Bridging the Gap: Web3 Technologies for Sustainable Food Systems

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Abstract

Emerging Web3 technologies show promise in achieving SDG2 (Zero Hunger) by tackling food supply chain, agriculture, land rights, and resource access challenges. This brief examines successful blockchain applications in enhancing supply chain transparency, smart agriculture, and decentralized crop insurance, highlighting their potential impact on sustainable development.

Blockchain technology holds immense promise for developing nations, offering pathways to greater financial inclusion through decentralized finance solutions and revolutionizing supply chains by ensuring transparency and efficiency. Additionally, its applications in land registry, digital identity management, and cross-border payments signify its pivotal role in fostering socio-economic empowerment and advancing global development goals.

However, to fully realize these benefits, there is a critical need to strengthen both physical and digital infrastructure in these regions. Limited access to reliable internet and electricity inhibits blockchain adoption, hindering financial inclusion efforts due to challenges in digital literacy, access to smartphones, and digital payment infrastructure. Moreover, addressing the energy-intensive nature of blockchain consensus mechanisms is crucial to ensuring sustainability and minimizing environmental impact, especially in regions with limited energy resources.

For challenges such as food security and sustainable agrifood systems, emerging Web3 technologies offer a promising solution to enhance food supply chain, agriculture, land rights, and resource access challenges. Given the emerging nature of these technologies, exploring proof of concept projects to demonstrate feasibility, highlight benefits, and inform regulatory discussions is essential to harnessing blockchain's transformative potential for sustainable development in developing countries.

Africa's Potential for Blockchain Adoption and Innovation

The digital transformation sweeping across Africa is laying the groundwork for widespread adoption of blockchain technology in several key ways.

Africa’s improved internet connectivity, reaching around 36% of the population as of 2022 [1], lays the foundation for blockchain adoption due to increased investment in internet infrastructure and mobile networks. Similarly, Africa’s growing mobile usage, with over 1.2 billion mobile subscribers as of 2022 [2], is creating an environment ripe for blockchain solutions that thrive on online connectivity.

The financial landscape in Africa has experienced a significant shift in the past 20 years due to the increasing digital financial inclusion. Mobile money platforms such as M-Pesa and others, have demonstrated the potential of digital financial services for the inclusion of underserved populations in regions with limited banking infrastructure. Peer-to-peer community money platforms with crypto interest groups such as Spark in Nigeria and Ghana are aimed at West Africa’s tech-savvy young adults, and are poised to offer community-driven blockchain integrations. The established trust in digital transactions through mobile money platforms creates a favorable foundation for the adoption of blockchain technology, known for its secure, transparent, and immutable transaction capabilities.

Africa's youth demographic shift, with its increasing tech literacy, is driving demand for digital innovations like NFT art and music within the blockchain space, fostering a culture of exploration and acceptance. A median age of 19 across Africa has also fueled continuing growth in the share of blockchain developer talent, from 0 to 3 percent of the global total, 2017 to 2022 [3]. India and Latam are the only other regions in the world with an increased share over that period. [3]

Moreover, as digital initiatives fuel economic growth and diversification across sectors such as finance, healthcare, and logistics, blockchain's ability to enhance efficiency and transparency makes it a natural fit for the continent's evolving digital landscape.

Case Studies in Sustainable Agriculture and Supply Chain Transformation

Empowering Farmers Through Blockchain-Based Parametric Insurance: The Etherisc Case Study

SDG2-related Project Partnerships: Sprout, Acre Africa, Chainlink, Celo, Lemonade Foundation, Hanover Re, Avalanche, Pula, DAOStack

Etherisc is the leading on-chain parametric insurance provider in the Ethereum Ecosystem. It offers an on-chain platform of insurance products in several areas including

those closely related to SDG2: crop insurance, carbon credit protection, and coverage against natural disasters. Orgs and investors can design an insurance product in partnership with Etherisc using their library of ERC20 smart contract templates called the Generic Insurance Format (GIF). In 2018 Etherisc launched their ERC20 decentralized insurance token (DIP) to allow staking in risk pools that help collateralize insurance products developed on their platform [4].

Only 20 percent of small-scale farmers globally have access to crop insurance [5]. Traditional index insurance premiums are too expensive, and claim/pay out processes are cumbersome and subject to significant delays. Collateralizing traditional lands with lack of clear title is not possible, and lack of access to bank relationships and finance creates significant financial gaps for farmers needing bridge funds between seasons and crop failures.

Policy / Action Taken

In 2020, a parametric insurance product was created in partnership with Acre Africa and Chainlink in Kenya to address flooding concerns on smallholder maize crops. Farmers could opt into weather-based insurance through scratch card and mobile premium payment under $1 USD, during their crop seed purchases [6].

