BLOCKCHAIN-BASED ORGANIC CERTIFICATION SYSTEM

BACHELOR OF TECHNOLOGY
IN
COMPUTER SCIENCE AND ENGINEERING

Use Case Report

submitted by

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Kanuru, Vijayawada-520 007

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CERTIFICATE

This is to certify that the Use Case report entitled **"Blockchain-Based Organic Certification System"** that is being submitted by **Lanka Swetha Sree (22501A0597)**, as part of Assignment-1 and Assignment-2 for the **Blockchain Technology (20CS4601C)** course in **3-2** during the academic year **2024-25**.

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1. INTRODUCTION

Organic production faces significant challenges in ensuring transparency, trust, and efficiency in the certification process. The current system suffers from fraudulent certifications, where fake organic labels undermine consumer trust and damage the reputation of legitimate producers. Additionally, there is a lack of transparency, making it difficult for consumers and regulators to verify the origin and authenticity of organic products, leading to disputes and mistrust. Manual verification processes further exacerbate the problem, as they are time-consuming, costly, and prone to human errors. Centralized databases, which are vulnerable to tampering, hacking, and data loss, also compromise the credibility of the certification process [1][2].

The organic certification process faces many problems, such as fake certifications, lack of transparency, slow and costly processes, and risks of data tampering. Blockchain technology can solve these issues by providing a secure, transparent, and decentralized system for managing certifications. Once a certification is issued on the blockchain, it cannot be changed or copied, which reduces fraud and builds trust. All stakeholders—farmers, certification bodies, retailers, and consumers—can access real-time, verified information, ensuring that organic products can be traced back to their source [3].

Smart contracts automate tasks like issuing, renewing, or revoking certifications, saving time and reducing errors. Blockchain's decentralized nature and strong security protect certification data from hacking or tampering. Consumers can also verify the authenticity of organic products by scanning QR codes linked to blockchain-stored certifications, increasing trust. Additionally, blockchain helps manage certifications across global supply chains, making it easier to follow international rules. By moving to a digital system, blockchain reduces paper waste and promotes sustainability, ensuring that producers are held accountable for their claims [4][5].

2. BACKGROUND

1. **Challenges in Traditional Organic Certification**
   Organic certification ensures compliance with specific farming standards, but traditional systems face inefficiencies due to centralized databases, manual processes, and paper-based documentation, making the process slow, costly, and prone to fraud .

2. **Lack of Transparency and Traceability**
   Consumers and regulators struggle to verify the authenticity of organic products due to the absence of real-time tracking. Traditional systems do not provide clear visibility into the supply chain, increasing the risk of fraudulent organic labeling.

3. **Vulnerability to Fraud and Data Tampering**
   Centralized databases used in organic certification can be hacked or manipulated. Fraudulent certifications undermine consumer trust and harm genuine organic producers, leading to market distortions.

4. **High Costs and Administrative Burden**
   The organic certification process is resource-intensive, requiring extensive paperwork, inspections, and renewals. Farmers and certification bodies incur high costs, and delays in approval further discourage participation in organic farming.

5. **Complexity in Global Organic Trade**
   Organic supply chains span multiple countries, each with different certification regulations. Lack of standardization makes international organic trade difficult, increasing compliance costs and the risk of mislabeling.

6. **Consumer Access to Certification Information**
   Consumers rely on physical labels, which can be forged or misplaced. Limited access to certification data reduces confidence in organic products and restricts consumer decision-making.

7. **Environmental Impact of Paper-Based Certification**
   Traditional certification systems rely heavily on paper documentation, contributing to deforestation and carbon emissions. The lack of digitization contradicts the sustainability principles promoted by organic agriculture.

8. **Need for Technological Solutions**
   Blockchain technology offers a decentralized, tamper-proof system that enhances transparency, security, and traceability. Smart contracts automate certification processes, reducing human error and administrative costs. QR codes linked to blockchain records allow consumers to verify organic products instantly, improving trust and market efficiency.

