

**DEVELOPMENT OF A BLOCKCHAIN-BASED
DECENTRALIZED APPLICATION WITH NFT FOR
LAND REGISTRATION**



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YOGYAKARTA
2025**

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**DEVELOPMENT OF A BLOCKCHAIN-BASED
DECENTRALIZED APPLICATION WITH NFT FOR
LAND REGISTRATION**

UNDERGRADUATE THESIS

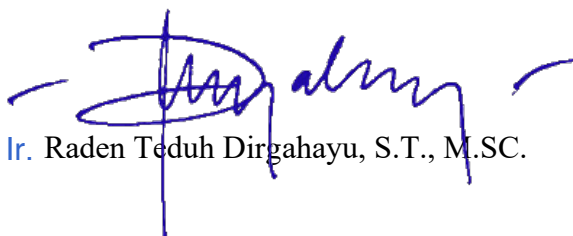
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Stating that all components and contents in this final project are my own work. If in the future it is proven that some parts of this work are not my own work, the final project submitted as my own work is ready to be withdrawn and ready to bear any risks and consequences.

Thus this statement letter is made, hopefully it can be used properly.

Yogyakarta, November 15, 2025



(Rahmat Nugrohoning Gesang)

DEDICATION

This final project is dedicated to Allah SWT, as a form of the author's worship and devotion to Him, and to my parents for their boundless love, prayers, and support which enabled the author to reach this point. It is also dedicated to all friends who have accompanied me and provided many invaluable lessons during my undergraduate studies.

MOTO

Dream without boundaries, pursue with absolute focus, and achieve with relentless consistency.

FOREWORD



Assalamu'alaikum Wr.Wb

Alhamdulillahirabbil'Alamiin, all praises and gratitude are extended to Allah SWT, The Most Gracious and The Most Merciful. It is through His countless blessings, guidance, and grace that the author has been able to successfully complete this Final Project, titled "Development Of A Blockchain-Based Decentralized Application With NFT For Land Registration". May Shalawat and Salam always be offered to our Prophet Muhammad SAW, his family, companions, and followers who faithfully adhere to his commands.

This Final Project has been prepared to fulfill the requirements for an undergraduate degree at the Informatics Study Program, Universitas Islam Indonesia. Throughout the process of writing this Final Project, the author has received invaluable assistance, encouragement, and guidance, both directly and indirectly, from various parties. Therefore, on this occasion, the author would like to express the sincerest gratitude to:

1. My beloved family, Mr. Komarodin Arief Kusuma and Mrs. Fina Notariyanti, who have always provided unwavering support and prayers, enabling the author to reach this point. Your tireless encouragement and constant reminders during moments of negligence and distance from Allah SWT have been truly instrumental.
2. Dr. Raden Teduh Dirgahayu, S.T., M.Sc., as the Thesis Supervisor and Head of the Department of Informatics, Universitas Islam Indonesia, for his dedication in guiding the author through the completion of this Final Project.
3. Mr. Irving Vitra Paputungan, S.T., M.Sc., Ph.D., as the author's Academic Advisor, for his guidance from the beginning to the end of the undergraduate study period.
4. Mr. Dhomas Hatta Fudholi, S.T., M.Eng., Ph.D., as the Head of the Undergraduate Program in Informatics Study Program.

5. To an individual whose presence was equally crucial, the holder of Student ID 21611060. Thank you for your tireless companionship, for always listening to the author's concerns, and for providing encouragement whenever the author was on the verge of giving up on this Final Project.
6. My fellow students of Informatics 21, especially those in the IP class Helga, Yasmin, Nadia, Diva, and Huda as well as friends from the “keluarga cemara” Dzikri, Emil, and Cikuy, who provided valuable assistance when the author faced confusion during the completion of this Final Project.

The author acknowledges that this Final Project is far from perfect, both in terms of structure and writing. Therefore, the author welcomes constructive criticism and suggestions from readers, which will serve as a valuable reference for future improvement. May this Final Project contribute to the readers' knowledge and be beneficial for the advancement of science and knowledge.

Wassalamu'alaikum Wr.Wb

Yogyakarta, November 15, 2025

A handwritten signature in black ink, appearing to read 'Nugro', with a stylized, circular flourish at the end.

(Rahmat Nugrohoning Gesang)

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Yogyakarta, October 22, 2025

(Rahmat Nugrohoning Gesang)

ABSTRACT

Development of a Blockchain-based Decentralized Application With NFT for Land Registration

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Land registration in Indonesia still faces many problems, such as duplicate certificates, document fraud, and slow administrative processes. These problems reduce trust and create conflicts between landowners. This research aims to develop a blockchain-based decentralized application (DApp) that uses Non-Fungible Tokens (NFTs) for managing land certificates. The goal is to improve the security, transparency, and efficiency of the land registration process. The system was built using smart contracts on the Ethereum blockchain. Each land certificate is represented as a unique NFT and contains metadata stored using the InterPlanetary File System (IPFS). Key features of the system include certificate issuance (minting), ownership transfer, and verification of land certificates. All transactions are recorded on the blockchain to ensure that the data cannot be changed or deleted. The result shows that the system can solve some key problems in the current land registration process. By using NFTs and smart contracts, land ownership becomes more secure and transparent. However, the system still has limitations, such as the lack of legal integration and user authentication. In the future, this system can be expanded to connect with national identity services and geographic data tools to support wider use in Indonesia.

Keywords: Blockchain, Decentralized Application, Land Registration, NFT, Smart Contract.

CHAPTER I

INTRODUCTION

1.1. Background

Land registration is a critical process in managing property rights and ensuring legal ownership of land parcels. It involves the systematic recording of land ownership, boundaries, and value, which is essential for establishing clear and reliable property rights. Land registration is necessary to provide legal security for landowners, facilitate land transactions, and support land-related economic activities. Without an efficient land registration system, landowners face risks of disputes, fraud, and uncertainty regarding their property rights.

In Indonesia, the land registration and certification system is managed by the National Land Agency (Badan Pertanahan Nasional, BPN). Despite its importance, the system faces significant challenges. By 2023, only 67% of land parcels in Indonesia had been certified, indicating a considerable gap in land registration coverage (Maharani, 2023). The system frequently leads to land disputes and inefficient administrative processes.

The existing land registration process involves multiple stakeholders, including BPN officers, notaries (Pejabat Pembuat Akta Tanah, PPAT), land surveyors, and property owners. Although electronic services like e-sertifikat have been introduced, the system still heavily relies on paper-based documentation and centralized databases, leading to various operational inefficiencies (Putra & Winanti, 2024). These inefficiencies are particularly pronounced in regions with high land transaction activities such as Java and Sumatra.

The prevalence of dual land certificates in Indonesia highlights significant weaknesses in the land registration system. A notable example of the system's shortcomings is the case of dual land certificates in Bogor Regency. This dispute involved PT Gaperi Prima and the local community over land intended for the construction of an apartment complex in Kedung Waringin Village. Both have certificates that were officially issued by the Land Office of Bogor Regency (Perdana Christa, 2018).

The complexity of these issues is further illustrated by a case in Kabupaten Nabire, Papua Tengah, where two individuals unknowingly purchased the same land parcel. The situation escalated when the original landowner initiated legal proceedings against both buyers. Investigations revealed that both purchases were made from the Chief of the Wate Tribe (Saputra et al., 2021).

A similar case occurred in Nganjuk, East Java. The issue began when Nurul attempted to divide a land certificate into her name and Muhtadin's. However, after a year, its process remained incomplete. It was later discovered that Nurul's certificate had been duplicated by a village official and used as collateral for a debt (Hadi, 2021).

Blockchain technology may offer an effective solution to many issues in Indonesia's land registration system. It uses a digital ledger to store every transaction permanently, ensuring that the data remains secure and transparent (Nugraha et al., 2022). A decentralized application (DApp), which operates on blockchain networks without centralized control, could potentially implement these features directly in a land registry system. Along with blockchain, Non-Fungible Tokens (NFTs), which are unique digital assets recorded on the blockchain, can be used to represent individual land parcels. Each NFT contains metadata, including ownership history, land boundaries, and legal status.

Kuznetsov et al., (2024) explain that NFT-based digital registries help prevent data loss, eliminate forgery, and enable permanent ownership verification. All of which are vital in land administration. NFTs are suitable for land certification because they provide a clear, unchangeable, and unique identity for each land parcels. This technology can help mitigate issues such as duplicate certificates, which are common in Indonesia's current system. NFTs can also be integrated with decentralized storage systems and smart contracts to automate and verify ownership records more reliably. It allows the land registration processes to be more efficient and less vulnerable to human error or manipulation.

Smart contracts are self-executing digital agreements built into the blockchain. In the context of land registration, they can be used to automatically perform tasks such as certificate issuance, ownership validation, and land transfer, as long as predefined conditions are met. Smart contracts offer a more secure

alternative. By recording each action in an immutable ledger, smart contracts combined with NFTs can create a transparent and legally accountable system (Nugraha et al., 2022).

Decentralized Applications (DApps) are software applications that operate on top of blockchain or peer-to-peer (P2P) networks without centralized control. Unlike traditional applications that rely on a single authority or server, DApps distribute their execution across multiple blockchain nodes, which enhances transparency, security, and resilience. In the context of land registration, DApps enable the automated execution of smart contracts, issuance of NFT-based land certificates, and peer-to-peer transfer of ownership. By removing single points of failure, DApps provide a stronger and more reliable system for secure land registries, making them practical for solving weaknesses in Indonesia's current land administration system (Zheng et al., 2023).

In remote areas of Indonesia, accessing land offices can be challenging, and administrative services are often slow or unavailable. A blockchain-based land registry that uses NFTs can reduce the reliance on a centralized system and make land registration services more available to rural residents. A Blockchain-based decentralized application using NFTs can improve access to secure land registration records, especially when integrated with decentralized digital tools such as smart contracts, IPFS, and MetaMask (Kuznetsov et al., 2024).

This research aims to propose a blockchain-based decentralized application using NFT for land registration to address current weaknesses and provide the foundation for a more secure and transparent digital land registry in Indonesia.

1.2. Problem Statement

How can a blockchain-based decentralized application using NFTs be developed to enhance the security, transparency, and efficiency of land registration in Indonesia?

1.3. Research Scope

This research focuses on:

1. Developing a blockchain-based decentralized application using NFT for land registration.
2. Implementing smart contracts to automate key process of land registration.
3. Using NFTs to represent land certificates.
4. Demonstrating key functions such as certificate issuance (minting), ownership transfer, and certificate verification.

The research does not include:

1. Physical land surveying and mapping processes.
2. Legal and regulatory reforms that is required to adopt blockchain-based certificates.
3. Integration with the BPN's existing database systems.
4. Complex cases that involve land conversion, land disputes, or customary rights (*hak adat*) on lands.

1.4. Research Objective

The objective of this research is to design and develop a blockchain-based decentralized application that uses NFTs for land registration, aiming to improve security, transparency, and efficiency compared to the existing centralized system.

1.5. Research Benefits

1. For the BPN : Provides an innovative proposal that potentially strengthens security, reduces fraud, and minimizes duplicate land certificates.
2. For landowners : Enables faster, transparent, and tamper-proof land administration.
3. For government : Provides reliable and transparent land ownership data to support taxation, urban planning, and dispute resolution.
4. For academia : Expands the research field on blockchain and NFT applications in public sector services.

1.6. Report Structure

This thesis consists of five structured chapters:

- a. Chapter I – INTRODUCTION

This chapter presents the background and significance of the study, followed by the problem statement, research scope, objectives, and expected benefits. It also outlines the overall structure of the report.

b. Chapter II – LITERATURE REVIEW

This chapter discusses the theoretical foundation relevant to the study, including concepts of land registration, blockchain technology, smart contracts, Non-Fungible Tokens (NFTs), and decentralized applications (DApps). It also reviews previous studies that serve as the academic basis and justification for the research.

c. Chapter III – METHODOLOGY

This chapter explains the methods used in the study, including analysis of the current land registration system, requirements identification, system architecture design, implementation, and testing. Each phase is described in detail to show how the proposed system was developed and validated.

d. Chapter IV – RESULTS AND DISCUSSION

This chapter presents the implementation results of the developed decentralized application. It includes the smart contract functions, black-box testing outcomes, user interface review, and simulation of system processes such as minting, transferring, splitting, and self-custody of land certificates. Comparative analysis with the conventional land registration system is also discussed.

e. Chapter V – CONCLUSION

This chapter provides the conclusions drawn from the research, summarizing key findings related to the system's performance and potential impact. It also presents the limitations of the study and recommendations for future research and practical adoption of blockchain-based land registration systems in Indonesia.

CHAPTER II

LITERATURE REVIEW

2.1. Theoretical Foundation

2.1.1. Function and Importance of Land Registration

A land registration is a record in the form of certificate that includes the area, value, and ownership of the land, and is used for taxation purposes (Syafaat, 2022). According to Article 1 point 20 of Government Regulation Number 24 of 1997, a certificate is a document that serves as proof of rights, applicable to land rights, management rights, waqf land, ownership rights to apartment units, and encumbrance rights that have been recorded in the relevant land register. This certificate provides legal certainty to the holder and functions as strong evidence in court in case of disputes over land ownership.

There are several types of land certificates in Indonesia, including the Freehold Title (Sertifikat Hak Milik, SHM), Building Use Rights Certificate (Sertifikat Hak Guna Bangunan, SHGB), Right to Use Certificate, and Business Use Rights Certificate (Sertifikat Hak Guna Usaha, SHGU). The existence of land certificates aims to provide legal certainty, prevent land disputes, and support economic activities by using certificates as collateral for loans (Santoso, 2019).

However, in practice, various problems related to land certification still occur. One common problem is overlapping ownership, also known as double certificates. For instance, a dispute occurred in Central Lombok Regency, where two parties each had a freehold title certificate for a 8,282 m² plot of land. This case happened due to administrative errors during the land registration process and the inaccuracy of officers in conducting measurements (Musmuliadi et al., 2023)

Another common problem is disputes over inherited land. These disputes usually happen because the process of dividing the inheritance and managing the land is unclear (Tampil et al., 2024) This situation can slow down the transfer of land rights and may lead to conflicts that need to be solved through legal means.

2.1.2. Blockchain

Blockchain is a technology used to store data in a series of records known as blocks, with each block connected to the next through cryptographic methods. It

serves as a decentralized ledger, allowing blockchain activities to remain transparent and unchangeable, which guarantees the integrity and security of the information it holds (Nakamoto, 2008). This technology offers a new solution to address issues related to document security and authenticity.

Some of the key features of blockchain include decentralization, where no single individual or organization controls the blockchain, making it more transparent and reducing the risk of fraud. Immutability means that once data is recorded, it cannot be altered or removed, ensuring that the blockchain remains tamper-proof. Transparency, in which every participant in the network has access to the same information, allows for verification and auditing by all parties. Consensus ensures that a new record can only be added when the majority of participants agree. This ensures the accuracy of data entered into the network (Nakamoto, 2008).

There are several components within blockchain. The distributed ledger stores all transaction data across the blockchain network, with every node (network maintainer) holding a complete copy of the ledger. Additionally, smart contracts are programs that enable transactions to automatically occur once specific conditions are met, eliminating the need for intermediaries. Moreover, cryptography is a vital component that secures data and ensures only authorized individuals can carry out transactions through the use of private and public keys (Guo & Yu, 2022).

The way blockchain works involves several steps. First, transaction details are added to a block. Then, most participants in the blockchain network validate the transaction through a consensus mechanism. After validation, the new block is linked to the previous ones by incorporating the cryptographic hash from the earlier block, ensuring the sequence remains intact and unchangeable (Nakamoto, 2008). Understanding the functioning and features of blockchain allows us to recognize its potential in various areas, including the management of land certificates.

2.1.3. Smart Contract

A smart contract is a program that automatically executes agreements based on predetermined conditions. In the context of blockchain, smart contracts are stored within the blockchain network, enabling transactions to occur without

intermediaries. This technology represents a significant advancement in automated contract execution and verification (Buterin, 2014).

Smart contracts possess several distinctive characteristics that make them superior to traditional contracts (Ante, 2021).

- a. Transparency : Smart contracts are stored in a distributed blockchain ledger, allowing all parties to view the contract's contents, which reduces the risk of fraud.
- b. Security : Smart contract activities happen within the blockchain network, ensuring that all activities or changes to the contract are recorded and cannot be deleted. Additionally, all transaction histories are publicly transparent but cryptographically secured, making them secure and difficult to change.
- c. Autonomy : Smart Contracts operate without intermediaries or third parties, meaning that when conditions are met. The program runs automatically, minimising errors and increasing efficiency.

The working process of a Smart Contract begins with writing code that includes specific conditions or requirements. The written Smart Contract is then deployed into the blockchain network. When certain conditions are met, the Smart Contract automatically executes (Buterin, 2014). For example, if someone wants to transfer property rights, the program will automatically transfer ownership rights once specific conditions have been met.

Smart Contracts represent a fundamental advancement in contract technology through their ability to self-execute and enforce agreements through code. The combination of automated execution, immutability, and cryptographic security makes them a significant evolution beyond traditional contract systems.

2.1.4. Non-Fungible Token (NFT)

A Non-Fungible Token (NFT) is a digital representation of ownership for a unique asset stored on a blockchain network. Unlike regular tokens that can be swapped for one another, NFTs are indivisible and contain unique 'metadata' (or specific data) that makes each one different (Patil, 2020). While NFTs are commonly used to represent digital artworks, music, and collectibles, their use has extended into real-world asset domains, including property and land ownership.

NFTs are typically created using smart contract standards such as ERC-721 or ERC-1155 on platforms like Ethereum. When an asset is “minted” into an NFT, its ownership information, description, and associated rules are permanently recorded on the blockchain. In the context of land registry, this enables each plot of land to be uniquely and immutably represented, reducing the risks of forgery or duplicate documentation (Patil, 2020).

The advantages of NFTs in land registration include authentication of ownership, transparency, and global accessibility. Since the transaction history is traceable and transparent, disputes arising from overlapping land titles can be minimized. Additionally, blockchain-based NFTs support decentralized systems, reducing reliance on intermediaries and making the land registration process more resistant to fraud and data manipulation (Dwivedi et al., 2023).

Despite its potential, the implementation of NFTs in property systems faces several challenges. One of the key issues is the need for robust digital infrastructure and the legal recognition of NFTs as a valid form of proof of ownership. Many jurisdictions have yet to establish laws or regulations that integrate blockchain-based tokens into the formal property registry system. Moreover, public understanding of NFT technology remains limited, which may hinder its large-scale adoption (Ilesanmi & Idowu, 2024).

NFTs offer a promising technological solution for digitizing land ownership systems. When combined with blockchain and smart contract functionalities, they can enable secure, efficient, and transparent management of land certificates in the future.

2.1.5. Decentralized Application (DApp)

Decentralized Applications (DApps) are applications that run on blockchain networks and are not controlled by a single entity. Unlike traditional applications that rely on central servers, DApps operate on peer-to-peer networks distributed across many computers (Buterin, 2014). This enables users to have greater control over their data and assets with reduced dependence on centralized third parties. These applications can be used across various domains to enhance transparency, security, and user autonomy in digital transactions.

DApps have several key characteristics that distinguish them from conventional applications.

- a. Open-source: The source code of DApps is available to the public, allowing anyone to inspect and contribute to its development.
- b. Decentralization: Data is stored across multiple nodes in the network, eliminating single points of failure and enhancing security through consensus mechanisms.
- c. Autonomous operation: DApps run on smart contracts that execute automatically without the need for intermediaries.
- d. Cryptographic security: All operations are secured through advanced cryptography.
- e. Incentivization: DApps often use tokens as incentives for users to participate in the network.

These characteristics make DApps a significant advancement in application development, particularly in scenarios where transparency, security, and user participation are essential (Verma et al., 2024).

The development process of DApps involves several technical steps. First, developers must choose an appropriate blockchain platform, such as Ethereum or Binance Smart Chain. They then select the programming language used on that platform, such as Solidity for Ethereum. Subsequently, they design and implement smart contracts that control the DApp's business logic. After testing and improvement are completed, a user interface (UI) is built to facilitate user interaction with the DApp. This process concludes with the launch of the DApp on the blockchain network (Popchev & Radeva, 2024).

The blockchain platforms used for DApp development continue to evolve, with popular options like Ethereum and Binance Smart Chain leading the way. These platforms provide the fundamental infrastructure and programming tools necessary for creating and deploying decentralized applications, each offering different advantages in terms of speed, cost, and scalability.

2.2. Previous Studies

Krishnapriya and Sarath (2020) investigate the application of blockchain technology to improve the security and efficiency of the land registration process.

The research stems from the persistent issues of inaccuracies and vulnerabilities in traditional land registration systems, which are often prone to illegal practices, data tampering, and integrity loss. These challenges emphasize the urgent need for a more secure and transparent system. The study aims to create a blockchain-based land registration framework that ensures higher levels of security, transparency, and operational efficiency.

The methodology includes several stages: identifying key issues in current systems, designing a blockchain architecture tailored for land registration, implementing consensus algorithms to verify transactions, and conducting rigorous system testing to ensure its effectiveness. The study also analyzes blockchain's ability to maintain data integrity and reduce fraud. By creating a distributed and immutable ledger, blockchain addresses the shortcomings of centralized systems.

Results indicate that blockchain technology significantly enhances the security and transparency of land registration processes while mitigating risks of fraud. This technology not only streamlines the registration process but also instils greater confidence among stakeholders by ensuring data immutability. The research concludes that adopting blockchain in land registration systems is a transformative step toward modernizing these services, particularly in regions with inefficient systems.

The study by Nugraha et al. (2022) examines the implementation of blockchain technology in enhancing land services provided by Indonesia's Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN). The background issue is the inefficiency and lack of reliability in traditional, paper-based administrative systems, which often result in delays and uncertainties during the issuance of land certificates. Blockchain is proposed as a solution to address these inefficiencies by providing a more secure, transparent, and efficient administrative system.

