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Blockchain and AI Integration for Agricultural Value Chains in African Markets

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ABSTRACT
Agriculture has always been the backbone of the economies of African nations, but most of the time it has been hampered by inefficient and opaque post-harvest losses. Digital technologies hold a promise to effectively solve these problems. Blockchain can create an end-to-end trackable system that is permissionless, traceable, and incorruptible. It makes available a smart contract framework for fair and self-executing transactions while reducing fraud. Predictive analysis through Artificial Inteigience(AI) can be useful in precision farming by optimizing yields, pest/disease detection, and market demand forecasting. These technologies working synergistically provide powerful combinations whereby blockchain ensures traceability of all information collected from the generated data from AI applications. Thus, accurate decision-making based on trustworthy sources is enabled and deals in specific applications; for example, supply chain efficiency improvements arise out of provenance verification, quality assurances, and logistics optimizations with minimized food wastage through increased observation capabilities.
Yet, despite the great promise, the obstacles to adoption are significant and include poor rural connectivity with the internet, a lack of digital literacy, high implementation costs, the mistrust arising from culture, and uneven and contradictory regimens across the continent. Possible areas for future development are scalable mobile solutions, a BaaS (Block-chain as a Service) model, private-public collaboration, and localized customizations for local normals. A successful integration of such technologies can substantially improve food security, sustainability, growth, and prosperity across Africa's agricultural landscape.

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I. Introduction

The agricultural sector serves as a critical engine for economic growth and a primary source of livelihood for a significant majority of the population across the African continent (Mwewa et al., 2024; Sama, 2023). However, despite its pivotal role, African agriculture is often beset by a complex web of challenges that hinder its full potential. These challenges include fragmented supply chains, inadequate infrastructure, limited access to financial resources and markets for smallholder farmers, and a lack of transparent and efficient systems for tracking and trading agricultural commodities (Mwewa et al., 2024; Sama, 2023). The consequences of these inefficiencies are far-reaching, contributing to substantial post-harvest losses, unstable pricing for farmers, reduced consumer trust in food safety and quality, and ultimately, hindering the overall economic development of the region (Mwewa et al., 2024; Sama, 2023).

In an era defined by rapid technological advancements, the integration of cutting-edge digital solutions offers a beacon of hope for transforming the agricultural landscape in Africa. Among these innovations, blockchain technology and artificial intelligence (AI) have emerged as particularly promising tools with the potential to address many of the deep-rooted challenges plaguing the sector (Tang et al., 2024; Chen et al., 2023). Blockchain, with its fundamental characteristics of decentralisation, immutability, transparency, and security, offers a novel approach to building trust and efficiency within agricultural value chains (Tang et al., 2024; Kshetri, 2021). By providing a tamper-proof and auditable record of transactions and product journeys, blockchain can enhance traceability, combat fraud, and facilitate fairer and more automated interactions between diverse stakeholders through the implementation of smart contracts (Tang et al., 2024; Kshetri, 2021).

Similarly, artificial intelligence presents a powerful suite of analytical and predictive capabilities that can optimise various aspects of agricultural production and supply chain management (Assimakopoulos et al., 2024; Gikunda, 2024). AI technologies, encompassing machine learning, big data analytics, computer vision, and the Internet of Things (IoT), can provide valuable insights for precision agriculture, enabling farmers to make data-driven decisions regarding planting, irrigation, pest and disease management, and harvesting, ultimately leading to increased yields and resource efficiency (Assimakopoulos et al., 2024; Gikunda, 2024). Furthermore, AI can play a crucial role in forecasting market demands, optimising logistics, and reducing waste across the agricultural value chain (Assimakopoulos et al., 2024; Gikunda, 2024).