3. BLOCKCHAIN BASICS

Blockchain technology is a decentralized and distributed ledger system that records transactions across multiple nodes, ensuring transparency, security, and immutability. Unlike traditional databases, blockchain operates on a peer-to-peer network, eliminating the need for central authorities. Each block in the chain contains a cryptographic hash of the previous block, making data tampering virtually impossible. Originally designed for cryptocurrency transactions, blockchain has now expanded into various domains, including finance, supply chain, healthcare, and organic certification.

3.1. Decentralization

Traditional databases are managed by centralized authorities, such as banks or corporations, which creates a single point of failure and makes them vulnerable to hacks or data manipulation. Blockchain, on the other hand, operates on a decentralized network, where multiple independent nodes validate and store data. This ensures that no single entity has full control over the system, making it resistant to censorship and fraud. In organic certification, decentralization ensures that certification data is not controlled by a single entity, reducing the risk of manipulation and enhancing trust among stakeholders.

3.2. Immutability

One of blockchain's defining characteristics is immutability, meaning once a transaction is recorded, it cannot be altered or deleted. This is achieved through cryptographic hashing, where each block is linked to the previous one, forming a secure chain that prevents unauthorized modifications. In organic certification, immutability ensures that once a certification is issued, it cannot be tampered with, reducing the risk of fraudulent certifications and enhancing the credibility of the system.

3.3. Transparency

Blockchain transactions are publicly verifiable, meaning anyone with access to the network can audit the transaction history. This transparency is ensured by distributed ledger technology (DLT), where every participant has access to an identical copy of the data, eliminating the risk of hidden alterations. In organic certification, transparency allows all stakeholders—farmers, certification bodies, retailers, and consumers—to access real-time, verifiable information about the certification status of a product, fostering trust and accountability.

3.4. Smart Contracts

Smart contracts are self-executing contracts with predefined conditions embedded in the blockchain. Once the specified conditions are met, the contract automatically executes the agreed-upon actions, eliminating the need for manual processing. In organic certification, smart contracts can automate processes such as certification issuance, renewal, and revocation, reducing administrative overhead and minimizing human errors. For example, a smart contract can automatically issue a certification upon successful inspection or revoke it in cases of non-compliance.

3.5. Consensus Mechanisms

Blockchain networks rely on consensus mechanisms to validate transactions and maintain system integrity. The most widely used mechanisms include:

- **Proof of Work (PoW):** Requires computational effort to validate transactions, making tampering difficult but energy-intensive.
- **Proof of Stake (PoS):** Transactions are verified based on the stake or reputation of validators, reducing energy consumption while maintaining security.
- **Delegated Proof of Stake (DPoS):** Users vote for delegates who validate transactions on their behalf, improving scalability and efficiency.

In organic certification, consensus mechanisms ensure that only valid certifications are recorded on the blockchain, enhancing the reliability of the system.

3.6. Cryptographic Security

Blockchain security relies on advanced cryptographic techniques to protect user data and transactions. Each transaction is authenticated using public and private keys, ensuring that only authorized individuals can initiate transactions. Hash functions further enhance security by converting data into fixed-length unique codes, making it nearly impossible to reverse-engineer original information. In organic certification, cryptographic security ensures that certification data is protected from unauthorized access and tampering, enhancing the overall integrity of the system.

4. USE CASE OVERVIEW

Organic certification ensures that agricultural products meet established organic standards. However, traditional certification systems face challenges such as fraud, lack of transparency, data tampering, and inefficiencies. Blockchain technology, with its decentralized, immutable, and secure nature, presents a robust solution to enhance the integrity of organic certification processes.

This use case explores how blockchain can be leveraged to create a transparent and tamper-proof certification system, ensuring authenticity, reducing fraud, and improving stakeholder trust.

