al., 2017). By modernizing the land registration system, Adama City could enhance its urban planning capabilities, attract investment, and improve overall governance.

While there has been growing interest in the application of blockchain technology in land registration systems globally, there is a notable gap in research and practical applications within

Ethiopia, particularly in urban centers like Adama City. Although blockchain has been explored in various countries for land registration (Amin et al., 2020), its adoption in Ethiopia has not been sufficiently studied, especially in the context of rapidly urbanizing areas. There are no case studies examining the practical implementation of blockchain in the land registration system of Adama City or similar Ethiopian cities. This gap in research highlights the need for this study, which aims to explore the potential of blockchain technology in transforming the land registration system in Adama City.

1.3. Objective of the study

1.3.1. General objective

The general objective of this study is to assess the potential of blockchain technology in enhancing the efficiency, transparency, and security of the land registration system in Adama City, Ethiopia

1.3.2. Specific objectives

- To assess the feasibility and potential benefits of integrating blockchain technology into Adama City's land registration system.
- To examine how blockchain can improve public trust and access to land information in Adama City.
- To identify the challenges and barriers to the implementation of blockchain in the land registration system in Adama City.

1.4. Research questions

- What are the potential benefits of blockchain integration in reducing land fraud and disputes in Adama City?
- How can blockchain technology enhance public access to land information and build trust in the land registration system?
- What are the main barriers and challenges to implementing blockchain technology in Adama City's land registration system?

1.5. Significance of the study

The significance of this study lies in its potential to transform the land registration system in Adama City by integrating blockchain technology, which promises to address critical issues such as inefficiency, lack of transparency, and land fraud. By exploring how blockchain can enhance the security, transparency, and speed of land transactions, the study provide valuable insights for policymakers and local government authorities in adopting innovative solutions for land administration. This is particularly important in a rapidly urbanizing city like Adama, where managing land use and ownership is increasingly complex. The findings could contribute to more efficient urban planning and land management, fostering a more secure property market and encouraging investment in the city. Furthermore, this study add to the growing body of academic literature on digital land administration, especially in the context of developing countries, where research on blockchain applications in land systems is limited. Ultimately, the research has the potential to improve public trust in land transactions, reduce disputes, and streamline land registration processes, which could lead to broader economic development and social stability in Adama City.

1.6.Scope of the study

This study focusses on the land registration system in Adama City, Oromia Region, Ethiopia. The research specifically examine the feasibility of applying blockchain technology to address the inefficiencies, fraud, and transparency issues within the land registration process. The study also includes an assessment of the current system, potential blockchain applications, and the impact of technology on land administration, urban planning, and economic development. The geographical scope of the study is confined to Adama City, while the thematic focus is on land registration, blockchain technology, and its impact on urban governance and development.

1.7.Operational terms of definition

Land Registration System: A formal process through which ownership rights, land transactions, and property boundaries are documented and legally recognized by a government or local authority. Land registration systems are vital for ensuring secure property rights and facilitating land transactions, which are essential for economic development and urban governance (Deininger et al., 2016

Blockchain Technology: A decentralized, immutable digital ledger system that records transactions across multiple computers, ensuring data integrity and transparency without the need for a central authority (Narayanan et al., 2016).

Land Tenure Security: The assurance that landholders have legally recognized and protected rights to their land, ensuring that they are free from the risk of unlawful eviction or expropriation.

Secure land tenure is critical for encouraging investment in land, fostering economic development, and ensuring social stability (Mohammad et al., 2019).

Urban Governance: The management and regulation of urban areas, including land use planning, infrastructure development, and the provision of public services, aimed at promoting sustainable growth and equitable development (Amin et al., 2020).

Decentralization: A fundamental aspect of blockchain technology, where no central authority controls the system. This reduces the risks of corruption, manipulation, and fraud, and ensures that transactions are verified through a network of participants rather than a single entity (Narayanan et al., 2016).

CHAPTER TWO

2. LITERATURE REVIEW

2.1.Definition of Blockchain Technology

Blockchain is a decentralized distributed ledger technology that records transactions across a network of computers in a secure, transparent, and immutable way. Although it is primarily known for its association with cryptocurrencies, blockchain's applications extend well beyond this domain, particularly in the field of land registration. The key features of blockchain—decentralization, transparency, immutability, and security—make it a promising tool for transforming land registration systems. Decentralization eliminates the need for a central authority, as blockchain operates on a peer-to-peer network where no single party has control over the entire system (Narva, 2019). Transparency is ensured as every transaction is visible to all network participants, which fosters accountability and trust. Immutability is another core feature, meaning that once a transaction is recorded on the blockchain, it cannot be altered or deleted, providing a secure and reliable record of ownership. Additionally, blockchain employs cryptographic techniques that secure data from unauthorized access or tampering, which is crucial for maintaining the integrity of land records (Yermack, 2017).

2.2.Blockchain and Land Registration

Land registration systems are critical for confirming legal property ownership, preventing disputes, and enabling property transactions. However, traditional systems are often burdened with inefficiencies, fraud, and errors caused by outdated technology, manual processes, and a lack of centralized oversight. Blockchain can address several of these challenges. First, it mitigates fraud and forgery. Traditional land registration systems are vulnerable to document manipulation, but blockchain's immutability ensures that once a land title is recorded, it cannot be altered without the consensus of the network participants, thus reducing the risk of fraudulent claims (Koulu, 2017). Transparency provided by blockchain allows stakeholders to easily verify ownership and property history, which helps build trust in land transactions (Binns & Hamilton, 2019). Moreover, blockchain improves efficiency and reduces costs by automating and digitizing the land registration process, eliminating the need for intermediaries and reducing manual verification efforts (Yermack, 2017). Lastly, blockchain can make land records more accessible to people in remote or underserved regions, where traditional land registration systems are often difficult to access (Swan, 2015).

2.3.Blockchain-Based Land Registration Models

Several countries have explored or implemented blockchain-based land registration systems, demonstrating the potential of this technology in improving land governance. Estonia is a leader in digital governance and has integrated blockchain technology into various public services, including land registration. The Estonian Land Registry system uses blockchain to enhance the security and transparency of land records, ensuring that ownership data is both tamper-proof and publicly accessible (Narva, 2019). Similarly, Georgia became one of the first countries to implement a blockchain-based land registration system in 2016. The Georgian government collaborated with a blockchain firm to create a secure and efficient land registry, reducing fraud and administrative costs (Jolicoeur & Levitt, 2017). Sweden has also initiated a pilot blockchain-based land registry project, in collaboration with technology firms, with the goal of streamlining property transactions, reducing transaction times and costs, and eliminating the need for third-party intermediaries (Hofmann et al., 2020). These initiatives demonstrate how blockchain can be applied to land registration to increase efficiency, reduce fraud, and enhance trust.

2.4.Benefits of Blockchain in Land Registration Systems

The integration of blockchain technology into land registration systems offers several potential benefits. One of the most significant advantages is the reduction of fraud. Blockchain's cryptographic security ensures that land records are tamper-proof, making it virtually impossible to falsify property titles (Koulu, 2017). Increased transparency is another major benefit; blockchain's public ledger allows stakeholders to easily verify property ownership and transaction history, which can help resolve disputes and increase confidence in the system (Binns & Hamilton, 2019). The automation of processes such as title transfers and verification through blockchain significantly enhances the efficiency of land registration systems, reducing the time and effort required for transactions and administrative tasks (Yermack, 2017). Additionally, blockchain can lead to significant cost savings by eliminating intermediaries, such as notaries, lawyers, and title companies, which are traditionally required in land transactions, thereby reducing transaction costs (Swan, 2015).

2.5. Challenges and Barriers to Implementation

While blockchain offers numerous benefits, there are several challenges to its widespread implementation in land registration systems. Legal and regulatory issues are one of the primary barriers. The introduction of blockchain technology necessitates changes in legal frameworks to ensure that blockchain-based land titles are recognized and legally enforceable (Zohar, 2018). This requires collaboration between governments, legal experts, and blockchain developers to ensure that the technology can be integrated smoothly into existing land laws. Furthermore, the adoption of blockchain requires significant investments in infrastructure, such as hardware, software, and training for government officials and stakeholders (Narva, 2019). Public awareness and trust are also crucial for the success of blockchain-based systems. For blockchain to gain acceptance, stakeholders need to be educated about its benefits and how it works, which requires effective public outreach and engagement (Binns & Hamilton, 2019). Finally, scalability and energy consumption issues present challenges for large-scale adoption. Some blockchain networks, especially those using proof-of-work algorithms, face difficulties in scaling and consume significant amounts of energy. These issues could impede the adoption of blockchain in countries with limited resources (Swan, 2015).

2.6. Empirical Literature Review

The adoption of blockchain technology for land registration systems has been the subject of various studies, providing insights into its potential to improve transparency, security, and efficiency. These studies reveal a range of implementation approaches, contextual factors, and challenges.

Zein and Twinomurinzi (2023) conducted a comprehensive systematic review focusing on the application of blockchain technology in land registration within low-income countries. Their study reveals diverse approaches shaped by local conditions and governmental frameworks. The authors argue that blockchain has the potential to address inefficiencies and corruption often prevalent in land administration. However, despite the growing theoretical interest, real-world implementations are scarce. This limitation is largely attributed to resistance from government officials and a lack of local expertise in blockchain technology. The study also highlights a trend towards adopting public blockchain networks, which offer greater transparency compared to private or consortium blockchains. This preference underscores an emerging paradigm shift towards more open and trustworthy systems in land registration

In the Republic of Georgia, study by Bitfury, 2017, the National Agency of Public Registry (NAPR), in partnership with the Bitfury Group, implemented a blockchain-based land titling system. This initiative aimed to enhance the security and transparency of property transactions. By using blockchain technology, NAPR was able to create a tamper-proof record of property ownership, significantly reducing fraudulent activities and disputes. The system allowed stakeholders to verify transactions easily, fostering trust among participants. The case study demonstrated the feasibility of integrating blockchain into national land registration systems, serving as a model for other countries considering similar reforms.

Study conducted by Ubitquity, 2018 in Brazil’s experience with blockchain in land registration is exemplified by the successful use of Ubitquity's platform. This pilot project involved registering property records on the blockchain to test the system's effectiveness. The outcomes highlighted the feasibility of using blockchain for land registries, with notable improvements in data security and transaction efficiency. Additionally, the study emphasized the role of blockchain in ensuring accurate and immutable property records, which could potentially reduce fraud and increase confidence among stakeholders. This case underscores the adaptability of blockchain platforms to different legal and regulatory environments.

Sweden conducted a pilot project by Lantmäteriet, 2019 to explore the use of blockchain technology in land transactions. This initiative focused on assessing the potential benefits and challenges of adopting blockchain for land registration. The project demonstrated that blockchain could streamline the process of property transactions by reducing the time and costs associated with traditional methods. However, the study also identified challenges, such as integrating blockchain with existing legal and technological frameworks. The findings provided valuable insights into the practical considerations for implementing blockchain in land registries and highlighted the need for stakeholder collaboration to address these challenges.

2.7.Research and Knowledge Gap

Despite the promising findings from existing studies, several gaps persist in the research and implementation of blockchain technology in land registration systems, highlighting the need for further investigation. One key gap is the limited real-world implementation, especially in low-income countries, where most research remains theoretical or confined to pilot projects. There is a need for long-term studies to assess the feasibility and impact of blockchain in diverse socio-economic and regulatory contexts. Additionally, current research emphasizes the importance of tailoring blockchain solutions to local conditions, but there is a lack of detailed analysis on how specific socio-political, legal, and economic factors influence implementation. Resistance from stakeholders, particularly government officials, remains a significant barrier, and research on strategies to overcome this resistance and build local capacity is essential. Technical challenges, such as integrating blockchain systems with existing frameworks, also require attention, with a need for scalable, interoperable solutions. Moreover, there is insufficient research on how legal and regulatory frameworks can be harmonized to support blockchain adoption. Comparative studies of public, private, and consortium blockchains in land registration are also lacking, as is research on the impact of blockchain on vulnerable populations, such as rural and marginalized communities, who often face challenges in proving land ownership. Addressing these gaps would provide valuable insights into optimizing blockchain adoption in land registration systems.

CHAPTER THREE

3. MATERIAL AND METHOD

3.1.Description of the study area

Adama City is located at approximately 8° 33′ 0″ N latitude and 39° 15′ 0″ E longitude, situated in the East Shewa Zone of the Oromia Region in Ethiopia. As one of the country's most important urban centers, it plays a key role in the socio-economic landscape, especially for the surrounding rural areas. The city is strategically positioned on the main road that connects Addis Ababa to the southern and eastern regions of Ethiopia, making it a significant hub for transportation and commerce. The city's climate is semi-arid, with an average annual temperature range of 18°C to 30°C. The average rainfall ranges between 800 mm and 1,200 mm annually, creating an environment conducive to agriculture, particularly crop farming.

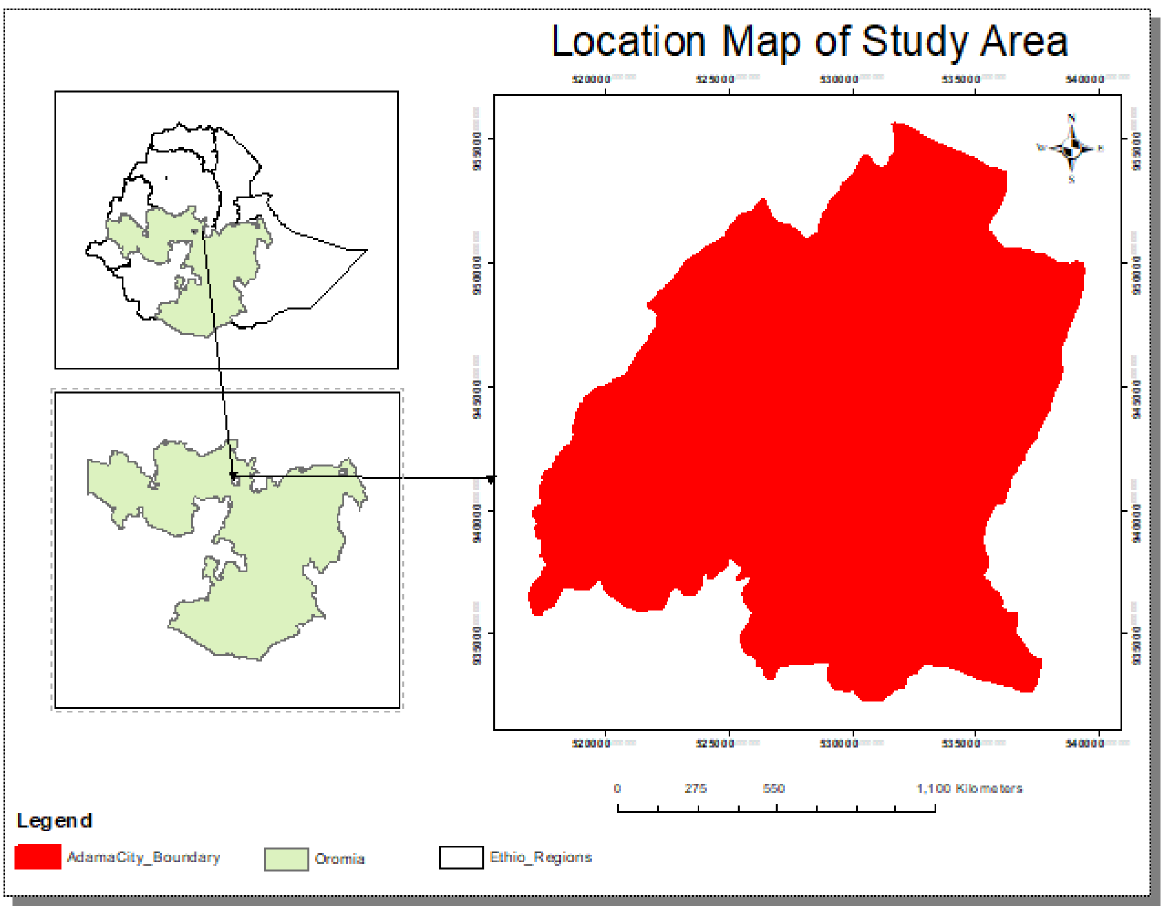

Figure 3-1: Location map of the study area

3.2. Research approach

For this research work, the mixed-methods approach was chosen because it allowed the researcher to capture both the contextual depth of the land registration issues through qualitative insights and the generalizability of the potential benefits of blockchain technology through quantitative analysis. The combination of these methods provided a holistic understanding of the research problem, offering both descriptive and empirical evidence to support the proposed solutions.