This paper seeks to provide a comprehensive review of the transformative potential of integrating blockchain and AI technologies within agricultural value chains across African markets. It will delve into the fundamental principles of these technologies and explore their specific applications in addressing key challenges within the sector. By examining the synergistic relationship between blockchain and AI, this paper will highlight how their combined strengths can create more resilient, transparent, and efficient agricultural systems. While acknowledging the significant promise these technologies hold, the article will also critically assess the substantial challenges and barriers that currently impede their widespread adoption in the African context. Finally, it will explore future prospects and propose strategic approaches that can facilitate the successful integration of blockchain and AI to support sustainable agricultural development, enhance food security, and drive inclusive economic growth throughout the African continent.

II. Understanding Agricultural Value Chains in Africa

The agricultural value chain in Africa encompasses the entire spectrum of activities involved in bringing agricultural products from their initial production on farms to the final consumer (Sama, 2023; Orwothwun & Qutieshat, 2022). This complex network typically includes several key stages: primary production (farming and cultivation), post-harvest handling and storage, processing, transportation and logistics, marketing and distribution, and ultimately, consumption (Sama, 2023; Orwothwun & Qutieshat, 2022). However, unlike more integrated value chains in developed economies, African agricultural value chains are often characterised by fragmentation, with numerous independent actors operating across different stages (Sama, 2023; Feyaerts et al., 2020).

A significant feature of African agriculture is the dominance of smallholder farmers, who constitute the majority of agricultural producers and contribute substantially to the region's food supply (Orwothwun & Qutieshat, 2022; Von Braun & Mirzabaev, 2015). These small-scale farmers often operate with limited resources, including access to land, capital, modern farming inputs, and technology (Balana & Oyeyemi, 2022). Consequently, they face numerous challenges that constrain their productivity and their ability to effectively participate in and benefit from agricultural value chains (Balana & Oyeyemi, 2022).

One of the primary challenges is limited access to formal financial services (Balana & Oyeyemi, 2022; Orwothwun & Qutieshat, 2022). Without adequate access to credit and financing, smallholder farmers often struggle to invest in improved farming practices, purchase quality inputs, or manage risks associated with weather variability and market fluctuations (Balana & Oyeyemi, 2022). Furthermore, access to reliable and efficient markets remains a significant hurdle (Orwothwun & Qutieshat, 2022). Many farmers lack adequate market information regarding prices and demand, and they often face logistical difficulties in transporting their produce to profitable markets due to poor infrastructure, including inadequate road networks and storage facilities (Sama, 2023; Orwothwun & Qutieshat, 2022). This often forces them to rely on intermediaries, who may offer lower prices, thereby reducing their income and market power (Abdulquadri et al., 2024).

Futhermore, information asymmetry is a pervasive issue within African agricultural value chains (Abdulquadri et al., 2024). Farmers often lack access to timely and accurate information about market trends, best farming practices, and quality standards. This information gap can lead to suboptimal decision-making, lower yields, and difficulties in meeting the requirements of higher-value markets (Abdulquadri et al., 2024). Coupled with these challenges, issues of transparency and accountability are significant concerns (Mwewa et al., 2024). The involvement of numerous intermediaries and the prevalence of manual record-keeping often obscure the flow of goods and information, making it difficult to track the origin and quality of agricultural products and increasing the risk of fraudulent practices (Mwewa et al., 2024). Addressing these multifaceted challenges within African agricultural value chains is crucial for unlocking the sector's potential to contribute to food security, economic growth, and improved livelihoods across the continent.

III. Role of Blockchain in Agricultural Value Chains

Blockchain technology, with its core principles of decentralisation, immutability, transparency, and security, offers a compelling framework for addressing many of the challenges inherent in African agricultural value chains (Tang et al., 2024; Kshetri, 2021). As a distributed ledger system, blockchain records transactions across a network of computers, eliminating the need for a central authority and ensuring that data is not controlled by a single entity (Tang et al., 2024; Kshetri, 2021). This decentralised nature enhances resilience and reduces the risk of single points of failure, making the system more robust and trustworthy (Tang et al., 2024; Kshetri, 2021).

