AN INVESTIGATION ON ADOPTION OF BLOCKCHAIN-BASED FERTILIZER DISTRIBUTION ECOSYSTEM IN NIGER STATE, NIGERIA

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Abstract
This paper proposes the use of a blockchain based fertilizer distribution ecosystem in Niger State, Nigeria. The system addresses major challenges such as the prevalence of counterfeit fertilizers, high costs, and inefficiencies within the distribution network, faced by farmers. By leveraging blockchain's core attributes of transparency, traceability, efficiency and immutability, the system ensures that fertilizer products are genuine and easily verifiable throughout the supply chain. A survey was conducted to assess the awareness and readiness of key stakeholders, including farmers, distributors, and government officials, to adopt a blockchain solution. The survey administered to 100 participants (farmers, distributors, retailers, and government officials) revealed a response rate of 46%. Farmers constituted the majority of respondents (78.3%), followed by retailers and wholesalers (8.7% each), and government officials (4.3%). On the issue of counterfeit fertilizers, 32.6% rated it as extremely severe, while 47.8% identified high costs as extremely severe. Furthermore, 63% of respondents had prior knowledge of blockchain, and 76.1% indicated they were likely or very likely to adopt a blockchain-based fertilizer distribution system. The findings revealed strong interest of the stakeholders, particularly in the area of improving the fertilizer distribution process. This research paper concludes that the developed system, combined with active stakeholder participation and regulatory support, has the potential to significantly reduce the circulation of counterfeit fertilizers, reduce corruption and the cost of the products. Furthermore, the study emphasizes the need for education, pilot programs, and infrastructure to ensure successful system implementation and long-term sustainability.

Keywords: Ecosystem; Blockchain; Fertilizer distribution; Agricultural sector; Supply chain management; Niger State, Nigeria.

Introduction
The current fertilizer supply chain ecosystem in Niger State, Nigeria is being plagued with a number of challenges ranging from inefficiencies, lack of transparency, and corruption from production to the point of delivery to the farmers (World Bank, 2020; FAO, 2020; World Bank, 2021).

Blockchain technology, a decentralized and immutable digital ledger that records transactions across multiple computers, offers a promising solution to these multifaceted problems. By enhancing traceability, accountability, and efficiency in supply chain management, blockchain has the potential to revolutionize the fertilizer industry. It can provide a secure platform for documenting transactions, monitoring the origins of products, and ensuring adherence to regulatory norms (Yang, 2016). With blockchain, stakeholders can obtain immediate and accurate information regarding the transportation of fertilizers from producers to farmers, minimizing the risk of fraudulent activities and guaranteeing that only high-quality products reach the end users (Kouhizadeh & Sarkis, 2018).

Figure 1 is a permissioned blockchain architecture using Hyperledger Fabric, where different

actors such as farmers, distributors, retailers, and regulators participate as peers, while endorsement and ordering services ensure transaction validity and consensus.

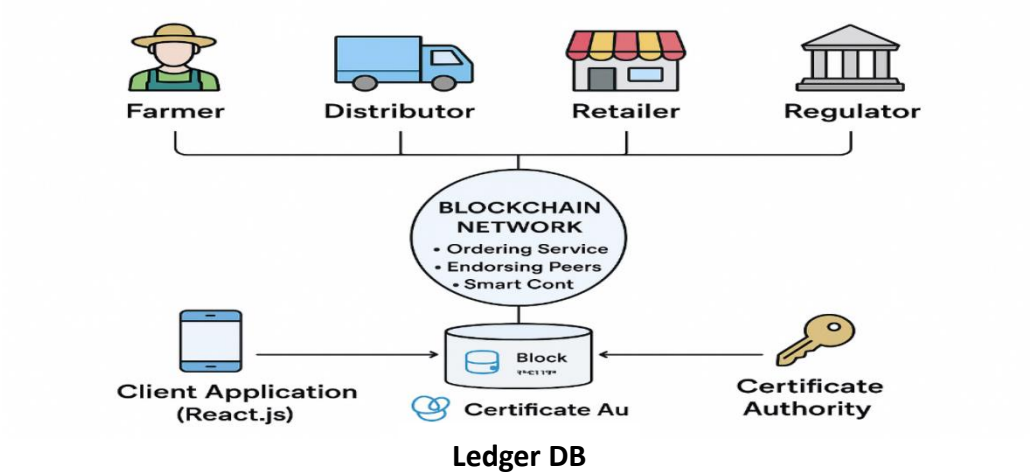

Figure 1: Hyperledger Fabric permissioned blockchain design for fertilizer distribution

