Blockchain Technology applications in agriculture

B Raja Madhushekar[1]*, Dr.K.Suhasini[2], Dr.R.Vasantha[3], T Rajeshwar Reddy[4], Dr C Sudhakar[5] and Dr C Sudharani[6].

[1]*Scientist (TOT),Dept of AgriculturalExtension, District Agricultural Advisory & Transfer of Technology Centre, PJTAU, Tandur (501 141), India,

[2] Professor, Dept of Agricultural Economics, PJTAU, Hyderabad, India,

[3] Professor, Extension Education Institute, Rajendranagar, Hyderabad, India,

[4] Scientist (Plant Pathology),Dept of Plant Pathology, District Agricultural Advisory & Transfer of Technology Centre, PJTAU, Tandur (501 141), India

[5] Principal Scientist (Agronomy), Agricultural Research Station, Tandur (501 141), India

[6] Principal Scientist (Agronomy) & Head, Agricultural Research Station, Tandur (501 141), India

Corresponding Author : madhushekar80@gmail.com

Manuscript No: KN-V3-10/003

Abstract

Current development and reforms call for new technologies, techniques and innovations to create a transparent and accountable environment in various sectors. The international supply chains are under pressure to provide information about environmental impact, quality, and safety. Goods travel increasingly large distances from producer to consumer ("Farm to Fork") because of globalization in the ecosystem. Information about the origin of a good or food product is essential in the supply chain, because it can indicate the use of raw materials, fair payment, and the environmental or carbon footprint.

Blockchain development closes the gap between the farm and the rest of the world. It is a ledger of accounts, and transactions are written and stored by all participants. It promises a reliable source about the state of farms, inventories, and contracts. These are digital systems that combines data management, incentive systems, cryptography, and networking to enable the execution, recording, and verification of transactions between parties. It is a middleman-free electronic system, which retains electronic records, validates, and verifies them. All users have access to the data, which is publicly available, and the records are unchangeable and cannot be altered or deleted. It allows users to transfer values or assets between each other without the need for a trusted intermediary.

Blockchain contains several blocks of information that are decentralized, traceable, and unalterable. The applications in different domains help in faster settlements in different systems. It reduces costs, risk, saves times and increases trust and transparency. It helps in information sharing, in decision making in a cooperative, collaborative and coordinated manner. It brings new innovations in supply chain, health care, banking etc., by providing security, trust and transparency. In this chapter, we will be elaborating on the concepts of blockchain technology and try to understand its purpose in today's world.

Keywords: Blockchain applications, Digital, Ledger, Traceability and Transparency.

Introduction

Blockchain along with Information and Communication Technologies (ICT) substantially increases the effectiveness and efficiency of collecting, storing, analyzing and using data in various sectors. Blockchain technology established itself as a research subject in various scientific disciplines and as an enabling technology

in various industries. In supply chain management and energy, blockchain applications establish trustful and traceable relations between multiple organizations. Furthermore, processes and transactions are executed in a trustful, transparent manner and automatized by the utilization of blockchain based smart contracts (Wright and Filippi, 2015). Blockchain technology is clustered in four directions: first, the food sector could benefit from decentralized, self-executing, digital smart contracts to automate transaction, processing and certification among supply chain actors. Second, blockchain may facilitate hardware and software integration, leading potentially to better system integration and performance. Third, blockchain offers an immutable record of chain transaction, accessible across (and sometimes beyond) chain peers. Fourth, blockchain technology could enhance the traceability & visibility of goods within the supply chain, by tracking goods from farm to fork (Kim 2017).

"**Blockchains are immutable digital ledger systems implemented in a distributed fashion and usually without a central authority**" Definition by National Institute of Standards and Tecnology, USDC, 2018 (Zheng *et al.,* 2018).

What is a block? A block consists of a set of database transactions, these blocks are shared in a distributed and decentralized manner that is each node has a complete set of blocks and everyone can see all the transactions.

What is a chain? Each block is linked to the previous block through a Hash Function forming a long chain. Each block in a chain is cryptographically signed to allow only the validated nodes have access to the data. All the blocks that are confirmed and validated via the consensus mechanism are linked together from the first to the last validated block, hence the name blockchain.

History of Blockchain

In the year 1976, the publication of "New Directions of Cryptograph" discussed about the concept of distributed ledger it laid the foundation for the development of blockchain (Narayanan *et al.,* 2016). With the advancement in the field of cryptography, another paper entitled as "Hot to Time stamp a digital document" by Stuart Haber and Scott starnetta, laid out the concept to time stamp the data instead of the medium. They ideated the concept of a cryptographically secure change of blocks in 1991(Haber and Stornetta, 1991).