The research employs various methods, including direct observation, stratified sampling, system analysis, and blackbox testing, to evaluate the performance of the blockchain system. Case studies are conducted at BPN to provide real-world insights into its application. The analysis focuses on how blockchain technology

enhances the security and operational processes of land certificate administration, addressing critical pain points such as fraud and procedural delays.

Findings reveal that the blockchain system has the potential to greatly reduce the complexities and risks inherent in traditional systems. By eliminating intermediaries and centralizing data on a distributed ledger, the technology speeds up administrative processes and enhances security. The study concludes that blockchain is an effective tool for modernizing land services and represents a significant innovation in addressing long-standing inefficiencies in Indonesian land management.

Negara, Maylinda, and Pratiwi (2021) emphasize the importance of implementing robust security measures for digital land certificates to address the high risk of forgery and inefficiencies in traditional systems. The background highlights that as digitalization becomes more prevalent, land certificates are increasingly susceptible to fraudulent activities. To address these challenges, the research proposes blockchain technology as a security solution that can safeguard digital land certificates.

The research adopts a multi-stage methodology that includes reviewing existing literature on land certificate systems, analyzing current security protocols, designing a blockchain-based security model, and evaluating the system's effectiveness through testing. By employing blockchain, the study aims to create a tamper-proof digital ledger that records transactions and changes to land certificates transparently and immutably.

The findings reveal that the blockchain system not only reduces forgery risks but also fosters greater trust among stakeholders, including landowners and governmental agencies. With a decentralized structure, blockchain ensures that digital land certificates are secure from unauthorized alterations while also simplifying the verification process. The study concludes that integrating blockchain technology into land management systems is crucial for enhancing public trust, reducing fraud, and achieving more efficient governance.

The study by Wang, Li, Wang, and Chen (2021) reviews the Non-Fungible Token (NFT) ecosystem. This paper outlines the key components of NFT, including the technical design, token standards, and security concerns, as well as the

opportunities and challenges presented by the technology. The authors write this review because NFTs are growing very fast and seen as a new way to trade and own digital assets, but the technology is still new and not easy to understand.

The paper collects and summarizes current NFT solutions. It explains blockchain structure, smart contracts, and token standards such as ERC-721 and ERC-1155. The authors also use the STRIDE model to study security risks, showing problems with privacy, scalability, and interoperability. To make it clearer, the study gives examples of NFT projects in areas like digital art, tickets, games, and virtual collections.

The results show that NFT has big potential to change digital ownership. But, the technology and regulation still need improvement before NFTs can be used by many people. This paper gives useful knowledge for both researchers and professionals, and it also opens discussion about the future of NFT in the global system.

Fikri and Anggoro (2022) examine the application of smart contracts based on blockchain technology in real estate transactions in Indonesia. Their research focuses on addressing the limited understanding and application of contract law and technology in the context of smart contracts, particularly in property-related transactions. The study's primary goal is to analyze the legality of smart contract implementation under Indonesia's existing legal framework and to identify potential obstacles to its adoption.

The research employs a normative juridical approach, analyzing various legal materials, including primary laws, secondary interpretations, and tertiary supporting documents. The methodology involves a detailed assessment of Indonesia's current legal system to determine whether smart contracts can be legally recognized and effectively applied in real estate transactions.

The results demonstrate that smart contracts can revolutionize the way real estate transactions are conducted, offering greater transparency, efficiency, and security compared to traditional methods. However, the study also highlights significant challenges, such as gaps in legal recognition, limited technical expertise, and a lack of supporting infrastructure. The research concludes that while smart

contracts have the potential to transform property transactions, these challenges must be addressed to ensure seamless implementation.

Table 2.1 Previous Studies

No.	Reference	Objective	Method	Result
1	Krishnapriya & Sarath (2020)	To develop a secure and transparent land registration system using blockchain technology.	<ol style="list-style-type: none"> 1. Identification of problems in the existing land registration system. 2. Design of a blockchain-based system architecture. 3. Implementation of a consensus algorithm for transaction verification. 4. System testing to ensure security and efficiency. 5. Analysis of results and system evaluation. 	The implementation of blockchain technology in land registration can significantly enhance the security, transparency, and efficiency of the land registration system.
2	Nugraha et al., (2022)	To analyze the effectiveness of the blockchain system in improving land services at the Ministry of Agrarian Affairs and Spatial Planning.	<ol style="list-style-type: none"> 1. Data collection through observation. 2. Stratified sampling. 3. System analysis. 4. Blackbox testing to test the effectiveness of blockchain. 	The blockchain system has high potential to enhance security and efficiency in land services at the Ministry of Agrarian Affairs and Spatial Planning.
3	Negara et al., (2021)	To analyze and propose an effective security system for digital land certificates.	<ol style="list-style-type: none"> 1. Literature review on land certificates and digitalization. 2. Analysis of existing security systems. 3. Development of a security system model for digital land certificates. 4. Testing and evaluation of the developed model. 	An effective security system for digital land certificates is crucial to protect land rights and encourage public trust in the land system.
4	Wang et al., (2021)	To give a systematic review of current NFT	<ol style="list-style-type: none"> 1. Gather and summarize current NFT solutions. 	NFT has strong potential to transform digital ownership. However, technology

		solutions and to evaluate the technical parts, security, opportunities, and challenges.	<ol style="list-style-type: none"> 2. Identify NFT technical components, protocols, and standards. 3. Conduct a security evaluation using the STRIDE model. 4. Analyze future NFT opportunities and challenges. 5. Present case studies and NFT projects for illustration. 	and regulation still need improvement before it can be widely adopted.
5	Fikri & Anggoro (2022)	To analyze the legality of smart contracts in real estate transactions based on the applicable laws and regulations.	<ol style="list-style-type: none"> 1. Conducted using a doctrinal or normative juridical(yuridis normatif) approach. 2. Examine secondary data consisting of primary, secondary, and tertiary legal materials. 3. Descriptive-analytical approach to provide a factual and accurate depiction. 	Smart contracts can be a legitimate alternative in real estate transactions, although there are still challenges in their implementation.

CHAPTER III

RESEARCH METHODOLOGY

This chapter describes the research methodology used to design, develop, and evaluate an innovative blockchain-based decentralized application using NFT for land registration. This methodology includes an overview of the existing system, the proposed innovation, its requirements, design, and testing procedures.

3.1. Overview of the Existing Land Registration System in Indonesia

3.1.1. The Existing Land Registration System

The land registration process in Indonesia is regulated by the BPN to provide legal recognition of land ownership and prevent disputes. This process involves several stakeholders, including landowners, notaries, surveyors, and government officials; each of whom performs specific roles under applicable regulations. The general procedural flow is as follows:

1. Application Submission

Actors : Landowner as applicant; village or kelurahan office for initial endorsement; PPAT or notary when the submission relates to transfer or new title formation (Peraturan Pemerintah No. 24 Tahun 1997, Pasal 10).

Inputs : Personal identification, proof of land possession or deed, tax proof such as PBB and BPHTB where relevant, letter of no dispute from the village office, site sketches or legacy maps, and contact details of boundary neighbors for later acknowledgement (Peraturan Pemerintah No. 24 Tahun 1997, Pasal 13; BPN, 2020).

Process : The applicant completes a standard BPN application form at the local land office counter or through an available e-service (Peraturan Menteri Agraria No. 3 Tahun 1997). Documents are checked for completeness, scanned, and indexed to a case number. Fees are calculated and a payment slip is issued.

Outputs : Payment receipt, case number, and a document checklist with any missing items noted.

2. Document Verification

Actors : BPN administrative officer and legal reviewer; PPAT or notary may be contacted for deed clarification; village officials may be asked to confirm prior letters.

Inputs : The complete case file containing all scanned documents and the internal index record.

Process : Officers validate identity consistency, deed authenticity, tax status, prior encumbrances, and whether the parcel overlaps with existing titles in the registry (Peraturan Pemerintah No. 24 Tahun 1997, Pasal 23). They prepare a verification note and determine whether the file is admissible for measurement.

Outputs : Verification memo that approves the file for survey or returns it for correction; an internal schedule request for field work if approved.

3. Survey and Measurement

Actors : Licensed surveyor or BPN survey team; landowner and boundary neighbors who witness; village representative for local confirmation (Peraturan Pemerintah No. 24 Tahun 1997, Pasal 14).

Inputs : Approved verification memo, provisional parcel sketch, historical or village map, and contact information of boundary neighbors

Process : Field measurement is scheduled. The surveyor visits the site, places or confirms boundary markers, measures with total station or GNSS equipment, records coordinates, and drafts a measurement sketch that reflects actual conditions (Peraturan Kepala BPN No. 3 Tahun 1997). Neighbors sign the boundary acknowledgment form to minimize future disputes (Peraturan Pemerintah No. 24 Tahun 1997, Pasal 15). The technical drawing is compiled into a measurement report that includes coordinate lists and area calculation.

Outputs : Measurement report with coordinate geometry, boundary acknowledgment forms, and an updated parcel map ready for technical validation in the office.

4. Certificate Issuance

Actors : BPN technical validation officer and head of office for authorization; printing and archival unit for certificate production; registry clerk for index updates (Peraturan Pemerintah No. 24 Tahun 1997, Pasal 26 & 30).

Inputs : Verified case file plus the approved measurement report.

Process : Office validation ensures the measured parcel does not overlap registered titles and that legal prerequisites are satisfied. The parcel is encoded into the cadastral index, a unique title number is assigned, and the certificate is produced physically or electronically where e-certificate is available (Peraturan Menteri ATR/BPN No. 1 Tahun 2021). The registry is updated and the case is closed.

Outputs : Land certificate containing owner identity, parcel boundaries, area, and title number; registry entry and digital scans stored in the office archive; release note for applicant collection.

Electronic services such as e-certificates have also been introduced to modernize several aspects of the registration process.

3.1.2. Areas for Potential Improvement

Although the existing system operates well, technological advancements open opportunities for further improvements in several areas:

1. Digital Integration

Integration with new technologies to improve the existing documentation system.

2. Process Efficiency

Modern technology can help streamline specific administrative processes.

3. Data Accessibility

Enhanced digital platforms could improve access to land information for authorized parties.

4. Security Enhancement

Cryptographic technology can provide additional layers of data protection.

These innovation opportunities are in line with Indonesia's broader digital transformation initiatives and the global trend of modernizing public services.

3.2. The Proposed Innovation of The Use of Blockchain and NFT for Land Registration

This research proposes a blockchain-based decentralized application using NFT for land registration as a technological advancement that can complement the existing land registration system. The application use blockchain technology to offer enhanced benefits in terms of transparency, security, and efficiency. This research aims to demonstrate how blockchain technology using NFTs can function in land registration.

3.3. Requirements Analysis

The requirement analysis was conducted to defines the application's functional requirements, users, limitations, and the assumptions that form the basis of the application's development.

The system must have the following main functionality:

1. Certificate Minting

A landowner can request the creation of a new digital land certificate by submitting signed data and documents. The institution verifies and executes the request on the blockchain, generating a unique NFT certificate.

2. Ownership Transfer

A certificate owners can transfer the ownership of his/her NFT certificates to other parties securely and transparently.

3. Certificate Splitting

A landowner can request to divide an existing certificate into several new ones. After verification and approval, the institution executes the process, creating child NFTs linked to the parent certificate.

4. Ownership and Authenticity Verification

Users, including the general public, can verify the ownership status, authenticity, and complete history of a certificate through the application interface.

5. Institution Management

The owner of the smart contract has the authority to add or remove addresses recognized as official institutions.

3.3.1. System Users

There are three main parties who can interact with the system:

1. Owner (System Administrator)

A user that deploys the smart contract and manage institutions such as the National Land Agency (BPN) and its regional land offices. In the initial deployment, the contract owner is also set as the first institution.

2. Institution (e.g., BPN)

A user authorized by the Owner to perform key functionalities such as execute minting new certificates and splitting certificates.

3. Land Owner (General User)

A user that owns one or more land certificate NFTs. He/she can request certificate minting and splitting, perform ownership transfers and view their property details.

3.3.2. Use Case Diagram

The Use Case Diagram in **Figure 3.1.** illustrates the interactions between actors and the system. It identifies the primary users, their roles, and the functionalities provided by the system.

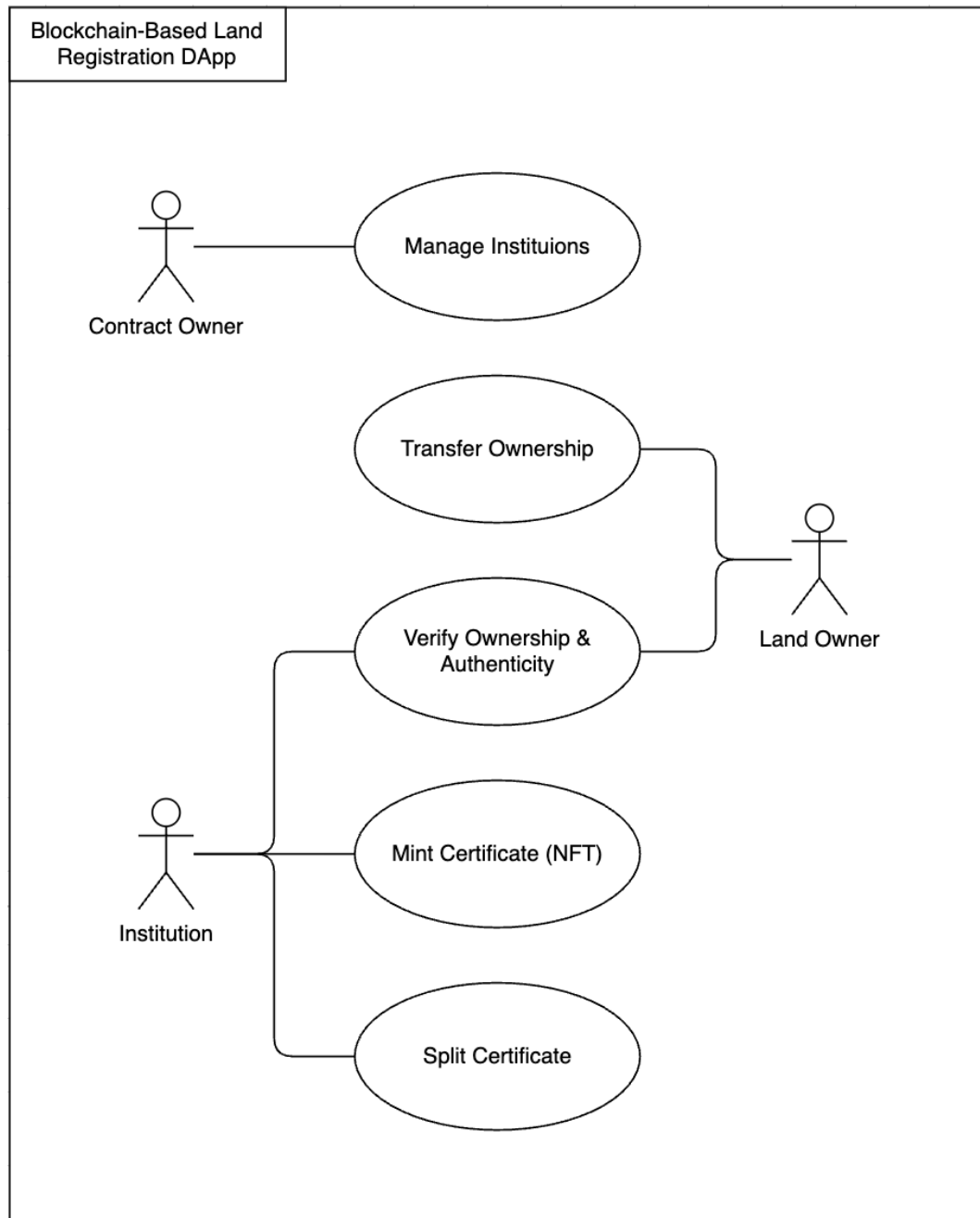


Figure 3.1 Use Case Diagram of the System

3.3.3. Scope of System Development

The developed system has the following constraints:

1. The system is developed as a website-based application prototype.
2. The application is not integrated with the BPN's existing databases or legacy systems.
3. Interaction between the application with the blockchain is only tested using the MetaMask browser extension digital wallet only.

4. Physical activities such as land surveying and mapping are beyond the scope of this system. Therefore, the system does not include functions for entering spatial data, recording coordinates, or connecting to mapping services.

3.4. Design

3.4.1. Decentralized Application (DApp) Architectural Design

The system has a fully decentralized architecture without a central server. The main components of this architecture include:

1. Blockchain Network

The blockchain serves as the decentralized storage and execution environment for the system. All transactions and state changes are recorded immutably across distributed nodes.

2. Smart Contract

The smart contract defines the core business logic of the system, including ownership management, certificate transfer, and splitting. It executes automatically within the blockchain environment to ensure transparency and eliminate manual intervention.

3. IPFS (InterPlanetary File System)

This component serves as a decentralized file storage system for all detailed NFT metadata (images, legal documents, and photos of land location). The NFTs on the blockchain only stores a reference to this data through a unique Content Identifier (CID), which acts as a hash-based address that permanently points to the file stored in IPFS.

4. Frontend (React.js)

This component serves as an interactive user interface accessed through a browser, which communicates directly with the smart contract to send transactions such as minting new certificates, transferring ownership, and splitting certificate.

5. MetaMask

It is a digital wallet used by users to manage their NFTs, connect to the DApp, and sign blockchain transactions.

The Dapp's architecture is depicted in **Figure 3.2**.

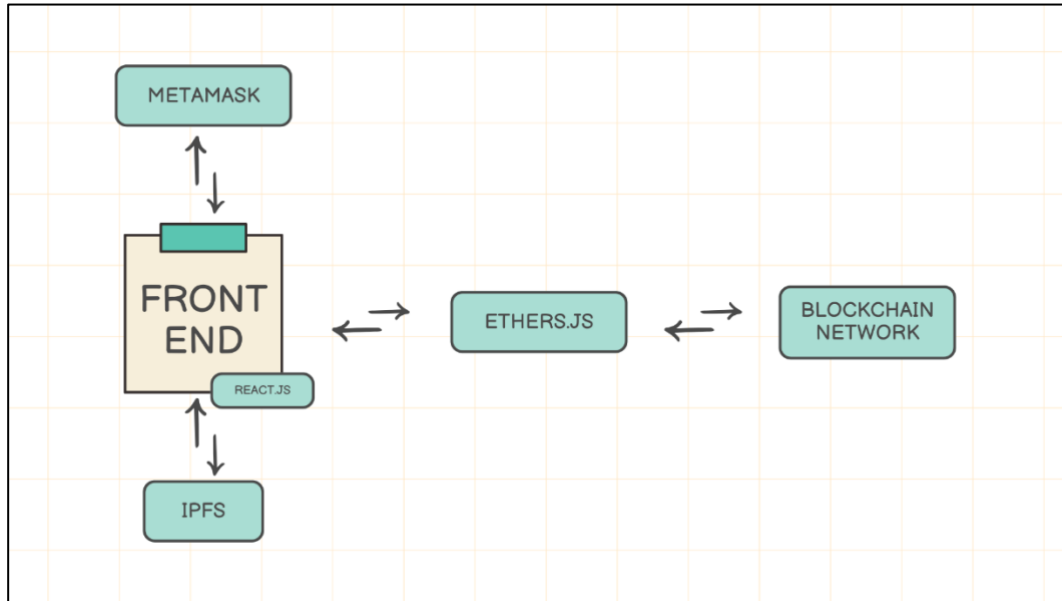


Figure 3.2 Architecture of the DApp for Land Registration

3.4.2. Functionality Logic

The following are the key processes in the DApp.

1. Certificate Minting Process

The certificate minting process begins when the landowner accesses the mint request page and fills out the form containing details such as location, area, and supporting land documents. Once the form is submitted, the data and documents are uploaded to IPFS, which generates a unique Content Identifier (CID) to represent the metadata file.

After obtaining the CID, the system automatically prepares a structured message following the EIP-712 standard. The landowner's wallet application (MetaMask) then displays a digital signature request for confirmation. When the owner signs it, a mint request is created, containing the signed data, CID, and other necessary information. This request is temporarily saved in the local storage until reviewed by the authorized institution.

The institution accesses the Execute Mint interface to view all pending requests. Once the institution selects a request and submits it for execution, the smart contract verifies the signature to ensure that it was signed by the correct owner and that the request is still valid within its allowed time. If everything is valid, the system creates a new NFT certificate on the

blockchain and assigns ownership to the landowner's wallet address. The minted NFT includes the metadata URI pointing to IPFS, making the certificate traceable and verifiable on-chain.

This process ensures that every minting process originates directly from the landowner's consent and that institutions act only as executors of verified requests. The complete flow is illustrated in **Figure 3.3**.