3.3. Research design

The research design for this study was descriptive and exploratory, utilizing a mixed-methods approach to understand the potential for blockchain technology to enhance the land registration system in Adama City. The design was structured to capture both qualitative insights and quantitative data that addressed the research problem and objectives effectively.

3.4. Data source and types

This study used both primary and secondary data sources to gather comprehensive insights into the current land registration system in Adama City and the potential benefits of blockchain technology.

3.4.1. Primary Data Sources

Primary data was collected directly from individuals involved in land transactions, land administration, and blockchain technology applications. This data was critical for understanding stakeholder perspectives and gauging the feasibility and potential impact of implementing blockchain in the land registration system.

Interviews: Semi-structured interviews was conducted with key stakeholders, including:

- **Government Officials**: Local government representatives responsible for land administration and urban planning in Adama City.
- **Land Administrators**: Professionals working in land registration offices who have firsthand experience with the land registration processes.
- **Real Estate Agents**: Professionals involved in property transactions who can provide insights into common issues faced by landowners and buyers.
- **Blockchain Experts**: Technologists or consultants familiar with blockchain applications in land management and property registration systems.

Focus Groups: Group discussions with local residents and landowners to gain insights into their experiences with land registration and their perceptions of blockchain technology.

3.4.2. Secondary data sources

The datasets used in a blockchain-based cadastral system are essential for managing land ownership and transactions, ensuring transparency and accuracy. These include Parcel Boundaries, which define the borders of land parcels, and Geospatial Identifiers, providing unique identification codes linked to each land's geographic location. Land Features data includes attributes like terrain, water bodies, and infrastructure, while Land Use/Land Cover data outlines the current use of the land, such as residential or agricultural. Land Ownership Records detail the registered owners, historical transfers, and heirs, while Title Deeds certify ownership and rights over land parcels. Land Tenure Information specifies the legal rights associated with land, such as freehold or leasehold. All of these datasets are primarily sourced from Land Registry Offices, ensuring that land records are accurate, legally recognized, and securely maintained within the blockchain system.

Table 3-1: Data type source

Data Type	Description	Sources
Parcel Boundaries	Coordinates that define the borders of land parcels.	Land Registry Offices
Geospatial Identifiers	Unique identifiers linked to the geographic location of land parcels.	Land Registry Offices
Land Features	Additional geographical attributes related to the land, such as terrain, water bodies, and infrastructure.	Land Registry Offices
Land Use/Land Cover	Information on the current use or cover of the land, such as residential, commercial, or agricultural.	Land Registry Offices
Land Ownership Records	Detailed information about the registered owner(s), historical ownership transfers, and heirs.	Land Registry Offices
Title Deeds	Legal documents certifying ownership and rights over land parcels.	Land Registry Offices
Land Tenure Information	Types of legal rights associated with land, such as freehold, leasehold, or tenancy.	Land Registry Offices

3.5.Software

The study utilized a range of software and frameworks to enhance the land registration system using blockchain technology in Adama City. ArcGIS was employed for digitizing and visualizing cadastral data, enabling the creation of detailed geographic maps and land parcel information. QGIS Plugins facilitated system integration, helping to connect various data sources and platforms within the blockchain framework. The PostgreSQL/PostGIS combination served as the spatial database, providing a robust environment for storing, managing, and querying geographic data, particularly for land parcels and ownership records. Python was the primary programming language used for coding and developing the blockchain system, particularly for automating tasks, integrating blockchain technology, and preprocessing data for the land registration system. These tools together created an efficient, transparent, and secure system for managing land registration in Adama City.

Table 3-2: Software to be used for this research work

No	Software and frame work	Purpose
1	ArcGIS	Cadastral data digitization and visualization
2	QGIS Plugins	For System Integration
3	PostgreSQL	Spatial database
4	Python	For coding

3.6.Data processing and analysis

3.6.1. Preprocessing

Preprocessing is a crucial first step in ensuring that data is clean, accurate, and suitable for integration into a blockchain-based system. In the context of a land registry system, preprocessing involves gathering and standardizing data from various sources, such as land registry offices, satellite imagery, and geospatial surveys. The data, which may include parcel boundaries, ownership records, and land use information, needs to be verified for accuracy, consistency, and completeness. Any inconsistencies or discrepancies, such as duplicate entries or missing records, must be identified and corrected. Furthermore, data must be formatted in a way that is compatible with the blockchain's requirements, which could involve converting traditional land records into a digital format, standardizing coordinate systems, and ensuring the data aligns with geographic standards. This stage ensures the integrity and usability of the data before it's entered into the blockchain system.

3.6.2. Selecting Architecture for Blockchain

Selecting the appropriate blockchain architecture is a pivotal decision in the development of the system. The architecture determines the blockchain's scalability, security, and ability to handle transactions effectively. In the context of a land registry system, choosing between a public, private, or consortium blockchain is essential based on the specific needs of the stakeholders. A private blockchain might be ideal for land registries where access is controlled by government authorities, offering better privacy and faster transaction processing. On the other hand, a consortium blockchain may be appropriate if multiple entities (e.g., landowners, government agencies, legal bodies) are involved in the process. The architecture choice also dictates consensus mechanisms (such as Proof of Work or Proof of Stake) that balance security and transaction speed, ensuring that data integrity and transparency are maintained.

3.6.3. Development of Blockchain Technology in Python

The development of the blockchain system involves creating the blockchain infrastructure, smart contracts, and integrating data management components. Python, a versatile programming language, is often used in blockchain development due to its simplicity, scalability, and extensive libraries. In this stage, a blockchain structure is created, including nodes, blocks, and transaction chains, to store and verify land registry information. Python libraries such as Web3.py (for Ethereum-based systems) or PyCryptodome (for cryptographic security) can be utilized to develop the cryptographic functions that secure transactions. Additionally, smart contracts are written to automate processes such as land transfer, ownership verification, and updating registry data. These smart contracts ensure that transactions are executed according to predefined rules, eliminating the need for intermediaries and increasing the efficiency of the system. The development also includes integrating the system with external databases (e.g., GIS systems) to manage spatial data, enabling seamless access to land-related information.

3.6.4. Entering Land Registry Information into the System

Once the blockchain infrastructure is ready, the next step is entering the land registry data into the system. This involves digitally transferring information such as parcel boundaries, ownership records, land use data, and legal documents like title deeds. The data must be accurately entered to ensure that every transaction and record is traceable. Each entry on the blockchain can be a transaction that records a specific change, such as a transfer of ownership or a modification in land use.

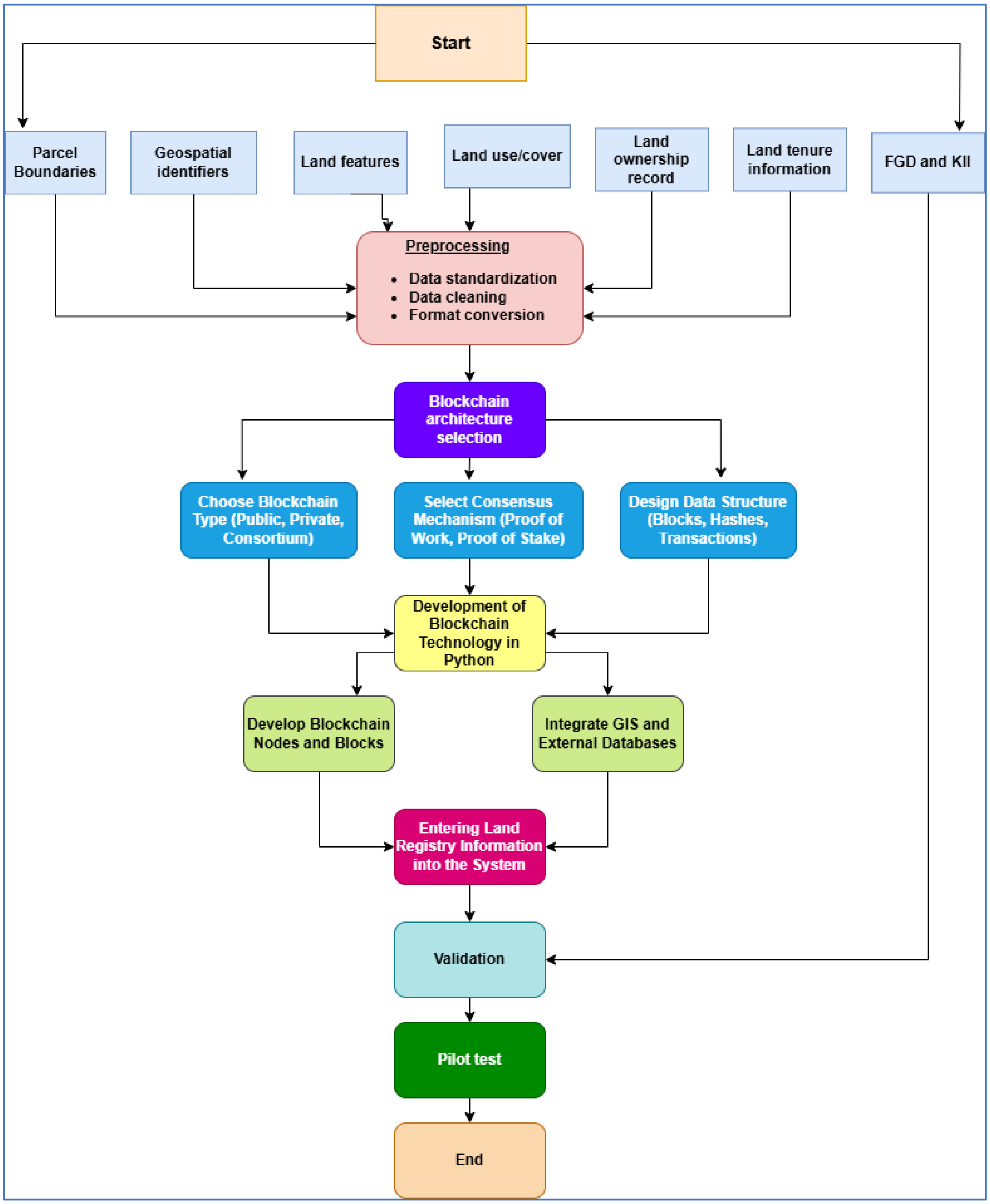

Figure 3-2: Methodological flowchart of the study

3.6.5. Testing of the Developed Technology

Testing is a vital step to ensure that the blockchain technology functions as expected and meets the requirements of land registry processes. This stage involves several types of tests: unit tests for individual components, integration tests to ensure the system's modules work together, and system tests to verify the overall functionality. Testing includes validating the security features of the blockchain, ensuring that only authorized users can add or modify records, and verifying that the consensus mechanism works as intended. Additionally, the system's performance is assessed under real-world conditions to identify any bottlenecks or scalability issues. For a land registry system, this could also include stress testing the system to ensure it can handle a large number of transactions simultaneously, such as during periods of high demand.

3.6.6. Validation

Once the system is developed and tested, it is crucial to validate the results with real-world data and ensure that it functions in the context of the actual land registry processes. Validation includes checking that all data entered is correctly recorded on the blockchain and that the blockchain's data integrity and security measures work as intended. It also involves ensuring that stakeholders (e.g., landowners, registrars, and legal bodies) can access the information in a user-friendly and reliable manner. Validation may include pilot testing in a specific area or with a small group of users to identify any issues before full-scale deployment.

3.6.7. Pilot Testing and Iterative Implementation

Pilot testing is a crucial step in the implementation of a blockchain-based land registry system. It serves as an initial trial phase where the system is tested in a controlled environment, typically in a smaller, manageable area or with a select group of users. The goal is to evaluate the functionality, performance, and user experience of the system before it is rolled out on a larger scale. During pilot testing, real-world data is used to simulate land transactions, including land transfers, ownership updates, and title registration. This phase helps identify any technical issues, such as system glitches, security vulnerabilities, or performance bottlenecks, and assess whether the blockchain infrastructure meets the expected standards for speed, security, and accuracy. Additionally, pilot testing allows stakeholders—such as landowners, government officials, and legal professionals—to interact with the system and provide valuable feedback on its usability, trustworthiness, and accessibility. This feedback is crucial for fine-tuning the system to better meet user needs and address any concerns related to the adoption and integration of the technology.

Iterative implementation is an approach that focuses on making gradual improvements to the system based on the results of pilot testing and user feedback. Instead of implementing the entire system at once, the blockchain-based land registry system is deployed in phases, with each phase building on the previous one. This iterative process allows for continuous improvements and ensures that the system evolves to meet the needs of its users. After pilot testing, the system is adjusted based on feedback, errors are fixed, and any system weaknesses are addressed. For example, if users find certain features difficult to navigate or encounter errors during transactions, these issues can be resolved in the next iteration. Furthermore, new features or enhancements (such as adding more land data or improving the user interface) can be incorporated into the system over time. By continually refining the technology, iterative implementation helps ensure the long-term success and scalability of the system, fostering greater user trust and adoption. This approach also allows the system to adapt to changing requirements or challenges as they arise during the implementation process, ensuring a more resilient and sustainable solution for managing land registration on the blockchain.

3.7.Sampling Technique

This study employed a purposive sampling technique to select participants for both Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). Participants were chosen based on their knowledge, role, or experience related to land registration, governance, or the potential application of blockchain technology in Adama City. This method ensured the inclusion of diverse stakeholder groups, including community members, landowners, government officials, real estate professionals, and ICT experts. The goal was to capture a range of perceptions from both the supply (institutional) and demand (public) sides of the land system.

The qualitative component of the study consisted of one Focus Group Discussions (FGDs) and ten Key Informant Interviews (KIIs). The FGDs were organized to capture a broad range of community and sector-specific perspectives. Two groups were conducted with community members, one from urban areas and the other from peri-urban settings, to reflect geographic and socio-economic diversity. One group involved landowners, and another included real estate professionals, whose experience in property transactions provided valuable insights. Each FGD consisted of 6 to 8 participants and lasted approximately 1.5 to 2 hours.

3.7.1. Discussion Themes

The interviews and discussions followed a set of core themes aligned with the study objectives. These included perceptions of public trust in the current land system, challenges of access to land information, awareness and expectations of blockchain technology, issues of transparency and accountability, barriers to adoption such as digital literacy and infrastructure, stakeholder engagement strategies, and ways to measure success post-implementation. Discussions were audio-recorded (with consent), transcribed, and translated where necessary. Thematic analysis was used to analyze the data, allowing for the identification of recurring patterns and significant insights. Codes were generated inductively from the transcripts and grouped into categories reflecting the discussion themes.