Satoshi Nakamoto posted the bitcoin white paper as "Bitcoin: A Peer-to-Peer Electronic Cash System" on P2P foundation website. Originally, Satoshi Nakamoto used the words "block" and "chain" as two different words, but later were combined to make a single word, "Blockchain" (Aung and Chang 2014). Nakamoto's paper stated the concept of public ledger where an electronic coin transaction history can be traced (Zheng *et al.*, 2018).

Blockchain is a chain structure, which is a decentralized public account book technology formed by combining data blocks in chronological order, time stamped and combining with cryptography, consensus mechanism, intelligent contract and other technologies (Ge *et al*., 2017).

Characteristics of Blockchain

1. Trust less operation: These are systems that can operate without the need to trust people or institutions, participants can reach a consensus without needing to know each other.

2. Shared and Public Interactions: Interactions among user/writer are easily auditable from a third party or

the users/writers. The task can be easily automated via smart contract.

3. Low Friction There is no single intermediary who controls the system. Users can interact directly. It brings visibility, reducing friction along the lengthy list of transactions.

4. A peer-to-peer: Peer to peer blockchain is a decentralized ledger that uses a network of computers (nodes) to record transactions without a central authority. These networks are the foundation of blockchain, and they enable the following benefits: Decentralization, transparency, security, scalability, cost-effectiveness, redundancy and reliability.

5. Immutability: Tamper-proof architecture of the blockchain protocol, once data or information is recorded with in the blockchain it cannot be changed.

6. Digital Ledger: It is a decentralized digital ledger that stores records across a network of computers. They are transparent, immutable, and resistant to tampering. Each block in a blockchain contains data about transactions & the blocks are linked in a chronological chain.

7. Chronologically and Time stamped: Timestamps are used to track when data is created modified, or accessed. They are used to record the date and time of digital media, such as photographs, radio broadcasts, and text messages etc.

8. Non-repudiation is the ability to ensure that someone cannot deny or contest an agreement, transaction, or action.

9. Cryptographically secured: means that data is protected and transmitted using algorithms and keys that only authorized parties can access. It uses encryption to scramble messages with a key that only the sender and recipient know. This ensures that the content of the data remains unknown to third parties. Cryptography is used in many aspects of our lives, including WhatsApp, which encrypts conversations to prevent hacking or interception.

10. Transparent and Verifiable: means something is easy to understand, see, or detect, or is free from deceit or fraud. For example, a birth certificate is verifiable.

Blockchain Modern Concepts: It is an emerging technology and used in various sectors like Land registration records, Health care records, birth and death certificates, cyber security, digital certificates, SHG microfinance etc., others include:

1. **Traceability & Auditability:** The blockchain technology allows peer-to-peer transactions to take place transparently and without the need for an intermediary like a bank or a middleman in the agriculture sector. It helps restore the trust between producers & consumers, which can reduce the transaction costs in the agri-food market (Madhushekar *et al.,* 2025).

2. **Food safety:** It offers a reliable approach of tracing transactions between anonymous participants. Fraud and malfunctions can be detected quickly.

3. **Transparency:** The blockchain technology provides transparency among all involved parties and facilitates the collection of reliable data. It can record every step in a product's value chain, ranging from a product's creation to its death.

4. **Agricultural Insurance:** Weather extremes threaten agricultural production, putting food security at risk. Both, crop and livestock production are affected, and climate change is expected to further exacerbate weather extremes in the future. Motivated by the drawbacks of indemnity-based insurances, the idea of index-based insurance was born as an alternative and to complement the classical products. Here the payout is not triggered by the loss itself but by a measurable index, such as rainfall at a nearby weather station. If this weather station has sufficiently long historical weather records, both parties, the farmer & the insurer, have identical information about the insured value and moreover, farming practices or methods have no impact on the insurance payout.

5. **Quality control:** Blockchain technology can help with food safety and quality control in a number of ways, including:

- **Traceability & Transparency:** Blockchain can help identify the source of contaminated food, which can help prevent the spread of food borne illnesses. It can help consumers see where their food came from and how it was produced (Xiong *et al.,* 2020).

- **Food recalls:** Block chain can record information about the entire journey of a food product, from the farm to the consumer helping in food recalls during contamination.

6. **Safety Compliance:** It can help companies comply with food safety regulations like

- **Data protection:** Its decentralized nature reduces the risk of data breaches and tampering.