4.1. Objectives

The primary objectives of implementing blockchain in organic certification are:

1. **Eliminate Fraudulent Certifications:** Blockchain's immutability ensures that issued certifications cannot be altered or forged.
2. **Enhance Transparency and Traceability:** A distributed ledger allows stakeholders to access real-time, verifiable certification records, improving product traceability.
3. **Reduce Administrative Overhead:** Smart contracts automate certification issuance, renewal, and revocation, reducing paperwork and manual errors.
4. **Ensure Data Integrity and Security:** Decentralization and cryptographic techniques prevent data manipulation and unauthorized access.
5. **Facilitate Consumer Trust and Confidence:** Consumers can verify product authenticity by scanning a QR code linked to blockchain-stored certification data.
6. **Support Global Supply Chains:** A standardized platform ensures seamless compliance with international organic regulations.
7. **Promote Sustainability:** Digital certification eliminates paper-based processes, contributing to environmental conservation.

4.2. Scope of the System

The blockchain-based organic certification system applies to various agricultural sectors, including:

- **Organic Farming:** Certifying crops, dairy, and livestock products.
- **Food Processing & Packaging:** Ensuring organic compliance during processing and packaging.
- **Supply Chain Management:** Tracking organic products from farm to consumer.
- **Retail & Consumer Verification:** Providing authentication for buyers and end-users.

The system involves multiple stakeholders:

- **Farmers:** Apply for organic certification and submit compliance documents.

- **Certification Bodies:** Review applications, inspect farms, and issue/revoke certifications.
- **Regulatory Agencies:** Oversee compliance and audit fraudulent certifications.
- **Retailers:** Verify the certification status of products before selling them.
- **Consumers:** Scan QR codes to verify the authenticity of organic products.

4.3. System Architecture

The blockchain-based certification system consists of multiple layers to ensure security, transparency, and usability (**Fig 4.1**).

4.3.1. Blockchain Layer

This is the core of the system, where certification data is recorded immutably.

1. **Blockchain Network**: A permissioned blockchain (e.g., Hyperledger Fabric, Ethereum) ensures controlled access while maintaining transparency.
2. **Decentralized Ledger**: Stores all certification records immutably, preventing unauthorized modifications (**Fig 4.1**).
3. **Consensus Mechanism**: Uses Proof of Stake (PoS) or Practical Byzantine Fault Tolerance (PBFT) to validate certification transactions.

4.3.2. Identity Verification Layer

1. **Farmer Authentication**: Farmers register using government-issued IDs and digital signatures.
2. **Zero-Knowledge Proofs**: Ensures farmers' identities are verified without exposing sensitive information.
3. **Public and Private Keys**: Farmers, certification bodies, and regulators use cryptographic keys for secure transactions.

4.3.3. Certification and Smart Contract Layer

1. **Smart Contracts**: Automate certification issuance, validation, renewal, and revocation.
2. **Encrypted Certification Data**: Certification records are encrypted and linked to blockchain addresses for security.
3. **Multi-Signature Validation**: Ensures only authorized certification bodies can approve applications, preventing unauthorized certifications (**Fig 4.1**).

4.3.4. User Interface Layer

1. **Web and Mobile Applications**: A user-friendly platform for farmers, certification bodies, retailers, and consumers to interact with the system.

2. **QR Code Verification**: Consumers and retailers scan QR codes to validate product authenticity (**Fig 4.1**).
3. **Real-Time Certification Dashboard**: Displays certification status, expiration dates, and compliance tracking.

4.3.5. Off-Chain Storage

1. **Inspection Reports Database**: Stores detailed inspection documents and supporting files.
2. **QR Code Generator**: Links certifications to blockchain records, enabling easy consumer verification (**Fig 4.1**).