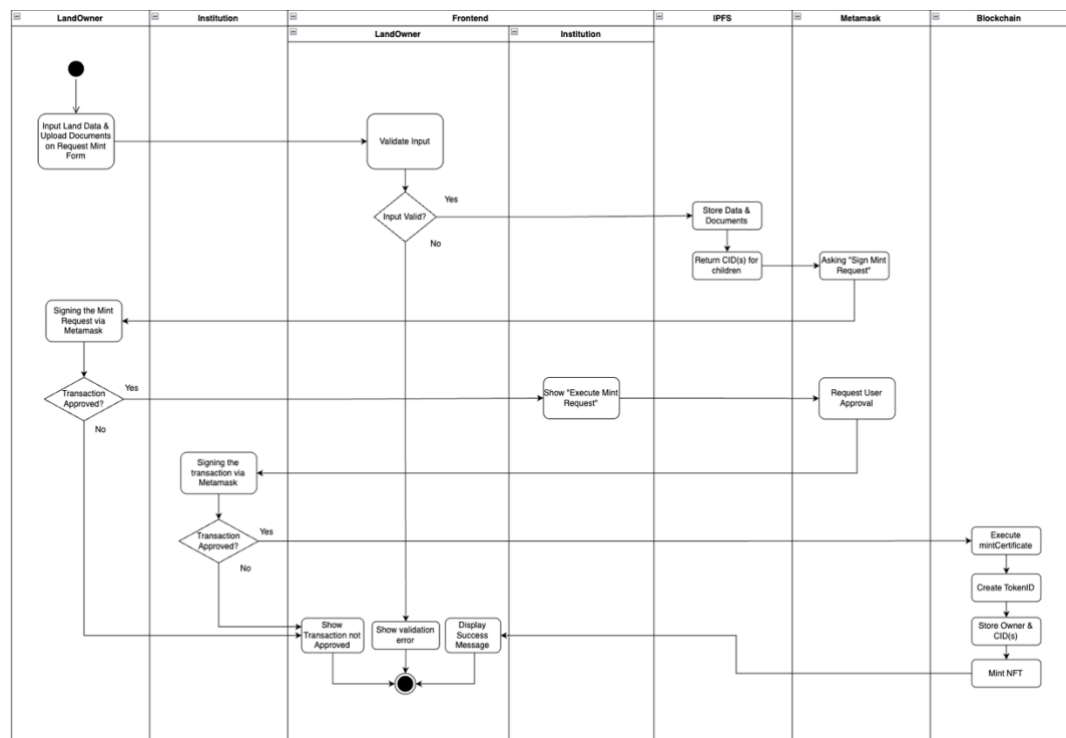


Figure 3.3 Minting Process Flowchart

2. Certificate Splitting Process

The certificate splitting process begins when the landowner opens the certificate details page and selects the option to split the existing certificate. The owner fills out the split form by adding the list of recipients and the details for each new land parcel. Each set of data and supporting documents is uploaded to IPFS, resulting in multiple CIDs that uniquely represent each child certificate's metadata.

The system then creates a structured EIP-712 message that summarizes the split details. The landowner signs this message digitally through MetaMask, producing a split request that is saved locally. To allow the

institution to perform the on-chain execution, the owner must provide approval for the specific parent certificate within the application interface.

After receiving the request, the institution accesses the Execute Split page and reviews all pending split requests. The system checks whether the approval from the landowner has been granted. Once verified, the institution executes the process. The smart contract confirms the validity of the signature, ensures that the parent certificate is still active, and checks that the institution has been granted permission to act. When all conditions are met, the parent certificate becomes inactive, and several new child NFTs are minted on the blockchain. Each new NFT stores its corresponding CID and is linked back to the original parent certificate, allowing transparent tracking of the land division.

This updated approach introduces a double-layer validation—landowner authorization through digital signature and institutional execution—resulting in a more transparent and secure certificate splitting workflow. The entire logic is shown in **Figure 3.4**.

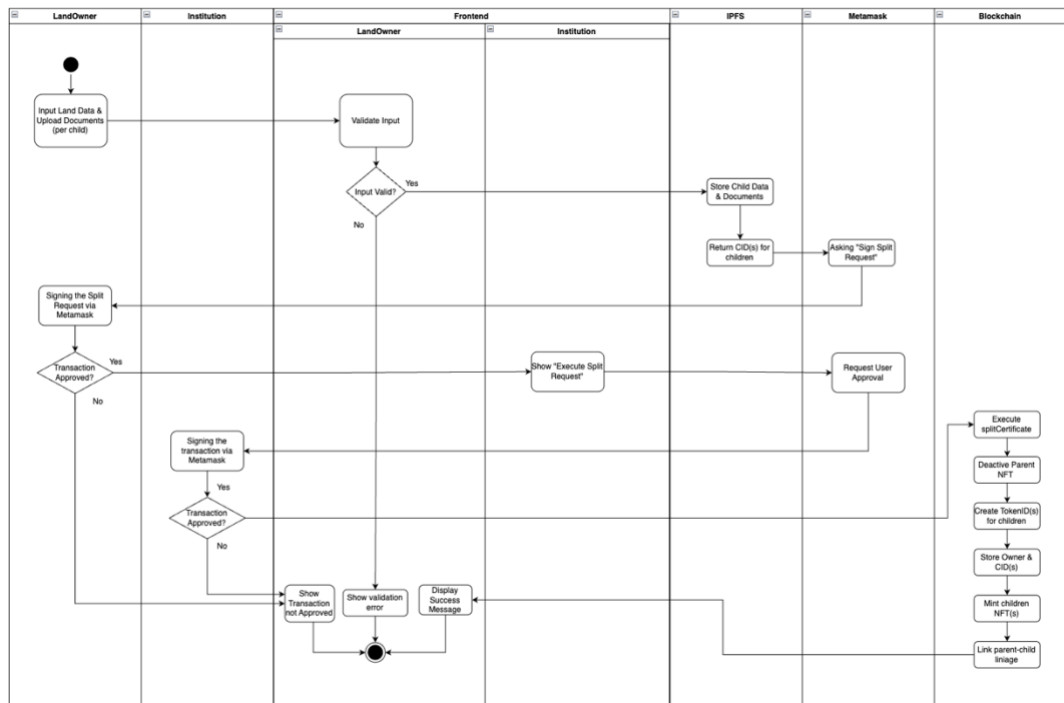


Figure 3.4 Split Certificate process flowchart

3. Certificate Transfer Process

The process starts when an NFT owner enters the recipient's wallet address. The DApp then prepares the transfer transaction. The owner must approve and sign this transaction via his/her digital wallet (Metamask). If the blockchain successfully validates the transaction, the ownership of the NFT will be transferred to the recipient. The process is depicted in **Figure 3.5**.

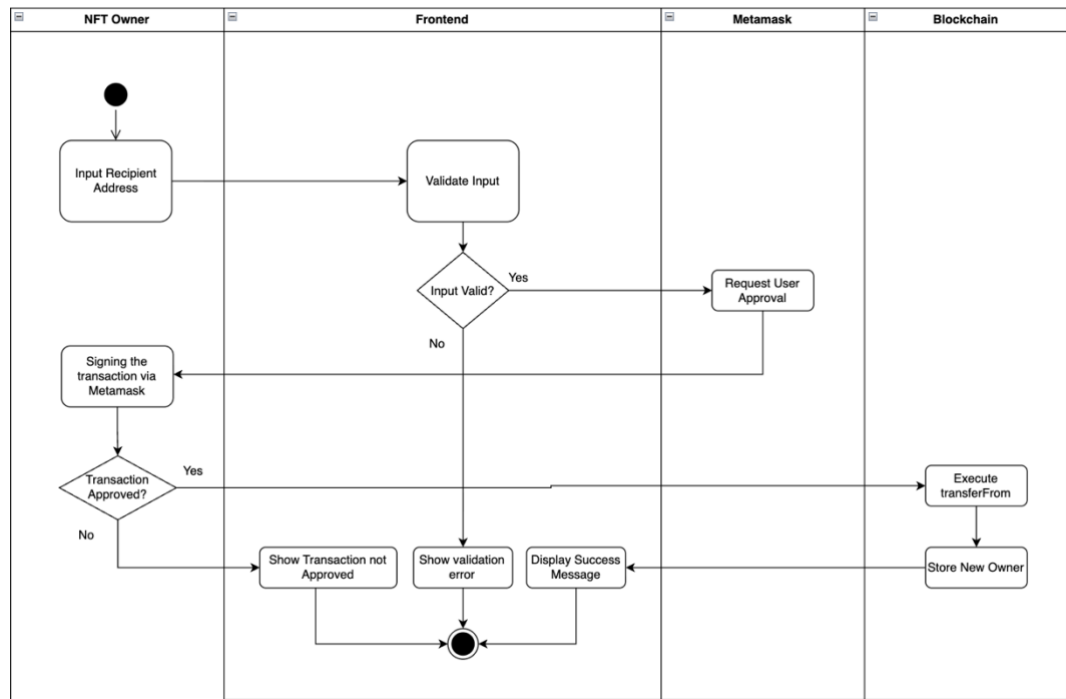


Figure 3.5 Certificate Transfer process flowchart

4. Ownership and Authenticity Verification Process

This process begins with a user enters a certificate's token ID into the verification field on the Dapp, which then queries the blockchain to check whether the token exists. If the token is found, the DApp retrieves and displays all relevant details, including the current owner's address, certificate metadata from IPFS, and the certificate's status (active or inactive). If the token does not exist or has been revoked, the DApp displays an "Error verifying NFT" message to the user. The process is illustrated in **Figure 3.6**.

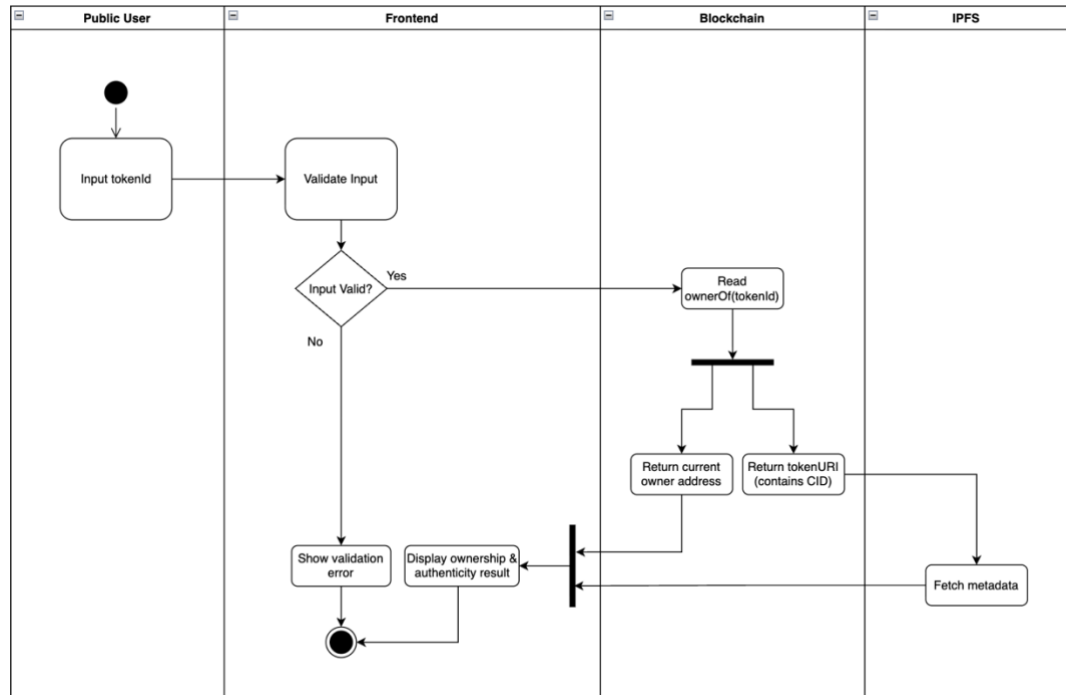


Figure 3.6 Ownership and Authenticity Verification Process Flowchart

5. Institution Access Management Process

The process begins with the contract owner accesses the DApp’s administrative interface. To add a new institution, the contract owner enters the public wallet address of the institution to be granted access and clicks the “Add Institution” button. The DApp prepares and submits a blockchain transaction to update the access control list in the smart contract. If the transaction is successfully validated, the institution gains permission to perform specific actions, such as minting and splitting certificates. The process is shown in **Figure 3.7**.

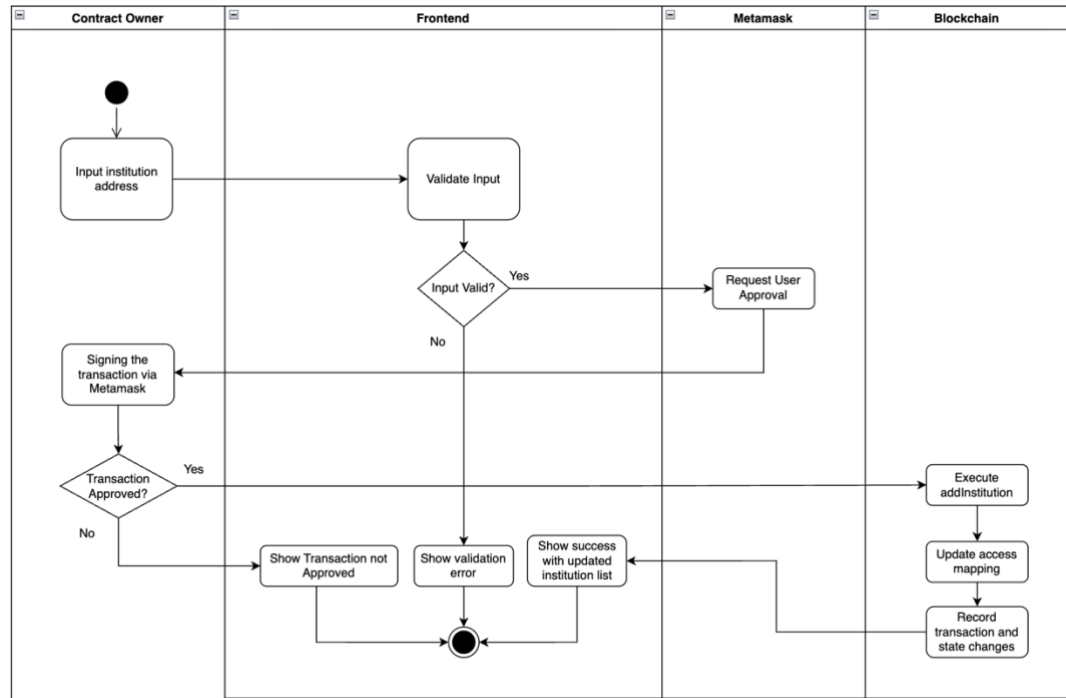


Figure 3.7 Institution Access Management Process flowchart

3.4.3. Smart Contract Design

The core of the smart contract is based on the ERC-721 standard for NFTs, with additional functionality for land registration. The contract inherits several OpenZeppelin contracts: ERC721, ERC721Enumerable, and Ownable.

In this smart contract, the key state variables are listed in **Table 3.1**. Among them, the **_tokenIds** variable uses the **Counters.Counter** data type provided by the OpenZeppelin library. This structure is used to safely manage incremental numeric values, ensuring that each token ID is unique and automatically generated without the risk of duplication or overflow.

Table 3.1 Key State Variable

No	Variable Name	Data Type	Description
1	_tokenIds	Counters.Counter	A counter to generate unique token IDs automatically.
2	_tokenURIs	mapping(uint256 → string)	Stores the IPFS metadata URI for each token.
3	parentOf	mapping(uint256 → uint256)	Maps a child token ID to its parent token ID for split certificates.
4	childrenOf	mapping(uint256 → uint256[])	Maps a parent token ID to an array of its child token IDs.
5	isInactive	mapping(uint256 → bool)	Tracks tokens that have been deactivated (e.g., after being split).
6	isInstitution	mapping(address → bool)	Manages a list of addresses with institutional authority.

Furthermore, in this smart contract, the main functions is listed in **table 3.2**.

Table 3.2 Smart Contract Function

No	Function	Description	Access Level
1	mintCertificate	Creates a new land certificate as an NFT with a metadata URI.	Institution
2	transferFrom	Transfers NFT ownership between addresses.	Certificate(NFT's) Owner
3	splitCertificate	Divides a land certificate(Parent NFT's) into several NFTs, marking the parent as inactive.	Institution
4	tokenURI	Returns the metadata URI for a specific NFT.	Public
5	ownerOf	Returns the owner's address for a specific NFT.	Public
6	isActive	Checks if a token is still active (not split).	Public

7	getChildren	Returns all child token IDs of a parent token.	Public
8	addInstitution	Adds institutional authority.	Contract Owner

3.5. Data Sources and Materials

This research uses simulated data that represent typical Indonesian land registration information. This approach ensures sufficient testing of various land registration scenarios while maintaining data privacy and security.

In addition, several development tools and technologies were employed to build and evaluate the blockchain-based decentralized application. These tools supported the creation, deployment, and testing of smart contracts, integration with decentralized storage, and interaction through a web-based interface. The details are presented in **Table 3.3**.

Table 3.3 Development Tools and Technologies

No	Name	Description
1	Node.js and npm	For project and dependency management.
2	Hardhat	Development environment for smart contract development and testing.
3	OpenZeppelin Contracts	A library of secure and audited smart contracts.
4	Solidity	Programming language for writing smart contracts.
5	Ganache	Local blockchain network for deployment and testing.
6	IPFS (via Pinata)	Decentralized file storage for off-chain metadata.
7	React.js and Ethers.js	Frontend development and interaction with the blockchain.

3.6. Testing Procedures

A structured testing methodology is essential to ensure a thorough evaluation of this blockchain-based land registration decentralized application. This process help identify and address potential issues before deployment, ensuring the system functions properly under various conditions.

Functional testing uses a black-box testing approach, focusing on whether the system delivers the correct output for a given input, without examining the internal code. This type of testing aims to validate that each function of the system behaves as expected. The main testing scenarios include:

1. New Land Registration (Minting NFT)

A landowner submits a mint request by filling in valid land data and signing it digitally. The institution reviews and executes the request, and the system must generate an NFT with correct metadata. Invalid or incomplete input must trigger an error message.

2. Land Ownership Transfer

A current NFT owner enters a valid recipient wallet address and approves the transfer transaction via MetaMask. The land ownership must be updated in the blockchain. If the recipient address is invalid, the transfer must be rejected.

3. Certificate Splitting (Splitting NFT)

A landowner requests a split by entering recipient data and signing it digitally. After the institution executes the approved request, the parent certificate becomes inactive, and new child NFTs are created. Invalid data or missing approval must cause the process to fail.

4. Ownership and Authenticity Verification

A user enters a token ID in the verification field. If the token exists, the DApp must display the owner details, certificate metadata, and status. If the token does not exist, the system must return a “NFT not found” message.

5. Institution Access Management

The contract owner adds or removes an institution by entering its wallet address and confirming the transaction via MetaMask. The blockchain must update the access list accordingly. Invalid addresses or insufficient permissions must result in a failure message.

In addition to functional testing, a user interview testing process was carried out to evaluate the system from the user’s perspective. This empirical method aimed to determine whether the developed decentralized application improves three key aspects: security, transparency, and efficiency in land registration activities. The participants were landowners or individuals who already possess a land certificate and are familiar with the conventional process.

The interviews were designed in a simple and friendly format to make the respondents comfortable. Each participant was asked to try the prototype interface and then answer several short questions regarding their impressions. The questions were focused on their perceptions of data safety, clarity of information, and ease of process. The details are presented in **Table 3.4**.

Table 3.4 Interview Question List

No	Evaluation Aspect	Interview Question	Expected Outcome
1	Security	“Do you feel that data stored in this system is safe and cannot be easily changed?”	Users understand that certificates are recorded permanently and securely.
2	Transparency	“Can you clearly see or verify ownership and certificate information?”	Users feel that the system makes information clearer and easier to check.
3	Efficiency	“Do you think this process is more efficient than the usual land registration?”	Users perceive the process as quicker and less complicated.

The responses were collected qualitatively and summarized to identify patterns of user satisfaction.

This testing complements the functional validation from black-box testing by adding empirical insights from real users, providing a human-centered perspective on system performance.

CHAPTER IV

RESULT AND DISCUSSION

4.1. Smart Contract Function Code

The LandCertificate smart contract is written in Solidity and is based on the ERC-721 Non-Fungible Token (NFT) standard from OpenZeppelin. This contract enables the representation of land certificates as unique digital tokens on the blockchain. The contract includes core features such as minting new certificates, splitting a parent certificate into multiple child certificates, and registering institution addresses with specific privileges. For ownership transfer is handled by the inherited ERC-721 functions (safeTransferFrom, getApproved, and isApprovedForAll), which already enforce standard ownership and allowance validation. And verification relies on existing public view functions (ownerOf, tokenURI, and isActive) to provide on-chain ownership and authenticity information without introducing new executable logic. The following section provides a detailed explanation of each function implemented within the smart contract.

4.1.1. mintCertificate Function

This function allows an authorized institution to mint a new NFT representing a land certificate. It can only be executed by institutions whose addresses have been registered as official institutions.

```
function mintCertificate(address to, string memory tokenURI,
bytes memory signature) public onlyInstitution returns (uint256) {
    // Verify signature
    bytes32 structHash = keccak256(abi.encode(
        MINT_REQUEST_TYPEHASH,
        to,
        keccak256(bytes(tokenURI))
    ));
    bytes32 hash = _hashTypedDataV4(structHash);
    address signer = hash.recover(signature);
    require(signer == to, "Invalid signature: signer must
be the recipient");
}
```

```

        _tokenIds.increment();
        uint256 newItemId = _tokenIds.current();

        _safeMint(to, newItemId);
        _setTokenURI(newItemId, tokenURI);

        emit CertificateMinted(newItemId, to, tokenURI);
        return newItemId;
    }

```

The creation of the NFT occurs when the `_safeMint(to, newItemId)` function is executed. This function is inherited from the ERC-721 standard, which handles the minting process by generating a unique token ID and assigning ownership to the specified address. Through this mechanism, each minted certificate becomes a verifiable non-fungible token (NFT) on the blockchain.