In 2022, the Lemonade Foundation used Etherisc's platform to provide almost 7,000 Kenyan farmers with automated flood protection of their mung bean and sorghum crops. Farmers signed up with a $.83 USD premium directly on their feature phones, and after the rainy season ended in January 2023, automated payments were triggered and paid directly to farmers' m-pesa accounts [7].

Outcomes / Evaluation

The four-year pilot program with Acre Africa, begun in April 2020, reduced payout times by 97%, from an industry average of 45 days to 5 days. Parametric automation increased coverage amounts by 27% for smallholders compared to the previous season. Acre Africa's operational costs were reduced by 80% [8].

Key Lessons Learned

Etherisc's open-source collaboration model allows a relatively frictionless entry into blockchain-based insurance for traditional insurance providers concerned with Web3 adoption and operational costs, and jurisdictional compliance obstacles. Etherisc's well-established governance token (DIP) and decentralized protocol for risk pools and payouts has built and maintained trust within Web3 ecosystems and among traditional insurance providers wanting to introduce innovative products. Lessons learned from both successful and failed use cases help sustain Etherisc as a going concern and viable partner in driving wider Web3 innovation in the insurance sector.

Transforming Coffee Supply Chains: IBM Food Trust's Case Study

In 2017, the IBM Food Trust [9][10] which is built on IBM Blockchain was launched to enhance the food ecosystem visibility and efficiency of the supply chain. In the context of the coffee industry, according to the Centre for Agriculture and Bioscience International (CABI), over 12 million African households rely on coffee as their primary source of income [11]. The International Coffee Organisation (ICO) estimated that 11.7 million bags for the 2021/22 coffee year were consumed only in Africa [12].

The complexity to track coffee crossing market geo-boundaries from farmers to consumers [13]. 87 percent of Ivory Coast's cocoa and coffee-growing households are estimated to earn less than a livable income despite producing a sizable amount of the world's cocoa [14][15].

Policy and Action Taken

In 2021, a collaborative effort by Farmers Connect used the IBM Food Trust platform [16], with Rainforest Alliance, IKEA Social Entrepreneurship, Cloetta, and GIZ in a pilot project "The Living Income Module Project" to transfer money directly to Farmers in Ivory Coast [17]. In 2015 Ethiopia Commodity Exchange implemented the IBM-enabled traceability system, eATTS, to increase global market access and coffee exports [18].

Outcomes / Evaluations

The pilot project in Ivory Coast saw a remarkable 11 percent increase in income levels for farmers. Approximately, 337 farmers were able to earn an extra EU500 per year as a result [19].

The eATTS was projected to benefit over 5 million coffee farmers by tracking the coffee origin and offering transparency, trust, and safety to consumers [20][21].

Key Lessons Learned

IBM Food Trust's success highlights the value of collaboration among different stakeholders, connecting producers (farmers), suppliers, regulators, and consumers, thereby fostering information sharing across the supply chain.

Current Challenges/Opportunities

Wider adoption of Web3 cryptographic solutions for food security and sustainable agrifood systems among others tied to SDG2 still face a number of significant challenges. In addition to those discussed here previously, jurisdictional regulatory environments, enterprise risk/reward calculation and current trends in capital markets currently favor newer AI-based enterprise solutions in food supply

chain management, insurance and credit profiling, and even agricultural knowledge management and exchange. But, utilizing Web3 cryptography in conjunction with these new AI-based products represents a valuable safeguard against AI hallucination, LLM model collapse, data misappropriation and identity theft, among other issues plaguing AI products.

In our view, the Web3 innovations below hold the greatest potential, both to strengthen emerging AI-based products, and as valuable standalone tools to help meet SDG2 goals.

Zero-Knowledge (ZK) Proofs: Zero-Knowledge proof algorithms allow a party to prove knowledge of something to another party without revealing the knowledge itself [22]. For example, sensitive or proprietary data—demographic, health, food crop, market, and weather insights over time—within a dataset could be transferred by some entity and kept private from the receiving entity even as that receiving entity is assured of the dataset's validity, and could further apply machine learning models to mine it for valuable inferences in generative AI-based products. This use of ZK proofs has become known as ZKML [23]. Speed and scale of privacy-enhancing data mining might be further enhanced by the use of emergent Fully Homomorphic Encryption (FHE) off-chain coprocessors and rollups which allow for analysis of encrypted datasets without decryption [28].