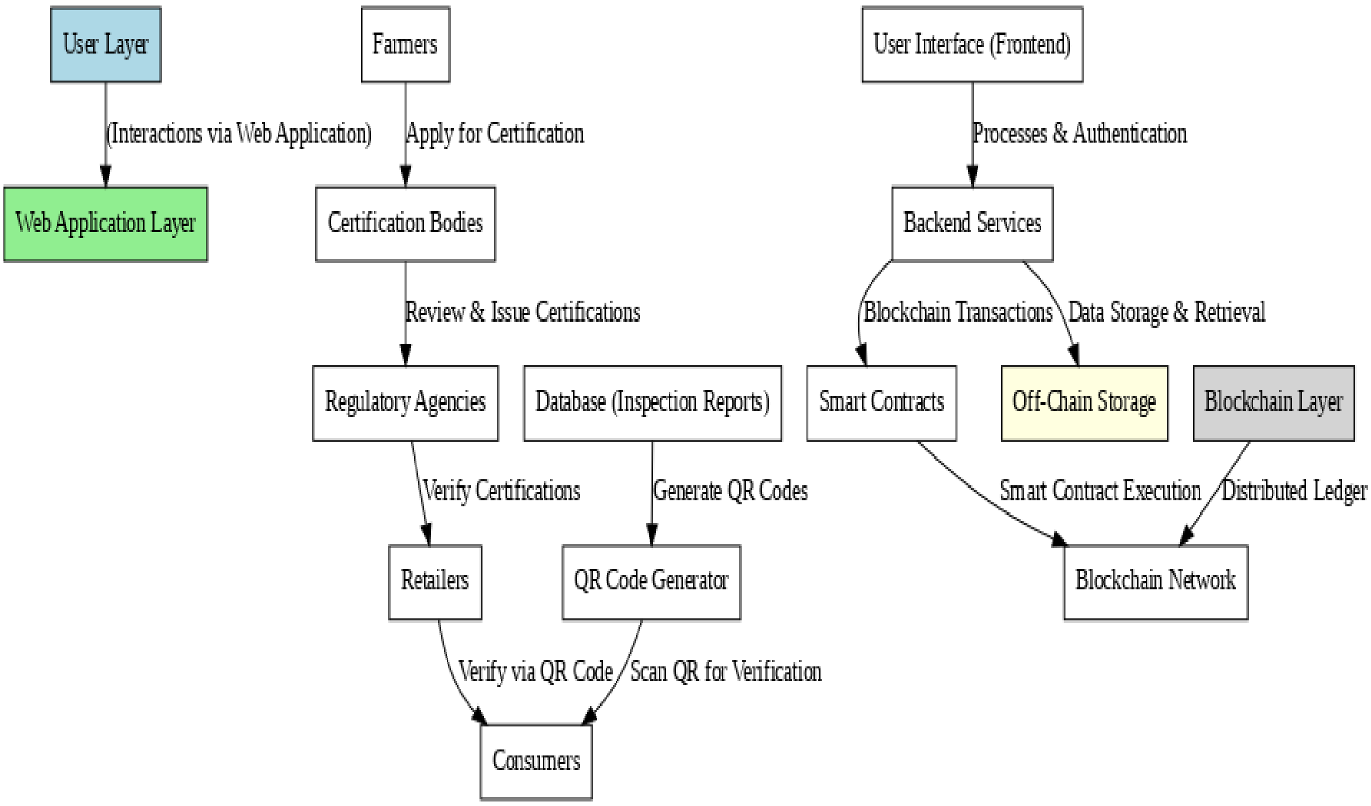

Fig4.1: Blockchain-Based Organic Certification System

4.4. Workflow of the System

1. **Farmer Registration**: Farmers apply for organic certification and submit required documents (**Fig 4.1**).
2. **Verification & Inspection**: Certification bodies review applications, conduct farm inspections, and validate compliance.
3. **Certification Issuance**: Approved certifications are recorded on the blockchain via smart contracts (**Fig 4.1**).
4. **Regulatory Oversight**: Authorities audit certifications to ensure compliance with organic standards.
5. **Retailer Verification**: Retailers verify product certification before sale using blockchain records (**Fig 4.1**).
6. **Consumer Authentication**: Consumers scan QR codes to check product authenticity and certification details (**Fig 4.1**).