4.1.2. splitCertificate Function

This function allows a parent certificate to be split into multiple child certificates. This functionality is essential for scenarios such as inheritance (*waris*) or subdivision of land parcels.

```

function splitCertificate(
    uint256 parentId,
    address[] memory recipients,
    string[] memory tokenURIs,
    bytes memory signature
) public onlyInstitution returns (uint256[] memory) {
    require(_isApprovedOrOwner(_msgSender(), parentId),
        "Not owner nor approved");
    require(!isInactive[parentId], "Parent already
inactive");
    require(recipients.length == tokenURIs.length, "Array
length mismatch");
    require(recipients.length > 1, "Must split into at
least 2");

    // Verify signature

```

```

        address owner = ownerOf(parentId);
        bytes32 recipientsHash =
keccak256(abi.encode(recipients));
        bytes32 tokenURIsHash =
keccak256(abi.encode(tokenURIs));

        bytes32 structHash = keccak256(abi.encode(
            SPLIT_REQUEST_TYPEHASH,
            parentId,
            recipientsHash,
            tokenURIsHash
        ));
        bytes32 hash = _hashTypedDataV4(structHash);
        address signer = hash.recover(signature);
        require(signer == owner, "Invalid signature: signer
must be the owner");

        // Nonaktifkan token induk
        isInactive[parentId] = true;

        uint256[] memory childIds = new
uint256[](recipients.length);

        for (uint256 i = 0; i < recipients.length; i++) {
            _tokenIds.increment();
            uint256 childId = _tokenIds.current();

            _safeMint(recipients[i], childId);
            _setTokenURI(childId, tokenURIs[i]);

            parentOf[childId] = parentId;
            childrenOf[parentId].push(childId);
            childIds[i] = childId;
        }

        emit CertificateSplit(parentId, childIds);
        return childIds;
    }

```

4.1.3. addInstitution and removeInstitution Function

This function allows the contract owner to register or remove institution addresses that will have special permissions to mint or split certificates.

```
function addInstitution(address institution) public onlyOwner
{
    isInstitution[institution] = true;
}

function removeInstitution(address addr) public onlyOwner {
    isInstitution[addr] = false;
}
```

4.1.4. Modifiers

Modifiers in Solidity define reusable preconditions that must be satisfied before specific functions can execute. They improve readability and enforce consistent access control across the contract.

In the LandCertificate contract, two modifiers are used:

1. onlyInstitution

Which restricts the execution of functions such as mintCertificate and splitCertificate to authorized institutions added by the contract owner. This ensures that only verified entities can issue or subdivide land certificates.

2. onlyOwner

Inherited from the OpenZeppelin Ownable module, which limits administrative actions (adding or removing institutions) to the contract deployer.

These modifiers strengthen the overall security model by preventing unauthorized users from performing sensitive operations and ensuring that the integrity of the land certificate registry is preserved.

4.2. User Interface Review

This section describes the user interface (UI) of the NFT-based land registration DApp. The UI is the primary means by which users access and utilise the application's features. It is built using React.js and connected to the blockchain

through Ethers.js. The application also uses MetaMask as a digital wallet for confirming transactions and managing assets.

The interface is designed to be clear and simple so that different types of users such as contract owners, registered institutions, and regular landowners can use it easily. Although the blockchain process behind the system is complex, the UI makes it easier for users to perform actions without needing to deal with technical details.

4.2.1. Main Layout

The main layout of the application is the Homepage of this application, consists of a navigation bar at the top and a main content area that changes depending on the page being accessed and the user's role.

When the application is first opened, users see the landing page, which features a “Connect Wallet” button to link their MetaMask account as in the **Figure 4.1**. After the Metamask wallet is successfully connected, the button changes into the public address of the user as in the **Figure 4.2**. This step must be done before any other feature can be used. The landing page layout is shown in **Figure 4.3**.

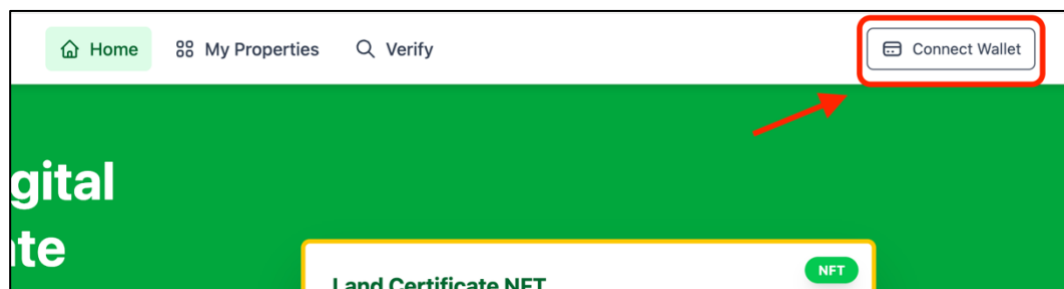


Figure 4.1 Before connect wallet

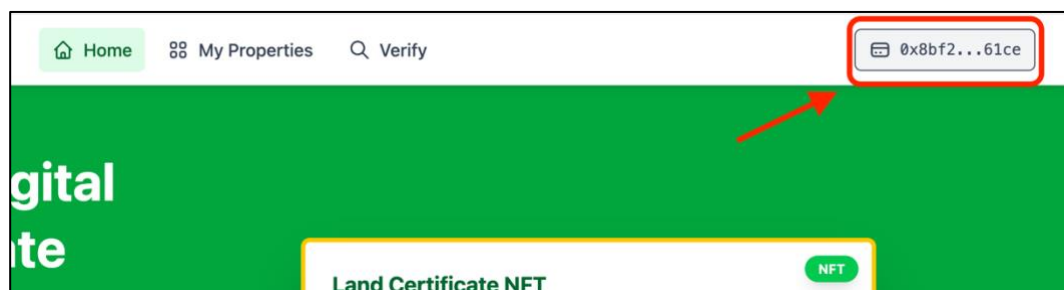


Figure 4.2 After connect wallet

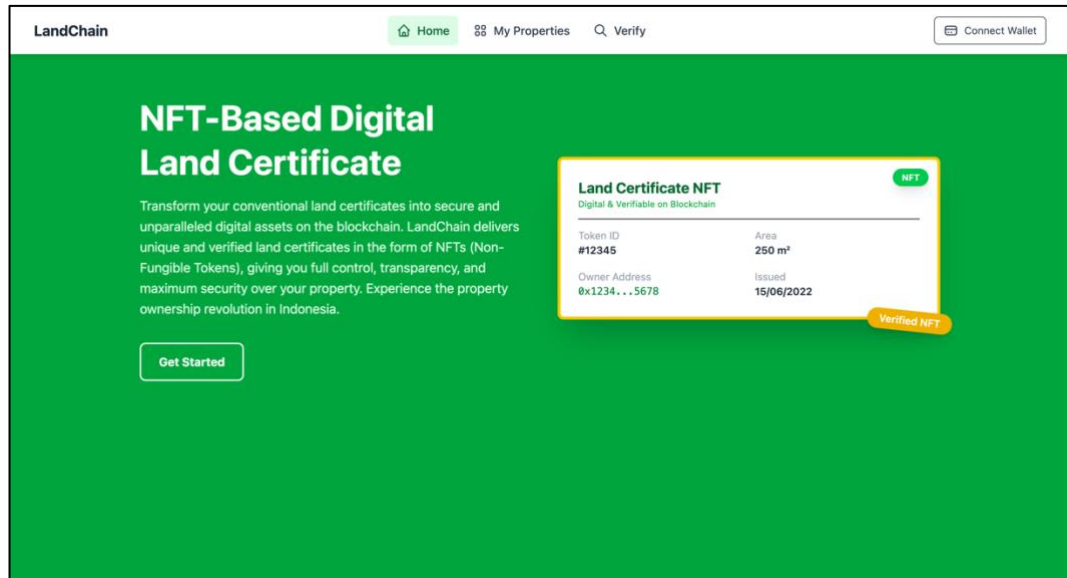


Figure 4.3 Main layout of the system

4.2.2. Navigation and Menu Functions

The navigation bar, located at the top of every page, provides quick access to all the application's features. The menus available are:

1. My Properties

This page shows a list of NFTs owned by a logged-in user. Each item displays certificate details such as token ID, property picture, and property location. This page gives users a quick overview of their registered properties. The view of My Properties is shown in **Figure 4.4**.

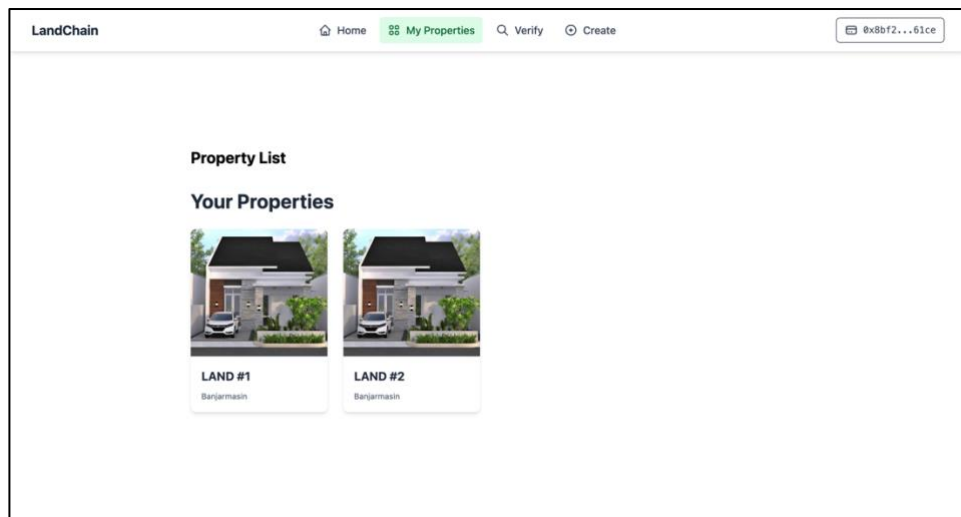


Figure 4.4 My Properties Page

Furthermore, the user can access the complete details of a specific NFT by selecting it from the list. When clicked, the system displays a detail page

that presents the token ID, certificate name, representative image or document stored on IPFS, and the metadata provided during minting. This page also includes ownership history and transaction records, allowing users to trace the certificate's lineage from its initial issuance to the most recent transfer. By consolidating this information in a single view, the system provides a transparent and verifiable record of authenticity and ownership without requiring consultation with external authorities. This feature is illustrated in **Figure 4.5**.

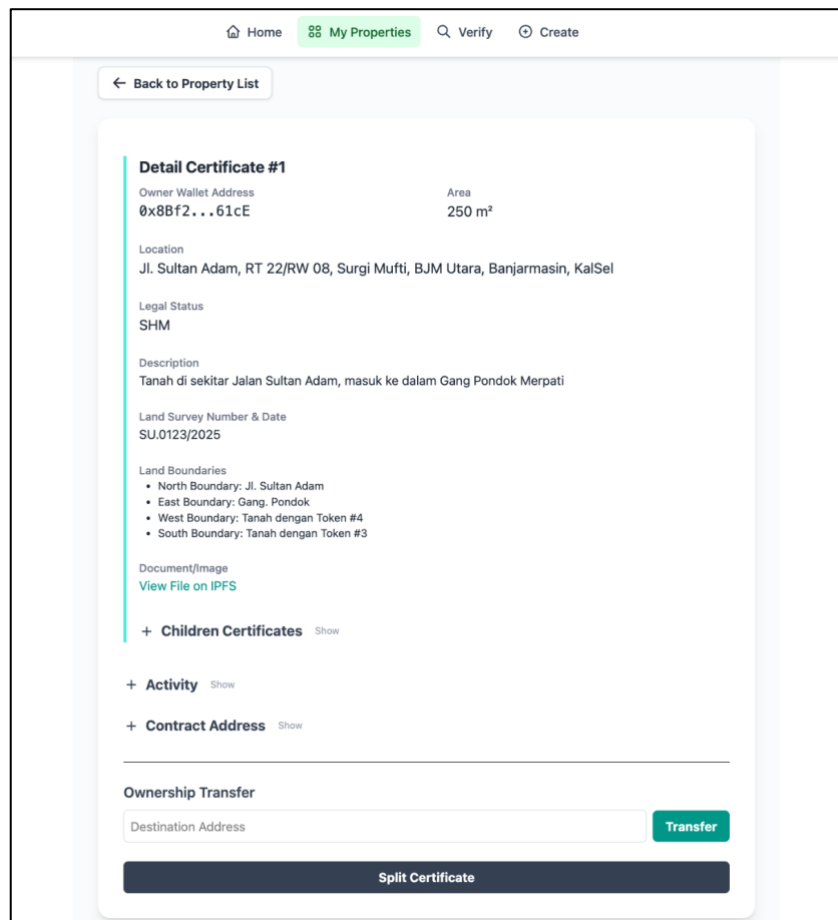


Figure 4.5 NFT details

2. Create

This page is used by a landowner to submit a mint request for a new land certificate. The owner fills in property details, uploads supporting documents to IPFS to obtain a CID, and signs a structured message through MetaMask. The signed request is stored by the application and later executed on-chain by an authorized institution to create the NFT certificate. The Request Mint page is shown in **Figure 4.6**.

The screenshot displays a web application interface for requesting a mint certificate. At the top, a navigation bar includes links for Home, My Properties, Verify, and a highlighted Request Mint button. The main heading is 'Request Mint Certificate', followed by a sub-instruction: 'Fill in all the details below to request a mint certificate. After signing, an institution can execute the mint for you.' A progress bar shows two steps: '1 Upload Data' (active) and '2 Sign Request'. The form is divided into three sections: 1. Property Information, 2. Location Details, and 3. Digital Document. Section 1 includes fields for Legal Status, Land Area, Additional Description, Land Survey Number & Date, and four boundary fields. Section 2 includes a Street Name field and four location fields. Section 3 features a file upload area with a dashed border and a plus icon, and a large 'Upload Data to IPFS' button at the bottom.

[Home](#) [My Properties](#) [Verify](#) [Request Mint](#)

Request Mint Certificate

Fill in all the details below to request a mint certificate. After signing, an institution can execute the mint for you.

1 Upload Data

2 Sign Request

1. Property Information

Legal Status
e.g. SHM, HGB

Land Area (m²)

Additional Description
Additional information about the property...

Land Survey Number & Date
e.g. SU.0123/2024

Land Boundaries

North Boundary

East Boundary

West Boundary

South Boundary

2. Location Details

Street Name

RT

RW

Village / Subdistrict

District

Regency / City

Province

3. Digital Document

Upload Image / Scan Document

Choose file to upload or drag and drop
PNG, JPG, GIF, PDF up to 10MB

Upload Data to IPFS

Figure 4.6 Request Mint Page

3. Execute Mint

This page allows an authorized institution to view and execute mint requests submitted by landowners. Each request contains signed data and IPFS metadata prepared beforehand. After selecting a request, the institution confirms the operation through MetaMask, and the system creates the corresponding NFT certificate on the blockchain. The Execute Mint page is shown in **Figure 4.7**.

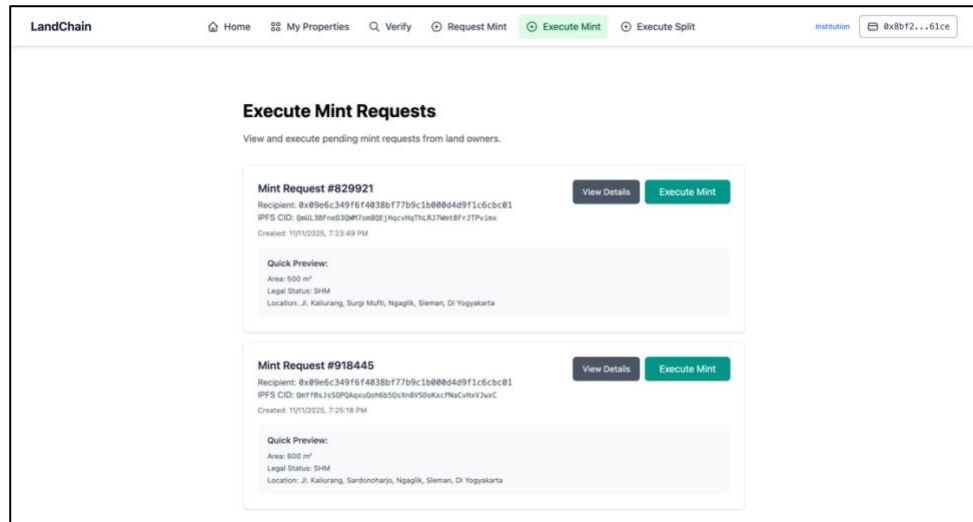


Figure 4.7 Execute Mint Page

4. Execute Split

This page is used by an authorized institution to process split requests made by landowners. The page displays pending requests along with their required approval status. After the necessary approval is confirmed, the institution executes the split through MetaMask, resulting in the parent certificate becoming inactive and new child NFTs being created. The Execute Split page is shown in **Figure 4.8**.

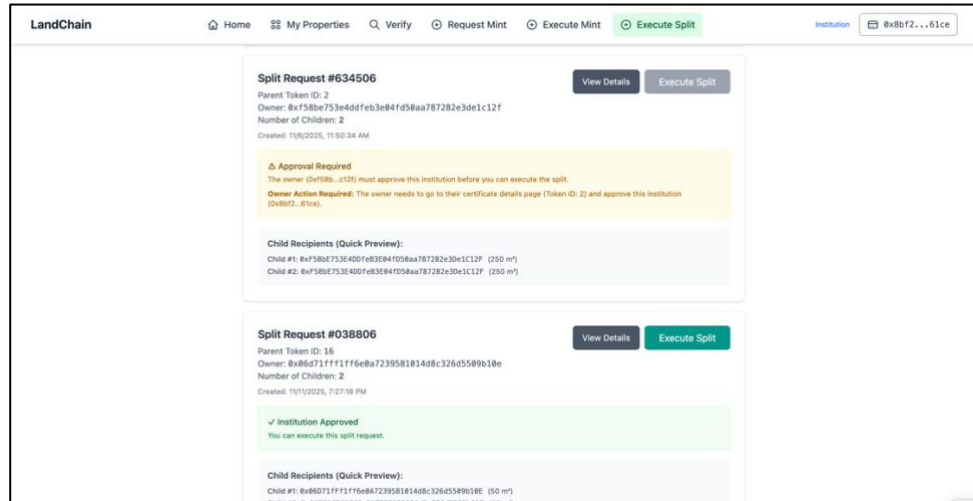


Figure 4.8 Execute Split Page

5. Verify Certificate

This page allows users to check the authenticity and ownership of a land certificate by entering its token ID. If the certificate exists, its details are shown. Otherwise, a “NFT not found” message appears. The Verify Certificate page is shown in **Figure 4.9**.

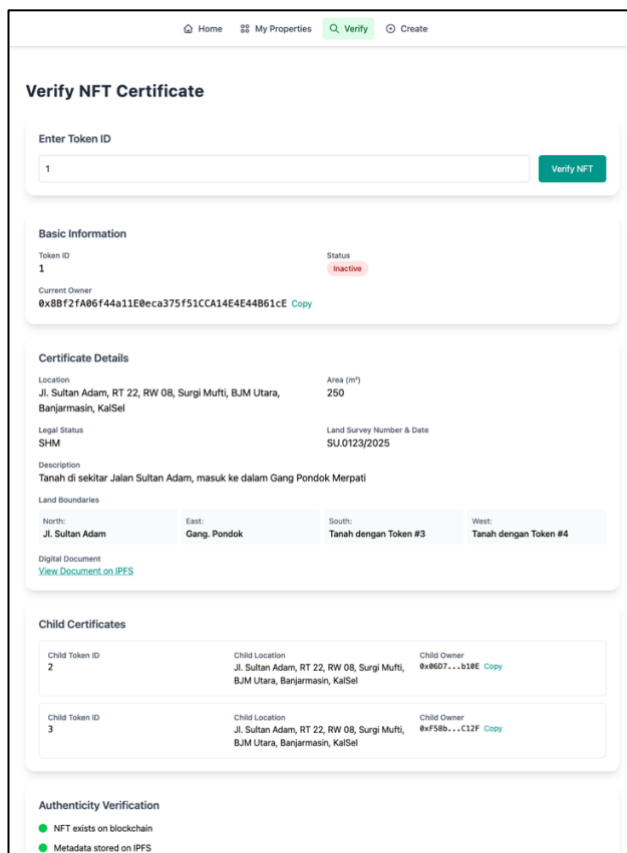


Figure 4.9 Verify Page

6. Admin Panel

This page is accessible only to the contract owner for managing institution access. The owner can add or remove an institution by entering its public wallet address. The Admin Panel page is shown in **Figure 4.10**.

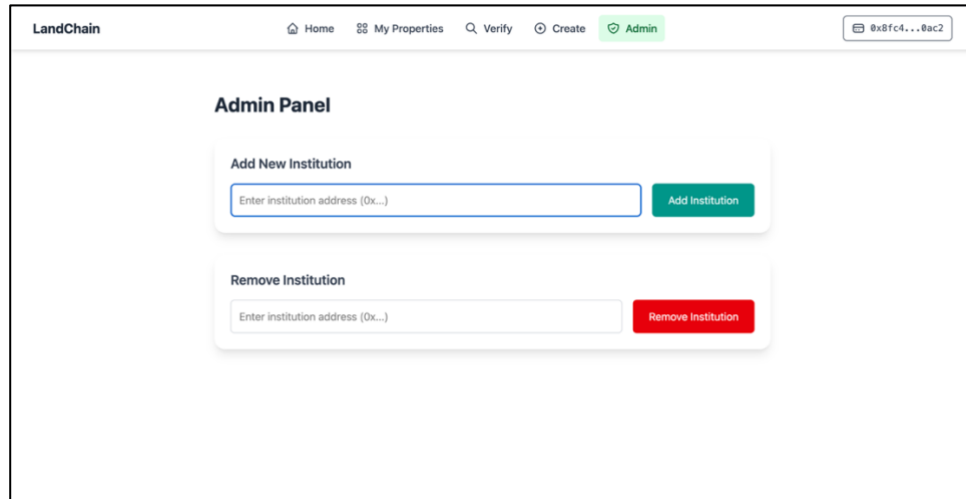


Figure 4.10 Admin Page

4.2.3. Role-Based Interface Elements

The system applies role-based access, meaning that the features displayed in the interface depend on the role of the logged-in user. There are three main roles:

1. Contract Owner

This role has full administrative access, including the ability to add or remove institutions via the Admin Panel. The dashboard for the Contract Owner is shown in **Figure 4.11**.

