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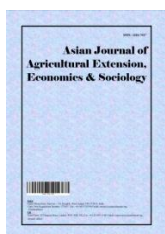
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Blockchain Technology in Agriculture

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The World Economic Forum marked Blockchain technology (BCT) as one of the seven revolutionary technologies of the future. It is a distributed ledger system ensuring transparency, security, immutability, interoperability, and provenance. This article tries to understand the technological aspects, working mechanism and explore different areas where BCT can be applied in agriculture. Data in BCT is stored in a series of blocks contains the hash value (previous and the current), timestamp, and difficulty details, secured cryptographically with a symmetric or asymmetric digital signature to avoid data tampering and fraud. Traceability (supply chain), using Smart contracts (in Agricultural insurance, Crop finance, Land records) achieved by the BCT and the companies (Carrefour, Trace harvest), states (Telangana, Andhra Pradesh), and countries (Kenya, European Union) practicing are discussed. The Farmer producer company- Sahyadri farms keen implementation of blockchain fetched benefits to farmers amid Covid times. Finally, addressing the barriers in practicing the BCT in India- Technology maturity, energy cost, and education. The massive potential of BCT is yet untapped, to reach up to the farmer level, which will flourish in the coming years.

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1. INTRODUCTION

After the Green revolution, India is now paving the way towards a digital revolution in Agriculture where AI, sensors, IoT, Big data analytics play a huge role. The advancement of the internet made the information accessible, faster communication to users but failed to build trust (100%) and reduce the intermediation. To overcome this drawback, decentralized technology which ensures transparency is needed.

All the transactions in the world are nothing but the mere entry of the details in the ledgers of respective holders. Ledger is a physical account book to note all these transactions. [1]

1.1 For Example

If a Person X sent Rs. Abc to a Person Y from Bank A of the xxx region to Bank C of yyy region at this particular time.

The transaction data maintained by the centralized system (BANK) is prone to manipulation; friction in the network causes a delay in executing the task. Here is when blockchain technology comes as a handy tool.

Blockchain technology is defined as a distributed ledger (DLT) to share transactions or sensitive data across multiple stakeholders in a decentralized manner [2].

1.3 Attributes of Blockchain [3]

1. The **shared ledger** means the distribution of data across the business network, eliminating the problems of failure in a centralized server.
2. **Transparent** – The stored database will be visible to all stakeholders without alterations.
3. **Secure** – The algorithm behind the technology makes it difficult to hack.
4. **Immutable** - It is impossible to delete or change the data once recorded, which increases the confidence, thereby reducing the occurrence of fraud.
5. **Interoperability** – The information generated collaboratively.
6. **Provenance** – Blockchain technology helps in tracing back the entire history available.

7. **Consensus** - Transactions happen only when all parties verify them. (Proof of work -Bitcoin- a massive amount of computational work done to add a block into the chain, Proof of Stake -Ethereum- need to buy some stakes (now it is 32 ethers) to earn the right to create a new block).
8. **Smart contracts** - These are the self-executing agreements that are triggered based on predefined and agreed events.

1.4 When to go for Blockchain Technology? [4]

Uses cases are structured to guide the companies to take up blockchain technology which is as follows-

- Does business compel reduction of intermediaries?
- Are multiple stakeholders involved?
- Does working include digital assets rather than multiple assets?
- Do multiple parties require shared write access?

Based on the requirement to keep transactions public or in controlled functionality, there are majorly three types of blockchain- Public, Consortium, Private.

1.5 Understanding the Technology

A) DATA structure of Blockchain [2,5]

In this, information is stored in the blocks (n, n+1, n+2...). The algorithm generates a unique hash value (which is case sensitive – means hash number changes with change in a single letter or even with Capitalization). Along with them, a timestamp (details about time of the entry of data), nonce (is a number only used once in cryptographic communication), and difficulty (level of difficulty in adding data to block (mining)) details are present in a single block.

When added, a new block (n+1) contains its current hash value and carries the previous transaction's hash ID, thereby forming a chain of transactions.