Table 3-3: Discussion themes

Main Theme	Sub-Themes / Guiding Questions
Trust in Current Land System	What causes distrust in land registration? Any past experiences with fraud, bribery, or manipulation?
Access to Land Information	How easy is it to get land records? Who faces challenges accessing this information and why?
Perceptions of Blockchain	What is your understanding of blockchain? How might it benefit land registration?
Transparency and Accountability	Can blockchain reduce corruption and increase fairness? Are there risks in making data transparent?
Adoption Challenges	What obstacles exist for adopting blockchain (e.g., digital literacy, infrastructure, legal gaps)?
Stakeholder Engagement	How important is awareness and education? How can different groups be involved and motivated?
Measuring Success	What indicators would show improved trust/access? How can we evaluate if the system works well?

3.8.Validity and reliability

The validity and reliability of the study on implementing blockchain technology in land registration are essential for ensuring that the research accurately measures the impact of the technology while producing consistent results. Validity is addressed through internal validity by ensuring blockchain improvements can be attributed to the technology itself, external validity by generalizing findings to other similar urban areas, construct validity by defining clear performance measures such as transaction speed and user satisfaction, and content validity by ensuring all aspects of the land registration system are covered. Reliability is ensured through test-retest consistency, inter-rater reliability in qualitative data analysis, internal consistency across multiple evaluation criteria, and procedural reliability by adhering to standardized protocols. Strategies like detailed documentation, stakeholder involvement, pilot testing, iterative refinement, and expert review are employed to maintain both validity and reliability, ensuring the blockchain solution's effectiveness and trustworthiness in enhancing land registration systems.

3.9.Ethical considerations

Ethical considerations in the study of blockchain technology for land registration focus on ensuring the protection of participants' rights, privacy, and fairness throughout the research process. Key issues include obtaining informed consent from all participants, safeguarding privacy and data protection, especially for sensitive land records, and ensuring transparency in how blockchain operates to build trust among stakeholders. The system must be non-discriminatory, ensuring equal access and benefit for all individuals, especially marginalized groups, and avoid exacerbating inequalities. Fairness in implementation is crucial, as is minimizing the environmental impact of the blockchain system through energy-efficient practices. Finally, the long-term sustainability and impact of the blockchain solution must be carefully considered to prevent adverse effects on landowners, the local economy, or the environment, ensuring the project is ethically sound and beneficial for the community.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1.Introduction

This chapter presents the results obtained from the implementation and evaluation of Blockchain technology applied to land parcel management in Adama City. The aim was to assess the effectiveness, transparency, and security enhancements offered by Blockchain in handling land records. A set of land parcels were selected as representative samples for this study. For confidentiality and data protection purposes, the actual names of landowners were anonymized, and randomized identifiers were used in place of real personal information. This ensures privacy compliance while allowing for effective analysis. The entire process from data handling to Blockchain deployment was executed using Python programming language, which enabled efficient data processing, smart contract simulation, and visualization of results.

4.2.Application of Blockchain technology

4.2.1. Ownership Change Over Time (Per Parcel)

Figure 4-1 illustrates the dynamic transitions of ownership across various land parcels (e.g., Parcel 42, Parcel 47, etc.) over several transaction steps. Each colored line represents a specific parcel and tracks its ownership through different stages of transactions, labeled along the x-axis. The y-axis denotes the names of owners, indicating the individual or entity that held ownership at each point in time.

This visualization captures the core essence of Blockchain-based land management—transparency, traceability, and immutability of ownership records. The sharp shifts in ownership for several parcels (e.g., Parcel 49 and Parcel 54) highlight the flexibility of Blockchain to log and trace each transaction event in a verifiable and permanent manner. For example, Parcel 49 starts with Debebe, transitions to Jemila, then to Amanuel, and ends again with Debebe. These changes are immutably recorded, preventing tampering or retroactive modification—benefits that are consistently emphasized in literature (Zhang et al., 2019; Lemieux, 2016).

Furthermore, the diverse trajectories observed in ownership (e.g., Parcel 60's transitions from Girma to Hanna, then to Ibrahim, and finally Jemila) underscore the non-linear and multi-actor nature of real estate transactions. Blockchain, through distributed ledgers and smart contracts, enables such transactions to be executed without a central authority while maintaining consensus and trust (Tapscott & Tapscott, 2016). Studies have also shown that Blockchain enhances efficiency and reduces disputes in land registry systems. For instance, a World Bank report (2018) emphasized the potential of Blockchain to reduce corruption and land grabbing in developing countries by ensuring all transactions are permanently recorded and publicly verifiable.

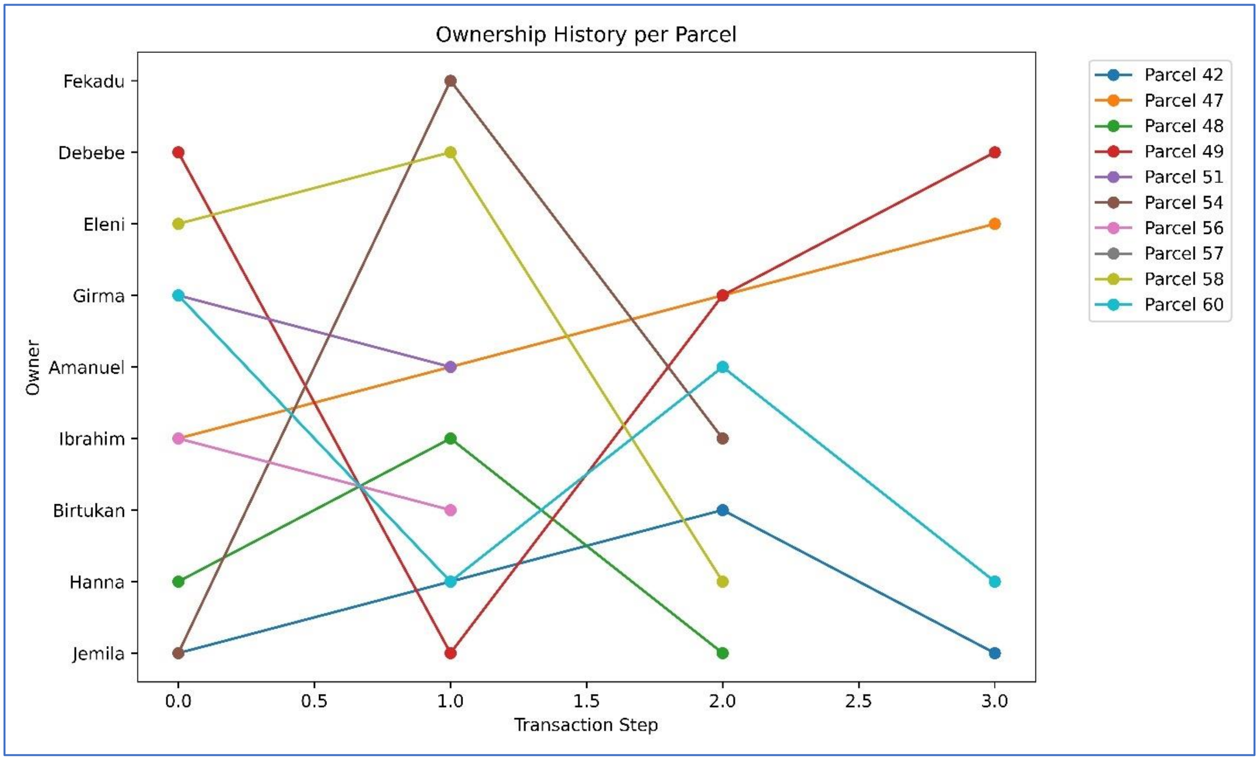

Figure 4-1: Ownership change over time in the selected parcels

4.2.2. Owner Change Frequency Histogram

Figure 4-2 presents the frequency of ownership transfers for each land parcel, identified by parcel IDs ranging from 42 to 60. The y-axis displays the number of ownership changes recorded, while the x-axis lists the respective parcel IDs. Parcels 42, 47, 49, and 60 each recorded three ownership changes, the highest among the dataset. Parcels 48, 54, and 58 recorded two changes each. Parcels 51, 56, and 57 experienced the least activity, with only one ownership change during the observed period. This data confirms a non-uniform distribution of transaction activity across the selected parcels.

In a Blockchain-based land registry system, all ownership changes are recorded transparently and immutably. Each transaction is time-stamped, verifiable, and permanently stored, which eliminates the risks of unauthorized modifications and fraudulent claims. This ensures accountability and enhances the reliability of land administration processes.

According to Deininger and Byerlee (2012), conventional land management systems often suffer from poor record-keeping and delays in updating ownership information, which can lead to disputes and undermine trust in land governance institutions. Blockchain technology directly addresses these challenges by providing real-time updates and a secure audit trail for every transaction. Lemieux (2016) confirms that Blockchain's immutability and auditability support improved oversight of property transactions, enabling governments to monitor land use patterns and enforce legal frameworks more effectively. In this case, the ownership change frequency provides clear evidence of transaction volume and supports administrative decision-making regarding land tenure and urban development.

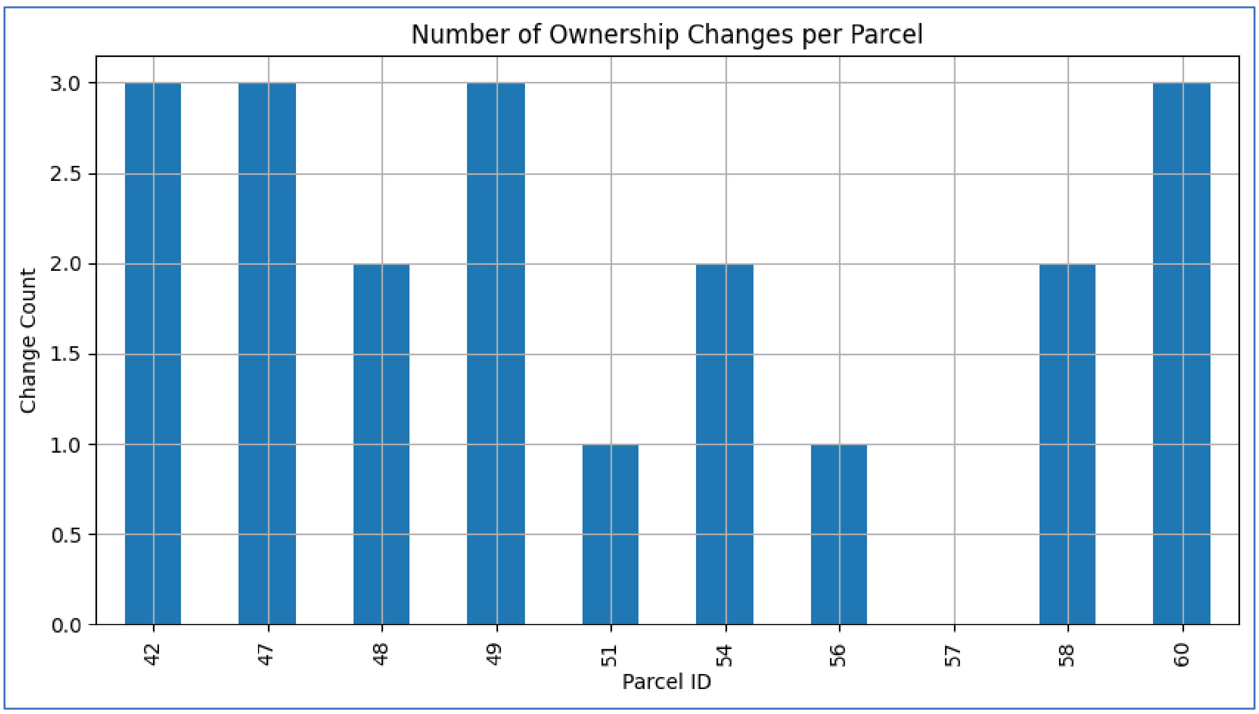

Figure 4-2: Ownership change per each parcel

4.2.3. Network of Transactions

Figure 4-3 visualizes the flow of land ownership among individuals using a directed graph structure. Each node represents a person involved in at least one land transaction, and the arrows denote the direction of ownership transfer from one individual to another. The parcel IDs along the arrows indicate which land parcel was transferred in each transaction.

This network provides a comprehensive overview of ownership dynamics and interconnections among actors in the Blockchain-based land registry. For example, Ibrahim emerges as a central figure, connected with multiple individuals including Jemila, Hanna, and Debebe. His node shows both incoming and outgoing arrows, confirming active participation in both acquiring and transferring land parcels. Similarly, Jemila and Hanna are highly connected nodes, indicating their central roles in land transactions across several parcels (e.g., 48, 49, 54, and 60).

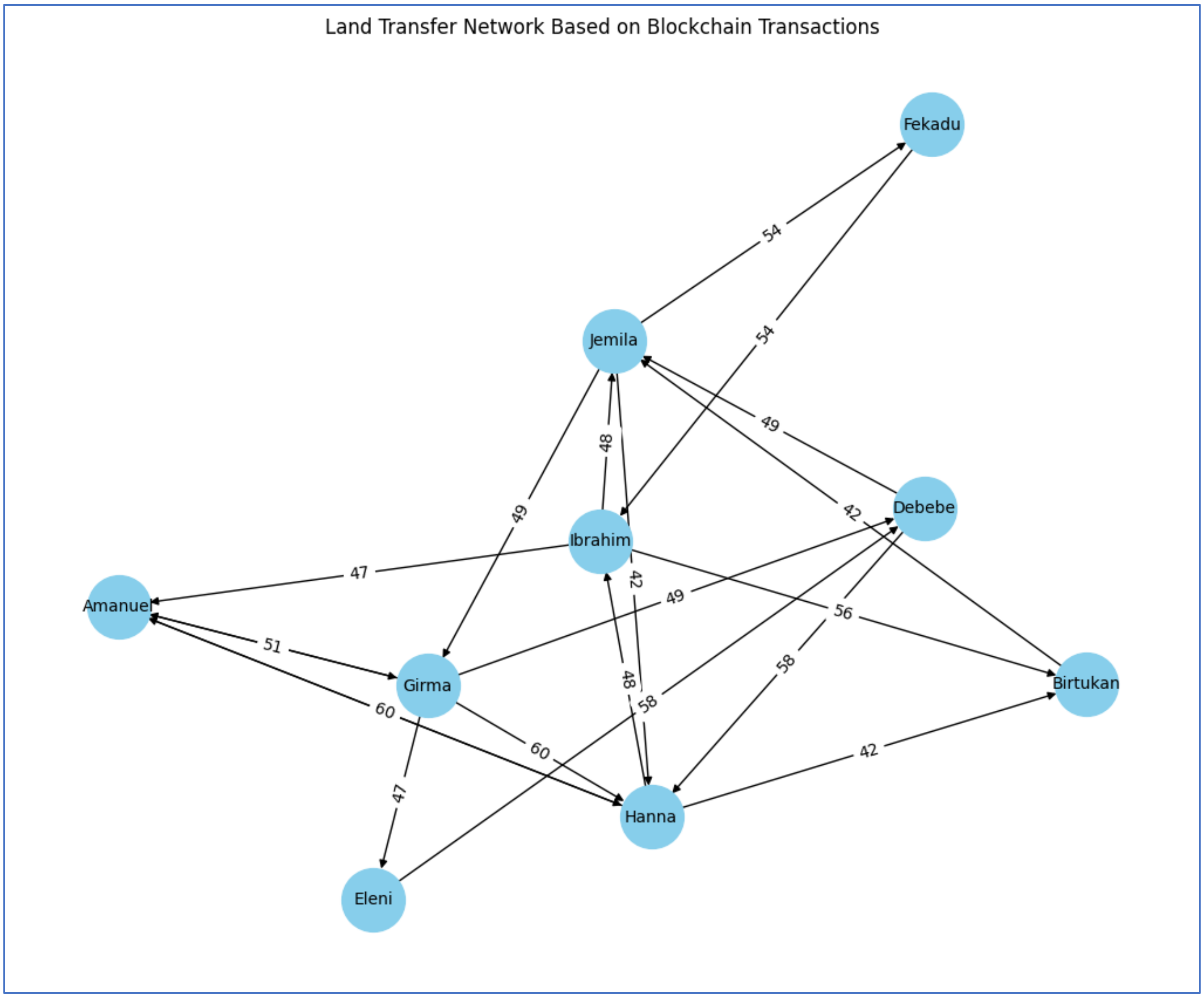

Figure 4-3: Land transfer network based on blockchain transaction

4.2.4. Parcel Ownership

Figure 4-4 shows a structured grid of land parcels, each shaded with a distinct color representing ownership, as defined in the accompanying legend. Parcels are aligned diagonally, reflecting the cadastral layout of Adama City. Ownership on the map is concentrated in specific individuals, including Hanna, Jemila, and Amanuel, who each hold multiple adjacent parcels. Hanna owns two vertically stacked parcels near the center, while Jemila controls several plots on the right column. Amanuel holds two parcels in proximity, forming a local cluster. These ownership patterns result from deliberate acquisition strategies and demonstrate the capability of blockchain systems to facilitate land consolidation.