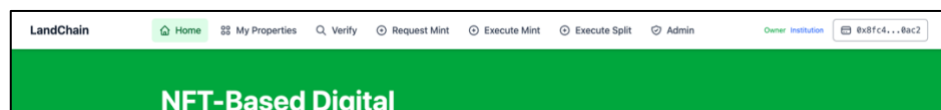


Figure 4.11 Contract Owner Menu

2. Institution

This role has the authorization to Execute mint new certificates and Execute split an existing certificate into multiple ones requested by the land owner's. This role cannot access the Admin Panel. The dashboard for institutions is shown in **Figure 4.12**.

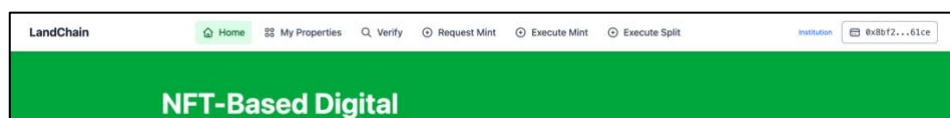


Figure 4.12 Institution Menu

3. Landowner

This role can view their owned NFTs, transfer them to another wallet, and verify certificates. This role is also able to request mint or split certificates. The dashboard for Landowner is shown in **Figure 4.13**.

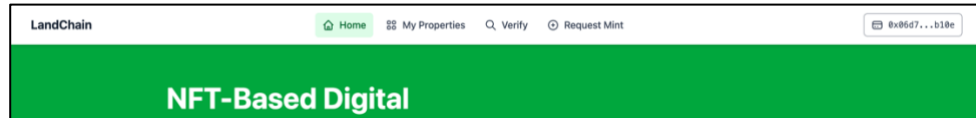


Figure 4.13 Landowner Menu

In general, the frontend of the system is designed to make blockchain-based transactions easier for users. By keeping the navigation simple, adjusting features based on user roles, and integrating MetaMask for secure transactions, the UI provides a balance between functionality and ease of use. The detailed step-by-step process for using each feature will be explained in the next section.

4.3. Simulation and System Output

This section presents the simulation process and outputs of the NFT-based land registration DApp that has been developed. The simulation aims to show that all system features function as intended.

The entire simulation was conducted in a local development environment, utilising Ganache as a local blockchain network, MetaMask as the digital wallet for transaction confirmation, and IPFS to store detailed NFT metadata, including property documents and location photos.

4.3.1. Initial Account and Blockchain Network Condition

Ganache provides a local simulation environment that works similarly to a real blockchain, allowing developers to test smart contracts and transactions without using a public network.

ACCOUNTS				BLOCKS	TRANSACTIONS	CONTRACTS	EVENTS	LOGS
MNEMONIC ankle shoulder nest nerve wife fix cause tent gauge point control wave				HD PATH m44'60'0'0account_index				
ADDRESS	BALANCE	TX COUNT	INDEX					
0x8FC4cBa432d20196f5e8b89e8f3F2941783A0AC2	100.00 ETH	0	0					
0x8Bf2fA06f44a11E0eca375f51CCA14E4E44B61cE	100.00 ETH	0	1					
0x06D71fFf1ff6e0A7239581014d8c326d5509b10E	100.00 ETH	0	2					
0xF58bE753E4DDfeB3E04fD50aa787282e3De1C12F	100.00 ETH	0	3					
0xd6c6B8c9A246767B8B94fe6D84af01Fa77B7d0Dd	100.00 ETH	0	4					
0x53f6AabB7B437F739fe72eedea89B1Be81e7C6c4	100.00 ETH	0	5					
0x5805deD0C0f8C0907541028c6a3886263CA68281	100.00 ETH	0	6					
0x0240C72a9d193A61cBfa46C99a0267190f3cE15a	100.00 ETH	0	7					
0xB82f0027fF43Db6654403bc3356f8d98006f355b	100.00 ETH	0	8					

Figure 4.14 Initial Condition of Ganache Accounts List

In **Figure 4.14**, by default Ganache starts with 10 accounts with public address and private key, each given 100 ETH for testing purposes. In this research, four accounts are used to represent specific roles, namely the Contract Owner, Institution (e.g., BPN), and Landowner. These accounts are added to MetaMask, that is connected to Ganache network. The public addresses of these accounts are listed in **Table 4.1**.

Table 4.1 Account Name and Public Address List

No	Name	Public Address
1	Contract Owner	0x8FC4cBa432d20196f5e8b89e8f3F2941783A0AC2
2	Institution (ex. BPN)	0x8Bf2fA06f44a11E0eca375f51CCA14E4E44B61cE
3	User 1	0x06D71fFf1ff6e0A7239581014d8c326d5509b10E
4	User 2	0xF58bE753E4DDfeB3E04fD50aa787282e3De1C12F

The initial appearance of the four selected accounts after they were imported into MetaMask is shown in **Figure 4.15**.

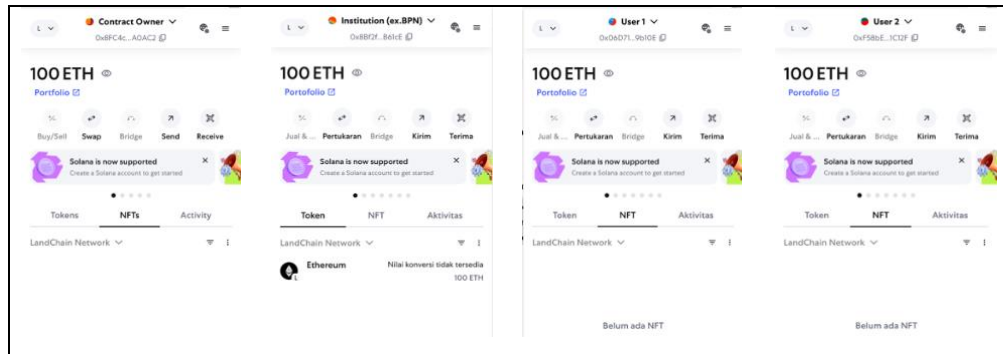


Figure 4.15 Initial Condition of Ganache Accounts on Metamask

The initial state of the blocks on the Ganache network is presented in **Figure 4.16**. The presence of “Block 0” indicates that no block have yet been added to the blockchain network. This represents the default block created upon network initialization.

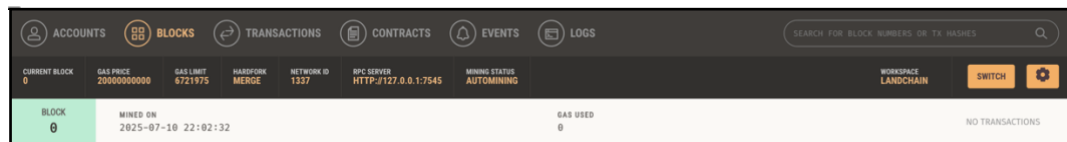


Figure 4.16 Initial Condition of Ganache Blockchain

As shown in **Figure 4.17**, The initial view of the Transactions page is also displayed in the figure below. Initially, no transactions have been added, as indicated by the message “No Transactions.”

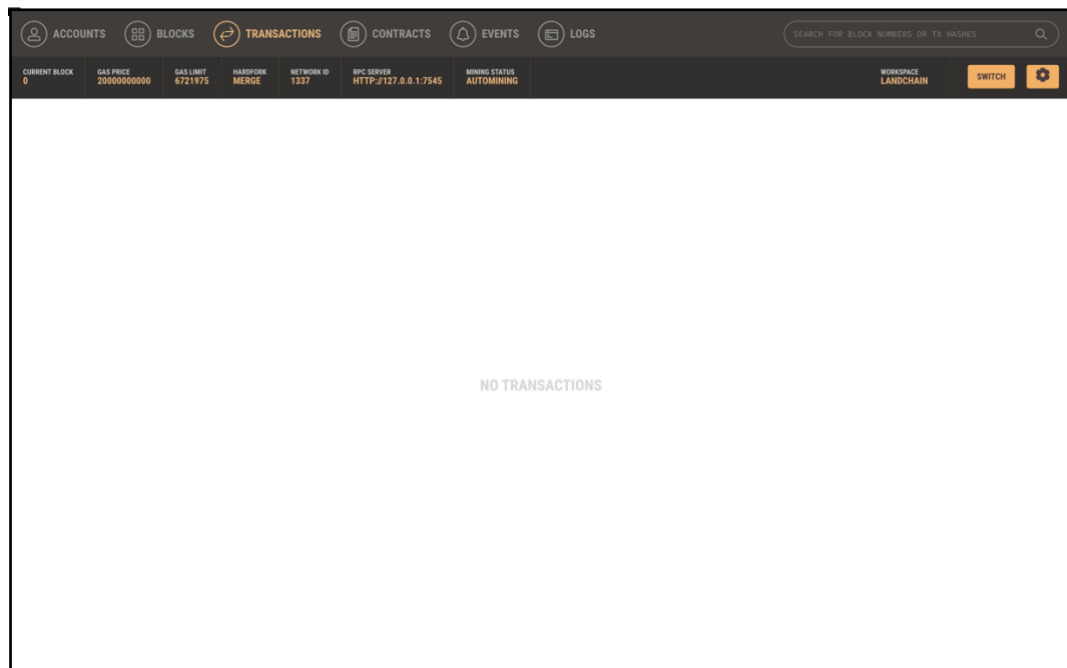


Figure 4.17 Initial Condition of Transaction List

Before simulation, the smart contract must first be deployed to the blockchain network using the “Contract Owner” account. Deploying a smart contract requires a certain amount of gas fee depending on the size and complexity of the contract, which in this case is approximately 0.00477612 ETH. The initial conditions of the “Contract Owner” account and the blockchain network after deployment are illustrated in the figures below.

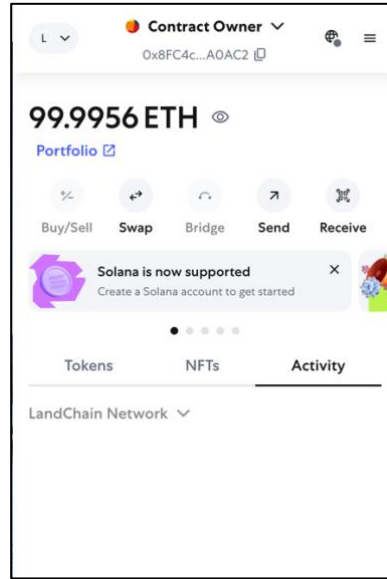


Figure 4.18 Contract Owner Account after deployment

In **Figure 4.18**, the Contract Owner's account balance is reduced to **99.9956 ETH** from an initial balance of 100 ETH after successfully deploying the smart contract.

ACCOUNTS	BLOCKS	TRANSACTIONS	CONTRACTS	EVENTS	LOGS	SEARCH FOR BLOCK NUMBERS OR TX HASHES
CURRENT BLOCK 1	GAS PRICE 20000000000	GAS LIMIT 6721975	HARDFORK MERGE	NETWORK ID 1337	RPC SERVER HTTP://127.0.0.1:7545	MINING STATUS AUTOMINING
WORKSPACE LANDCHAIN	SWITCH	SETTINGS				
BLOCK 1	MINED ON 2025-07-10 22:13:23	GAS USED 3958502	1 TRANSACTION			
BLOCK 0	MINED ON 2025-07-10 22:02:32	GAS USED 0	NO TRANSACTIONS			

Figure 4.19 Blockchain condition after deployment

ACCOUNTS

BLOCKS

TRANSACTIONS

CONTRACTS

EVENTS

LOGS

SEARCH FOR BLOCK NUMBERS OR TX HASHES

CURRENT BLOCK

1

GAS PRICE

20000000000

GAS LIMIT

6721975

HARDFORK

MERGE

NETWORK ID

1337

RPC SERVER

HTTP://127.0.0.1:7545

MINING STATUS

AUTOMINING

WORKSPACE

LANDCHAIN

SWITCH

TX HASH

0x1c8fa8550504c578e336f9b2b509f592fd98d7d7c3c1a008f5e4bd5bfe636f

CONTRACT CREATION

FROM ADDRESS

0x8FC4cBa432d20196f5e8b89e8f3f2941783A8AC2

CREATED CONTRACT ADDRESS

0x546c9b61a16bf2970d992f6443eA29361103252D

GAS USED

3958502

VALUE

0

Figure 4.20 Transaction list after deployment

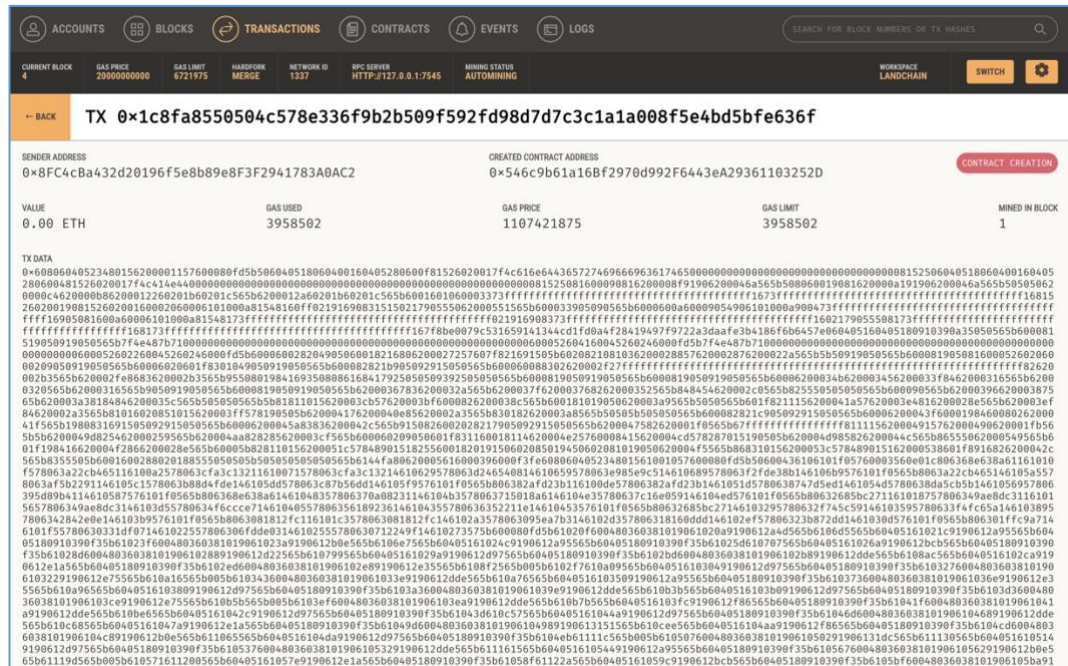


Figure 4.21 Transaction Information of Smart Contract Deployment

Furthermore, **Figure 4.19** and **Figure 4.20** confirm the creation of “Block 1” and the first transaction, which refer to the deployment of the smart contract to the blockchain network. **Figure 4.21** shows detailed information about the transaction, including the Transaction Hash, the sender address (Contract Owner), and most importantly, the Created Contract Address, which in this case is 0x546c9...3252D.

4.3.2. Institutional Registration Process

This process begins with the Contract Owner connecting their wallet. After the connection is established, the Contract Owner can fill in the “Add New Institution” field on the Admin page with the public address of the account to be granted the “Institution” role, and then click the “Add Institution” button. Once this role is assigned, the account will gain exclusive access to the features of NFT minting and NFT Splitting. The process is shown in **Figure 4.22**.

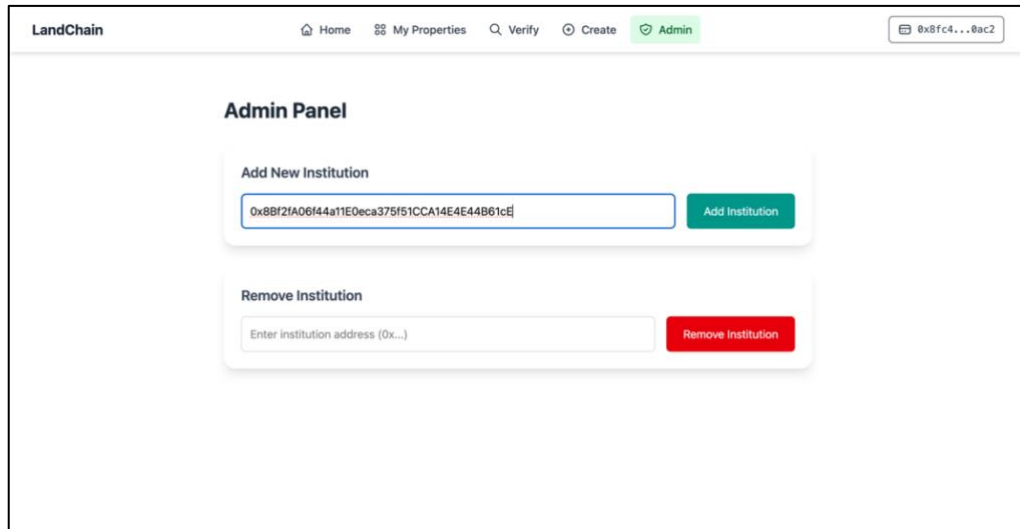


Figure 4.22 Adding New Institution

This process is mined on the Ganache network, resulting in blocks that contains only one transaction for each block. This behavior differs from public blockchain networks, in which a block typically contains multiple transactions. The result of a successful registration is visible on the blockchain and can be queried by any party for audit purposes.

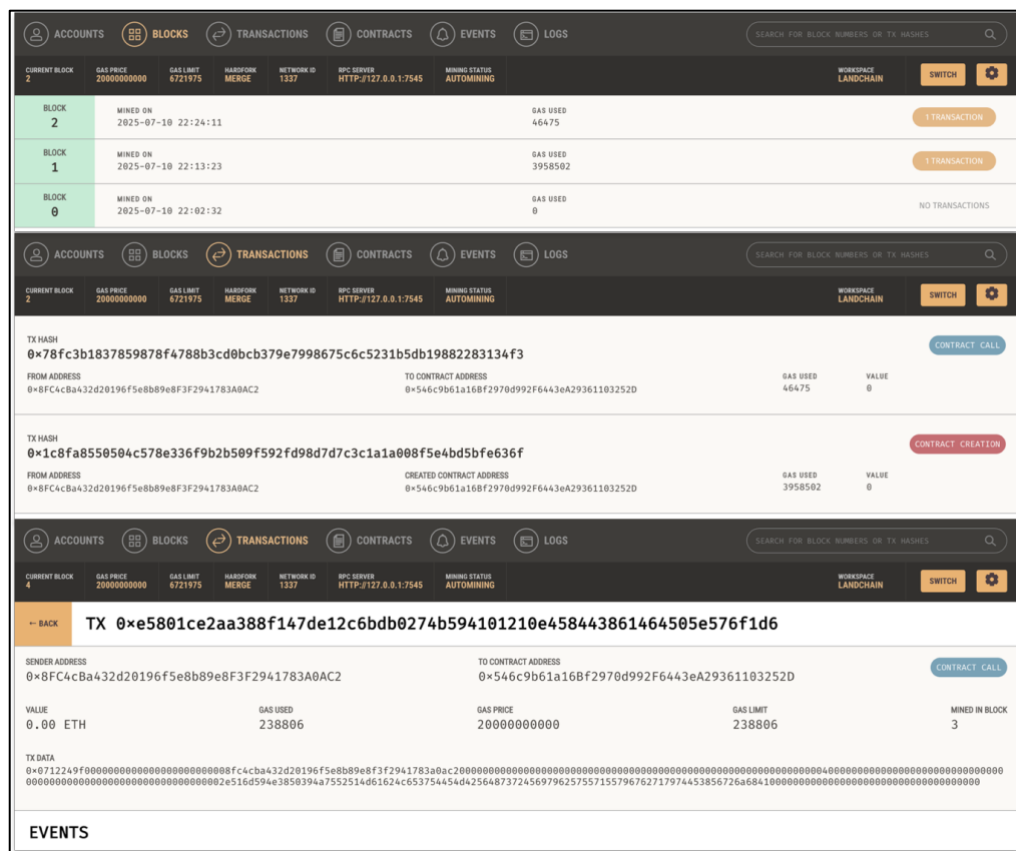


Figure 4.23 Transaction Information of Smart Contract Deployment

Figure 4.23 shows that a total of three blocks have been mined following the assignment of institutional authority to the account with address 0x8Bf2...4B61cE. As a result, this account is now authorized to mint and split NFTs.

4.3.3. Land Certificate Issuance Process (Minting NFT)

The issuance process begins when the landowner opens the mint request page and enters the key property details, including location, area, and supporting documents, as shown in **Figure 4.24**

The screenshot displays a web interface for requesting a mint certificate. At the top, there is a navigation bar with links for Home, My Properties, Verify, and a highlighted Request Mint button. Below the navigation bar, the title 'Request Mint Certificate' is followed by a brief instruction: 'Fill in all the details below to request a mint certificate. After signing, an institution can execute the mint for you.' A progress bar indicates two steps: '1 Upload Data' (active) and '2 Sign Request'. The form is divided into three main sections: 1. Property Information, 2. Location Details, and 3. Digital Document. The Property Information section includes fields for Legal Status (SHM), Land Area (250 m²), and an Additional Description (Tanah Dekar Ull). The Location Details section includes fields for Land Survey Number & Date (SU.0123/2025), North Boundary (Jalan A), East Boundary (Jalan B), West Boundary (Jalan C), and South Boundary (Jalan raya kaliurang). The Digital Document section includes a field for Street Name (Jl. Kaliurang), RT (12), RW (02), Village / Subdistrict (Sardonoharjo), District (Ngaglik), Regency / City (Sleman), and Province (DI Yogyakarta). A large dashed box for uploading a digital document is shown, with a prompt to 'Choose file to upload or drag and drop' and a file named 'contoh rumah.jpg' listed below. At the bottom, there is a green button labeled 'Upload Data to IPFS'.