One of the most significant applications of blockchain in agricultural value chains is its ability to provide transparent and tamper-proof tracking of agricultural produce from its origin to the final consumer (Tang et al., 2024; Kshetri, 2021). Every transaction and event in the product's journey, such as planting dates, fertiliser and pesticide use, harvesting times, transportation details, and storage conditions, can be securely recorded on the blockchain, creating an immutable and auditable trail (Tang et al., 2024; Kshetri, 2021). This

enhanced traceability offers numerous benefits, including improved food safety by enabling rapid identification of contamination sources and facilitating efficient recalls (Tang et al., 2024). It also empowers consumers with greater transparency about the origin, quality, and handling of their food, thereby building trust and confidence in the supply chain (Tang et al., 2024). Furthermore, for farmers seeking access to export markets that require stringent quality and provenance standards, blockchain can provide verifiable proof of compliance, opening up new opportunities for trade (Mwewa et al., 2024).

In addition to traceability, blockchain technology facilitates the use of smart contracts, which are self-executing agreements with the terms of the contract directly written into code (Tang et al., 2024; Kshetri, 2021). These smart contracts can automate various processes within the agricultural value chain, such as payments, quality verification, and transfer of ownership, based on predefined conditions being met (Tang et al., 2024; Kshetri, 2021). For instance, a smart contract could automatically release payment to a farmer upon confirmation of delivery and quality inspection of their produce, without the need for intermediaries or manual intervention (Mokgomola et al., 2022). This automation can reduce transaction costs, minimise delays, ensure fair and timely payments to farmers, and build trust between trading partners (Mokgomola et al., 2022). Moreover, blockchain can streamline agricultural financial services, such as facilitating access to credit and insurance for smallholder farmers by providing a secure and transparent record of their activities and transactions (Omanwa, 2023; Mavilia & Pisani, 2021). By creating a more efficient and trustworthy ecosystem for recording and exchanging value and information, blockchain technology holds significant potential to transform African agricultural value chains, making them more transparent, efficient, and equitable for all stakeholders.

IV. Role of Artificial Intelligence in Agricultural Value Chains

Artificial intelligence (AI) is playing an increasingly pivotal role in modernising and optimising agricultural practices and value chains across the globe, including in African markets (Assimakopoulos et al., 2024; Gikunda, 2024). By leveraging its advanced analytical and predictive capabilities, AI offers a powerful toolkit for addressing key challenges related to productivity, efficiency, sustainability, and risk management within the agricultural sector (Assimakopoulos et al., 2024; Gikunda, 2024).

One of the most transformative applications of AI in agriculture lies in the realm of precision agriculture (Assimakopoulos et al., 2024; Gikunda, 2024). AI-powered systems can analyse vast amounts of data collected from various sources, such as satellite imagery, drone surveillance, ground-based sensors (monitoring soil conditions, weather patterns, and crop health), and historical agricultural data . By applying machine learning algorithms to this data, AI can provide farmers with valuable insights for making more informed decisions (Assimakopoulos et al., 2024; Gikunda, 2024). This includes optimising planting schedules based on weather forecasts and soil conditions, precisely managing irrigation and fertiliser application to maximise resource efficiency and minimise environmental impact, and enabling targeted interventions for pest and disease management, reducing the need for broad-spectrum treatments (Assimakopoulos et al., 2024; Gikunda, 2024). Finally, precision agriculture practices driven by AI can lead to significant increases in crop yields, improved product quality, and reduced input costs for farmers

Furthermore, AI plays a crucial role in predictive analytics within agricultural value chains (Assimakopoulos et al., 2024; Odeyemi et al., 2024). By analysing historical data on crop yields, weather patterns, market trends, and economic indicators, AI models can forecast future production levels and market demands with greater accuracy (Odeyemi et al., 2024). This capability enables better planning across the supply chain, from optimising inventory management and logistics to informing farmers' decisions on what and when to plant based on anticipated market demands and prices. Similalry, AI can be leveraged to predict potential risks, such as disease outbreaks or pest infestations, by analysing environmental and biological data, allowing for timely interventions to mitigate crop losses (Assimakopoulos et al., 2024; Gikunda, 2024). Moreover, AI-powered tools can assist in optimising agricultural logistics, including transportation routes, storage conditions, and distribution networks, by analysing real-time data and predictive models to reduce waste, improve efficiency, and enhance market access for farmers (Assimakopoulos et al., 2024). By providing actionable insights and enabling data-driven decision-making across the agricultural value chain, AI holds immense potential to transform the sector in Africa, leading to increased productivity, improved sustainability, and enhanced resilience to various challenges.