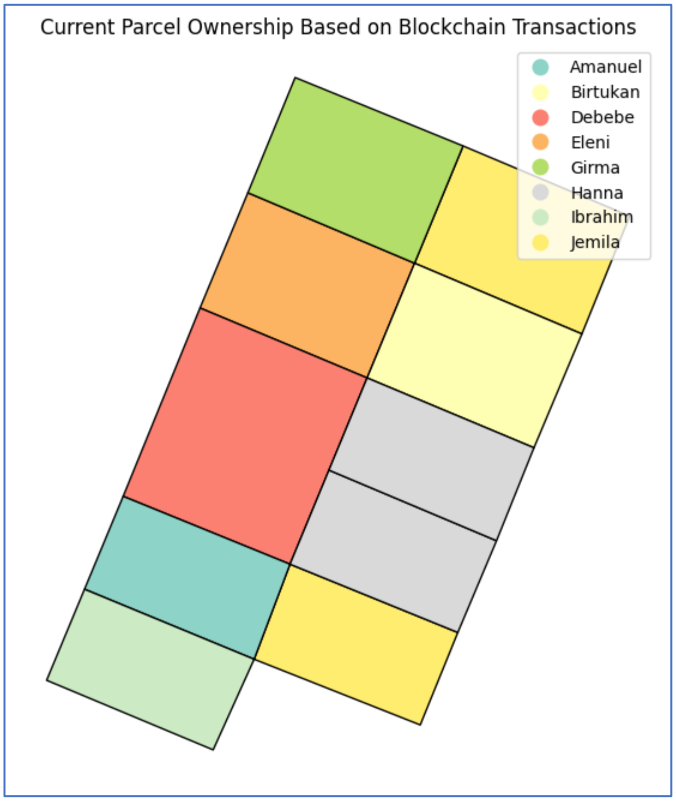

Figure 4-4: Parcel ownership based on Blockchain transactions

The map reflects the final state of multiple verified blockchain transactions, with parcels such as Parcel 49 and Parcel 60 transitioning through owners like Debebe, Jemila, Amanuel, and Girma. The current ownership of these parcels is the direct outcome of recorded transaction chains, as preserved in the blockchain ledger. Jemila and Amanuel emerge as final owners of parcels that underwent multiple exchanges. The system ensures complete traceability of each parcel's history, establishing a secure and accountable land transaction environment.

Land ownership on the map is distributed across ten individuals, with most parcels under unique ownership and only a few held by repeat owners. The system delivers an equitable distribution of land, preventing monopolization while still supporting strategic acquisition. This distribution confirms active market participation across multiple stakeholders. The blockchain framework lowers transaction barriers, enabling accessible and inclusive engagement in the land market.

The spatial distribution of owners matches the findings from the transaction network analysis. Individuals like Ibrahim, Hanna, and Jemila hold central positions in the transaction network and retain significant parcels on the map. Ibrahim, although involved in multiple transactions, holds a single parcel in the final state, confirming his role as a dynamic trader. Hanna and Jemila, with multiple holdings, demonstrate strong acquisition capability. These spatial outcomes align with the recorded transaction behavior and network centrality metrics.

4.2.5. Parcel transfer history

Figure 4-5 provides a comprehensive chronological account of land ownership transitions within a defined spatial boundary. Each labeled block in the diagram indicates a parcel, annotated with a directional arrow that shows the transfer of ownership from one individual to another. This visual representation allows for immediate recognition of transactional sequences and highlights the role of each participant in the evolving land tenure structure. The spatial organization of parcels reinforces the traceability of each transaction and the logical flow of land redistribution across time.

Girma is a central figure in the early phase of parcel transactions. He transferred ownership of four distinct parcels to Eleni, Debebe, and Amanuel. This recurring presence positions Girma as a foundational distributor in the initial stages of the blockchain-based land market. His actions structured much of the downstream ownership pattern, since recipients of his parcels either retained ownership or initiated further transactions. Notably, Debebe and Amanuel, after acquiring parcels from Girma, did not maintain passive roles; they became active intermediaries themselves, each passing their holdings to Hanna. These transactions reveal a layered ownership path where early recipients catalyze further redistribution.

The role of Ibrahim reflects a similar early-stage influence. He acquired a parcel from Fekadu and subsequently distributed parcels to Birtukan and Jemila. This dual action indicates a transitional role, where Ibrahim acted not only as a recipient but also as a facilitator in redistributing land. The direction of these transactions shows that his tenure was temporary but impactful, contributing directly to the current distribution of land among final owners. Ibrahim's transfers led to Birtukan and Jemila, two participants with different roles in the system: Birtukan later transferred her parcel, while Jemila retained both parcels she received.

Hanna and Jemila emerge as final-stage consolidators. Hanna received parcels from both Amanuel and Debebe, while Jemila acquired parcels from Ibrahim and Birtukan. These acquisitions were not random or isolated; they represent intentional accumulation, resulting in each of them holding two contiguous parcels. The transaction paths leading to them demonstrate active participation and strategic behavior within the blockchain system. These patterns imply an emergent land consolidation trend where certain individuals expand their holdings through legal, traceable exchanges.

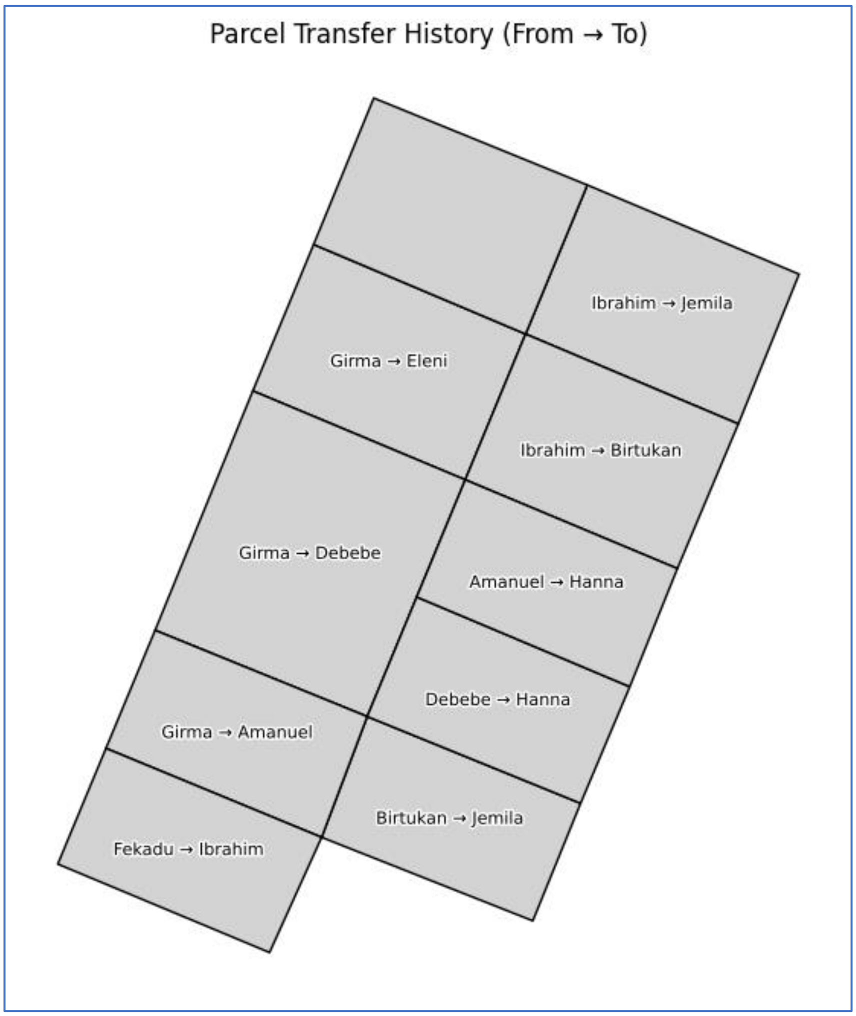

Figure 4-5: Parcel transfer history

4.2.6. Spatial Analysis of Transfers

The figure titled "Spatial Distribution of Parcel Transactions" visually quantifies the intensity of land transaction activity across the study area. Each parcel is color-coded based on the number of transactions associated with it, ranging from 0 (lightest shade) to 3 (darkest red), as indicated by the accompanying legend. This representation provides immediate spatial insight into which parcels experienced higher turnover and which remained comparatively inactive.

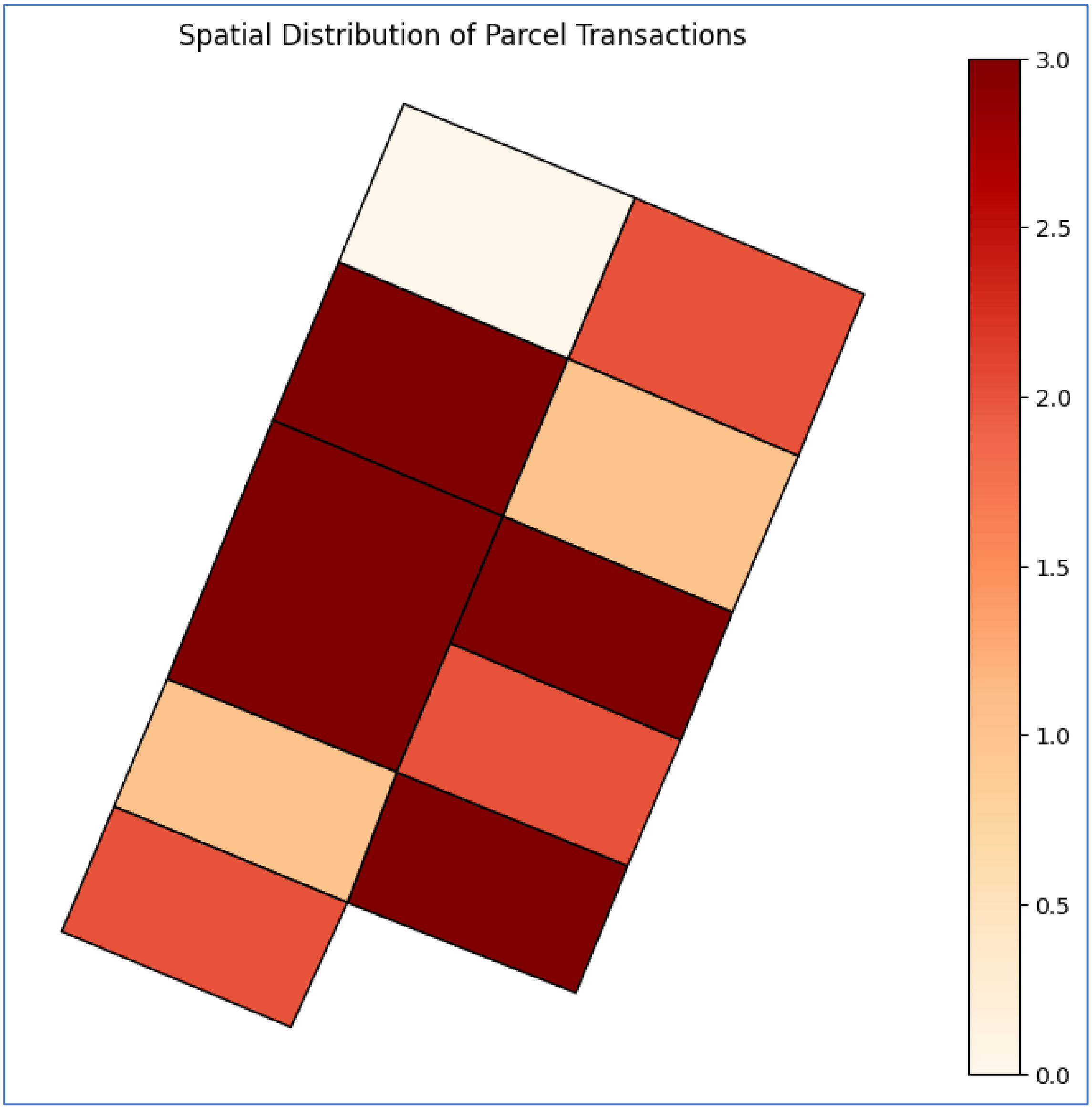

Figure 4-6: Spatial distribution of parcel transactions

The darkest red parcels, which indicate the highest number of transactions (value = 3), are spatially clustered in the central and mid-northern portions of the grid. These parcels form a contiguous core of activity, signaling that this subregion served as a transaction hub. Such a pattern suggests these central parcels were either highly desirable or belonged to early distributors who reallocated land to multiple recipients. Their prominence in transaction frequency marks them as pivotal nodes within the broader transfer network.

Surrounding this core, parcels with moderate transaction intensity (value = 2) form a buffer zone. These parcels exhibit intermediate activity, suggesting involvement in the land transfer process but to a lesser extent. Their placement adjacent to high-frequency parcels supports a spatial diffusion hypothesis, where transaction activity spread outward from central nodes.

The lightest shaded parcels, especially those at the northern and southwestern edges, represent minimal or no transactional history. These parcels were either acquired and retained without further redistribution or were simply not active in this recorded cycle. Their low activity level isolates them from the denser transaction network, implying a more static role in the ownership landscape.

4.2.7. Owner tenure duration

The owner tenure duration presents a clear view of landholding patterns and transactional behavior over time. As shown in Figure 4-7, four parcels remained under the ownership of a single individual for a continuous period of four years. This uninterrupted tenure indicates stability in land use and ownership, reflecting long-term engagement with the land. Such cases of prolonged control often reflect consistent usage such as agricultural cultivation or residence and a lack of external pressures leading to transfer or sale. The owner's decision to retain these parcels over an extended period demonstrates a deliberate and sustained interest in maintaining control over the land.