4.5. Benefits of the System

1. **Enhanced Security:** Blockchain's immutability prevents certification fraud and tampering.
2. **Improved Transparency:** Real-time, verifiable certification data enhances trust across the supply chain.
3. **Reduced Costs:** Automation through smart contracts minimizes administrative expenses.
4. **Increased Consumer Confidence:** QR code verification reassures buyers about product authenticity.
5. **Scalability & Global Compliance:** A blockchain-based approach standardizes organic certification across borders, facilitating international trade.

5. IMPLEMENTATION

5.1 Define the Certification Workflow

- **Identify stakeholders:** Farmers, Certification Authorities, Consumers, Retailers.
- **Determine stored data:** Farmer ID (hashed for privacy), Product Details, Certification Status, Issuance Date, Expiration Date, Certification Hash.
- **Define key operations:** Farmer Registration, Certification Issuance, Certification Verification, Certification Renewal.

5.2 Choose the Blockchain Type

- **Private Blockchain (Hyperledger, Quorum):** Suitable for controlled access by certification bodies and government agencies.
- **Hybrid Blockchain (Ethereum, Polkadot):** Allows public verification while keeping farmer identities private.
- **Public Blockchain (Ethereum, Polygon):** Fully transparent but incurs higher transaction costs.

5.3 Design Smart Contracts for Certification Management

Smart contracts automate certification processes, ensuring security and transparency. The following outlines key functionalities:

A. Farmer Registration – Secure Identity Verification

- Farmers provide identity credentials (e.g., government ID, biometric data, cryptographic keys).
- The smart contract verifies identity using cryptographic techniques (e.g., Zero-Knowledge Proofs).
- A unique blockchain address (wallet) is assigned to registered farmers.
- The registration status is hashed and stored on the blockchain to prevent duplication.

B. Certification Issuance – Ensuring Authenticity

- Certification bodies verify product authenticity before issuing a certification token.
- A certification smart contract records details like product category, certification period, and unique certification ID.
- The issued certification is linked to the farmer’s blockchain address.

C. Certification Validation – Secure and Transparent Verification

- Consumers and retailers can verify certifications by checking the blockchain.
- The smart contract ensures that expired or revoked certifications are invalidated.
- QR codes can be generated for easy verification of blockchain-stored certifications.

D. Certification Renewal – Automatic and Secure Updates

- Certification authorities can renew certifications upon successful re-evaluation.
- The smart contract updates the expiration date while maintaining the previous records.
- Farmers are notified through blockchain-based messaging systems.

5.4 Develop & Deploy Smart Contracts

```
pragma solidity ^0.8.0;

contract OrganicCertification {
    struct Certification {
        string product;
        address farmer;
        uint256 issueDate;
        uint256 expiryDate;
        bool isValid;
    }

    address public certifier;
    mapping(uint256 => Certification) public certifications;
    mapping(address => bool) public registeredFarmers;
    uint256 public certCount;

    event CertificationIssued(address farmer, uint256 certId);
    event CertificationVerified(uint256 certId, bool isValid);
    event CertificationRenewed(uint256 certId, uint256 newExpiryDate);

    constructor() {
        certifier = msg.sender;
    }

    function registerFarmer(address farmer) public {
        require(msg.sender == certifier, "Only certifier can register farmers");
        registeredFarmers[farmer] = true;
    }

    function issueCertification(address farmer, string memory product, uint256 expiryDate)
public {
        require(registeredFarmers[farmer], "Farmer not registered");
        certCount++;
        certifications[certCount] = Certification(product, farmer, block.timestamp, expiryDate,
true);
```

```
        emit CertificationIssued(farmer, certCount);
    }

    function verifyCertification(uint256 certId) public view returns (bool) {
        return certifications[certId].isValid;
    }

    function renewCertification(uint256 certId, uint256 newExpiryDate) public {
        require(msg.sender == certifier, "Only certifier can renew certifications");
        certifications[certId].expiryDate = newExpiryDate;
        emit CertificationRenewed(certId, newExpiryDate);
    }
}
```

5.5 Integrate QR Code & Digital Identity for Verification

- **QR Code-Based Verification:** Consumers and retailers scan QR codes linked to blockchain-stored certifications.
- **Digital Identity:** Farmers use blockchain-based digital IDs for authentication.