V. Integration of Blockchain and AI

The integration of blockchain and artificial intelligence (AI) presents a powerful synergy that can amplify the benefits and address some of the limitations of each technology when applied independently to agricultural value chains (Chen et al., 2023; Krupitzer, 2024]. Blockchain technology excels in providing a secure, transparent, and immutable infrastructure for recording and sharing data across a network of stakeholders (Tang et al., 2024; Kshetri, 2021). Its inherent characteristics ensure data integrity, traceability, and

trust, making it an ideal platform for capturing critical information related to agricultural products and transactions (Tang et al., 2024; Kshetri, 2021).

Alternatively, AI technologies are adept at analysing vast datasets to extract valuable insights, identify patterns, make predictions, and automate decision-making processes (Assimakopoulos et al., 2024; Gikunda, 2024). The effectiveness of AI heavily relies on the availability of high-quality and reliable data (Assimakopoulos et al., 2024; Gikunda, 2024). This is where the integration with blockchain becomes particularly compelling. By leveraging blockchain as the underlying data management system, the data that AI algorithms analyse can be secured against tampering, ensuring its integrity and trustworthiness (Chen et al., 2023). The immutability of blockchain records provides a reliable foundation for AI-driven insights, as stakeholders can have greater confidence in the accuracy and provenance of the data being used for analysis and prediction (Chen et al., 2023).

The combined use of blockchain and AI can create more efficient and reliable systems for various applications within agricultural value chains. For instance, in traceability systems, blockchain can securely record the entire journey of a product, while AI can analyse the data collected at different stages (e.g., temperature, humidity, location) to predict potential quality issues or inefficiencies (Vilas-Boas et al., 2023). This integration allows for proactive interventions to reduce food loss and ensure product quality (Vilas-Boas et al., 2023). Similarly, in optimising supply chain logistics, blockchain can provide a transparent record of all transactions and movements, while AI algorithms can analyse this data along with other factors (e.g., weather, traffic) to optimise routes and schedules (Richey et al., 2023). Furthermore, the integration of these technologies can enhance the functionality of smart contracts. Blockchain can securely store and execute smart contracts, while AI can provide the intelligence to trigger and manage the conditions within these contracts based on real-time data analysis (Mokgomola et al., 2022). For example, AI could analyse weather data and crop conditions to automatically trigger an insurance payout via a blockchain-based smart contract in the event of a natural disaster (FAO & ITU, 2019).

Moreover, the integration of blockchain and AI can address concerns related to data privacy and security. While blockchain provides a secure and transparent ledger, AI algorithms can be used to analyse data in a privacy-preserving manner, ensuring that sensitive information is protected while still generating valuable insights (Chen et al., 2023). This synergy between blockchain's security features and AI's analytical power can foster a more trustworthy and efficient data ecosystem for agricultural value chains in African markets, empowering stakeholders with reliable information for better decision-making and fostering greater collaboration across the sector.

VI. Improving Supply Chain Efficiency

The integration of blockchain and artificial intelligence (AI) holds significant promise for enhancing the efficiency of agricultural supply chains in African markets by addressing key bottlenecks and optimising various operational aspects (Tang et al., 2024; Odeyemi et al., 2024). Blockchain technology provides a robust foundation for ensuring the provenance and quality of agricultural products through its transparent and immutable record-keeping capabilities (Tang et al., 2024; Kshetri, 2021). By recording every step of a product's journey from farm to consumer on the blockchain, stakeholders can readily verify its origin, handling conditions, and authenticity, thereby building trust and reducing the risk of fraud and counterfeit products (Tang et al., 2024; Kshetri, 2021). This enhanced transparency and traceability contribute to a more efficient supply chain by enabling quick identification of issues, facilitating smoother transactions, and reducing the need for lengthy manual verification processes (Tang et al., 2024; Kshetri, 2021).