Home My Properties Verify Request Mint

Request Mint Certificate

Fill in all the details below to request a mint certificate. After signing, an institution can execute the mint for you.

1 Upload Data 2 Sign Request

1. Property Information

Legal Status SHM Land Area (m²) 250

Additional Description Tanah Dekar Ull

Land Survey Number & Date SU.0123/2025

Land Boundaries

North Boundary Jalan A East Boundary Jalan B

West Boundary Jalan C South Boundary Jalan raya kaliurang

2. Location Details

Street Name Jl. Kaliurang

RT 12 RW 02 Village / Subdistrict Sardonoharjo District Ngaglik

Regency / City Sleman Province DI Yogyakarta

3. Digital Document

Upload Image / Scan Document

Choose file to upload or drag and drop

PNG, JPG, GIF, PDF up to 10MB

contoh rumah.jpg

Upload Data to IPFS

Figure 4.24 Request form after all fields is filled

After the required fields are completed, these documents are uploaded to IPFS through Pinata, which returns a CID representing the stored metadata. Instead of directly submitting a blockchain transaction, the system prepares a structured EIP-712 message summarizing the mint request.

The landowner then signs this message through MetaMask, and the signed request is stored temporarily by the application.

Once the request is created, the authorized institution connect into the system and accesses the page that displays all pending mint requests. After reviewing the submitted data, the institution selects a request and click “Execute Mint” and then confirm it through MetaMask. Which you can see in **Figure 4.25**

The screenshot displays a web application interface for managing mint requests. At the top, there is a navigation bar with links: Home, My Properties, Verify, Request Mint, Execute Mint (highlighted in green), and Execute Split. The main heading is "Execute Mint Requests" with a subtext "View and execute pending mint requests from land owners." Below this, a card for "Mint Request #018836" is shown, featuring a "Hide Details" button and an "Execute Mint" button. The card contains the following information:

- Recipient:** 0x06d71fff1ff6e0a7239581014d8c326d5509b10e
- IPFS CID:** QmaE2c4oZzmGvTeb7CY1678MyDLGVb1qj5gTNP7mMs5ST7
- Created:** 11/11/2025, 6:03:38 PM

Below the card, a "Complete Request Details" section is expanded, showing:

- Basic Information:**
 - Request ID:** 1762859018836
 - Recipient Address:** 0x06d71fff1ff6e0a7239581014d8c326d5509b10e
 - IPFS CID:** QmaE2c4oZzmGvTeb7CY1678MyDLGVb1qj5gTNP7mMs5ST7
 - Created:** 11/11/2025, 6:03:38 PM
- Property Details:**
 - Land Area:** 250 m²
 - Legal Status:** SHM
 - Survey Number:** SU.0123/2025
 - Description:** Tanah Dekar Ull
 - Location Information:**
 - Street:** Jl. Kallurang
 - RT:** 12
 - RW:** 02
 - Village:** Sardonoharjo
 - District:** Ngaglik
 - Regency/City:** Sleman
 - Province:** DI Yogyakarta
 - Full Address:** Jl. Kallurang, RT 12/RW 02, Sardonoharjo, Ngaglik, Sleman, DI Yogyakarta
 - Land Boundaries:**
 - North:** Jalan A
 - East:** Jalan B
 - West:** Jalan C
 - South:** Jalan raya kallurang
- Signature Information:**
 - EIP-712 Signature:** 0x9a6c8edef175435673a527d90b19a8994d19114ce158891cbdbad53c28f64db32183029ed987cc43ea4de8b06bd98392eff3c48eb520e291af748a189eccc31c
 - This signature was created by the recipient address (0x06d71fff1ff6e0a7239581014d8c326d5509b10e) and verifies their consent for this mint request.**

At the bottom of the details section, there is a link: [View Full Metadata on IPFS →](#)

Figure 4.25 Request from Land Owner

At this stage, the smart contract validates the owner’s digital signature and processes the minting on the blockchain. When the transaction is confirmed, a new

NFT certificate is created and assigned a unique token ID. A confirmation message is displayed in the application interface, indicating that the issuance process has been successfully completed.

The result of the minting operation can be observed on the My Properties page. The newly minted certificate appears in the list of NFTs owned by the issuing institution, labeled with its token name (e.g., “LAND #15”) and token ID, as presented in **Figure 4.26**. By selecting the NFT, the institution can access its detailed information, including its metadata from IPFS, ownership history, and transaction records. An example of this detailed view is shown in **Figure 4.27**.

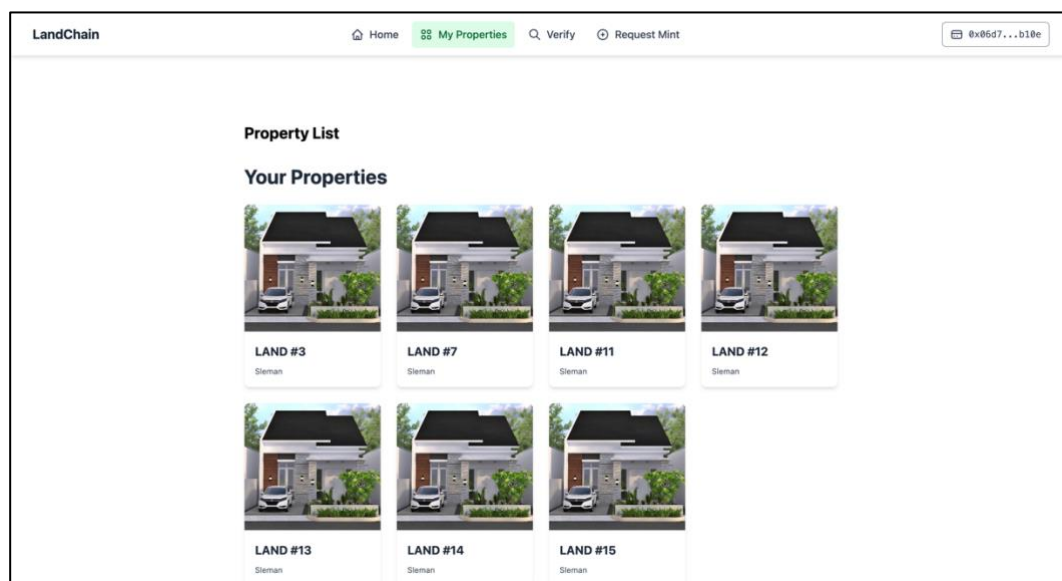


Figure 4.26 My properties page with owned NFT

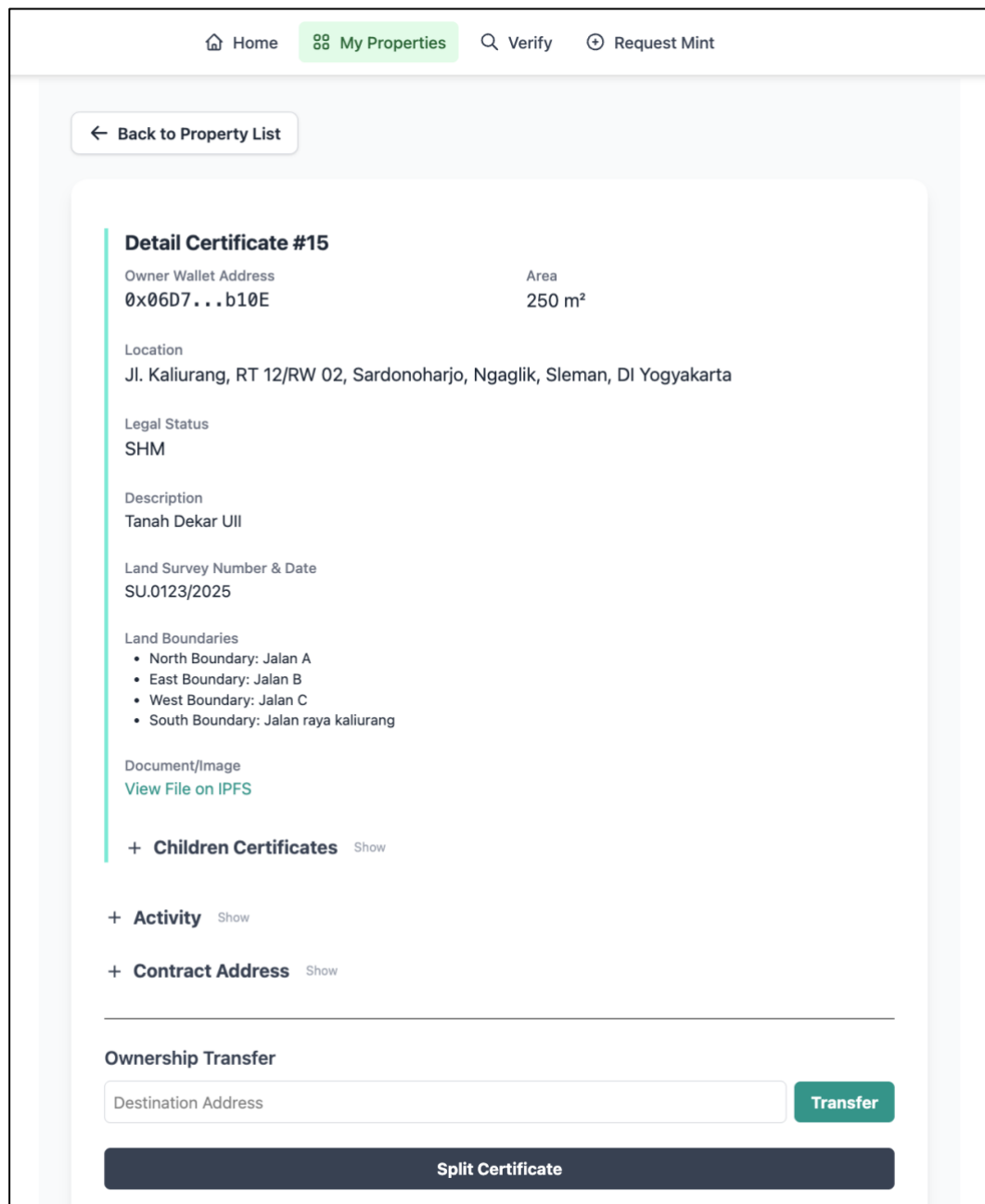


Figure 4.27 NFT details of LAND

The Ganache's state reflects the minting event. A new block is added to the Ganache network containing the minting transaction, while the IPFS dashboard records the uploaded certificate metadata and associated files. The blockchain records is shown in **Figure 4.28**.

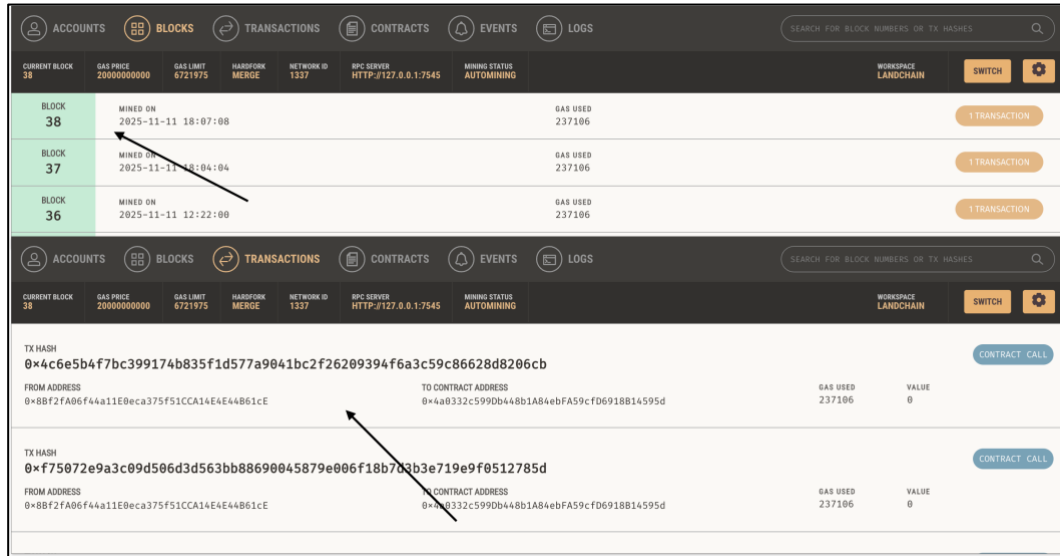


Figure 4.28 Blockchain Information After Minting an NFT

The detailed transaction information includes:

1. The Block Number where the minting transaction was mined (Block 38),
2. The Transaction Hash (e.g., 0x4c6e5...d8206cb),
3. The Sender Address (Institution's wallet),
4. The Contract Address where the NFT was minted,

These details provide evidence that the NFT minting process not only produces a visible certificate on the user interface but also generates immutable records at the blockchain level. The transparency of blockchain ensures that every minted certificate can be traced back to its originating transaction, which makes strengthening the system's credibility.

To summarize the results of the minting process, the data generated during the experiment are presented in **Table 4.2**.

Table 4.2 Example Result of Minting NFT Land Certificate

Token Id	Token Name	IPFS Metadata CID	IPFS Document CID	Owner Address
15	LAND #15	QmaE2...Ms5ST7	QmaW5...2TUfb	0x06D71fF...9b10E

The table shows that the NFT **LAND #15** was successfully created with Token ID 15, containing metadata stored in IPFS under CID QmYN8...VrjhA and linked to a supporting document with CID QmaW5...2TUfb. The initial owner of the NFT is the land owner's wallet with public address 0x06D71fF...9b10E.

4.3.4. Land Certificate Verification Process (Verify NFT)

Verification is one of the most important features of the system because it allows any user, whether an institution or landowner to independently verify the authenticity and validity of a certificate recorded on the blockchain.

The process begins when a user navigates to the Verify Certificate page shown in **Figure 4.29**, where a simple input form is provided to enter the token ID of the certificate to be verified. Once the user submits the ID, the system calls the smart contract functions “ownerOf” and “tokenURI” to retrieve ownership and metadata information.

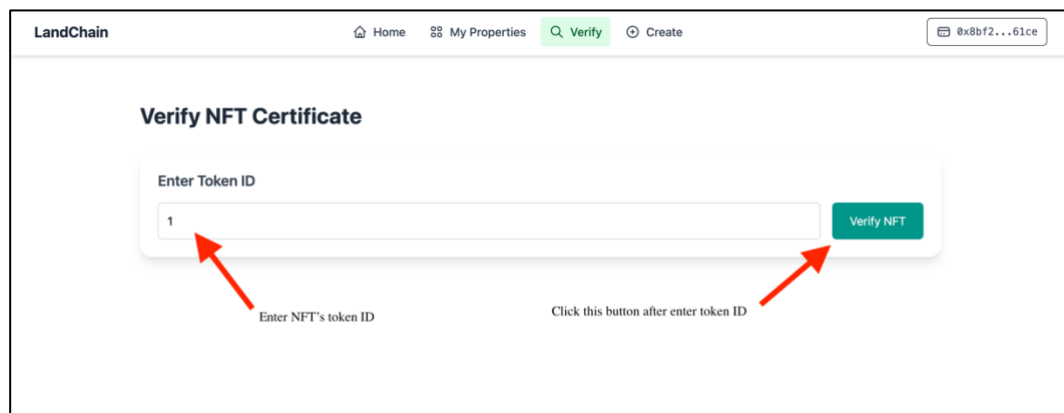


Figure 4.29 Verify Page Appearance

If the token is valid, the system displays the certificate’ information, including:

1. The Token ID and Token Name,
2. The Current Owner’s Wallet Address,
3. The Certificate Metadata (retrieved from IPFS),
4. The Status of the certificate (active or inactive).

An example verification output is shown in **Figure 4.30**, which confirms that the certificate with Token ID “1” belongs to a registered landowner and presents its supporting metadata. The verification result page also displays transaction records associated with the token by clicking “Activity” button, making it possible to trace the certificate’s full history from issuance to its latest transfer.

[Home](#)
[My Properties](#)
[Verify](#)

Verify NFT Certificate

Enter Token ID

1

Verify NFT

Basic Information

Token ID

1

Status

Active

Current Owner

0x8Bf2fA06f44a11E0eca375f51CCA14E4E44B61cE

Copy

Certificate Details

Location

Jl. Sultan Adam, RT 22, RW 08, Surgi Mufti, BJM Utara, Banjarmasin, KalSel

Area (m²)

250

Legal Status

SHM

Land Survey Number & Date

SU.0123/2025

Description

Tanah di sekitar Jalan Sultan Adam, masuk ke dalam Gang Pondok Merpati

Land Boundaries

North:	East:	South:	West:
Jl. Sultan Adam	Gang. Pondok	Tanah dengan Token #3	Tanah dengan Token #4

Digital Document

[View Document on IPFS](#)

+ Activity
Show

Authenticity Verification

- NFT exists on blockchain
- Metadata stored on IPFS
- Token URI verified
- Smart contract verified

Figure 4.30 Verify Page showing NFT Details

If the token does not exist or is no longer, the system shows an “Error Verifying NFT” error message. This is illustrated in **Figure 4.31** where the system prevents invalid certificates from being mistakenly considered authentic.

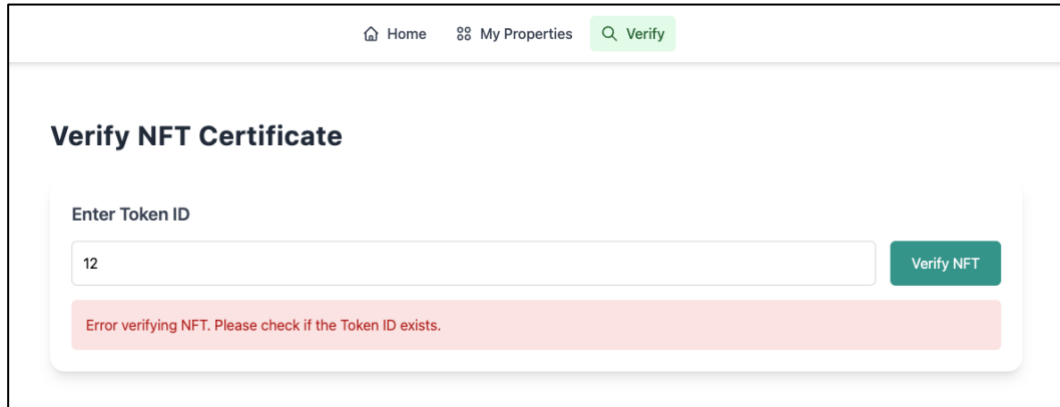


Figure 4.31 Verify Page showing Invalid NFT's

Through this process, the application demonstrates how blockchain technology supports data reliability and public accessibility. The verification feature enables users to validate ownership information directly through the DApp interface, while the underlying blockchain ensures that the recorded certificate data remains immutable and transparently verifiable. As a result, users can access trustworthy certificate information without filing manual verification requests to institutions, thereby reducing administrative effort and strengthening confidence in data integrity.

4.3.5. Land Certificate Transfer Process (Transfer NFT)

The transfer process allows the owner of a land certificate NFT to hand over ownership to another wallet address. This feature simulates the real-world scenario of selling or giving land to a new owner, while ensuring that the blockchain transparently records the transfer event.

To initiate a transfer, the owner first navigates to the My Properties page and selects the NFT certificate he/she wants to transfer. This action opens the detailed view of the chosen certificate, which includes metadata, ownership information, and transaction history. At the bottom of this page, as illustrated in **Figure 4.32**, there is a section labeled “Ownership Transfer”.

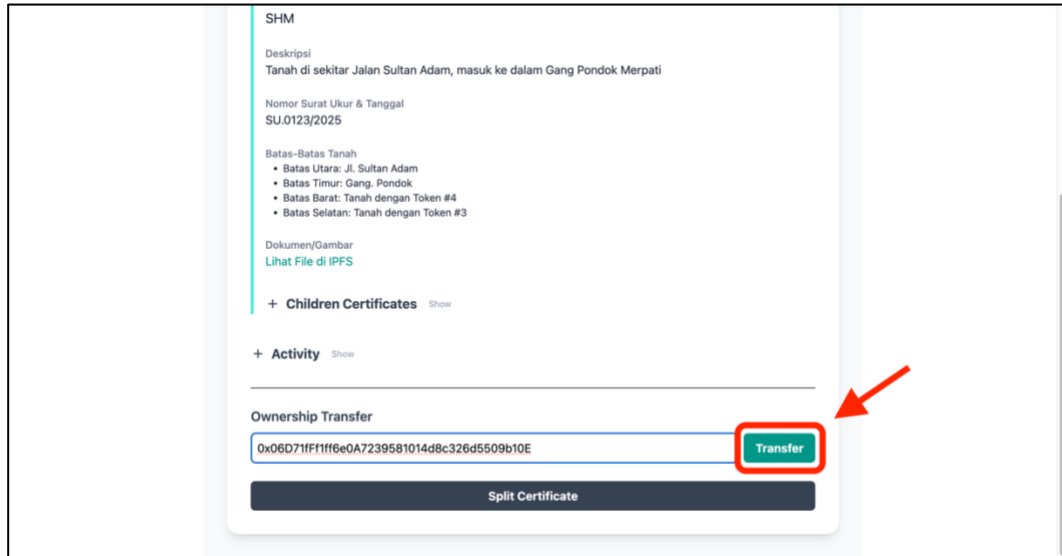


Figure 4.32 Ownership Transfer on My Properties Page

In this section, the owner enters the destination public address of the recipient wallet and then clicks the Transfer button. Once clicked, a MetaMask confirmation window appears, requiring the owner to authorize the transaction. By approving it, the system calls the `transferFrom` function in the smart contract, which reassigns the token to the new wallet address.