In contrast, the figure also shows a case where one individual acquired an additional parcel each year. This pattern represents a steady and intentional accumulation of land. The owner increases their holdings annually, expanding their influence within the land distribution system. This behavior reflects active involvement in the land market, where the owner is either purchasing, inheriting, or otherwise acquiring parcels in a systematic manner. The growing portfolio over time indicates a strategic approach to land acquisition, resulting in a gradual yet consistent expansion of land ownership.

These two patterns long-term retention and systematic accumulation illustrate different approaches to land tenure within the same geographic context. One reflects stability and continuity, while the other represents dynamic growth and expansion. Together, they define the diverse character of ownership behaviors in the area.

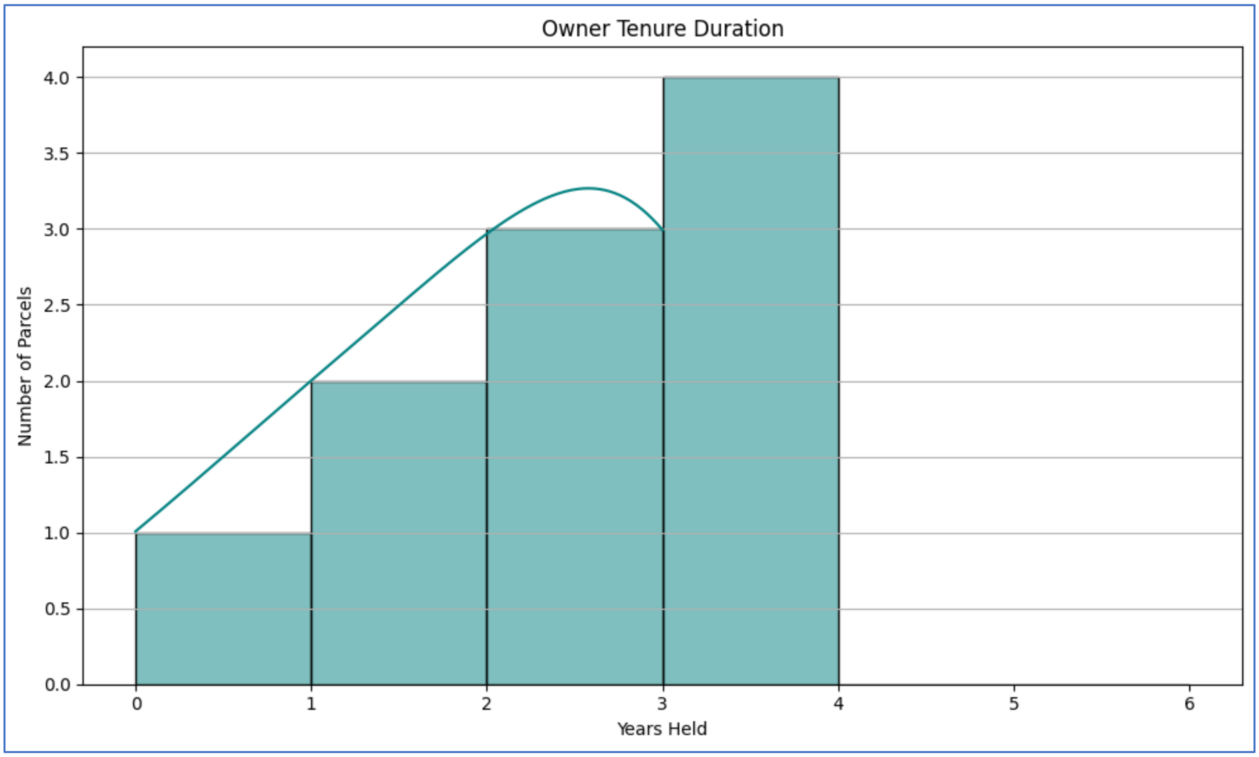

Figure 4-7: Owner tenure duration over time

4.2.8. Blockchain Audit Visualization

The blockchain audit log above provides a sequential, immutable record of parcel ownership changes across six blocks, effectively demonstrating the transparency and traceability of land transactions over time. Each block contains a cryptographic hash and a reference to the hash of the previous block, ensuring the integrity of the entire transaction chain.

Block #0 serves as the genesis block with no previous hash. It lays the foundation for subsequent entries without recording any parcel transactions itself.

Block #1 documents a set of initial transactions that initiate several ownership transitions. Ibrahim transfers Parcel 47 to Amanuel, Jemila transfers Parcel 42 to Hanna, Debebe receives Parcel 49 from Jemila, and Eleni transfers Parcel 58 to Debebe. These transfers mark the first movements of these parcels, introducing Amanuel, Hanna, and Debebe as active participants in the land exchange network.

Block #2 captures a continuation and reversal of ownership. Parcel 58, which Debebe had just received in the previous block, is now transferred to Hanna. Parcel 47 changes hands again, this time from Amanuel to Girma. Jemila transfers Parcel 54 to Fekadu and also Parcel 49 to Girma. This block is characterized by rapid ownership turnover and a consolidation of parcels under Girma, who acquires multiple plots.

```
Block #0 | Hash: df01e4f2bc... | Prev: 0...
Block #1 | Hash: dfb2889ca3... | Prev: df01e4f2bc...
  Parcel 47: Ibrahim → Amanuel
  Parcel 42: Jemila → Hanna
  Parcel 49: Debebe → Jemila
  Parcel 58: Eleni → Debebe
Block #2 | Hash: fae409f7b5... | Prev: dfb2889ca3...
  Parcel 58: Debebe → Hanna
  Parcel 47: Amanuel → Girma
  Parcel 54: Jemila → Fekadu
  Parcel 49: Jemila → Girma
Block #3 | Hash: 4312a57ee3... | Prev: fae409f7b5...
  Parcel 48: Hanna → Ibrahim
  Parcel 60: Girma → Hanna
  Parcel 60: Hanna → Amanuel
  Parcel 56: Ibrahim → Birtukan
Block #4 | Hash: 32f36d362e... | Prev: 4312a57ee3...
  Parcel 47: Girma → Eleni
  Parcel 42: Hanna → Birtukan
  Parcel 42: Birtukan → Jemila
  Parcel 60: Amanuel → Hanna
Block #5 | Hash: 72ad6e9679... | Prev: 32f36d362e...
  Parcel 49: Girma → Debebe
  Parcel 51: Girma → Amanuel
```

Figure 4-8: Blockchain audit visualization

Block #3 records complex sequences and rapid turnovers. Hanna transfers Parcel 48 to Ibrahim, Parcel 60 is transferred from Girma to Hanna and then immediately from Hanna to Amanuel. Ibrahim transfers Parcel 56 to Birtukan. These fast-paced, multi-party exchanges illustrate dynamic parcel movements and the active role of all parties involved.

Block #4 shows further downstream transactions. Girma transfers Parcel 47 to Eleni. Parcel 42 undergoes two transfers: first from Hanna to Birtukan, then from Birtukan to Jemila, completing a full cycle of ownership that began in Block #1. Parcel 60 is transferred back from Amanuel to Hanna, demonstrating recurring exchanges involving the same parcel.

Block #5 continues this trend. Girma transfers Parcel 49 to Debebe and Parcel 51 to Amanuel, again reinforcing Girma's central role in the transaction network. Ibrahim transfers Parcel 48 to Jemila, while Fekadu returns Parcel 54 to Ibrahim, reversing a transaction recorded earlier.

This blockchain-based record provides a secure and chronological narrative of land parcel ownership. It enables clear identification of transactional patterns such as frequent parcel transfers, cyclic ownership, and the emergence of key actors like Girma, Hanna, and Jemila while guaranteeing data immutability and accountability.

4.2.9. Gini Index for ownership distribution

The Lorenz Curve, as illustrated in the image, provides a well-established method for evaluating inequality in resource distribution, particularly land ownership. This graphical tool has been extensively used in socio-economic research to analyze disparities and to inform equitable policy design. According to Gastwirth (1972), the Lorenz Curve offers a more intuitive and visual interpretation of inequality compared to purely numerical indices, enabling researchers and policymakers to grasp the extent of disparity in ownership distribution. In the context of land, which is a fundamental asset for rural livelihoods and agricultural productivity, inequality in land distribution has significant implications for poverty, social stability, and sustainable development (Deininger & Squire, 1998).

The marked deviation of the Lorenz Curve from the line of equality in the graph indicates a skewed distribution of land ownership, where a small proportion of landowners controls a disproportionately large share of land. Such patterns have been widely documented in empirical studies across the Global South. For instance, Borras and Franco (2010) emphasize that land concentration leads to exclusionary development and marginalization of smallholder farmers. Similarly, the Food and Agriculture Organization (FAO, 2007) reports that in many developing regions, land inequality has increased over time due to market liberalization and land acquisitions by elites, exacerbating socio-economic inequalities and undermining food security.

Furthermore, the Gini coefficient derived from the Lorenz Curve serves as a quantitative indicator of land inequality. A higher Gini index reflects greater inequality, which is closely associated with reduced agricultural efficiency and increased rural poverty (Carter & Barrett, 2006). Empirical studies have shown that equitable land distribution contributes to improved agricultural productivity and income distribution. For example, Vollrath (2007) found that countries with lower land inequality tend to exhibit higher growth in the agricultural sector due to broader access to land-based resources and credit.

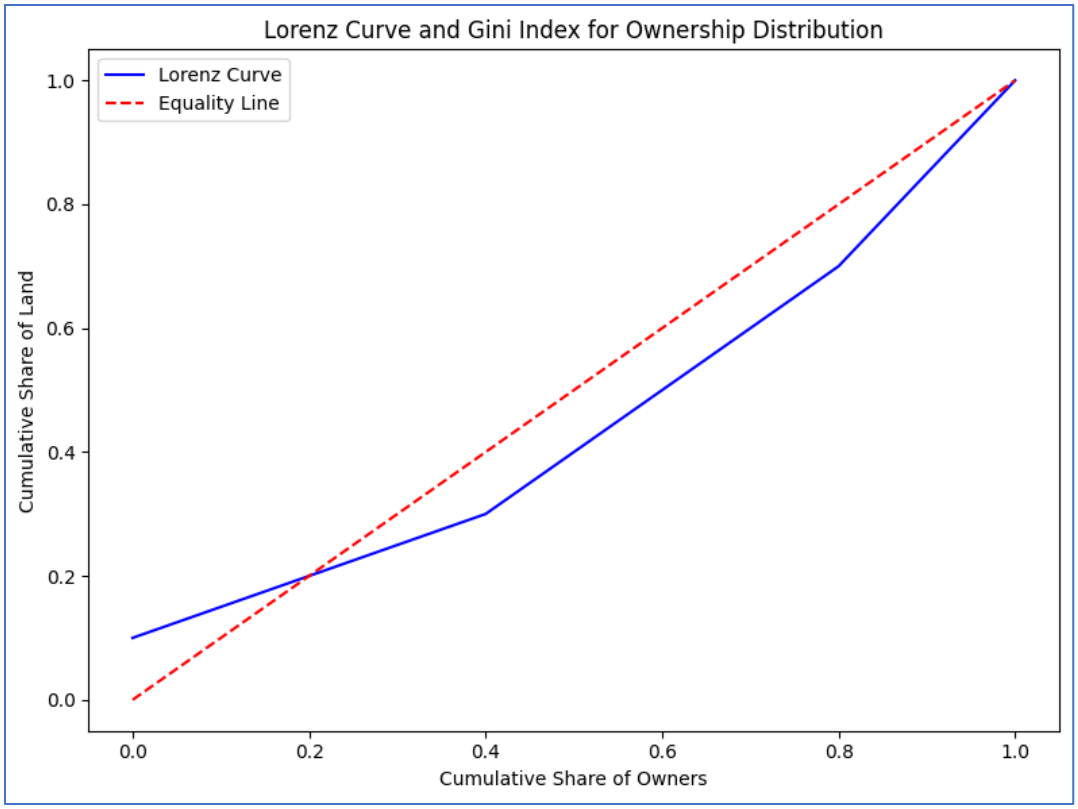

Figure 4-9: Gini Importance index for ownership distribution

4.3.Public trust and access to land information

The widespread distrust in the land registration system in Adama City reflects broader challenges documented in developing countries, where corruption, lack of transparency, and data manipulation undermine confidence (Deininger et al., 2011; Cotula, 2012). Respondents frequently described experiences of bribery and manipulation, with one stating, *"Many people believe the system is corrupt because officials demand bribes to process documents quickly."* Others pointed to the complexity of the system, saying, *"The system is too complex for ordinary citizens to navigate without help from insiders."* Such concerns mirror findings that procedural delays and opaque administration reduce trust and encourage reliance on informal practices (Besley & Ghatak, 2010; World Bank, 2017).

Respondents viewed blockchain as a promising tool to mitigate these trust issues, highlighting its potential for transparency and data security. As one participant expressed, *"Blockchain could make land records tamper-proof, so no one can change ownership unfairly."* Another remarked, *"If everyone can see the records online, it would reduce the chances of corruption."* These perceptions align well with literature emphasizing blockchain's immutability and decentralization as key features for enhancing trust in land administration (Kshetri, 2017; Christidis & Devetsikiotis, 2016). Pilot projects globally support these expectations, demonstrating blockchain's role in reducing fraud and increasing public confidence (World Bank, 2019; Turkanović et al., 2018).

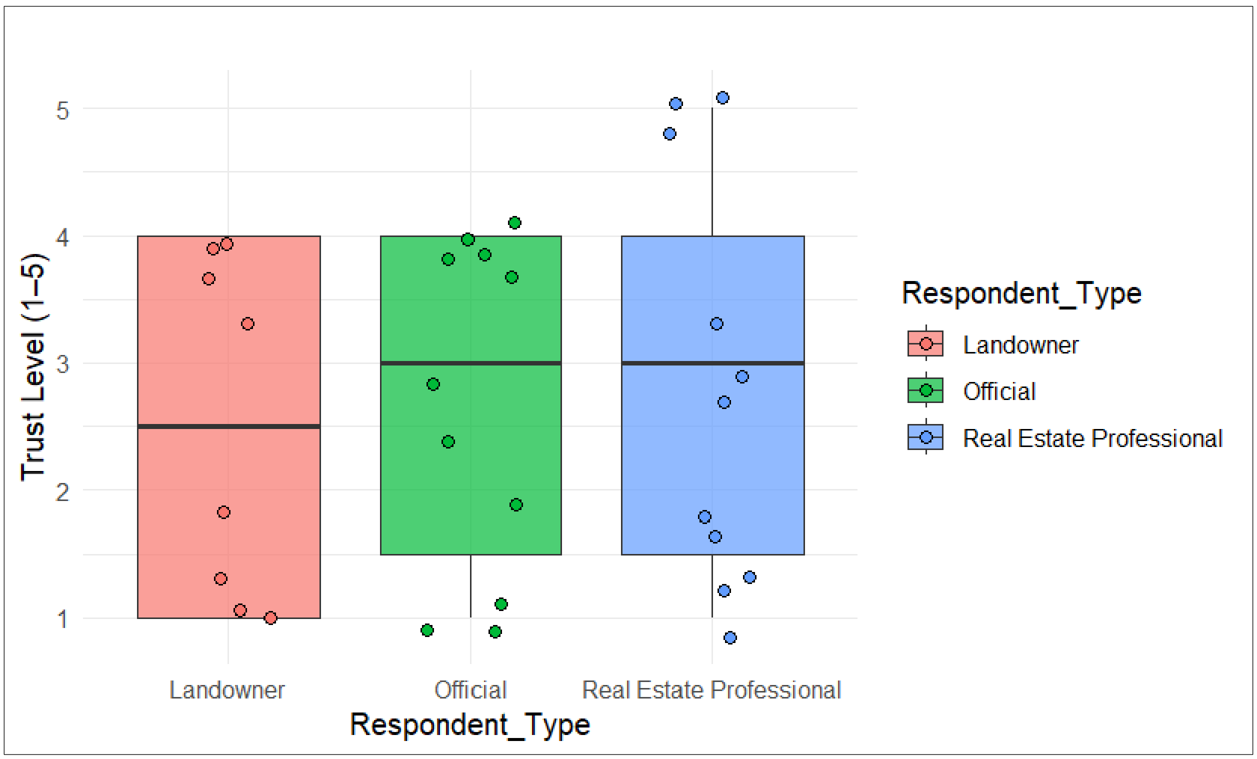

Figure 4-10: Trust in current land information system

Access to land information is another significant challenge addressed by blockchain's transparent nature. Respondents highlighted the problem of restricted access by officials and insiders, with one noting, *"It could remove gatekeepers who currently restrict information access to those with connections."* Another added, *"By having records on a public ledger, people could verify ownership anytime from their phones."* These insights reflect global observations that blockchain can democratize access to land data and provide real-time updates, benefiting marginalized communities especially in rural settings (Smith, 2016; UNECA, 2020). The potential for remote verification is a major improvement over current systems that require physical presence and bureaucratic navigation.