- **Recall management:** It can help reduce food waste by enabling selective recalls.

- **Shelf life:** It helps merchants in handling goods, by providing accurate shelf-life data.

- **Rapid response:** Blockchain can help identify the source of a problem quickly in the event of an epidemic.

8. Food supply chain: Blockchain for the food supply chain is built around a distributed ledger that contains data on all food supply chain transactions and events. The ledger is formed by time stamped and encrypted data blocks linked in chronological order. Food supply chain participants interact with the blockchain ledger using the role-specific web and/or mobile applications. This can help eliminate concerns about illegal and unethical practices and make it easier to track contamination (Hughes *et al.,* 2019). The **Main user groups are**

➢ **Raw food suppliers** transact data on the food origin & movement across the supply chain.

➢ **Food manufacturers** provide information on the food products, ingredients and manufacturing process

➢ **Food inspectors & certification entities:** verify documents related to product origin & quality.

➢ **Transportation and logistics providers:** upload details on the location and storage conditions of food products in transit.

➢ **Food product distributors:** trace food supply chain activities to assure responsible sourcing practices, food product quality and safety.

➢ **End Consumers:** access details and food products provenance to verify their authenticity.

9. **Land registration:** Blockchain technology can be used for land registration to make the process more secure, transparent, and efficient. The features include

- **Security:** Blockchain uses cryptographic principles to create an immutable ledger that is tamper-proof and time-stamped.

- **Transparency:** All participants in the network can verify property transactions.

- **Efficiency:** Smart contracts can automate processes like ownership transfers.

- **Reduced fraud:** It reduces the risk of fraud by making it difficult to change land ownership.

- **Reduced manual effort:** It can reduce the manual effort required for record keeping.

- **Create a profile**: Users create a profile on a blockchain land registry platform with their name, government-issued ID, and status.

- **Upload property**: Sellers upload property details, including pictures and documents, and pin the location on a map.

- **Record transactions**: Each transaction is recorded as an unchangeable block on the blockchain.

- **Authenticate participants**: Participants are authenticated using cryptographic keys.

- **Generate deeds digitally**: Users can receive deeds digitally, which are uploaded as a new block in the chain (Kim and Laskowski 2018).

- **Access to databases**: Databases can maintain local maps & images of the areas being transacted.

10. **Logistics and payments:** Blockchain technology can improve logistics and payments in several ways, including Secure transactions, Faster payments, Smart contracts, Improved traceability, Increased transparency, Sustainability.

11. **Data security:** Blockchain offers a robust & tamper-proof way to protect data by using a decentralized system, cryptography along with consensus & no single point of failure.

12. **E-commerce of Agricultural Products:** Blockchain has the potential to transform the agricultural e-commerce supply chain by increasing trust, transparency and traceability, accountability, lower expenses, more equitable ecosystem & reducing the risk of fraud:

13. **Improved financial inclusion:** Blockchain can help improve farmers' financial inclusion by enabling safe and effective cross-border transactions.

14. **Healthcare:** Blockchain can help with healthcare by addressing challenges like transparency, data privacy, and medical record keeping. Data are encrypted from each block and this provides security and confidentiality.

15. **Identity management:** Blockchain can help with identity management, which is a challenge for millions of people who lack access to formal identification documents.

16. **Governance:** Blockchain can be used in governance to issue legal documents, provide citizens with a

unique state ID, file and track complaints.

17. **Online Voting System:** Smart contracts are a secured way of conducting a poll as it does not allow the manipulation of transactions made. All the votes that are cast by the nodes are protected by ledgers, so it is difficult to decode and manipulate.

18. **Precision farming:** Blockchain can be combined with the Internet of Things (IoT) to create smart farms that can be more efficient and optimized. For example, farmers can use sensors to measure growing conditions like temperature, humidity and soil health and record the data in the blockchain (Zheng *et al.,* 2018).

19. **Payment mechanisms:** Blockchain can enable prompt and transparent payment mechanisms between stakeholders. Efficiency and fair payments for farmers.

20. **Blockchain and Smart Agriculture Ecosystem:** Blockchain technologies can bring smart agriculture and food traceability system many benefits. Farm companies, farming processing plants, plantation companies, planting processing plants, logistics companies and food retail storefronts as well as the customers can use their smart mobile phone as a portal or blockchain thin node to access the data stored in the chain.

21. **Blockchain and Geographical Indication:** The blockchain technology came in handy to prove origin of around 360 GI products and prevent counterfeits. The technology platform generates a unique hash and integrated QR codes for the seed. Experts mapped each step in the value chain, captured related information and stored the data in a ledger or blockchain. It is a natural fit for GIs as they depend on origin, authenticity and quality.