5.6 Frontend & Web3 Integration

- **Frontend:** Built using React.js/Next.js for user-friendly certification management.
- **Web3 Integration:** Uses Web3.js or Ethers.js to interact with the blockchain.
- **Wallet-Based Authentication:** MetaMask or private key-based authentication for stakeholders.

5.7 Test the Smart Contracts

- **Local Testing:** Deploy on Ganache (Ethereum test environment).
- **Unit Testing:** Validate contract logic using Truffle or Hardhat.
- **Security Audits:** Check vulnerabilities using Slither or MythX.

5.8 Deploy on a Blockchain Network

- **Testnet Deployment:** Deploy on Ethereum Testnet (Goerli, Sepolia) before the main launch.
- **Mainnet Deployment:** Deploy finalized contracts on Ethereum or Polygon for transparency.
- **Decentralized Storage:** Store certification-related documents on IPFS for security.

5.9 Monitor & Maintain the System

- **Real-Time Monitoring:** Use Chainlink oracles for data verification.
- **Event Logging:** Maintain a log of all certifications issued for auditing.

- **Security Updates:** Perform periodic smart contract upgrades to address vulnerabilities.

5.10 Ensure Compliance & Scalability

- **Regulatory Compliance:** Align with organic certification standards and data privacy regulations.
- **Optimized Gas Fees:** Utilize Layer 2 solutions like Polygon or Optimism for cost efficiency.
- **Scalability Measures:** Implement sharding or sidechains to handle high certification volumes.

6. BENEFITS

Blockchain technology revolutionizes organic certification management by introducing transparency, security, and automation. Traditional certification systems rely on centralized databases, which are prone to fraud, inefficiency, and data loss. By leveraging blockchain, organic certification becomes tamper-proof, cost-effective, and highly efficient. Below are the key advantages:

6.1. Enhanced Security and Immutability

Blockchain ensures **that** once a certification is issued, it cannot be altered or deleted. This prevents fraudulent certifications and makes all transactions tamper-proof. The cryptographic security of blockchain also protects sensitive certification data, reducing the risk of hacking and unauthorized modifications.

6.2. Elimination of Fake and Duplicate Certifications

A major issue in traditional certification systems is the creation of fake or duplicate certifications. With blockchain, each certification is stored as a unique, verifiable token, making it easy to validate and preventing unauthorized claims. This enhances trust between farmers, certification bodies, and consumers.

6.3. Transparency and Auditability

Blockchain-based certifications provide real-time visibility to all stakeholders, including farmers, certification authorities, retailers, and consumers. Since all transactions are recorded on a distributed ledger, anyone can verify a certification's authenticity without relying on intermediaries. This reduces disputes and increases confidence in the certification system.

6.4. Easy Transferability of Certifications

Traditionally, transferring product certifications between owners is complex and requires paperwork. With blockchain, certification tokens can be easily transferred between users. When a product is resold, the new owner automatically receives the certification without requiring approval from the certification body, ensuring smooth resale transactions.

6.5. Cost Reduction and Efficiency

Blockchain eliminates the need for manual verification, paperwork, and intermediaries, significantly reducing administrative costs. Since all certification records are stored on-chain, processing times are faster, and operational expenses are lower.

6.6. Smart Contracts for Automated Certification Processing

Smart contracts automate certification validation, eliminating manual verification. When a certification claim is made, the smart contract automatically checks if the product meets the required standards. If all conditions are met, the certification is approved instantly, reducing processing time and operational costs.