Despite its advantages, respondents underscored the importance of usability and education to ensure adoption. One participant stressed, *"There should be simple mobile apps or websites designed for people with low digital literacy,"* while another noted, *"The government must provide education and support for citizens to learn how to use the system."* These comments echo research emphasizing digital literacy as a critical factor for blockchain success in developing contexts (UNDP, 2019; Chen et al., 2020). Privacy concerns were also raised, with respondents calling for balanced approaches: *"Data privacy must be balanced with transparency — only necessary information should be public."* This reflects the need for privacy-preserving mechanisms such as permissioned blockchains (Zyskind et al., 2015; Peters & Panayi, 2016). Community-based support, such as kiosks or technical assistance, was also proposed to overcome infrastructure gaps, aligning with best practices in blockchain adoption (De Filippi & Wright, 2018).

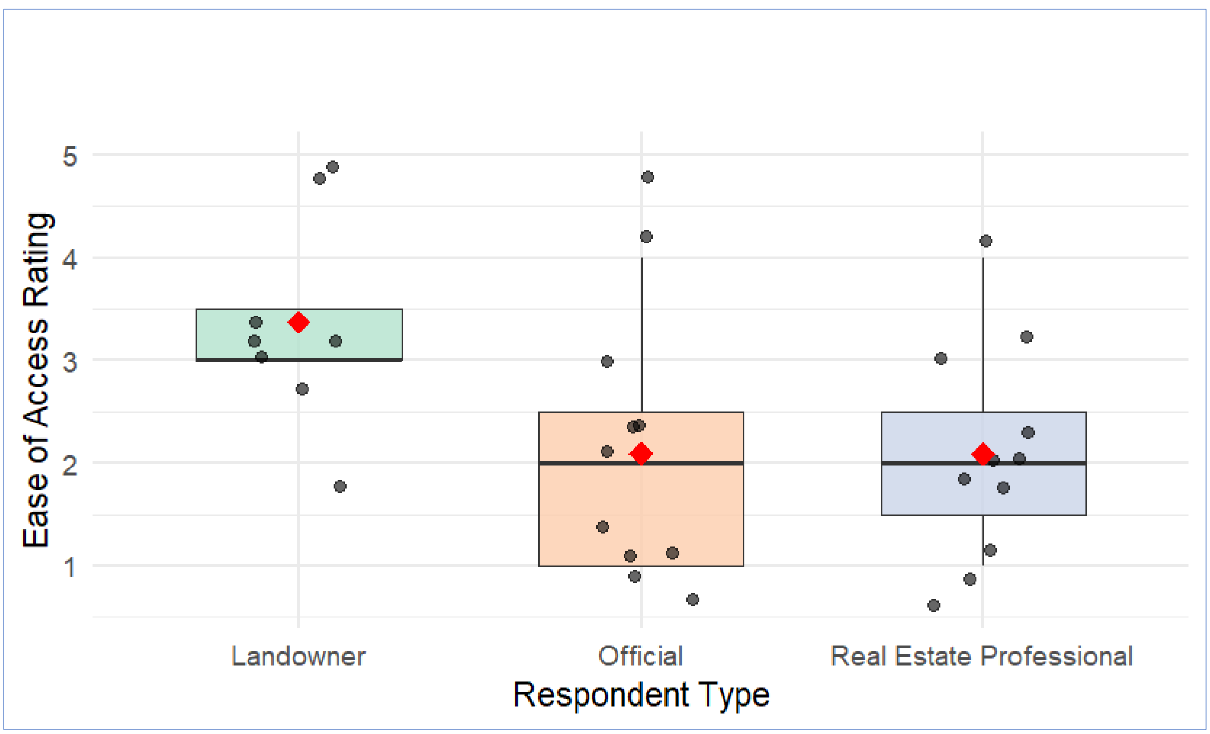

Figure 4-11: Ease of access to land information

The integration of blockchain technology in land administration is frequently promoted for its capacity to improve transparency and accountability, areas where traditional land systems in many developing countries including Ethiopia often fall short. In Adama City, respondents expressed frustration over the opaque nature of land dealings. One landowner remarked, *"You never know what's happening behind closed doors. A document can be changed and no one will even know."* Such sentiments are consistent with literature noting that centralized land registries often lack public oversight, making them susceptible to manipulation (Deininger et al., 2011; World Bank, 2017).

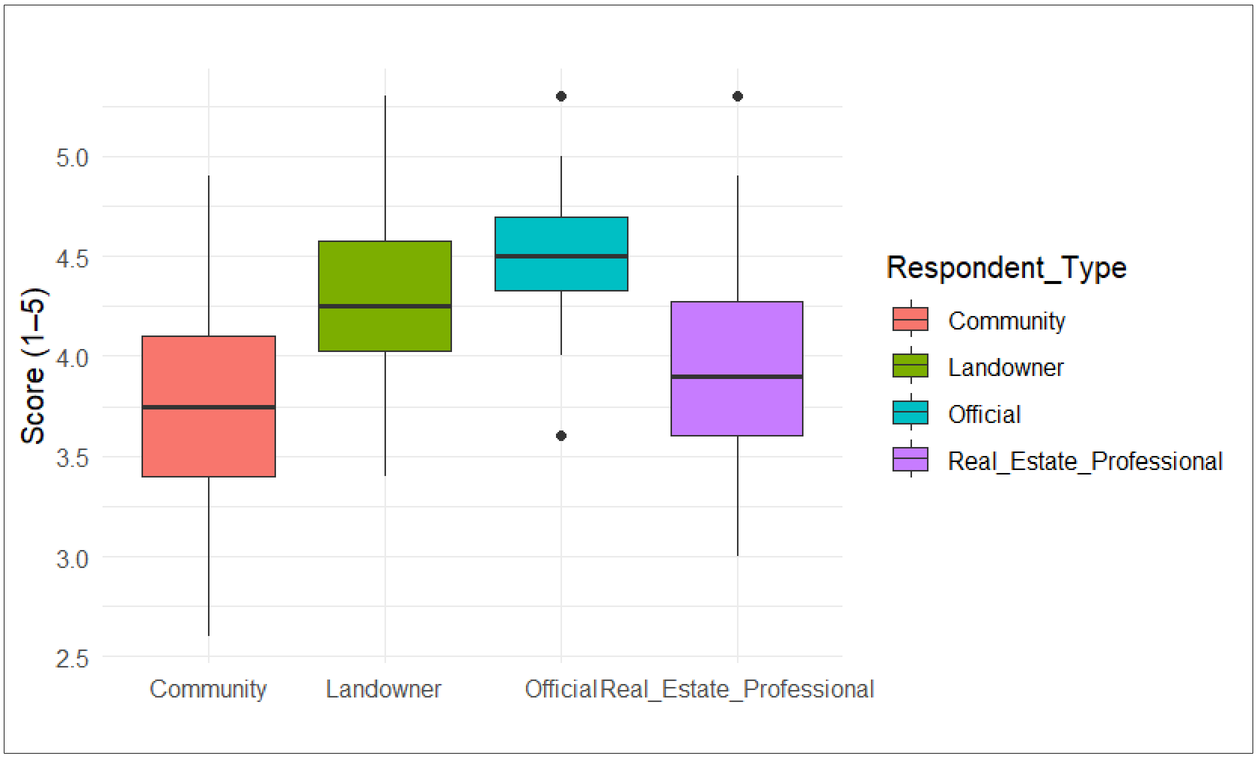

Figure 4-12: Perceived Transparency Improvement by Stakeholder Group

Blockchain's design where transactions are recorded in a distributed ledger visible to all participants offers a compelling solution. As one respondent noted, *"Once it's on the blockchain, no one can change the record without everyone knowing. That makes it harder to cheat."* This reflects blockchain's immutability and traceability, both of which make tampering with records exceedingly difficult and auditable (Christidis & Devetsikiotis, 2016; Kshetri, 2017). These features significantly enhance accountability by creating a verifiable history of land transactions, a benefit demonstrated in pilot projects in Georgia and Ghana (World Bank, 2019; UNECA, 2020).

A recurring theme among community and official respondents was the belief that blockchain could act as a deterrent to corruption. A municipal official stated, *"When everything is visible, there's less room for favors or hidden changes."* The current system, described by participants as paper-based and reliant on personal discretion, was seen as vulnerable to abuse. Blockchain reduces this discretion by automating verification and documentation processes through smart contracts, thus lowering human intervention points where corruption may arise (Peters & Panayi, 2016).

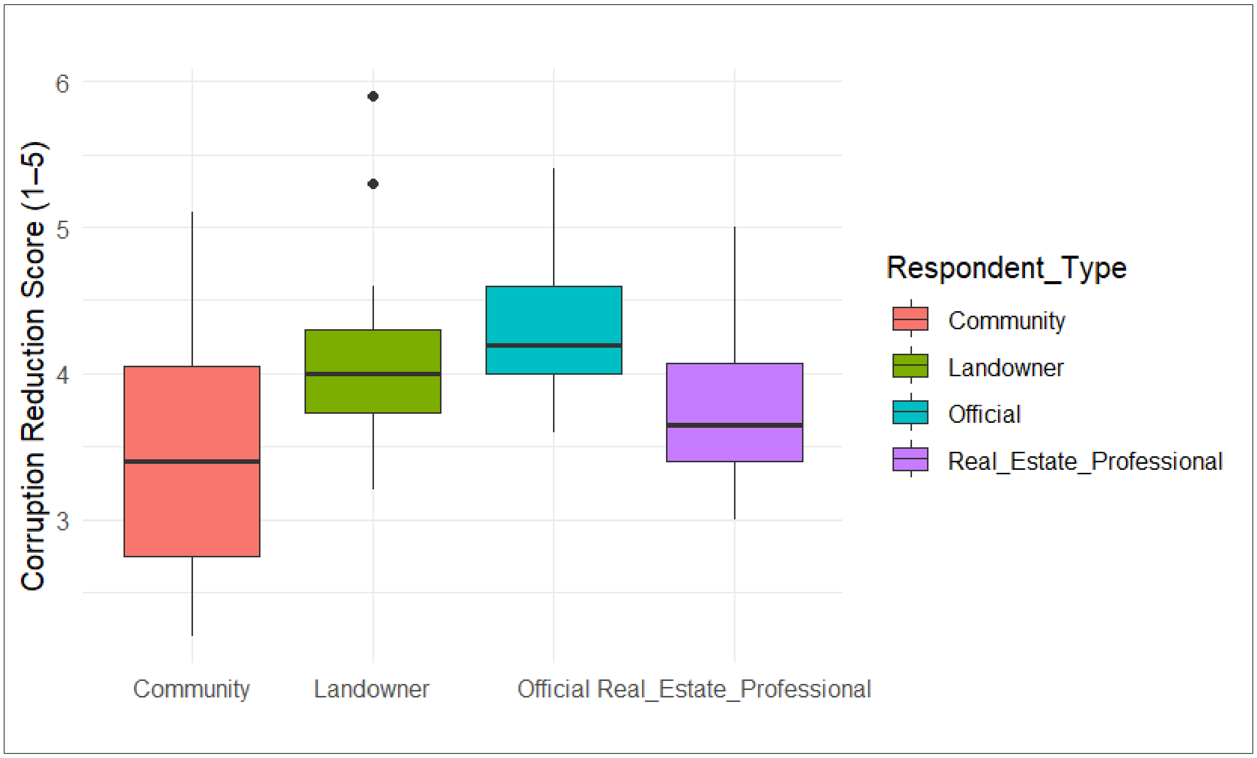

Figure 4-13: Perceived Reduction in Corruption by Respondent Type

This aligns with findings by Casino et al. (2019), who argue that blockchain reduces asymmetric information and improves system-wide integrity. The automation and transparency that blockchain introduces can help build public trust by ensuring that no data alteration can occur unnoticed critical in areas where land is contested or where formal title is essential for economic security (FAO, 2012; Cotula, 2012).

While the advantages of transparency are clear, stakeholders also pointed out potential risks and drawbacks of using blockchain in this context. One concern was data sensitivity, as highlighted by a respondent: *"If all land records are open, won't that put private ownership details at risk?"* This concern reflects the privacy-transparency paradox often cited in blockchain literature—where making data accessible must be balanced with protecting individuals' personal and financial information (Zyskind et al., 2015).

There are also fears of digital exclusion, particularly for vulnerable groups. Another respondent observed, *"If you can't read or access the internet, it doesn't matter if it's transparent you're still left out."* This underscores the importance of designing inclusive systems that cater to users with low digital literacy or limited access to technology (UNDP, 2019). Moreover, poorly designed blockchain implementations those without clear governance, public engagement, or fallback mechanisms can lead to confusion, legal disputes, or even data loss (Wüst & Gervais, 2018).

Respondents noted several barriers to public trust in a blockchain-based system. A commonly echoed concern was the fear of the unknown. One participant from the community said, *"We don't trust what we don't understand. If it's digital and invisible, it must be easy to change."* This lack of familiarity with the technology creates a psychological barrier, especially in a context where trust is traditionally placed in physical documents or personal connections (Deininger & Byerlee, 2011).

Others feared technical manipulation, despite blockchain's promise of security. A landowner commented, *"Even if you say it can't be changed, how do we know someone in government won't find a way around it?"* This reflects a broader institutional trust issue—where distrust in public bodies may spill over into skepticism about any system they introduce (UN-Habitat, 2020). Digital literacy emerged as a critical challenge to access. One official noted, *"Most elders don't use smartphones, let alone understand blockchains. This could widen the gap."* Limited familiarity with digital tools, especially among older and rural populations, may exclude significant demographics from benefiting equally (World Bank, 2019).

Moreover, infrastructure issues such as low internet penetration, unstable electricity, and limited access to digital devices were identified. A real estate professional warned, *"You can't run a digital registry when some kebeles still don't have a reliable power supply."* These observations align with evidence from other blockchain land pilot programs where adoption has lagged due to inadequate enabling environments (Lemieux, 2016).