Futhermore, AI plays a crucial role in optimising the logistics and demand forecasting aspects of agricultural supply chains (Odeyemi et al., 2024; Assimakopoulos et al., 2024). AI algorithms can analyse vast datasets, including historical sales data, weather patterns, market trends, and transportation information, to generate accurate demand forecasts. This enables better production planning, inventory management, and resource allocation, minimising the risks of overstocking or stockouts, and reducing overall operational costs (Odeyemi et al., 2024; Assimakopoulos et al., 2024). Furthermore, AI can optimise transportation routes and schedules by analysing real-time traffic data, weather conditions, and delivery locations, leading to reduced transportation times, lower fuel consumption, and improved delivery efficiency (Assimakopoulos et al., 2024). The integration of AI with IoT devices, such as GPS trackers and environmental sensors, provides real-time visibility into the location and condition of goods in transit, allowing for proactive management of potential delays or spoilage (Vilas-Boas et al., 2023). Blockchain can then securely record this real-time data, ensuring its accuracy and providing an auditable record of the product's journey and condition upon arrival.

In addition, AI-powered platforms can facilitate more efficient market linkages by connecting farmers directly with buyers, reducing the reliance on numerous intermediaries (Abdulquadri et al., 2024). By providing farmers with access to real-time market information and demand forecasts generated by AI, they can make more informed decisions about what and when to sell their produce, potentially leading to better prices and reduced

post-harvest losses (Abdulquadri et al., 2024). Blockchain can further enhance these direct market connections by providing a secure and transparent platform for transactions and payments, facilitated by smart contracts that automate the execution of agreements (Mokgomola et al., 2022). This combination of AI-driven insights and blockchain's secure transactional capabilities can create more streamlined, transparent, and efficient agricultural supply chains in African markets, benefiting all stakeholders involved.

VII. Addressing Food Loss and Waste

Food loss and waste represent a significant challenge within African agricultural value chains, contributing to economic losses, food insecurity, and environmental degradation (Sama, 2023; Benyam et al., 2021). The integration of blockchain and artificial intelligence (AI) offers promising solutions for mitigating FLW across various stages of the supply chain through enhanced monitoring, prediction, and management capabilities (Shiraishi et al., 2025; Benyam et al., 2021).

Blockchain technology can play a crucial role in monitoring the conditions under which agricultural products are stored and transported (Shiraishi et al., 2025; Pearson et al., 2019). By recording data from environmental sensors (e.g., temperature, humidity) embedded in storage facilities and transportation vehicles onto the blockchain, stakeholders can gain real-time visibility into the conditions that affect the quality and shelf life of perishable goods (Shiraishi et al., 2025; Pearson et al., 2019). The immutability of blockchain records ensures the integrity of this data, providing an auditable history of the product's environment throughout its journey (Shiraishi et al., 2025). This enhanced monitoring enables proactive interventions to prevent spoilage and reduce post-harvest losses. For instance, if temperature deviations are detected, alerts can be automatically triggered, allowing for timely corrective actions to be taken (Vilas-Boas et al., 2023). Furthermore, blockchain's traceability capabilities allow for quick identification and isolation of affected batches in case of quality issues, minimising the scope of potential food waste (Shiraishi et al., 2025).

Complementing blockchain's monitoring capabilities, AI can provide powerful predictive analytics to address food loss and waste (Odeyemi et al., 2024; Assimakopoulos et al., 2024). By analysing historical data on crop yields, weather patterns, storage conditions, and market demands, AI algorithms can forecast harvest times and predict potential surpluses or shortages . This predictive capability allows for better planning of harvesting, storage, and distribution, ensuring that produce reaches markets in a timely manner and minimising the risk of overproduction and subsequent waste (Odeyemi et al., 2024; Assimakopoulos et al., 2024). AI can also optimise storage management by analysing data on product perishability and storage conditions to recommend optimal storage durations and conditions, thereby extending shelf life and reducing spoilage (Onyeaka et al., 2023).