6.7. Preventing Certification Fraud and Unauthorized Claims

Blockchain prevents certification fraud by ensuring that certification details cannot be manipulated. Fraudulent activities such as altering certification details or making multiple claims for the same product are prevented because the blockchain maintains an immutable history of all issued certifications.

6.8. Scalability and Integration with IoT

Blockchain-based certification systems can integrate with IoT (Internet of Things) devices to monitor farming practices and product conditions in real time. This ensures that only genuine organic products receive certifications, making the process more accurate and fraud-resistant.

6.9. Increased Consumer Trust and Satisfaction

A transparent and fraud-resistant certification system builds consumer trust. Since consumers can easily verify certification details and product history on the blockchain, they are more likely to trust brands that use blockchain-powered certifications, leading to higher customer retention and loyalty.

6.10. Sustainability and Paperless Certification Management

Blockchain helps companies eliminate paper-based certifications, reducing environmental impact. Since all certification records are digitally stored, businesses can transition to a fully paperless system, making certification management more sustainable and eco-friendly.

7. CHALLENGES

While blockchain-based organic certification systems offer numerous advantages, they also present challenges that must be addressed for effective implementation. Below are some key limitations:

7.1. Scalability Issues

Public blockchains often face scalability constraints, leading to slow transaction processing and high gas fees. This can become a bottleneck for large-scale certification management, especially when multiple transactions are executed simultaneously. Implementing scalable blockchain solutions such as layer-2 networks or private blockchains can help mitigate these issues.

7.2. Regulatory and Legal Compliance

Blockchain regulations vary across countries, making it challenging for businesses to comply with data privacy laws, smart contract legality, and organic certification standards. Additionally, organic certification laws differ from region to region, making it difficult to create a globally unified certification system.

7.3. Lack of User Awareness and Adoption

Many businesses, farmers, and consumers lack familiarity with blockchain technology, leading to resistance to adoption. Educating stakeholders on how to access, verify, and manage blockchain-based certifications remains a significant challenge. User-friendly interfaces and awareness programs are essential to drive adoption.

7.4. Dependence on Internet Connectivity

Blockchain-based certification systems require internet access for verification and transactions. Users in remote or rural areas with poor connectivity may struggle to access and manage their certifications, limiting the system's effectiveness in such regions.

7.5. Challenges in Certification Transfers

While blockchain simplifies certification transfers, disputes over product ownership and eligibility can still arise. Some certification bodies may impose restrictions on resale certifications, complicating transactions for secondary buyers. Standardizing transfer policies can help mitigate these issues.

8. CONCLUSION

The report explores the integration of **blockchain technology** into **organic certification systems**, addressing key challenges in traditional certification management. It highlights the inefficiencies of **paper-based certifications**, such as **fraud risks, manual verification delays, and lack of transparency**. By leveraging blockchain's **immutability and decentralization**, the proposed system enhances **security, trust, and efficiency** in certification transactions.

The use of **smart contracts** automates the **issuance, transfer, and validation** of certifications, reducing reliance on **intermediaries** and ensuring a **seamless user experience**. This automation minimizes errors, speeds up processes, and enhances overall trust in the certification system.

The implementation of the blockchain-based certification system, as described in the report, offers a **structured and secure** approach to certification management. **Companies** can efficiently **register, issue, and track certifications**, while **consumers** can easily **verify authenticity and transfer ownership**. The system **automatically invalidates expired certifications**, preventing **misuse and fraud**.

By transitioning to a **blockchain-powered model**, organizations can significantly **reduce paperwork, improve operational efficiency, enhance customer satisfaction, and promote sustainability**. This shift aligns with the growing demand for **transparent, reliable, and eco-friendly certification systems** in the organic industry.