After the blockchain validates the transaction, the certificate's ownership is updated immediately. The My Properties page of the sender no longer lists the transferred NFT, while the recipient's (if connected to the system) will now display the certificate under their properties list. The blockchain records is shown in **Figure 4.33**,

Table 4.3 Example Result of NFT Land Certificate Transfer

Token ID	Token Name	Previous Owner	New Owner	Transaction Hash
1	LAND #1	0x8FC4...0AC2	0x06D7...B10E	0x2405C...2566B

The table shows that the certificate LAND #1 (Token ID 1) was transferred from wallet address 0x8FC4...0AC2 to wallet address 0x06D7...B10E. The blockchain transaction hash 0x2405C...2566B provides a permanent and verifiable record of this event.

Through this process, the application demonstrates how blockchain-based land certificates can be securely transferred without requiring physical paperwork or lengthy administrative procedures. Every transfer is automatically recorded in the blockchain, ensuring transparency and reducing the risk of disputes or fraud.

4.3.6. Self-Custody by Land Owners

After the minting and transfer processes have been completed, the next step focuses on how land owners can access and manage their NFTs independently. The landowners need to understand that adding the NFT to their MetaMask wallet is necessary in order to monitor, verify, and interact with their digital land certificate. Otherwise, they will not be able to see or manage their NFTs directly through the wallet interface.

Landowners are not automatically shown their newly received NFTs in the MetaMask wallet interface, even though ownership has already been recorded on the blockchain. To view the asset, the landowners must manually import the NFTs into their MetaMask wallet by providing the contract addresses and token IDs.

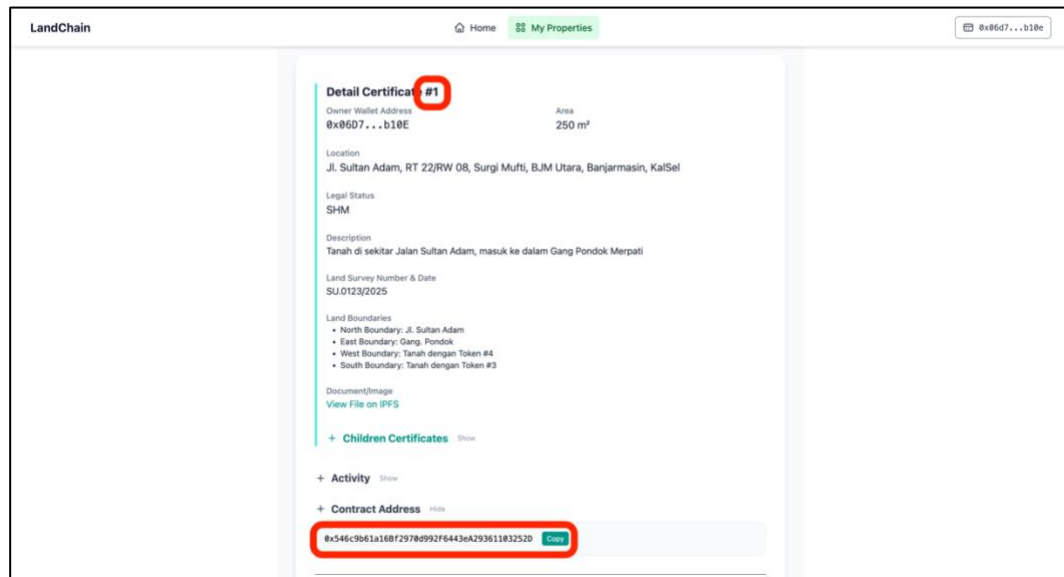


Figure 4.34 Collect Token ID and Contract Address

After obtaining a token ID and contract address as shown in **Figure 4.34**, a landowner can import the NFT into their wallet by opening MetaMask. In the NFT section, click the three-dot icon and then select “Import NFT.”

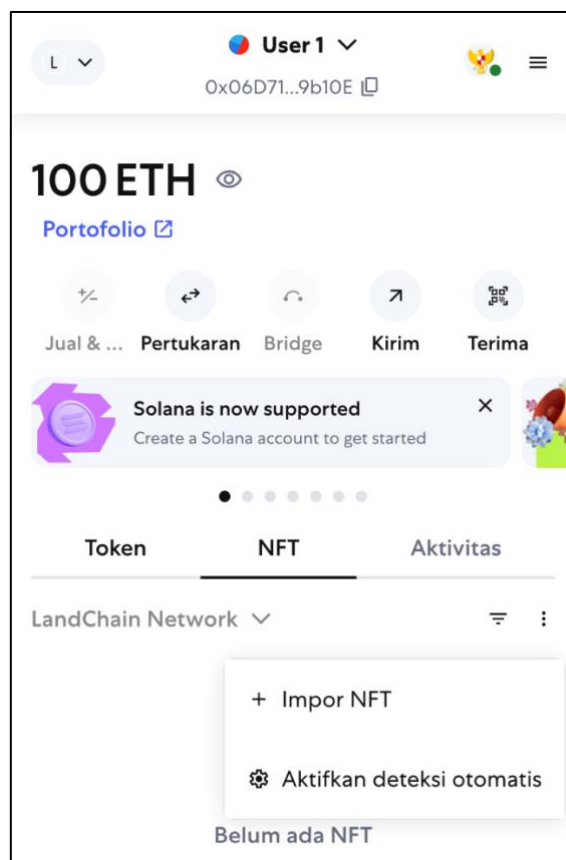


Figure 4.35 NFT section in MetaMask

Import NFT

LandChain Network

Address ⓘ
0x546c9b61a16Bf2970d992F6443eA29...

Token ID ⓘ
1

Cancel Import

No NFTs yet

Figure 4.36 Import NFT form in MetaMask

Figure 4.36 shows the import NFT form in MetaMask. The landowner should first select the appropriate network. In this example, the Ganache network is labeled “LandChain Network.” Next, enter the contract address and token ID, then click the Import button. Once the import is successful, the landowner’s NFT will appear in his/her MetaMask wallet, as shown in **Figure 4.37**.

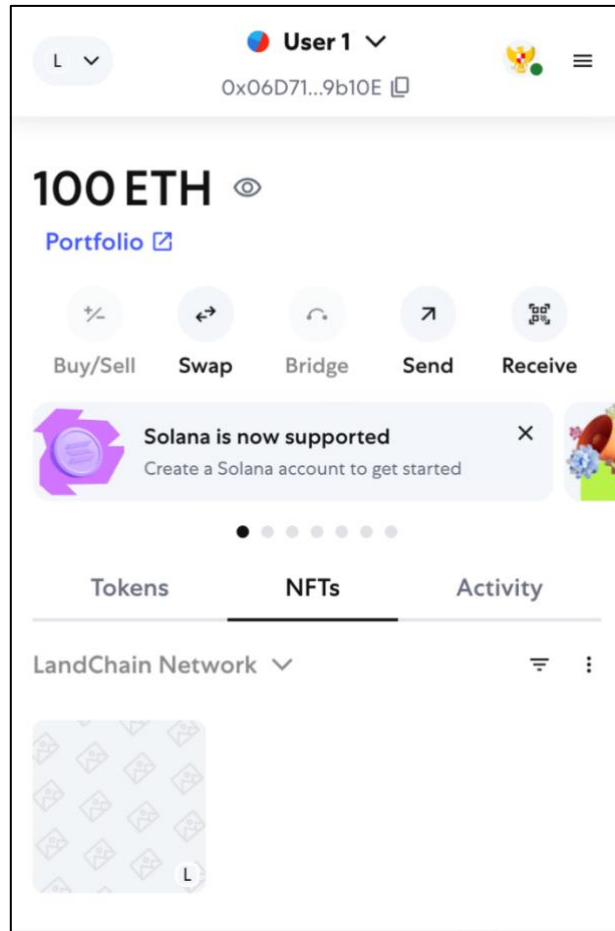


Figure 4.37 Listed NFT's in MetaMask

Manually importing the NFT is part of the landowners' responsibility in a decentralized system. Landowners must take an active role in handling their digital assets. This reflects a key aspect of Web3, where ownership also comes with the responsibility to understand and control one's property directly.

4.3.7. Land Certificate Splitting Process (Splitting NFT)

The splitting process is the act of breaking down an existing NFT that represents a land certificate into several NFTs. Each new NFT represents a part of the original land ownership. This feature is essential for enabling the segmentation of land certificates in practical legal contexts, such as inheritance distribution (*waris*), land grants (*hibah*), or when the owner wants to separate the land into smaller parts before selling it. By using smart contract logic, the split mechanism ensures that each newly generated NFT inherits verifiable metadata from the original NFT and is securely linked to the blockchain. This approach allows for transparent and traceable splitting process of digital land ownership.

The certificate splitting process begins when the landowner opens the certificate details page and selects the option to split an existing land certificate, as shown in **Figure 4.38**. After that the owner enters the required information on the dynamic form for the subdivision, including the list of recipients and the metadata for each new land parcel. An example of this dynamic form is illustrated in **Figure 4.39**. These data files are then uploaded to IPFS, and the system returns multiple CIDs representing each child certificate. Instead of directly interacting with the blockchain, the system prepares a structured EIP-712 message containing the split details, and the landowner signs it using MetaMask. The signed request is stored temporarily within the application. Before the institution can perform the on-chain execution, the landowner must approve the institution to operate on the parent certificate. As shown in **Figure 4.40**.

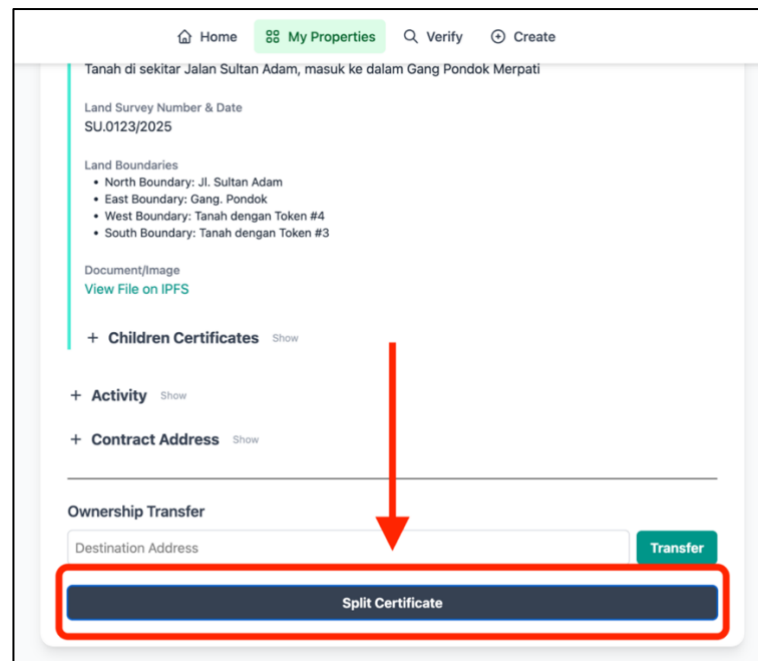


Figure 4.38 Split Certificate button on NFT details section

Home

My Properties

Verify

Request Mint

Close Split Form

You can create and sign the split request. Approval from Institution can be done later if needed.

Number of Child Certificates

2

Child #1

Receiver Address

0x06D71FF1ff6e0A7239581014d8c326d5509b10E

Total Area (m²)

100

Legal Status

SHM

Description

Tanah Dekar Ull

Land Survey Number & Date

cth. SU.0123/2024

Land Boundaries

North Boundary

East Boundary

West Boundary

South Boundary

Upload New Image/Document (Optional)

Choose File

No file chosen

Child #2

Receiver Address

0x06D71FF1ff6e0A7239581014d8c326d5509b10E

Total Area (m²)

150

Legal Status

SHM

Description

Tanah Dekar Ull

Land Survey Number & Date

cth. SU.0123/2024

Land Boundaries

North Boundary

East Boundary

West Boundary

South Boundary

Upload New Image/Document (Optional)

Choose File

No file chosen

Create Split Request & Sign

Figure 4.39 Split Certificate dynamic form

West Boundary

South Boundary

Upload New Image/Document (Optional)

[Choose File](#) No file chosen

✓ Split Request Created Successfully!
Your split request has been signed and saved. An institution can now execute it.

⚠ Approval Required for Institution
To allow an institution to execute this split request, you need to approve them first. Enter the institution address below and approve.

Institution Address

0x8Bf2fA06f44a11E0eca375f51CCA14E4E44B61cE

Enter the address of the institution that will execute this split

Approve Institution

Close Form

Figure 4.40 Institution Address Approval

After the request is completed, the authorized institution accesses the Execute Split interface, where pending split requests are displayed as seen in the **Figure 4.41**. Once the institution verifies that the approval has been granted, it proceeds with the execution of the split. During this transaction, the smart contract validates the owner's digital signature and checks the status of the parent certificate. If the request is valid, the contract marks the parent certificate as inactive and creates multiple child NFTs corresponding to the new land parcels. Each child token is generated with its respective metadata URI, and a direct linkage is recorded between the parent and child certificates for clear traceability.

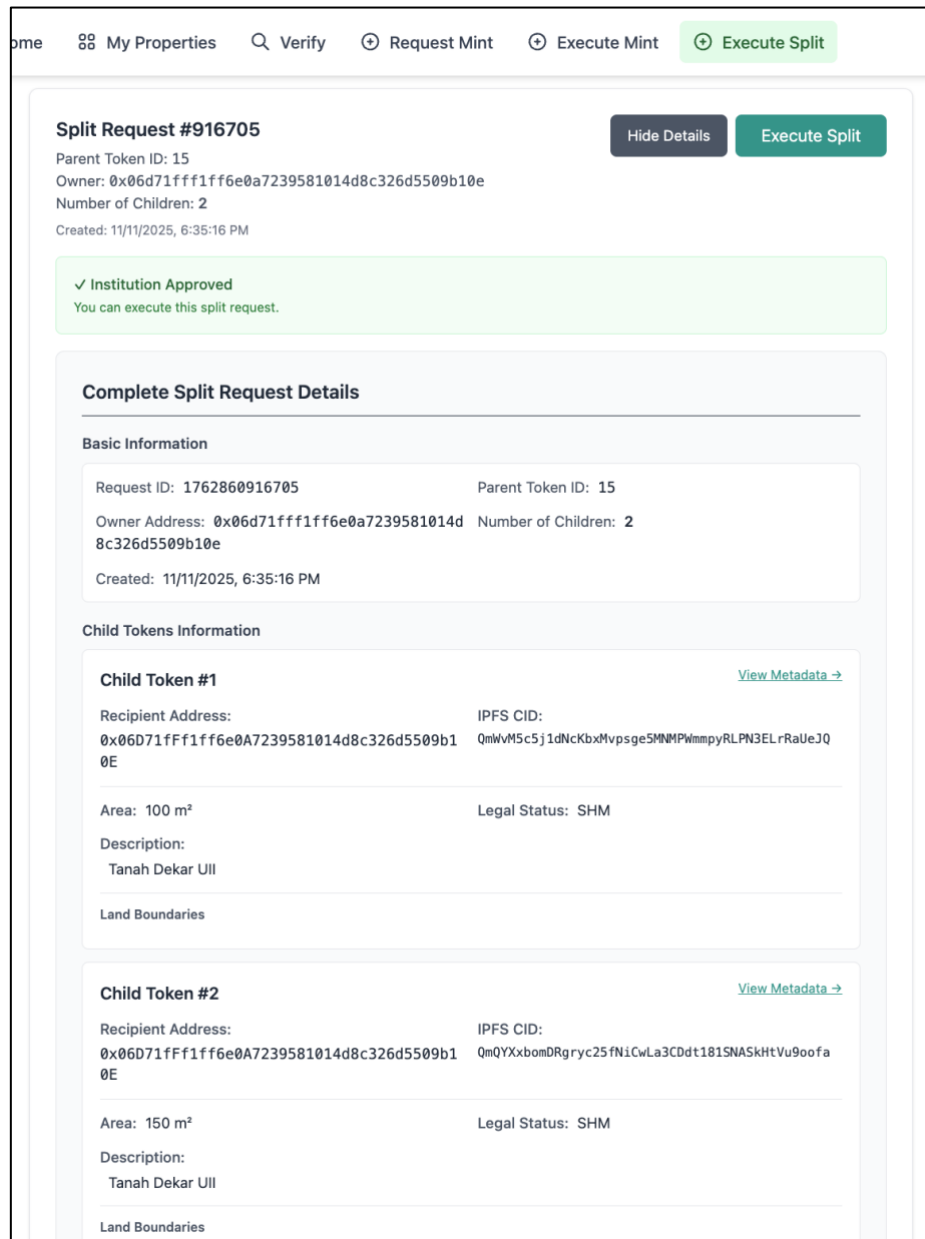


Figure 4.41 Split NFT Pending Request

An important feature of this process is the transparent linkage between parent and child certificates that mentioned before. On the parent NFT page, a new section labeled Children Certificates is added, which displays the complete list of all child tokens generated through the split. Instead, on every child NFT page, a Parent Certificate section is presented, which shows the originating parent token ID and its relevant details. These mutual reference, illustrated in **Figure 4.42** and **Figure 4.43**, ensure that the relationship between parent and child certificates remains permanently traceable within the system.

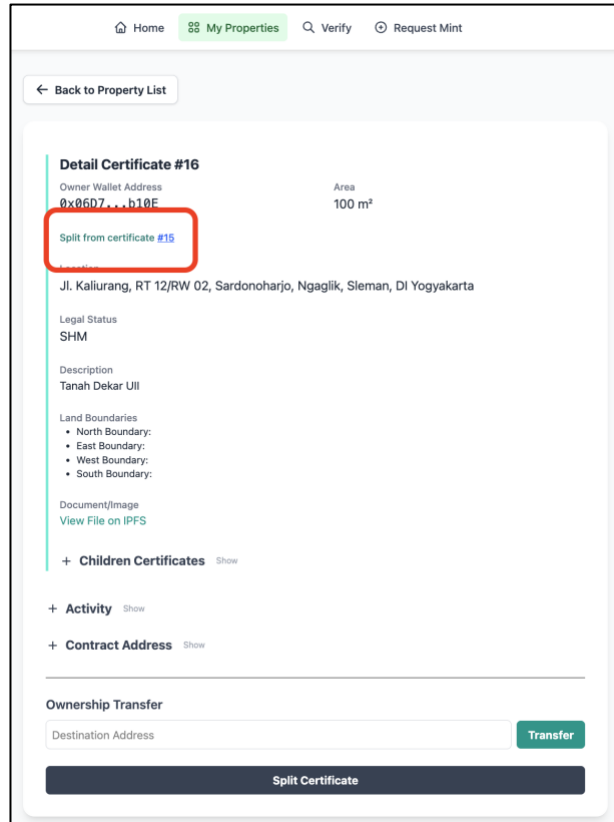


Figure 4.42 Child NFT details with Parent NFT Token ID

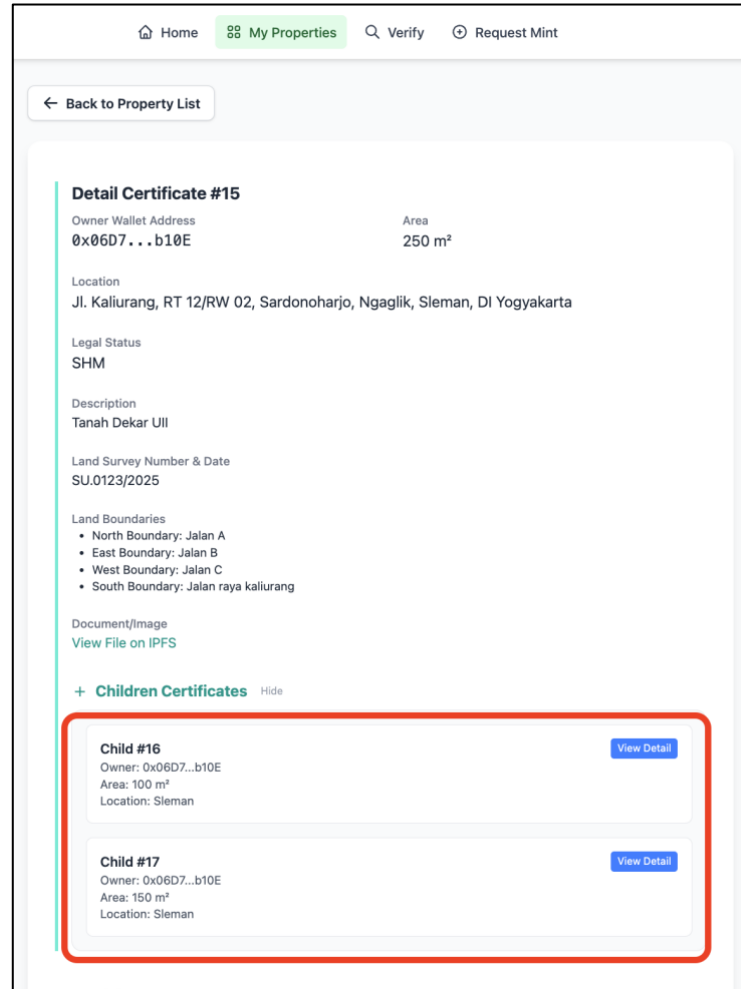


Figure 4.43 Children NFTs in Parent NFT Details

To strengthen this integrity, the system also includes a safeguard against improper operations. If a user (parent NFT holder) attempts to transfer a parent NFT that has already been split, the system rejects the request and displays an error message. This validation is shown in **Figure 4.44**, ensuring that ownership can be transferred for active and valid certificates only.

The IPFS dashboard records the metadata and supporting documents of the newly created child NFTs, each associated with its own CID. This ensures that the child certificates inherit the same level of immutability and verifiability as the original parent. By combining both the blockchain transaction log and the IPFS records, as depicted in **Figure 4.46**, the system provides irrefutable proof that the subdivision has been executed transparently and securely.