22. **Reduce risk and increase accountability:** Record of transactions and accounts is recorded and preserved by all parties involved, which increases security and lowers the risk of corruption.

The applications of blockchain in various fields include: product certification, reputation systems, incentive mechanisms, a circular economy, food safety, food supply chain. Agri Inputs supply, Managing agricultural Finance, Environmental sustainability, Agricultural product transactions, Smart agriculture, Cloud computing, Data analytics, Crop and food production and disbursement of subsidies.

Challenges within blockchain technology

Selfish Mining: Selfish mining forbids the sharing of information related to mined node with all other nodes in the network as it can lead to network vulnerability.

Initial Cost and Investment: The initial cost of developing a blockchain network is very high; this is due to the fact that there are comparatively less experts available in this. Moreover, the cost of specialized software also contributes to the high initial cost. **Technological Barriers:** Many smaller and medium-scale farms, lack the technological infrastructure or expertise to implement and manage blockchain systems. Large amount of traffic within its system; transactions are maintained for multiple nodes, multiple users, a huge number of blocks and multiple devices.

Adoption Resistance: There can be resistance to adopt new technologies, especially in traditional communities,

due to unfamiliarity or perceived complexity.

Regulatory Hurdles: The Development sector is subject to various regulations, proper policy implications and blockchain integration may face legal and compliance obstacles.

Data Privacy and Security: The sensitive nature of data necessitates robust security measures, and there may be concerns regarding data privacy and ownership.

Lack of infrastructure: There may not be enough infrastructure to support blockchain technology in agriculture.

Processing and storing data: It may be challenging to process and store product traceability information directly on the blockchain.

Connecting technology to business models: It may be challenging to connect blockchain technology with viable business models and technical use cases.

Conclusion: Blockchain technology has different use cases spread among different fields. Blockchain is a decentralized technology that can be merged with many technologies, such as the IoT, smart contracts, cryptography and cloud computing. It was first introduced with Bitcoin. It can provide many benefits in networked areas. It always works with a large amount of data. It is a technology that is not coming alone: business ecosystems, governance and business models are its companions. This combination can be disruptive in democratizing supply chains changing stakeholders' positions.

References

• Aung, M. M. and Chang, Y. S., 2014. Traceability in a food supply chain: Safety and quality perspectives. Food Control. 39, Pg:172–184.

• Ge, L., Brewster, C., Spek, J., Smeenk, A. and Top, J. 2017. Blockchain for Agriculture and Food; Findings from the Pilot Study. Wageningen Economic Research.

• Haber, S. and Stornetta, W.S. 1991. How to time-stamp a digital document. Journal of Cryptology. 3 (2), Pg:99–111.

• Hughes, A., A., Park., J., Kietzmann, C. and Brown, A. 2019. "Beyond bitcoin: What blockchain and distributed ledger technologies mean for firms," Bus. Horizons. 62 (3), Pg:273–281.

• Kim, H. J. 2017. Information technology & firm performance: the role of supply chain integration. Operations Management Research. 10(1), 1–9. doi: 10.1007/s12063-016- 0122-z.

• Kim, H. M. and Laskowski, M. 2018. Toward an ontology-driven blockchain design for supply chain provenance. Intelligent Systems in Accounting Finance and Management. 25 (1), 18–27. doi: 10.1002/isaf.1424

• Madhushekar, B.R., Kruparani, P., Pravallika, K., and G Narender, G. (2025). Modern Concepts of Blockchain Technology. Modern Advances in Agriculture and Allied Technologies Vol 1, Pg: 52-65.

• Narayanan, A., Bonneau, J., Felten, E., Miller, A. and Goldfeder, S. 2016. Bitcoin and cryptocurrency technologies: A comprehensive introduction, Princeton University Press, Princeton.

• *Wright, A and De Filippi, P. 2015. Decentralized Blockchain Technology and the Rise of Lex Cryptographia. Available at: https://ssrn.com/abstract=2580664*

• *Xiong, H., Dalhaus, T., Wang, P., and Huang, J., 2020. Blockchain Technology for Agriculture: Applications and Rationale. Front. Blockchain 3:7. doi: 10.3389/fbloc.2020.00007*

• *Zheng, Z., Xie, S., Dai, H.N., Chen, X. and Wang, H. 2018. "Blockchain challenges and opportunities: A survey," International Journal of Web and Grid Services. vol. 14 (4), Pg:352–375.*