ZK rollups—in the Ethereum ecosystem, blockchain transactions bundled as a ZK proof on a Layer 2 network and verified, or "rolled up" on Ethereum main chain—offer higher transaction speed and lower cost than transacting on the main chain alone [24]. These Layer 2 networks, therefore, have great potential to be used in IoT applications—e.g. precision agriculture, water and energy use metrics, and food supply chains—where multiple data points must be transmitted, validated, and stored on-chain in very short time intervals.

ERC-4337 Account Abstraction: Account Abstraction (AA) simplifies the end user experience of crypto wallet accounts by removing the need for a traditional externally owned account (EOA) wherein a browser extension, mobile app, or hardware wallet holds an alphanumeric public/private key pair to sign on-chain transactions. Instead AA can create wallet accounts on-chain as smart contracts, so that users can access their accounts with a simple log-in on a device-dependent smartphone app, through a biometric signature, or possibly even using SIM card functionality on a basic feature phone [25][26][27]. AA also allows Ethereum validator nodes to act as bundlers of multiple wallet transactions and as paymasters who can set and/or pay transaction fees for users. Using AA, groups in under-resourced areas could more easily set up quorums for multi-signature transactions to validate identity or financial needs, govern and disburse loan circle funds, and share or sell crop, supply chain, or market information.

Conclusions

Africa's digital transformation, characterized by improved internet connectivity, growing mobile usage, and increased adoption of digital financial services, is paving the way for widespread blockchain adoption.

The case studies highlight the critical role of collaborative efforts involving technology firms, insurers, NGOs, and government agencies for successful implementation. These innovations drive down operational costs, boost transparency, and enhance livelihoods in agriculture and supply chain management, aligning with sustainable practices.

Blockchain adoption in Africa isn't merely a technological shift but a transformative force catalyzing economic and social empowerment, specifically addressing global development challenges under SDG2.

Policy Recommendations

By addressing scalability challenges and investing in innovative Web3 education, the following recommendations aim to empower communities, promote economic growth, and bridge the digital divide.

Develop comprehensive digital literacy programs, covering blockchain basics and practical training, while establishing Web3 learning hubs in rural areas and collaborating with local businesses to foster economic growth.

Utilize income-generating validator nodes, which validate blocks or transactions, in places like schools, for sustainable funding and digital inclusion, enhancing education and emerging ecosystem sectors like Decentralized Physical Infrastructure Networks (DePIN).

Promote financial inclusion by digitizing traditional lending circles with Web3 technologies, enabling secure peer-to-peer lending, and fostering economic growth in rural areas through enhanced access to financial services.

Improve agriculture with mesh networking and satellite backhaul investments, facilitating data collection, smart farming, and supply chain traceability for enhanced food security and sustainable agrifood systems.

References

[1] World Bank. (2023). *From Connectivity to Services: Digital Transformation in Africa.* Retrieved from https://www.worldbank.org/en/results/2023/06/26/from-connectivity-to-services-digital-transformation-in-africa

[2] GSMA. (2023). *5G in Africa: Realizing the Potential.*

[3] Electric Capital. (2023). *2023 Crypto Developer Report. Retrieved from*

https://www.developerreport.com/developer-report-geography

[4] Etherisc. (2020). *Etherisc's crop insurance initiative in Kenya earns support from Ethereum Foundation.* Retrieved from https://blog.etherisc.com/etheriscs-crop-insurance-initiative-in-kenya-earns-support-from-ethereum-foundation-4f951df1db86

[5] Parm. (2022). *INSURED at COP27: Strengthening farmers' resilience through climate risk insurance: Who pays and how?.* Retrieved from https://www.p4arm.org/insured-at-cop27-strengthening-farmers-resilience-through-climate-risk-insurance-who-pays-and-how/#:~:text=However%2C%20current%20levels%20of%20insurance,cent%20in%20sub%2DSaharan%20Africa

[6] Etherisc. (2023). *Etherisc protects another 7,000 Kenyan farmers as part of the Lemonade Crypto Climate Coalition.* Retrieved from https://blog.etherisc.com/etherisc-protects-another-7-000-kenyan-farmers-as-part-of-the-lemonade-crypto-climate-coalition-e169eca3d6bc

[7] Etherisc. (2023). *Next exciting chapter for Etherisc: Acre Africa crop insurance is now on Celo blockchain*. Retrieved from https://blog.etherisc.com/next-exciting-chapter-for-etherisc-acre-africa-crop-insurance-is-now-on-celo-blockchain-46b555422eac

[8] IBM. (2022). *IBM Supply Chain Intelligence Suite - Food Trust.* Retrieved from https://www.ibm.com/products/supply-chain-intelligence-suite/food-trust