Moreover, the integration of AI and blockchain can facilitate more efficient matching of supply and demand (Abdulquadri et al., 2024). AI-powered platforms can provide farmers with real-time insights into market demands and connect them directly with buyers, reducing the likelihood of produce going unsold and wasted (Abdulquadri et al., 2024). Blockchain can secure the transactions and agreements made through these platforms, ensuring fair and transparent trading (Mokgomola et al., 2022). By combining blockchain's ability to track and monitor product conditions with AI's predictive and optimising capabilities, African agricultural value chains can make significant strides in reducing food loss and waste, contributing to greater food security and sustainability.

VIII. Challenges

Despite the considerable potential of blockchain and artificial intelligence (AI) to revolutionise African agricultural value chains, several significant challenges and barriers impede their widespread adoption and effective implementation (Tang et al., 2024; Gikunda, 2024). Addressing these hurdles is crucial for unlocking the full transformative power of these technologies within the region.

One of the most fundamental challenges is the **limited internet connectivity and digital literacy** prevalent in many rural areas across Africa, where the majority of agricultural activities take place (Tang et al., 2024; Alobid et al., 2022). Blockchain technology relies on network connectivity for data recording and sharing, while AI applications often require significant data processing and access to cloud-based resources (Tang et al., 2024; Alobid et al., 2022). The lack of reliable internet infrastructure and the low levels of digital literacy among smallholder farmers and other value chain actors create a significant barrier to the adoption and effective use of these technologies. Many farmers may lack the skills and familiarity needed to operate digital platforms, use smartphones for data input, or understand the benefits of these technologies .

Another significant impediment is the **high costs of adoption** associated with implementing blockchain and AI solutions (Tang et al., 2024; Sama, 2023). These costs can include investments in hardware (e.g., sensors, smartphones, computers), software development and platform subscriptions, data storage and processing infrastructure, and training programs for users . For smallholder farmers and small and medium-sized enterprises (SMEs) in the agricultural sector, who often operate with limited financial resources, these upfront

and ongoing costs can be prohibitive, discouraging them from adopting these technologies despite their potential benefits (Tang et al., 2024; Sama, 2023).

Cultural mistrust and a lack of awareness about the benefits of blockchain and AI also pose significant challenges (Mwewa et al., 2024; Kraft & Kellner, 2022). The novelty of these technologies, coupled with a potential lack of understanding of their functionalities and security features, can lead to skepticism and resistance to change among stakeholders who are accustomed to traditional practices . Building trust in these digital systems requires effective awareness campaigns, demonstration of tangible benefits through successful pilot projects, and the involvement of trusted intermediaries to facilitate adoption (Mwewa et al., 2024; Kraft & Kellner, 2022).

Finally, **regulatory inconsistencies and the absence of clear legal frameworks** for blockchain and AI in many African countries create uncertainty and can hinder investment and adoption (Tang et al., 2024; Sama, 2023). The lack of specific regulations governing data privacy, security, smart contracts, and the legal recognition of blockchain-based records can create barriers to widespread implementation and interoperability across different jurisdictions (Tang et al., 2024; Sama, 2023). Harmonising regulatory standards and establishing supportive policy frameworks are essential for fostering a conducive environment for the adoption of blockchain and AI in African agricultural value chains.

IX. Future Prospects

Despite the challenges, the future prospects for the integration of blockchain and AI in African agricultural value chains are promising, driven by ongoing technological advancements, increasing digital penetration, and a growing recognition of the potential of these technologies to address critical sector challenges (Tang et al., 2024; Gikunda, 2024). Several key trends and opportunities point towards a more widespread adoption and impactful use of blockchain and AI in African agriculture in the coming years.