9. SDG's ADDRESSED

The **Blockchain-Based Organic Certification System** aligns with several **United Nations Sustainable Development Goals (SDGs)** by enhancing **transparency, reducing waste, promoting industry innovation, and ensuring secure transactions**. Below are the key SDGs addressed, listed in order of priority:

1. SDG 12: Responsible Consumption and Production

The system **eliminates paper-based certifications**, reducing **electronic and paper waste** while ensuring **tamper-proof, immutable digital records**. By preventing fraudulent claims and unnecessary product replacements, blockchain technology **enhances resource efficiency**. Additionally, integrating **AI-driven predictive maintenance** extends product lifespan, promoting **sustainable consumption and reducing early disposal**.

2. SDG 9: Industry, Innovation, and Infrastructure

Blockchain technology drives **digital transformation** in the organic certification industry, ensuring **secure, decentralized, and transparent** records. The use of **smart contracts** automates **issuance, validation, and transfer** processes, reducing manual intervention and increasing operational efficiency. This contributes to **industrial modernization and enhanced infrastructure reliability**.

3. SDG 13: Climate Action

By **digitizing certifications** and **removing paper-based processes**, the system helps **reduce deforestation** and **lower carbon footprints** associated with traditional record-keeping. The automation of smart contracts **eliminates the need for physical paperwork and transportation**, leading to an **indirect reduction in CO_2 emissions** from administrative operations.

10. REFERENCES

1. **Blockchain Framework for Certification of Organic Agriculture Production.**
    - This study proposes a blockchain framework tailored for certifying organic agriculture, emphasizing transparency and trust in the certification process.
    - **Link:** https://www.mdpi.com/2071-1050/14/19/11823
2. **Blockchain for Organic Food Traceability: Case Studies on Drivers and Challenges.**
    - This paper examines the application of blockchain in organic food traceability, highlighting the motivations and obstacles faced by companies in the organic supply chain.
    - **Link:** https://www.frontiersin.org/articles/10.3389/fbloc.2020.567175/full
3. **Blockchain-based Food Traceability System and Pro-environmental Behavior.**
    - This research explores how blockchain-enabled traceability systems can influence consumer behavior towards organic food products.
    - **Link:** https://www.sciencedirect.com/science/article/pii/S2666954424000231
4. **Blockchain-enabled Food Traceability System and Consumers' Organic Food Purchasing Intention.**
    - This study investigates the impact of blockchain-based traceability systems on consumers' intentions to purchase organic food.
    - **Link:** https://www.sciencedirect.com/science/article/pii/S2666188824001655
5. **Smart Agriculture Assurance: IoT and Blockchain for Organic Food Certification.**
    - This article discusses the integration of IoT and blockchain technologies to enhance the certification process in organic agriculture.
    - **Link:** https://www.sciencedirect.com/science/article/pii/S0168169924005751
6. **Y. Manteghi, J. Arkat, A. Mahmoodi (2024). Organic Production Competitiveness: A Bi-level Model Integrating Government Policy, Sustainability Objectives, and Blockchain Transparency.**
    - This paper presents a model that integrates blockchain technology to enhance transparency and sustainability in organic production while aligning with government policies.
    - **DOI:** 10.1016/j.cie.2024.110147
    - **Link:** https://www.sciencedirect.com/science/article/pii/S0360835224000363
7. **F. Hao, Y. Guo, C. Zhang, K.K.S.K.-S Chon (2024). Blockchain = Better Food? The Adoption of Blockchain Technology in Food Supply Chain.**
    - This research explores how blockchain adoption impacts food supply chains, emphasizing its role in improving transparency and traceability.
    - **DOI:** 10.1108/ijchm-06-2023-0752
    - **Link:** https://www.emerald.com/insight/content/doi/10.1108/IJCHM-06-2023-0752/full/html

11. APPENDIX

Link:
https://drive.google.com/drive/mobile/folders/166GvWPDaSWSvTvb99WcUONqWDNLpqFCv?pli=1