Hyperledger Fabric's modularity and scalability make it suitable for agricultural supply chains requiring transparency and security (Androulaki *et al.*, 2018). The design in Figure 1 illustrates how the fertilizer supply chain actors are connected to a blockchain network. Farmers, distributors, retailers, and regulators are the key stakeholders, each with peer nodes participating in the network. Transactions are validated by endorsing peers and ordered through the ordering service before being permanently stored in the distributed ledger. Smart contracts (chaincode) enforce business logic such as product authentication and subsidy management. Stakeholders interact with the system via a decentralized application developed with React.js. The Certificate Authority (CA) ensures that only verified and authorized participants are allowed access. This helps to prevent fraud and strengthen trust across the fertilizer distribution process.

Review of Related Work

In recent years, the use of blockchain technology in supply chains has fascinated a lot of attention. A considerable amount of research has been carried out across different businesses and applications. The potentiality of blockchain in bringing sanity into supply chain in terms of accountability, transparency, traceability, effectiveness, efficiency and trust has been highlighted by the following studies:

A study (Okanlawon *et al.,* 2024) has revealed that the adoption of blockchain in the Nigerian agricultural sector remains limited due to factors like inadequate awareness, little technical expertise, lack of regulatory frameworks and insufficient infrastructure. In their findings, they discovered barriers of poor infrastructure and limited expertise hindering blockchain adoption.

Bosona and Gebresenbet (2023), propounded that blockchain technology possesses the ability to boost the traceability of agricultural products, ensuring improved food safety and quality anchoring on tamper-proof records across the product lifecycle. The decentralized and immutable landscape of blockchain makes it an ideal tool for tracking the movement of goods and verifying their authenticity, thus reducing the risk of fraud and counterfeiting. This is particularly relevant to the Nigerian fertilizer industry, where traceability and transparency play crucial roles in combating counterfeit products and ensuring product quality. They were able to conclude that blockchain improves traceability

and reduces fraud in agri-food supply chains.

An evolutionary game theory was used to model the intricate interactions between the government, agricultural initiatives, and telecom operators in the adoption of blockchain technology for a workable agricultural supply chain. In the research, the authors (Song *et al.*, 2022) emphasized the impact of numerous factors, such as the initial green level, costs of equipment deployment, and technology operation, on the strategic decisions of each party. The findings from this paper, highlighted the critical role of the government in guiding and incentivizing collaboration among the stakeholders, in order to promote a successful integration of blockchain technology in the agricultural sector to achieve improved sustainability outcomes. The authors' model showed government motivations accelerate adoption, whereas lack of support delays incorporation of blockchain.

It has been revealed through a systematic mapping of literatures that there is a lack of research on blockchain and traceability in small business social selling, but emphasized the potential of blockchain to enhance trust and transparency in food supply chains, even in social selling scenarios (Valencia-Payan *et al.,* 2023). They were also able to identify a gap in the use of smart contracts for confirming data generated outside the blockchain network. They discovered that blockchain can put trust in small-scale food social selling but highlighted lack of smart contract usage.

Ehsan *et al.,* (2022) have discussed the possible benefits of blockchain in the agri-food supply chain, such as reduction of intermediaries, enhanced communication, transparency, accountability, traceability and security. They also proposed a decentralized blockchain-based traceability model that uses smart contracts to ensure the integrity and transparency of the system, so as to eliminate the communication gaps and lack of product provenance information prevalent in traditional models.

A framework, called "Agri-4-All" that combines IoT, blockchain, and smart contracts to digitize and automate agricultural supply chains had been proposed by Raza and Muneeb (2023). The paper highlighted the potential of these technologies to address challenges such as lack of transparency and security in traditional supply chains. It is also aimed to be compliant with Industry 4.0, showcasing its relevance in the context of modern industrial practices. Their "Agri-4-All" framework established that the integration IoT and blockchain reduces cloudiness in traditional supply chains.

In their paper titled, "Blockchain for consortium: A practical paradigm in agricultural supply chain system", the highlights of the traditional Agricultural Supply Chain Systems (ASCSs) had been given by Eluubek *et al.* (2021). Such limitations include demand uncertainty and transaction costs, The authors argued that the emerging technologies such as, blockchain and Cyber-Physical Systems (CPSs) can address these challenges. They found blockchain to reduce transaction costs and ambiguity in agricultural supply chains.