Scalable and affordable mobile solutions

The development of scalable and affordable mobile solutions tailored to the specific needs and constraints of smallholder farmers holds significant promise (Mwangakala et al., 2024; Sama, 2023). As smartphone adoption continues to rise across Africa, leveraging mobile-based applications that integrate blockchain and AI functionalities can lower the barrier to entry for farmers These applications can provide user-friendly interfaces for data input, access to real-time market information and AI-driven advisories, and secure transaction capabilities powered by blockchain, all accessible through devices that farmers are increasingly familiar with

Blockchain as a Service (BaaS) platforms

The adoption of Blockchain as a Service (BaaS) platforms can further streamline the implementation of blockchain technology by providing cloud-based solutions that abstract away the complexities of managing and maintaining the underlying blockchain infrastructure (Tang et al., 2024). BaaS platforms can offer cost-effective and scalable models for businesses and organisations in the agricultural sector to develop, host, and use blockchain applications without significant upfront investment or technical expertise (Tang et al., 2024).

Public-private partnerships (PPPs)

Fostering public-private partnerships (PPPs) will be crucial for driving the adoption and scaling of blockchain and AI solutions in African agriculture The Case for Digital Smart Platform For Agricultural Value Chains In Africa .Collaborations between governments, technology providers, agribusinesses, research institutions, and non-governmental organisations can pool resources, share expertise, and create an enabling environment for innovation and implementation . Governments can play a vital role in establishing supportive regulatory frameworks, investing in digital infrastructure, and promoting digital literacy, while the private sector can contribute technological expertise and drive the development of market-relevant solutions

Future work

Future research and development efforts must focus on **c**ontext-specific adaptationsof blockchain and AI technologies to address the unique socio-economic, infrastructural, and agricultural realities of different regions within Africa (Tang et al., 2024). Generic solutions may not be effective across the diverse landscapes and farming systems of the continent. Therefore, tailoring these technologies to local contexts, considering factors such as prevalent crops, existing infrastructure, cultural nuances, and the specific needs of smallholder farmers, will be essential for successful adoption and impact.

Finally, the emergence of generative AI presents new possibilities for the agricultural sector, particularly in areas such as data augmentation for training AI models (e.g., generating synthetic images of crop diseases), creating more intuitive user interfaces (e.g., AI-powered chatbots for farmer support), and potentially even generating novel agricultural practices or solutions based on learned patterns (Krupitzer, 2024). While still in its early stages of application in agriculture, generative AI holds the potential to further enhance the capabilities and accessibility of AI tools for African farmers and agricultural stakeholders .

X. Conclusion

The combination of AI and blockchain is a conceptual structure that has significant possibilities to answer Africa's historical concerns of trust, efficiency, and transparency within African agricultural value chains. The use of blockchain offers a safe and auditable ledger for transaction registration and tracing, while the AI provides significant analysis capabilities to improve production, logistics, and decision-making. The synergistic integration of these technologies can create more sustainable, resilient, and equitable agricultural systems throughout the African continent.

By improving traceability, blockchain can make food quality and safety better, reduce fraud, and establish consumer trust, while AI can maximize the utilization of resources, predict yields, and facilitate more effective market connections, ultimately increasing productivity and waste reduction. The possible impacts are to empower smallholder farmers by more balanced trade, wider access to finance, and better market information.

However, the path to mass adoption and useful integration of blockchain and AI technologies in African agriculture comes with major challenges. Limited infrastructure, digital literacy, cost, cultural, and regulatory infrastructure challenges have to be managed strategically through coordinated efforts from governments, the private sector, research institutions, and development partners.

In the coming times, the future of African agricultural revolution is likely to become increasingly intertwined with the strategic application of digital technologies like blockchain and AI. Scalable mobile solutions, BaaS platform adoption, public-private partnerships, context-specific innovations, and forays into newer AI applications are promising paths for realizing the revolutionary potential of these technologies. By adopting innovation, fostering collaboration, and addressing the current challenges, African nations can leverage the power of blockchain and AI to create more transparent, efficient, and sustainable agricultural value chains, thereby enhancing food security, ensuring economic growth, and improving the livelihoods of millions of Africans.

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