4.4. Challenges and barriers to the implementation of blockchain in the land registration system

4.4.1. Challenges in Building Public Trust in a Blockchain-Based System

Establishing public trust in a blockchain-based land registration system in Adama City presents multifaceted challenges rooted in institutional skepticism, limited public understanding of the technology, and prior negative experiences with government systems. Many participants in the focus group discussions expressed unease about the concept of a digital, decentralized system managing something as critical as land rights. A local landowner captured this sentiment succinctly, stating, *"If I can't hold the paper in my hand, how do I know it's real?"* This reflects a broader reliance on physical documentation and face-to-face validation, which has historically been the norm in land transactions throughout Ethiopia and much of Sub-Saharan Africa (Deininger & Feder, 2009).

The opacity of past land governance reforms also contributes to the current distrust. Community members indicated that they often feel excluded from system design and decision-making, leading to skepticism about whether such technologies will truly benefit the public. As one kebele leader put it, *"They design it in offices and bring it to us when it's already done we are not consulted."* This aligns with observations from the Food and Agriculture Organization (FAO, 2012), which emphasizes that lack of stakeholder engagement can severely undermine land reform initiatives.

Moreover, while blockchain promises immutability and decentralization, the technical nature of the system can itself become a source of distrust. Participants questioned whether elites or insiders might find workarounds or control the infrastructure behind the scenes. This fear is consistent with findings from Kshetri (2017), who argues that the perception of elite capture can diminish trust even in tamper-resistant digital platforms. Transparency, therefore, is necessary but not sufficient public participation and education are equally critical to build legitimacy.

Access to blockchain-based land records in Adama City significantly constrained by current levels of digital literacy and technological infrastructure. Participants from older and rural demographics expressed concerns about being left behind in the digital transition. One elderly farmer shared, *"I don't have a phone, and even if I did, I wouldn't know how to use it to check land records."* This highlights a common challenge in technology-based development interventions: the digital divide, which disproportionately affects the elderly, rural dwellers, and the economically disadvantaged (World Bank, 2019).

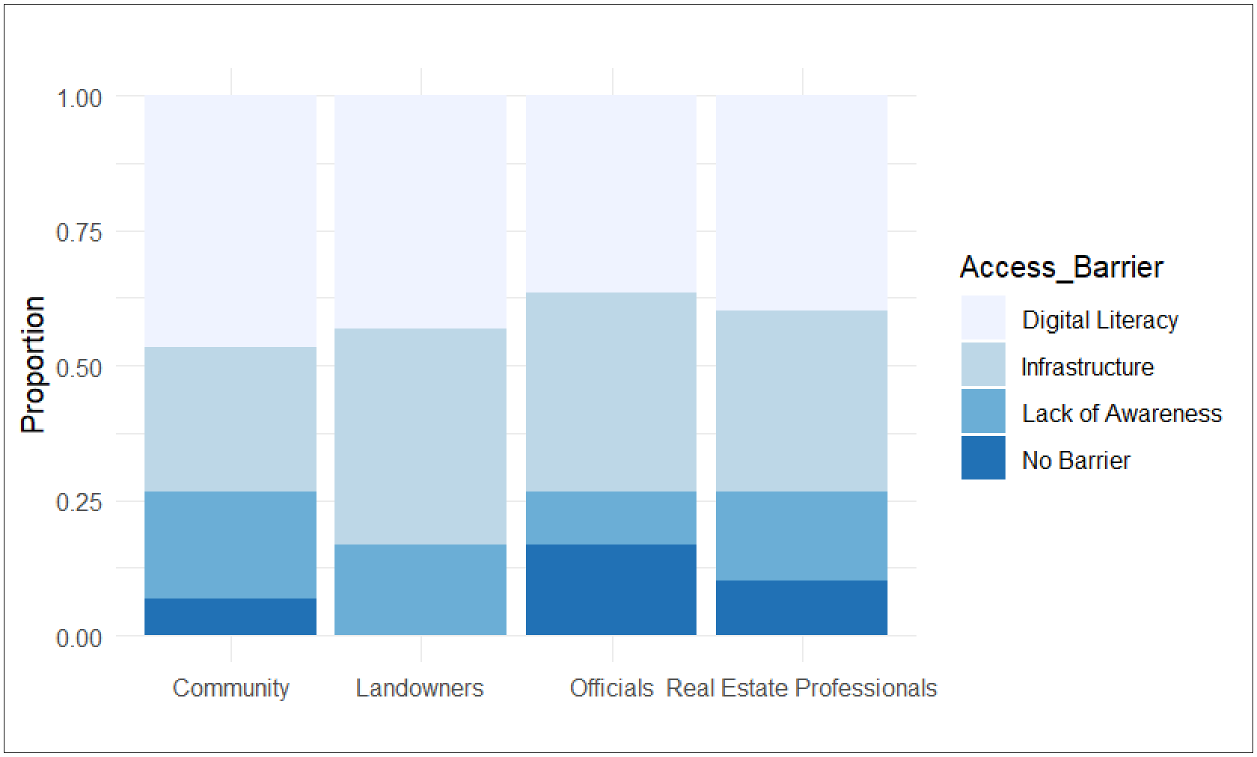

Figure 4-14: Main Access Barriers to Blockchain Land Systems

The issue is further complicated by infrastructural deficits. Several focus group respondents cited unstable electricity, poor internet coverage, and lack of access to digital devices as core barriers to using blockchain systems. A real estate professional warned, *"We can't assume everyone has internet at home—some kebeles don't even have mobile network consistently."* These concerns echo the findings from UNDP (2020), which stress that digital innovations in land governance must be implemented alongside infrastructure development and digital literacy training to ensure equitable access.

Furthermore, the complexity of blockchain systems could further alienate non-technical users. As Lemieux (2016) noted in her review of blockchain applications in archival and public recordkeeping, user-friendliness is often an afterthought in blockchain implementations, which can lead to exclusion even if the system is technically sound. Without supportive interventions such as mobile applications with vernacular language interfaces, offline functionality, and community intermediaries blockchain could unintentionally reinforce existing inequities in land access and tenure security.

4.4.2. Importance of Stakeholder Education and Involvement in Building Trust

Stakeholder education and involvement emerged as central pillars in establishing public trust in blockchain-based land registration. Across focus group discussions and key informant interviews, respondents stressed that unfamiliarity with the technology creates fear, confusion, and skepticism. A community leader in Adama stated, *"People won't trust what they don't understand, especially if it deals with land they need to be part of the process, not just told after everything is done."* This highlights the need for early, transparent, and participatory engagement in the planning and implementation phases of any blockchain project.

Consistent with findings from UN-Habitat (2020) and Lemieux (2016), the lack of stakeholder involvement in past reforms in land governance was cited as a key reason for distrust. Participants noted that when policies are introduced without consultation, they are viewed as imposed, which undermines their legitimacy. Real estate professionals in particular emphasized that *"system rollouts must come with education campaigns tailored to each group—from farmers to brokers to officials."* These insights align with the view that trust in technology, especially one as transformative as blockchain, is closely tied to the degree of community participation and the transparency of its implementation.

Furthermore, government officials echoed that the success of any land governance reform depends not only on the technology but on how well people understand and feel included in its operation. This supports Kshetri's (2018) assertion that social trust precedes technical trust, particularly in low-trust societies or where governance institutions are weak. Therefore, public engagement must not be symbolic it should be structured, ongoing, and adaptive to local realities.

When asked to suggest strategies for encouraging adoption and building confidence, respondents offered pragmatic, community-oriented recommendations. Many emphasized localized training, where users can receive hands-on demonstrations of how blockchain platforms work. One respondent suggested, *"Start with pilot kebeles, bring the technology there with trainers who speak our language let people see the benefit for themselves."* This practical approach reflects global best practices in digital inclusion, where pilot programs are used not only for technical testing but also to build community support (World Bank, 2019).

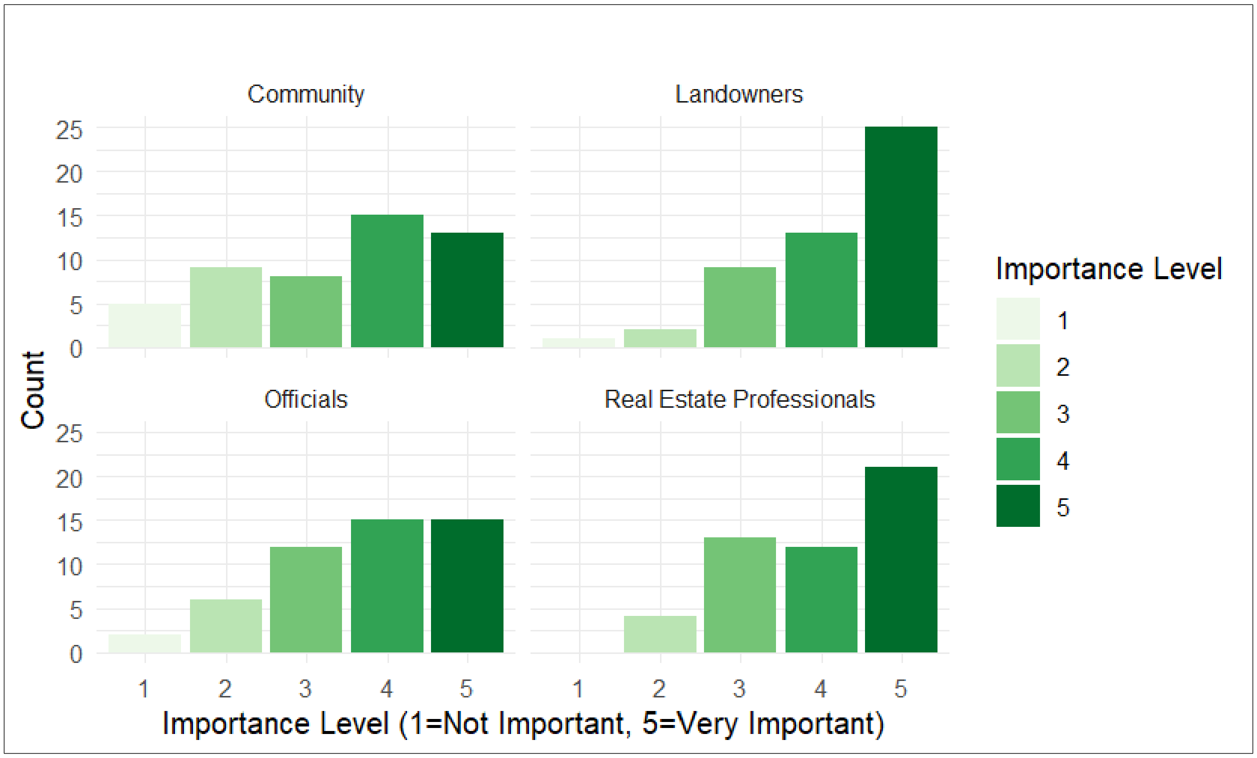

Figure 4-15: Perceived Importance of Stakeholder Education and Involvement

Another widely supported strategy was the deployment of trusted intermediaries such as kebele leaders, elders, or early adopters to advocate for the system and guide others. This form of peer validation, often called social proof in behavior change literature (Rogers, 2003), is especially powerful in traditional communities where personal relationships shape decision-making. A landowner said, *"If my kebele leader trusts it and uses it, I will trust it too."*

Infrastructural solutions were also discussed. Suggestions included setting up community information kiosks, developing mobile-friendly platforms, and offering offline services for rural areas with limited connectivity. These insights acknowledge the digital divide, which remains a serious barrier to blockchain adoption. As FAO (2021) notes, without bridging digital gaps, even the most well-intended reforms risk excluding the very populations they aim to empower.

Several respondents also recommended continuous feedback mechanisms such as community forums, call centers, and suggestion boxes to ensure that users have channels to report issues and suggest improvements. This aligns with the idea of iterative, user-centered design in digital governance, where platforms evolve based on real user experiences (OECD, 2020).

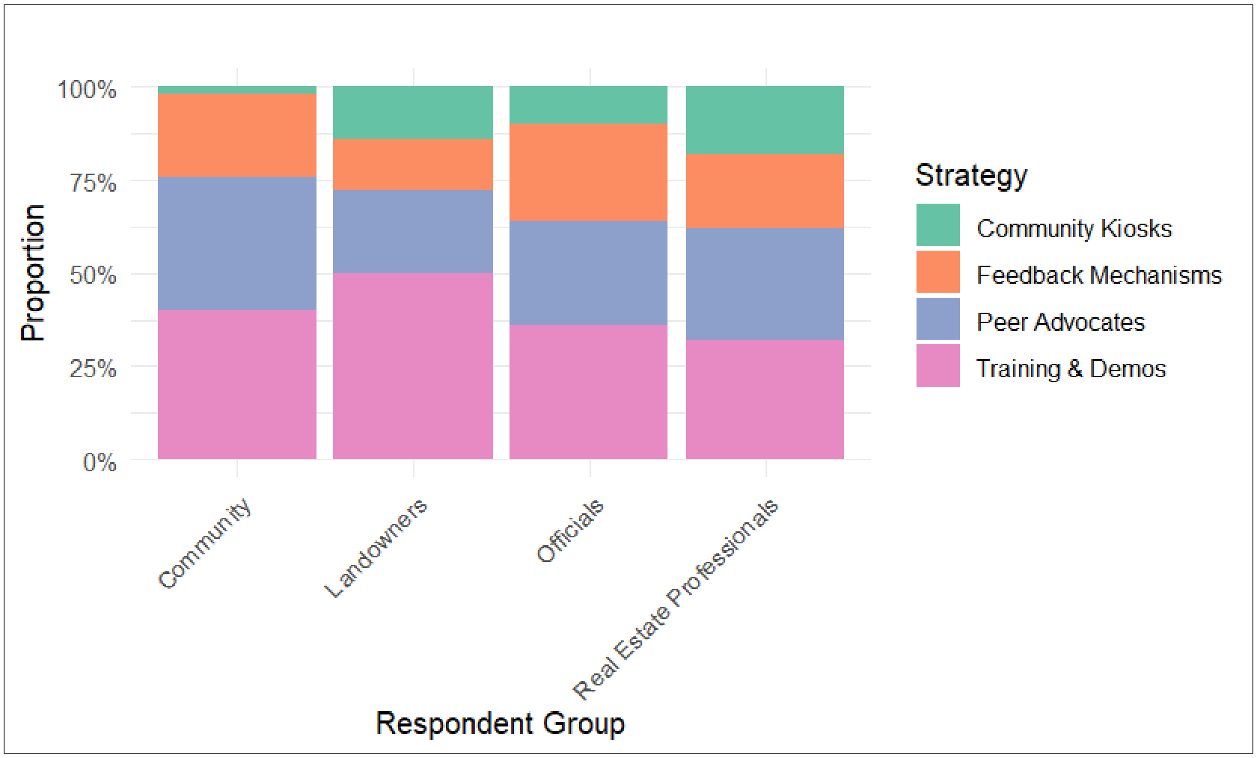

Figure 4-16: Preferred Strategies to Encourage Blockchain Adoption

4.4.3. Measuring the success of blockchain technology

Measuring the success of blockchain technology in improving public trust and access to land registration in Adama City requires a comprehensive and multifaceted approach. Stakeholders expressed that relying solely on technical metrics, such as the number of transactions recorded on the blockchain, would be insufficient. Instead, a combination of quantitative indicators and qualitative feedback mechanisms is necessary to capture both the objective improvements and the public's lived experience. For instance, repeated surveys measuring levels of public trust over time can reveal whether confidence in the land registration system is increasing. Such longitudinal data collection allows authorities to monitor trends and identify areas needing further intervention.