Zheng *et al.* (2023), conducted an investigation on adoption of blockchain technology for traceability in the agricultural supply chain. In their approach, they engaged the use of an evolutionary game theory to model the decision-making process of producers, processors, and the government, stressing the importance of government incentives and penalties in promoting the adoption of blockchain and ensuring food safety and quality in the sector of agriculture. The evolutionary model of these authors showed penalties and incentives were crucial to ensuring adoption by farmers and processors.

Methodology

This paper employed a quantitative research design, which is suitable for acquiring standardized data from a wide range of stakeholders ranging from farmers, fertilizer distributors, retailers, and government officials in Niger State. Figure 2 shows the interaction of the various stakeholders and their roles with the blockchain.

Figure 2: The various stakeholders on the Blockchain

Conducting a survey will facilitate the quantitative assessment of their attitudes, perceptions, and behaviors concerning blockchain technology in the fertilizer supply chain. This also allows for statistical analysis to derive regionally relevant conclusions.

A survey data collection method was administered to a selected sample of farmers, fertilizer distributors, retailers, and government officials, employing a combination of closed-ended questions with predefined responses and facilitated quantitative analysis. A survey questionnaire was carefully designed to cover such aspect as: awareness and understanding of blockchain technology, perceptions of the current fertilizer supply chain challenges, potential benefits and drawbacks of blockchain adoption, willingness to adopt and use blockchain-based solutions and factors influencing adoption decisions.

During the data collection process, strict ethical guidelines, to ensure informed consent, confidentiality, and anonymity of the participants were adhered to. The cultural and social context of the study area were also put into consideration.

The implementation tools used are the Visual Studio Code: lightweight source code editor running on Windows 11 Operating System with 12GB Ram.

The decentralized application was developed using React.Js, which is a JavaScript based framework, and was chosen for its component-based architecture and Tailwind CSS, a utility-first CSS framework was selected for building custom user interfaces. The smart contract is developed using the Ethereum Sepolia test network, which offers a reliable and stable environment for the deployment of the smart contract, and Alchemy, a blockchain developer platform that provides tools and infrastructure for interacting with the Ethereum blockchain.
Figure 3 is the framework representing a three-phase mixed-method research design that integrates social science data collection with technical proof-of-concept development.

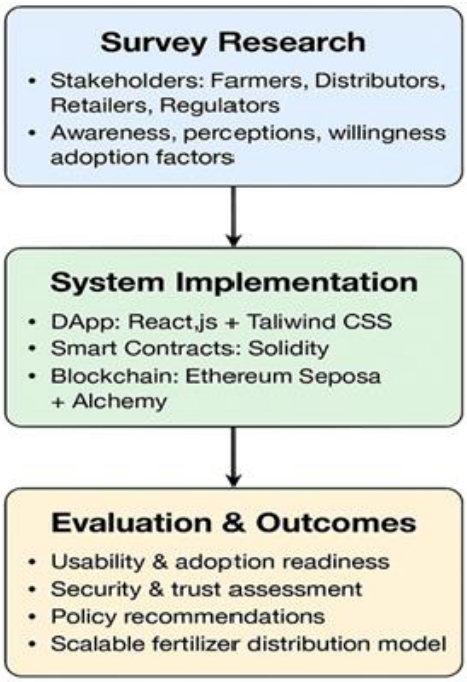

Figure 3: Design approach framework of a three-phase mixed-method research design

The framework represents a three-phase mixed-method research design that integrates social science data collection with technical proof-of-concept development (Creswell & Plano Clark, 2017).

Survey Research: A structured questionnaire was administered to varied supply-chain actors (farmers, distributors, retailers, regulators). It captured quantitative measures of blockchain awareness, willingness to adopt, perceived benefits and drawbacks, and other adoption factors. Similar quantitative adoption studies have been conducted in Nigeria, highlighting the determinants of blockchain readiness (Aliyu, *et al.,* 2024; Fasola, *et al*., 2024). Statistical analysis, both descriptive and inferential, provided a locally appropriate adoption baseline.

System Implementation: A decentralized application (DApp) was developed using React.js (frontend), Tailwind CSS (UI design), Solidity smart contracts, and tested on Ethereum's Sepolia test network via Alchemy. Previous agricultural blockchain models confirm that smart contracts and Ethereum networks can provide transparent and tamper-proof systems in supply chain contexts (Adeniyi & Jauro, 2024). This stage demonstrated the technical feasibility of a transparent, auditable fertilizer distribution ecosystem.