[9] IBM. *Coffee on IBM Blockchain.* Retrieved from https://www.ibm.com/thought-leadership/coffee/

[10] CABI. (2020). *Promoting domestic coffee consumption in Africa.* Retrieved from https://www.cabi.org/projects/promoting-domestic-coffee-consumption-in-africa/

[11] International Coffee Organization. (2022). *Annual Review 2021/2022.* Retrieved from https://www.ico.org/documents/cy2022-23/annual-review-2021-2022-e.pdf

[12] Bager, S. L., Singh, C., Persson, U. M. (2022). *Blockchain is not a silver bullet for agro-food supply chain sustainability: Insights from a coffee case study.* Current Research in Environmental Sustainability, 4. https://doi.org/10.1016/j.crsust.2022.100163

[13] Benjamin, D., & Deaton, A. (1993). *Household welfare and the pricing of cocoa and coffee in Côte d'Ivoire: Lessons from the living standards surveys.* The World Bank Economic Review, 7(3), 293–318. http://www.jstor.org/stable/3989823

[14] R., Corinne, M., David, M., Collins. (n.d.). *National Survey and Segmentation of Smallholder Households in Côte d'Ivoire. CGAP Research & Publications.* Retrieved from https://www.cgap.org/research/publication/national-survey-and-segmentation-of-smallholder-households-in-cote-divoire

[15] IBM. (2020). *Farmer Connect Uses IBM Blockchain to Bridge the Gap Between Consumers and Smallholder Coffee Farmers.* Retrieved from https://newsroom.ibm.com/2020-01-06-Farmer-Connect-Uses-IBM-Blockchain-to-Bridge-the-Gap-Between-Consumers-and-Smallholder-Coffee-Farmers

[16] Farmer Connect. *Unlocking the value of end-to-end supply chains.* Retrieved from https://www.farmerconnect.com/news/unlocking-the-value-of-end-to-end-supply-chains

[17] K., David. (2015). *ECX Launches Independent Food Traceability System.* U.S. Agency for International Development. https://2012-2017.usaid.gov/ethiopia/press-releases/ecx-launches-independent-food-traceability-system

[18] Rainforest Alliance. (2023). *Innovative Ways to Enhance Living Income for Cocoa Farmers*. Retrieved from [https://www.rainforest-alliance.org/business/tailored-services/the-living-income-module-project-bridging-the-gap-for-cocoa-farmers/

[19] Singh, C., Wojewska, A. N., Persson, U. M., & Bager, S. L. (2022). *Coffee producers' perspectives of blockchain technology in the context of sustainable global value chains.* Frontiers in Blockchain, 5, 955463. Retrieved from https://www.frontiersin.org/articles/10.3389/fbloc.2022.955463/full

[20] Ayeche, K. (2019). *An assessment on market integrity of Ethiopian Commodity Exchange.* Retrieved from http://repository.smuc.edu.et/bitstream/123456789/4841/1/Thesis%20Final%20by%20Kirubel%20Ayecha%202019.pdf

[21] Writer, S. (2015). Over 5 million Ethiopian farmers to benefit from IBM's ECX traceability system. CIO Africa. Retrieved from https://cioafrica.co/over-5-million-ethiopian-farmers-to-benefit-from-ibms-ecx-traceability-system/

[22] Ethereum. (2024). What are zero-knowledge proofs? Retrieved from https://ethereum.org/en/zero-knowledge-proofs/

[23] Worldcoin. (2022). An introduction to Zero-Knowledge Machine Learning (ZKML). Retrieved from https://worldcoin.org/blog/engineering/intro-to-zkml

[24] Chain Link. (2023). What Are Zk-Rollups (Zero-Knowledge Rollups)? Retrieved from https://chain.link/education-hub/zero-knowledge-rollup

[25] Ethereum. (2024). Account abstraction. Retrieved from https://ethereum.org/en/roadmap/account-abstraction/

[26] Cointelegraph. (2023). Account Abstraction: A beginner's guide to Ethereum's ERC-4337 standard. Retrieved from https://cointelegraph.com/learn/account-abstraction-guide-to-ethereums-erc-4337-standard

[27] GitHub. (2023). Semaphore Network EthSIM Wallet. Retrieved from https://github.com/SemaphoreNetwork/semaphore_network_ethsim

[28]Fhenix. (2023). *FHE-Rollups: Scaling Confidential Smart Contracts on Ethereum and Beyond – whitepaper.* Retrieved from https://www.fhenix.io/fhe-rollups-scaling-confidential-smart-contracts-on-ethereum-and-beyond-whitepaper/