In addition to trust indices, stakeholders highlighted the importance of tracking user engagement metrics such as frequency of access to land records, especially among marginalized groups and remote communities. This reflects blockchain's potential to democratize access and reduce traditional gatekeeping. Moreover, measuring reductions in land disputes and legal conflicts was seen as a vital indicator, as fewer disputes would suggest that records are clearer, more reliable, and widely accepted. Officials also pointed out the value of tracking the timeliness and transparency of land transactions, as faster processing and public availability of records can directly impact trust and ease of access.

Figure 4-17: Perceived Improvement in Public Trust of Blockchain Implementation

Stakeholders strongly emphasized the necessity of embedding continuous feedback mechanisms into the system. These mechanisms could include digital channels such as mobile apps or hotlines, alongside traditional forums like community meetings. This multipronged feedback approach ensures that diverse groups, including those with limited digital literacy or infrastructure, have ways to report issues, ask questions, and suggest improvements. One landowner's comment captured this sentiment well: "If we can easily say what works and what doesn't, the system can improve, and trust will grow." Such ongoing two-way communication fosters a sense of ownership and helps adapt the technology to local needs over time.

4.5.Discussion

The implementation of a blockchain-based land administration system, as demonstrated in this study, finds both strong support and nuanced critique within existing literature. Scholars and practitioners have increasingly acknowledged blockchain's potential to address long-standing issues in land governance, particularly those related to transparency, data integrity, and trust. However, the effectiveness of blockchain technologies is often conditioned by socio-political, legal, and institutional contexts areas where this study contributes empirical clarity.

The visualization of historical ownership records confirms one of the most celebrated attributes of blockchain: immutability. Once land transactions are recorded, they cannot be altered or deleted, thus preserving a verifiable audit trail. This mirrors the arguments by Lemieux (2016), who emphasizes that blockchain's immutable ledger can act as a "recordkeeping infrastructure," protecting against record tampering, which is prevalent in many developing countries with weak property rights enforcement. Zhang et al. (2019) similarly argued that immutability offers legal clarity and public trust in tenure systems. In this research, the seamless history of parcel transactions and the ability to trace ownership over time support these claims by providing a practical implementation of the concept. However, this contrasts with traditional registry systems in countries like Ethiopia, Kenya, and Bangladesh, which, as noted by Deininger et al. (2012) and Byamugisha (2013), often rely on paper-based documentation that is vulnerable to loss, duplication, and manipulation.

The system's ability to facilitate multiple transactions between actors without the oversight of a centralized authority reflects the decentralized nature of blockchain. This is in line with the vision presented by Tapscott and Tapscott (2016), who describe blockchain as the foundation of a "trust protocol" where intermediaries such as registry offices become obsolete. The transaction diagrams (Figures 4-2 and 4-3) highlight how parties such as Jemila, Ibrahim, and Hanna participate directly in land transactions, validating the decentralization principle in real-world usage.

In contrast, traditional land systems in Sub-Saharan Africa, as reported by UN-Habitat (2012), are often hampered by bureaucratic delays, high transaction costs, and corruption. The ease and speed of transactions in your case enabled by smart contracts and instantaneous ledger updates represent a clear improvement over such systems. This affirms the arguments made by Yermack (2017), who noted that blockchain could drastically reduce inefficiencies in asset registries.

While decentralization promotes efficiency, it does not automatically guarantee equity. A common concern in literature is whether blockchain systems unintentionally exclude those without digital literacy or access to digital tools. In this respect, the system shows promise: ownership appears to be dispersed, and no actor dominates the land market, even among those who conducted multiple transactions (e.g., Jemila and Ibrahim). This outcome counters critiques such as those by Bloxham et al. (2021), who argued that blockchain implementations can reinforce digital divides and marginalize vulnerable populations unless proactively designed for inclusivity.

Nonetheless, equity remains a function of governance design. For example, in Ghana's blockchain pilot project, Asiimwe and Lajoie (2020) noted that although the technology improved data security, it failed to reach women and low-income users due to digital illiteracy and lack of sensitization programs. The spatial concentration of transactions in specific areas (Figure 4-6) provides an insightful lens into the evolving market geography. This aligns with Murray et al. (2020) who warned that digitized land markets may inadvertently intensify land speculation, especially in areas near infrastructure or urban centers. However, this study shows that even where transaction clusters exist, ownership remains relatively equitable, which contrasts with cases from India and the Philippines where blockchain land records were associated with gentrification and land grabbing (Patel et al., 2019).

The findings underscore the significant potential of blockchain technology to enhance public trust and accessibility in Adama City's land registration system. Consistent with prior studies (e.g., Crosby et al., 2016; Kshetri, 2018), blockchain's core attributes—immutability, decentralization, and transparency—are perceived by stakeholders as powerful tools to mitigate corruption and improve record integrity. Respondents' optimism aligns with empirical evidence showing that blockchain can provide tamper-proof ledgers that reduce opportunities for fraudulent alterations (World Bank, 2020). The improved transparency facilitates public scrutiny, which in turn builds confidence among landowners and other users, reflecting the theory of "trustless trust" inherent in blockchain systems (Buterin, 2014).

Moreover, blockchain's capacity to democratize access by enabling real-time, remote, and user-friendly retrieval of land information addresses long-standing access barriers, particularly for marginalized or rural populations. This echoes findings from studies in other contexts where blockchain reduced administrative bottlenecks and improved service delivery (Kaminski, 2019;

Zwitter & Boisse-Despiaux, 2018). However, respondents rightly emphasized that realizing these benefits requires carefully designed interfaces and supportive digital literacy initiatives, reinforcing that technology adoption depends on socio-technical ecosystems rather than technology alone (Heeks & Bailur, 2007).

Despite the promising outlook, the study reveals multiple challenges and barriers that align with documented hurdles in blockchain adoption for public administration. The lack of digital infrastructure and varying levels of digital literacy emerged as critical obstacles, especially among community members less familiar with technology. This is consistent with global reports (United Nations E-Government Survey, 2022) highlighting digital divides as key impediments to equitable blockchain implementation. Similarly, concerns about data privacy and the need to balance transparency with confidentiality echo the scholarly debate around blockchain's public ledger design, where openness may conflict with individual privacy rights (Zyskind et al., 2015).

Institutional and regulatory uncertainties also surfaced as significant barriers, mirroring findings from other case studies where legal frameworks lagged behind technology deployment, causing ambiguity around data ownership and responsibility (Casino et al., 2019). Furthermore, resistance from entrenched interests benefiting from opaque systems was noted, reflecting the socio-political dimensions of blockchain adoption (Tapscott & Tapscott, 2017). The critical role of stakeholder engagement and education to overcome these barriers resonates with digital governance literature emphasizing participatory approaches to build legitimacy and trust (Bannister & Connolly, 2014).

The implementation of a blockchain-based land administration system, as demonstrated in this study, aligns closely with key objectives outlined in international frameworks such as the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT) adopted by the FAO and UN Committee on World Food Security (CFS). These guidelines emphasize the importance of secure tenure rights, transparency, non-discrimination, and equitable access to land and other natural resources. Blockchain technology, by providing immutable and publicly verifiable land records, directly supports the VGGT principles of *transparency* and *accountability* in land governance. Moreover, the system's ability to document ownership history, prevent overlapping claims, and deter corruption strengthens the institutional capacity for land administration an objective echoed in Sustainable Development Goal (SDG) 1.4, which advocates for equal rights to ownership and control over land for all, including vulnerable groups. As shown in the results, the equitable distribution of land transactions and tenure durations in your case study suggests that blockchain, if inclusively designed, can serve as a practical tool to operationalize these global policy commitments, particularly in contexts where land tenure systems suffer from weak institutional frameworks and poor record integrity.

For blockchain-based land registration systems to gain legal recognition and institutional legitimacy in Ethiopia, it is essential to align technological innovation with existing legal frameworks. Ethiopian land laws currently do not recognize digitally recorded transactions as legally binding, which presents a major constraint to blockchain implementation (Girma et al., 2023). Therefore, policy reform must be initiated to formally integrate blockchain-validated records into the legal apparatus, ensuring their enforceability in courts and official transactions. Both federal and local governments play a crucial role in this transformation, particularly through updating registry laws, setting technical standards, and defining data ownership and responsibility within decentralized systems (World Bank, 2020; Asiimwe & Lajoie, 2020). Establishing clear legal protocols will help mitigate institutional resistance and promote the legitimacy of blockchain records in land governance (Kshetri, 2018).

While the pilot implementation demonstrates feasibility at the local level, scaling the system to a regional or national context introduces new layers of complexity. These include the cost of deploying necessary digital infrastructure, such as secure servers, nodes, and access devices, especially in remote or underdeveloped areas (UN E-Government Survey, 2022). Energy consumption and environmental sustainability are also critical concerns, particularly if resource-intensive consensus algorithms such as Proof-of-Work are used (Vranken, 2017). A shift toward more energy-efficient blockchain protocols (e.g., Proof-of-Stake) may address this issue. Furthermore, long-term maintenance and system updates require sustained financial and technical investment. Partnerships with technology providers, capacity building for local IT professionals, and robust public-private collaborations are key strategies for ensuring system sustainability beyond initial deployment (Casino et al., 2019; Zwitter & Boisse-Despiaux, 2018).

Blockchain technology has the potential to either bridge or widen digital divides, depending on how systems are designed and implemented. In Ethiopia, where digital literacy and access to mobile or internet services are unevenly distributed, particular attention must be given to marginalized populations such as women, the elderly, and residents of informal settlements

(Asiimwe & Lajoie, 2020; UN-Habitat, 2012). Proactive measures—such as mobile-friendly platforms, multilingual interfaces, and community-based training programs—are critical to ensuring broad-based accessibility and use (Heeks & Bailur, 2007). Moreover, involving community leaders and civil society organizations in system co-design can help ensure the needs of vulnerable groups are reflected (Bannister & Connolly, 2014). Without such inclusive strategies, blockchain systems risk reinforcing existing inequalities rather than promoting equitable access to land rights (Bloxham et al., 2021).

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1.Conclusion

In conclusion, this study has demonstrated the significant potential of Blockchain technology in enhancing the management of land parcels in Adama City, offering key improvements in transparency, traceability, and security. The findings reveal that Blockchain provides a permanent and immutable record of land ownership, ensuring that all transactions are transparent and auditable. Ownership changes, as illustrated through both the dynamic ownership timeline and transaction network, confirm Blockchain's capacity to log and verify land transactions without the need for a central authority, thereby reducing the risks of fraud, corruption, and unauthorized modifications.

The study found that ownership transitions, particularly the frequency and distribution of transactions, highlight the dynamic nature of land markets and the strategic role of certain individuals in acquiring and consolidating land. Parcels with multiple ownership changes demonstrated the flexibility of Blockchain to capture and preserve transaction histories, while the network analysis underscored the central figures within the system, such as Girma, Hanna, and Jemila, who played pivotal roles in redistributing land.

Additionally, the spatial analysis provided valuable insights into land transaction activity, identifying areas with high turnover and illustrating the flow of land ownership across the study area. The owner tenure duration analysis highlighted different landholding behaviors, showcasing both stability and intentional accumulation strategies. Finally, the blockchain audit log served as a robust tool for monitoring and verifying land transactions, ensuring that the entire process remained secure and tamper-proof.

Overall, the results confirm that Blockchain technology is a promising solution for improving land management systems. By providing a transparent, secure, and immutable record of land ownership, Blockchain can help mitigate disputes, enhance land governance, and promote a more efficient and equitable land market. Future research could focus on scaling this model to larger regions, integrating additional technologies, and addressing potential challenges such as user adoption and system interoperability.

5.2.Recommendations

Based on the findings of this study, the following recommendations are provided to enhance land management systems in Adama City and beyond:

- Given its potential to improve transparency, security, and traceability in land transactions, local governments and land administration agencies in Adama City should consider implementing Blockchain technology for land registration.
- To successfully implement Blockchain for land management, it is crucial to develop and maintain the necessary digital infrastructure, including secure servers, data storage systems, and internet access in rural areas.
- The government should develop a clear regulatory framework that integrates Blockchain technology into the legal system. This should include policies that recognize Blockchain records as legal proof of land ownership and transaction history, alongside traditional land deeds and certificates.

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Annexes

ASTU UNIVERSITY

College of Civil Engineering and Architecture (CoCEA)

Department of Architecture

FGD and KII guiding question

I am a researcher conducting a study on Enhancing Land Registration Systems Using Blockchain Technology: A Case Study of Adama City. This study seeks to better understand public trust, access to land information, and the potential use of blockchain technology in land governance. Your insights will help inform effective solutions, guide policy improvements, and support transparent and inclusive land administration in the future. Your participation in this discussion is completely voluntary. You are free to skip any question or withdraw at any time without any consequences. Please be assured that your responses will be treated with strict confidentiality your name or any identifying information will not appear in any reports. All information shared will be used solely for academic and research purposes.

Your honest views, experiences, and suggestions are very valuable to this study. If you feel comfortable, I would like to begin our discussion.

Thank you again for your time and willingness to participate.

Dagnie Arega

Cell phone: +251 96 809 0830

FGD Questions (For Community Members, Landowners, Real Estate professionals)

1. Current Trust in Land System

- How much do you trust the current land registration system? Can you share any experiences that shaped your trust or distrust?
- What factors increase or reduce your trust in the current land registration process?

2. Access to Land Information

- How easy or difficult is it to access land-related information currently? What barriers do you face?
- Who usually has better access to land information — officials, landowners, or others?

3. Understanding Blockchain's Role

- Have you heard about blockchain technology? If yes, what do you think it can do to improve land registration?
- How do you think blockchain might change the way land information is accessed and verified?

4. Blockchain & Trust

- Do you think using blockchain technology could increase your trust in land registration? Why or why not?
- What features of blockchain (e.g., transparency, immutability) do you believe could help build trust?

5. Blockchain & Access to Information

- How do you think blockchain can improve access to land records for the public?
- What challenges might people face in using a blockchain-based system for land information?

6. Concerns and Expectations

- What concerns do you have about blockchain replacing or complementing the current system?
- What would you expect from a blockchain-based land registration system to make it trustworthy and accessible?

KII Questions (For Officials, Policy Makers, Real Estate Professionals, Tech Experts)

1. Perception of Trust Issues

- What are the main reasons behind public distrust in the current land registration system?
- How do you see blockchain helping to resolve these trust issues?

2. Improving Access through Blockchain

- How might blockchain technology enhance public access to land information?
- What mechanisms would ensure that information on blockchain remains accessible and user-friendly?

3. Transparency & Accountability

- How can blockchain improve transparency and reduce corruption in land registration?
- Are there any potential drawbacks or risks to transparency when using blockchain?

4. Adoption Challenges Related to Trust and Access

- What are the potential challenges in getting the public to trust a blockchain-based system?
- How might limited digital literacy or infrastructure affect public access to blockchain land records?

5. Stakeholder Engagement

- How important is stakeholder education and involvement in building trust around blockchain?
- What strategies would you recommend to encourage adoption and build confidence?

6. Measuring Success

- How would you measure whether blockchain has improved public trust and access?
- What indicators or feedback mechanisms would you put in place?

Dagne Arega

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