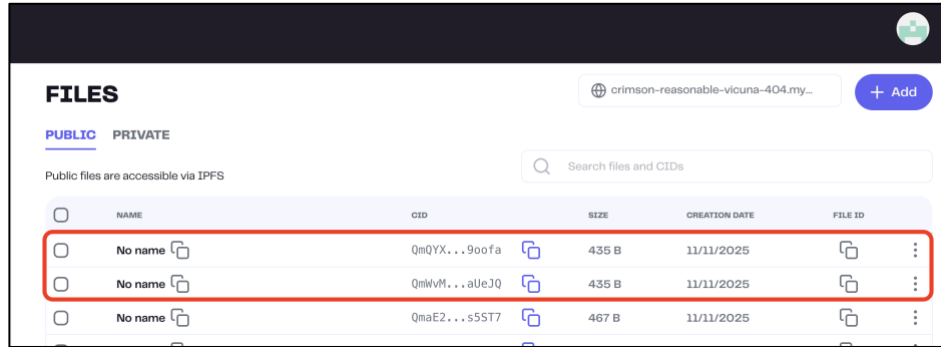


Figure 4.46 IPFS dashboard containing Metadata and CID of Children NFTs

To illustrate the result of a splitting operation, **Table 4.4** presents an example dataset.

Table 4.4 Example Result of NFT Land Certificate Split

Parent Token ID	Child Token ID	Token Name	Area(m ²)	IPFS metadata CID	Status
15	-	LAND #15	250	QmaE2...Ms5ST7	Inactive
15	16	LAND #16	100	QmWvM...aUeJQ	Active
15	17	LAND #17	150	QmQYX...9oofa	Active

In this example, parent token **LAND #15** (250 m²) is divided into **LAND #16** (100 m²) and **LAND #17** (150 m²). Both child tokens are active and independently valid, while the parent token has been marked inactive.

This feature ensures that the system can accommodate real-world land transactions where subdivision of property is required. By recording the split on both the blockchain and IPFS, the process maintains transparency, traceability, and data integrity, while preventing duplication or fraudulent use of the original certificate.

4.4. Analysis of Implementation Results

The blockchain-based land registration system proposed in this research was implemented and tested in a controlled simulation environment using Ganache, MetaMask, IPFS (Pinata), and a React-based frontend application. Each function of the system, including smart contract deployment, institution registration, certificate minting, certificate transfer, self-custody in MetaMask, and certificate splitting, has been demonstrated successfully. This section provides a detailed analysis of the results obtained from these simulations, highlighting their implications in the context of land registration management.

4.4.1. Smart Contract Deployment Analysis

The successful deployment of the smart contract serves as the first technical validation of the system architecture, confirming that the designed components can be compiled and executed correctly within the blockchain environment. Once deployed on the Ganache network, the smart contract was assigned a unique contract address, indicating that it had become a permanent component of the network.

The immutability of this contract ensures that its logic covering minting, transferring, splitting, and access control cannot be changed arbitrarily by any party, not even the contract owner. This guarantees a trustless environment in which participants can rely on code execution rather than human intervention.

The deployment process consumed approximately 0.00477612 ETH in gas fees. While negligible in a local testing network, this highlights an important real-world consideration: the economic cost of running blockchain applications. On mainnet Ethereum or other public blockchains, such costs could become significant. Thus, this aspect is critical for assessing scalability and suitability for nationwide adoption.

4.4.2. Institutional Registration Analysis

The institutional registration step using the “addInstitution” function successfully authorized a specific account to act as an institution. This demonstrated that the system supports role-based access control (RBAC), restricting sensitive operations such as minting and splitting of certificates to only trusted entities.

This mirrors the structure of the existing Indonesian land registration system, where only certified parties (such as BPN) are permitted to issue or modify land certificates. The blockchain-based approach, however, goes one step further, in which the process of authorization is publicly recorded and auditable on the blockchain. This provides an additional layer of transparency compared to the conventional system, where such authorizations may not be directly verifiable by the public.

4.4.3. Minting of Land Certificates Analysis

The process of minting certificates successfully produced NFTs (e.g., “LAND #1”), each linked to metadata stored on IPFS. This metadata contains land ownership details and supporting documents.

By embedding certificate information in IPFS and linking it through a unique Content Identifier (CID), the system guarantees tamper-proof storage of land records. Unlike a centralized database, which may be vulnerable to manipulation, this decentralized approach ensures that once recorded, metadata cannot be changed without detection.

The presence of the newly minted certificate on the “My Properties” page confirmed the smooth integration between frontend (React), blockchain (Ganache), wallet (MetaMask), and decentralized storage (IPFS). The transaction history logs further enhanced traceability by recording every action taken on the certificate. This reflects one of blockchain’s main strengths which is immutable audit trail.

4.4.4. Ownership Transfer Analysis

The ownership transfer simulation demonstrated the peer-to-peer nature of blockchain transactions. When a certificate was transferred from the contract owner to a user account, the process was validated and recorded directly on the blockchain without requiring an intermediary authority.

This represents a significant improvement over the conventional land registration process, which involves multiple layers of bureaucracy and verification. The ability to transfer ownership autonomously and transparently reduces both time delays and the risk of corruption or data tampering.

However, this approach raises legal challenges. Without control from an institution, conflicts or fake transfers could happen. While technically valid on the

blockchain, such transactions may not yet be recognized by Indonesian law unless supported by complementary legislation. This highlights the importance of aligning blockchain technology with legal frameworks.

4.4.5. Self-Custody in MetaMask Analysis

The requirement for landowners to manually import NFTs into their MetaMask wallets reflects the principle of self-custody in decentralized systems. Although ownership is automatically registered on the blockchain, visualization and interaction with the asset require active steps by the user.

This has two main effects. First, landowners are given full control over their assets, independent of third-party institutions. This aligns with the spirit of decentralization and reduces dependency on intermediaries. Second, not all users are familiar with blockchain wallets, private keys, or NFT imports. This creates a potential barrier to adoption, especially in rural communities where digital literacy may be limited.

So, even though the system gives users more control, it also gives them new tasks. This makes user education and a simple interface very important for real use.

4.4.6. Certificate Splitting Analysis

The splitting process was successfully demonstrated, where a parent certificate NFT was subdivided into child NFTs. The parent NFT was marked as Inactive, while the child NFTs maintained a direct reference to the parent's token ID. This ensured traceability of lineage, allowing the system to preserve historical ownership records.

In practical terms, this replicates real-world scenarios such as inheritance or land subdivision. The ability to digitally split certificates provides greater flexibility and reduces administrative complexity compared to manual processes.

However, it is important to note that splitting can only be executed by an authorized institution, not by landowners. This hybrid approach strikes a balance between decentralization (traceability, immutability) and institutional control (legitimacy, oversight).

4.5. Analysis with Conventional Land Registration System

The blockchain-based decentralized application for land registration introduces a new paradigm compared to the conventional system managed by the Indonesian

National Land Agency (Badan Pertanahan Nasional/BPN). While the traditional process relies heavily on centralized institutions, physical documentation, and manual verification, while the proposed system focus on decentralization, transparency, and cryptographic security. This section provides a detailed comparative analysis between the two systems across several key dimensions.

Table 4.5 Comparison Between Conventional and Blockchain-Based Land Registration Systems

Aspect	Conventional Land Registration System	Blockchain-Based Land Registration System
Process Efficiency	Multi-stage procedures requiring manual document submission, physical attendance, and long processing times.	Automated issuance and ownership transfer through smart contracts, reducing manual intervention and administrative delay.
Transparency and Traceability	Data access is restricted; ownership records are stored in centralized databases, which may be prone to manipulation.	All transactions are immutably recorded on a public ledger, allowing transparent and verifiable ownership history.
Security and Data Integrity	Vulnerable to data breaches, insider manipulation, and certificate forgery due to centralization.	Protected by cryptographic validation and distributed storage; ownership records are tamper-evident and traceable.
Cost Consideration	Administrative, legal, and intermediary fees are often unpredictable and location-dependent.	Costs are limited to blockchain transaction fees (gas fees), which varies with network activity but remove intermediary expenses.
Accessibility and User Experience	Simple for the public but inefficient; dependent on physical offices and paperwork.	More efficient but requires digital literacy, wallets, and private key management, limiting accessibility for non-technical users.

Legal Validity and Institutional Acceptance	Legally recognized by BPN as the official ownership record.	Technically secure but not yet legally recognized.
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4.5.1. Process Efficiency

In the conventional land registration process, multiple stages are required, including application submission, document verification, surveying, approval, and final issuance of certificates. Each of these stages often involves physical attendance at BPN offices, reliance on paper documents, and significant waiting times. Delays caused by bureaucracy, missing documents, or lack of staff.

In contrast, the blockchain-based system makes some parts of the process simpler. For example, certificate issuance (minting NFTs) and transfer of ownership are executed automatically through smart contracts. Once transaction fees are confirmed and blocks are validated, ownership updates occur automatically on the blockchain without the need for manual intervention. This represents a significant improvement in efficiency, especially for ownership transfers and certificate verification.

However, physical processes such as surveying and mapping remain outside the system's scope, meaning the blockchain approach cannot fully eliminate all delays. Instead, it makes the existing process more efficient by digitizing and automating specific functions.

4.5.2. Transparency and Traceability

The conventional system provides limited transparency. While citizens may request land ownership data, such requests often require official approval and are subject to restricted access policies. Furthermore, records are typically stored in centralized databases, creating the potential for **data manipulation** or unauthorized changes.

The blockchain-based system, on the other hand, records every action, including minting, transfers, and splitting, on an immutable public ledger. This ensures complete **traceability of ownership history** from the initial issuance of the certificate to its most recent transfer. Each certificate carries verifiable metadata stored on IPFS, which is permanently linked to the blockchain record.

This level of transparency could reduce risk for corruption, double ownership, or fraudulent claims, issues that have historically happened in land administration in Indonesia.

4.5.3. Security and Data Integrity

Conventional land registration databases rely on centralized servers maintained by BPN. While security measures exist, centralized systems remain vulnerable to data breaches, insider threats, and technical failures. Moreover, physical certificates can be forged, stolen, or duplicated.

The blockchain-based approach leverages **cryptographic principles** to secure ownership records. Each transaction requires digital signatures from private keys, making unauthorized changes practically impossible without access to those keys. Furthermore, metadata stored on IPFS is content-addressed and therefore cannot be altered without generating a new content identifier (CID) , ensuring long-term data integrity.

The system's reliance on decentralization also reduces the risk of a **single point of failure**, as records are distributed across multiple nodes. This makes the system more robust against both technical problem and malicious attacks.

4.5.4. Cost Consideration

In the conventional process, costs are associated with administrative fees, surveyor services, notary services, and other intermediaries. These costs are often unpredictable and may vary depending on location, complexity of the case, and bureaucratic requirements.

In a blockchain-based system, the primary cost is in the form of **transaction fees (gas fees)** for minting, transferring, or splitting certificates. While transaction fees in local test environments (e.g., Ganache) are negligible, on public networks like Ethereum, these costs can fluctuate significantly depending on network congestion, as higher transaction volume increases competition among users to include their transactions in the next block, thereby driving gas prices upward.

Although blockchain reduces reliance on intermediaries and administrative costs, it introduces dependency on blockchain economics, where transaction pricing is determined by network demand and computational cost. For practical implementation, adopting a private or government-regulated blockchain could be

considered to stabilize transaction costs, although its feasibility depends on institutional readiness and policy alignment.

4.5.5. Accessibility and User Experience

The conventional system is accessible to the general public through physical offices, though it is often criticized for its complexity and lack of efficiency. Many citizens are familiar with the process, despite its shortcomings.

The blockchain system requires **digital literacy**, including knowledge of wallets, private keys, and Web3 applications. While early adopters or technologically savvy users may adapt easily, large portions of the population may find it challenging. Manual steps such as importing NFTs into MetaMask could be a barrier to accessibility.

This indicates a trade-off: blockchain enhances efficiency, but requires more user education and robust infrastructure before it can be widely adopted.

4.5.6. Legal Validity and Institutional Acceptance

The most important difference is legal recognition. Traditional certificates from BPN have full legal power and can be used in court. Blockchain-based certificates, while technologically secure, currently lack explicit legal recognition under Indonesian law.

For the proposed system to replace or complement the existing framework, legal reforms would be required to recognize blockchain records as valid proof of ownership. Without such legal recognition, the system may only serve as a complementary digital record-keeping platform that operates alongside the official BPN registry, rather than as a legally binding replacement.

4.6. Strengths and Weaknesses of the Proposed System

The development and implementation of a blockchain-based land registration system in this research highlight several strengths and weaknesses. These aspects provide a balanced perspective regarding the possibility of adopting blockchain technology in land administration, particularly in the context of Indonesia.

4.6.1. Strengths of the System

The proposed system offers a number of strengths that distinguish it from conventional land registration methods:

1. Transparency and Auditability

Every action performed in the system, such as minting, transferring, or splitting certificates, is permanently recorded on the blockchain. This immutability ensures that historical ownership data can be transparently verified by all stakeholders, thereby minimizing opportunities for corruption and fraudulent practices.

2. Enhanced Security and Data Integrity

The integration of blockchain with IPFS guarantees the protection of land certificate data from unauthorized modifications. Cryptographic signatures ensure that only legitimate owners or authorized institutions can perform transactions, while distributed storage reduces the risks associated with centralized data breaches or server failures.

3. Improved Efficiency

Certain processes, particularly the issuance of land certificates (minting NFTs) and ownership transfers, can be executed in real-time without the need for intermediary approvals. This automation reduces delays caused by bureaucracy and minimizes the time required for updating land records.

4. Role-Based Access Control (RBAC)

By assigning specific privileges to institutions through the `addInstitution` function, the system maintains a level of control over sensitive operations while still leveraging decentralization for auditability. This approach mirrors the existing land registration structure but enhances it with transparency and digital verification.

5. Traceability of Land Splitting

The ability to split a parent certificate into multiple child certificates while preserving historical linkage strengthens the accountability of land subdivision processes. This feature reflects real-world practices such as inheritance and land partition, while simplifying record management.

4.6.2. Weaknesses Of The System

Despite its strengths, the proposed system also faces several weaknesses that need to be considered for real-world deployment:

1. Limited Legal Recognition

Blockchain-based certificates are not yet recognized as legally binding documents under Indonesian law. Without legal reforms, the system can only function as a supplementary record-keeping mechanism, limiting its practical adoption at the national level.

2. User Accessibility and Digital Literacy Barriers

The requirement for users to manage wallets, private keys, and manually import NFTs introduces significant challenges, especially in regions with low digital literacy. This creates the risk of excluding communities that are not familiar with blockchain technology.

3. Dependence on Network Economics

Transaction execution requires gas fees, which, on public networks, may fluctuate considerably depending on network activity. While local simulations using Ganache incur negligible costs, the economic feasibility of deploying such a system on public blockchains remains uncertain.

4. Infrastructure and Adoption Challenges

Nationwide implementation would require robust digital infrastructure, including reliable internet access and compatible devices. In rural areas, where land conflict are common, limited connectivity may restrict access and slow adoption of blockchain-based land registration.

5. Complexity of Integration with Existing Processes

Although the blockchain system automates certificate issuance and transfer, it does not cover physical processes such as land surveying and validation. These steps must still be conducted through conventional procedures, meaning full digitization of land administration cannot be achieved simply through blockchain.

4.7. Testing Result

System testing was divided into two types such as : black-box testing to ensure technical correctness, and user interview testing to evaluate practical usability and perceived improvements.

4.7.1. Black Box Testing

Black Box Testing was conducted to validate whether the blockchain-based application for land registration performed according to its intended functionality. This testing approach focuses on the input–output relationship of each feature without analyzing the internal source code of the smart contracts or frontend component. The main system functions tested include institution registration, certificate minting (NFT creation), certificate verification, ownership transfer, self-custody in MetaMask, and certificate splitting. Through these scenarios, the testing ensures that the system behaves as expected from both institutional and user perspectives.

Table 4.6 Black Box Testing Result

NO	Test Scenario	Input/Action	Expected Output	Result
1	Institution Registration	Contract Owner fills add instituton column and clicks “Add Institution” then confirms via Metamask.	Address successfully registered as institution; account can access “Create” page	Success
2	Institution Registration	Contract Owner enters an invalid or empty address, then clicks “Add Institution.”	System rejects action and displays error message; institution not added	Success
3	Mint Certificate(NFT Creation)	Landowner submits mint request by uploading metadata to IPFS and signing the request; Institution selects the request on “Execute Mint” page and confirms via MetaMask.	New NFT appears in “My Properties” page with unique Token ID and CID stored on IPFS	Success
4	Mint Certificate(NFT Creation)	Institution clicks “Execute Mint” but cancels the Metamask confirmation.	Minting aborted; no NFT created	Success
5	Verify Certificate	User enters Token ID in “Verify Certificate” page	Displays certificate details	Success
6	Verify Certificate	User enters a Token ID that does not exist	System displays error or “Certificate Not Found”	Success

7	Transfer Ownership	Owner selects certificate in “My Properties,” enters recipient’s address, and clicks “Transfer” then confirms via Metamask.	Recipient sees NFT in wallet, sender no longer listed as owner	Success
8	Transfer Ownership	Owner attempts to transfer a certificate that is inactive (e.g., parent token already split).	Transaction rejected; NFT remains unchanged	Success
9	Self-Custody in Metamask	Owner imports NFT into MetaMask (using Token ID & Contract Address)	NFT successfully appears in wallet under “NFTs” section	Success
10	Self-Custody in Metamask	Owner attempts to import NFT using wrong Token ID or incorrect contract address.	NFT does not appear; MetaMask displays invalid import error	Success
11	Split Certificate (NFT Splitting)	Landowner submits split request by uploading child metadata to IPFS, signing it, and approving the institution address; Institution executes the request via “Execute Split” page and confirms via MetaMask.	Parent NFT set as inactive, child NFTs created with linkage to parent Token ID	Success
12	Split Certificate (NFT Splitting)	Landowner enters child certificate areas with a total that does not match the parent NFT area.	Split Button cant be clicked; parent NFT remains active and no child NFTs created	Success

4.7.2. User Interview Testing

This section presents the results of interviews conducted with landowners who tested or reviewed the decentralized application prototype. The purpose was to understand their impressions regarding the system’s security, transparency, and efficiency.

Table 4.7 User Interview Result

Respondent	Security	Transparency	Efficiency
R1	This respondent believes that with this system, their land certificate will be more secure because the data cannot be easily altered.	This respondent believes that with this system, their land certificate will be more secure because the data cannot be easily altered.	This respondent believes that with this system, their land certificate will be more secure because the data cannot be easily altered.
R2	The respondent feels more confident in the system's data protection since information is stored digitally and cannot be forged.	The respondent stated that ownership details are easier to verify, making the process more transparent for users.	The respondent believes this system helps save time by reducing the number of steps in the registration process.
R3	This respondent mentioned that blockchain storage makes the certificate safer from duplication or tampering.	The respondent said that all transaction histories can be viewed, which helps avoid data manipulation.	The respondent thinks the process is simpler and faster compared to the traditional method.

Based on the interview results, all three respondents expressed positive perceptions of the developed decentralized application. In terms of security, they agreed that the use of blockchain technology and digital records makes land certificates safer from forgery or alteration. Respondents also appreciated that once the certificate data is stored, it cannot be changed without detection, which enhances their sense of data protection and ownership trust.

Regarding transparency, respondents stated that the system allows users to view certificate information and transaction histories openly, making ownership data easier to verify and reducing the potential for disputes. They felt that this level of clarity represents a significant improvement compared to traditional paper-based processes where access to data is limited.

In the aspect of efficiency, all participants agreed that the system reduces the number of manual steps in land registration, such as physical document submission and verification at multiple offices. The digital workflow was considered faster, simpler, and more practical.

Overall, the interviews show that users believe the proposed DApp improves the main objectives of a land registration system such as increasing data security, ensuring transparency, and streamlining the administrative process. These findings support the system's design goals and confirm its potential for real-world adoption.

CHAPTER V

CONCLUSION

5.1. Conclusion

This research focused on developing a blockchain-based decentralized application (DApp) that uses Non-Fungible Tokens (NFTs) for land registration in Indonesia. The system was designed to solve problems in the current land registration system, such as duplicate certificates, fraud, and slow processes. By using blockchain and NFTs, land certificates can become more secure, transparent, and efficient.

The system was built with smart contracts and NFT functions. It included the main features of land certificate creation (minting), ownership transfer, Land Certificate Splitting Process (Splitting NFT), Institution registration and certificate verification. Metadata of the certificates was stored in IPFS to make sure it stays safe and cannot be changed. All actions in the system were recorded in the blockchain to prevent tampering.

In conclusion, this research shows that blockchain and NFTs can be used to build a better land registration system that is more secure, transparent, and efficient. Although there are still legal and technical challenges, this system gives a strong starting point for improving land management in Indonesia using modern technology.

5.2. Key Findings

The main findings of this research can be summarized as follows:

1. The DApp was able to create unique land certificates as NFTs, reducing the risk of duplication or fraud.
2. Smart contracts helped automate important processes such as ownership transfer and certificate creation.
3. The use of IPFS for metadata storage improved the security and decentralization of land data.
4. The system improved transparency and made land registration easier to track.

5. The Implementation showed how blockchain can help solve problems in Indonesia's land registration system, especially in areas with high land conflict.

5.3. Limitation

There are some limitations in this research:

1. The system does not connect with the government's existing databases, such as the electronic certificate and land ownership records managed by BPN.
2. It does not include physical land survey or legal verification of land ownership.
3. User identity verification was not included in this version of the application.
4. The legal framework in Indonesia does not yet fully support blockchain-based land certificates.

5.4. Suggestion for Future Work

Future projects can focus on connecting this system with Indonesia's national ID system for better user authentication. It can also be linked to GIS systems to show the exact land location and borders. Legal studies should be conducted to ensure the legal validity of NFT-based land certificates. Finally, further testing should be done in various parts of Indonesia to see if the system can be used widely.

In conclusion, this research shows that blockchain and NFTs can be used to build a better land registration system that is more secure, transparent, and efficient. Although there are still legal and technical challenges, this system gives a strong starting point for improving land management in Indonesia using modern technology.

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