Evaluation and Outcomes: A comparative analysis of survey findings and model usability testing was conducted to assess adoption readiness, security, and trust. Similar blockchain adoption frameworks emphasize combining survey-driven adoption insights with system usability evaluations for deriving policy implications and scalability strategies (Kouhizadeh, *et al.*, 2021). The results informed policy recommendations and scalability strategies for blockchain adoption in fertilizer distribution in Niger State.
In summary, the framework links empirical adoption research with technical system demonstration, ensuring both societal acceptability and technical feasibility.

Results and Discussion
A total of 100 survey questionnaires were distributed via the Google Forms platform. Of these, 46 responses were valid (46%), while 54 were non-responses (54%). The majority of

respondents were farmers (78.3%), reflecting strong representation of the primary beneficiaries within the fertilizer supply chain. Retailers and wholesalers each accounted for 8.7% of respondents, whereas government officials comprised 4.3%, indicating relatively lower engagement from regulatory stakeholders. Table 1 shows the distribution.

Table 1: Distribution of survey respondents by stakeholder category

Stakeholder Category	Frequency	Percentage (%)
Farmers	36	78.3
Retailers	4	8.7
Wholesalers	4	8.7
Government Officials	2	4.3
Total Valid Responses	**46**	**100**

On the key challenges of fertilizer distribution in Niger State, the respondents rate the issue of counterfeit or adulterated fertilisers on the scale of 1 (not severe) to 5 (extremely severe) with 32.6% of respondents rating it as extremely severe, 26.1% rating it as very severe, moderately severe, and 19.6% selected as severe. Also, on the high cost of fertilizers, 47.8% of the respondents rate it as "extremely severe." This indicates the financial burden faced by farmers in terms of fertilizers procurement, which can significantly impact the agricultural productivity, profitability and economy.

According to the survey, the primary causes of these challenges are "corruption and unethical practices" (37%), followed by "lack of government support" (26.1%). "Inefficient distribution networks" and "lack of farmer awareness and knowledge" are each identified as the primary cause by 19.6% and 17.4% of the respondents respectively.

On a scale of 1 (very poor) to 5 (excellent), 63% of the respondents indicated having prior knowledge of blockchain technology, while 37% had no previous knowledge of it.

On the basis perception of blockchain technology, the most prevalent perception was "a secure and transparent ledger" (33.3%). Among those who expressed an opinion, the second most common perception was that blockchain is "a complex and confusing technology" (25%). 22.2% of the respondents viewed it as "a potential solution for supply chain challenges" and a smaller proportion who had heard about blockchain expressed, "I do not know about blockchain". Surely, there is a moderate level of awareness and understanding of blockchain technology among stakeholders. The most common perception of blockchain is as a "secure and transparent digital ledger," suggesting a positive association with its potential benefits, but concerns about its complexity requires targeted education and awareness-building initiatives.

Regarding readiness to adopt blockchain technology, half of the respondents (50%) indicated they were *likely* to adopt the system, while 26.1% reported being *very likely*. About 19.6% remained *neutral*, whereas only 4.4% expressed *unlikely* or *very unlikely* responses. See Figure 4.

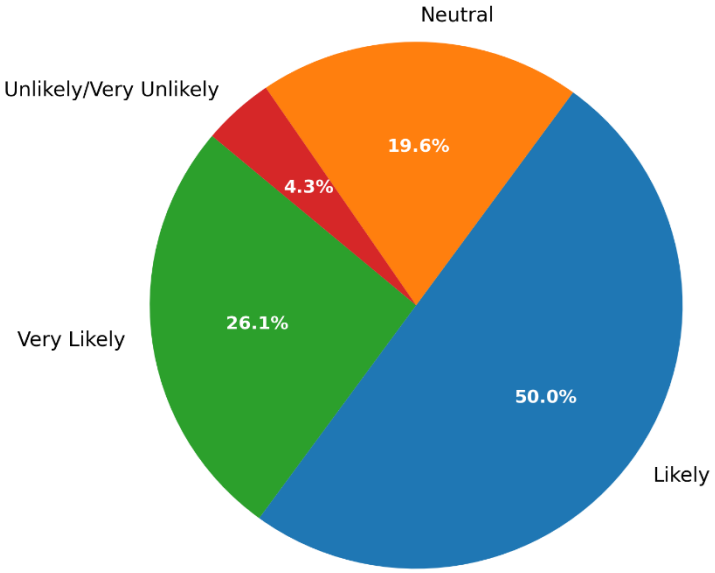

Figure 4: Respondents' readiness to adopt Blockchain technology (N = 46)

With respect to the factors influencing adoption of blockchain technology, the most frequently quoted was improved transparency (47.8%). This was closely followed by ease of use (41.3%) and cost-effectiveness (41.3%). Government support (34.8%) also emerged as an important factor, while access to finance (23.9%) was identified as the least influential among the listed factors.

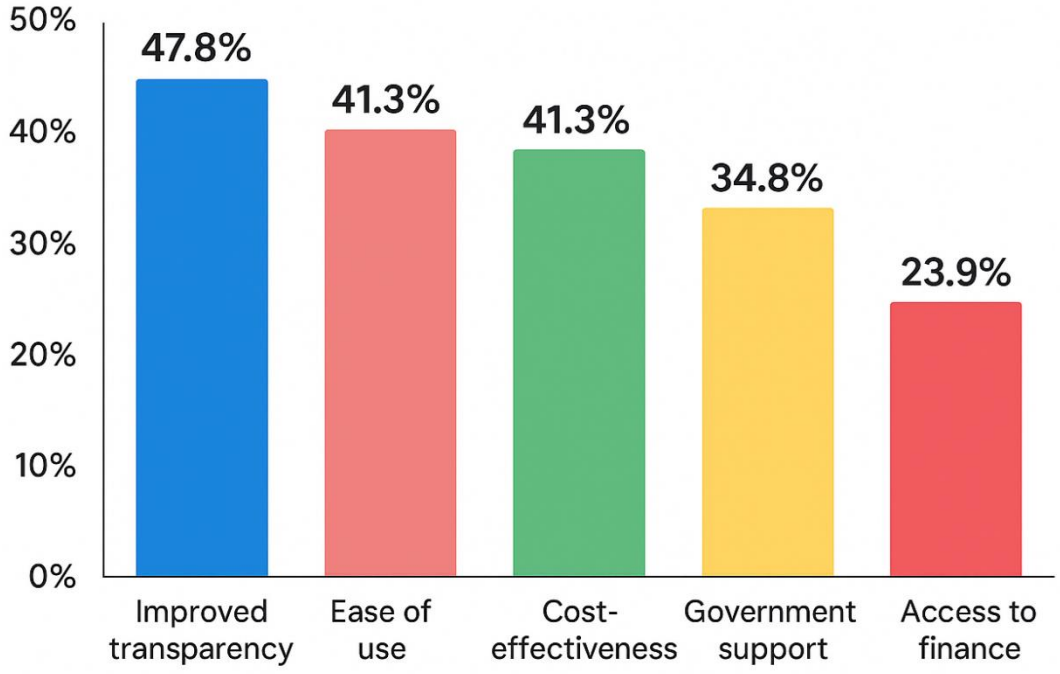

Figure 5: Factors influencing adoption of Blockchain Technology.

The findings from the research work demonstrate a favourable environment for the adoption of blockchain technology in the fertilizer supply chain in Niger State. The potential benefits of Blockchain in reducing costs, combating counterfeits, facilitating access to finance, and improving overall efficiency are recognized by the stakeholders.

Considering the ease of use of the system, 60% of the respondents agreed that the system is very easy to use while 40% designated that it was just easy to use. Additionally, in relation to

the product authentication, 80% of the respondents agreed that it is very seamless to check the product authenticity while 20% said it is just easy.

Conclusion

This paper highlights the persistent challenges in the supply chain of fertilizer in Niger State, Nigeria. The prevalence of the cost and adulteration of the products are of particular concern. These challenges have continued to hinder agricultural productivity and food security in the region, and consequently in the country. Although, there is a considerable knowledge gap among the farmers, a reason portion of the stakeholders exhibited awareness of blockchain technology. The knowledge gap among the farmers underscores the need for targeted educational initiatives aimed at promoting a deeper understanding of the potentials of blockchain technology.

A strong willingness to adopt blockchain-based solutions was demonstrated, though there is the need to address the implementation challenges like exorbitant costs and absence of technical expertise. Generally, the technology offers significant potentials to address the challenges within the fertilizer supply chain, in as much as adequate stakeholder engagements and the right support mechanisms from the government are provided.

This paper propounds recommendations such as: educating fertilizer supply chain stakeholders of blockchain technology and its potential benefits, piloting for testing the feasibility of blockchain-based solutions in fertilizer supply chain in Niger State, government support through policy development, infrastructure development and internet services provision. Also, there is the need to dive into the scalability and sustainability of blockchain-based solutions to ensure their effective application across different regions and agricultural sectors.

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