Table 1. Types of Blockchain [5]

	Public	Permissioned or Consortium	Private
Who can access it?	Anyone can do transactions (anonymous), but transparent to everyone.	Accessible only to permission participants.	Restrictive environment (closed network)
Control	Join a network irrespective of region, nationality, etc.	Created and controlled by a group of members.	Centrally controlled blockchain which permits only specific authorized members to add records.
Use case-	Voting	Banking and payments, food tracking	Supply chain, Asset ownership
Example –	Bitcoin, Ethereum.	IBM Food trust	Quorum, Hyperledger, Corda

The data present in blockchain ensure

- Confidentiality –means no disclosure of private information,
- Integrity- Data cannot be changed by anyone,
- Nonrepudiation – No chance of questioning the authorship,
- Authentication – valid employing CRYPTOGRAPHY.

B) Cryptography-

It means - Concealed or Secret in our case ANONYMOUS.

It is a technique to send secure messages between two or more participants where the sender encrypts/ hides the message using a type of algorithm and key which the receiver can on' decrypt.

The key is the DIGITAL SIGNATURE which makes the block tamper-proof ensuring the origin of data from the intended user.

Cryptography is of two types based on the number of keys. If the sender and user have an exclusive key to encrypt and decrypt the message, it is called Symmetric cryptography. It requires the maintenance of separate keys for each user, making it a bit complex.

Asymmetric or Public-key cryptography has two keys - the one shared with others a *Public* key like an email id and a Private Key that stays confidential to the user as a password. To encrypt a message and send it requires the usage of both Public and Private Keys.

With this basic understanding of the technical aspects of BCT, let us look into the operational and application arenas in the field of agriculture.

2. METHODOLOGY

Supply chain, Crop insurance, Microfinance, Land records are few such arenas where BCT is actively focusing. This article summarizes the efforts/ practices initiated by various entities in line of BCT. To understand how blockchain technology works and its various applications in the agriculture sector, articles are reviewed. As it is an emerging area of interest, the release of several official reports on the practical utility of blockchain by institutions and Governments as FAO [6], NITI AYOOG, and FICCI were studied. The news articles by Down to earth [7], Ledger insights, etc., follow up on technology-oriented companies official websites to obtain first-hand information.

3. RESULTS AND DISCUSSION

3.1 Applications in Agriculture

Of various areas, 4 key areas where BCT is currently practiced and has the potential to widen its scope of action and make it accessible at the farm/individual level are discussed.

1. Supply chain
2. Crop insurance.
3. Microfinance - Self-help Groups
4. Land records

3.2 Blockchain Technology in Supply chain Management

A supply chain is a network between a company and its suppliers to produce and distribute a specific product or service (Investopedia, 2020). It involves a series of activities to reach the final customers as - procuring raw materials for production, transportation, and distribution to end customers.

The current supply chain has many factors hindering the efficiency as-

- Complex and heavy paperwork makes it difficult to keep track of events.
- Inconsistent or Unavailable data.
- Lack of transparency increases the vulnerability of fraud.
- Lack of interoperability, i.e., absence of collaboration while generating the data.
- Most importantly, increasing the overall transaction cost. The cost of operating supply chains makes up two-thirds of the final cost of goods (Niforos, 2017). [8]

3.2.1 Including Blockchain Technology will benefit all the Stakeholders as Follows

The BCT, in association with IoT's (Internet of things), RFID's (Radio Frequency Identification) is the kind of collaboration that enhances their usage.

For example- using RFID, which implements data acquisition, circulation, sharing in production

processing, warehousing, distribution, and sales when used with BCT, guarantees the information shared and published is reliable and authentic and creates space for easy traceability [10]. Putri et al. (2020) suggested that- In the future, hyper ledger blockchain when implemented using Artificial Intelligence, users can make accurate predictions with the data classified and clustered over the period [11].

Carrefour is a pioneer on this subject in Europe with the first application, in March 2018, of the blockchain technology in chicken from Auvergne Filière Qualité Carrefour (FQC). In 2019, they gradually integrated blockchain technology into Carrefour Quality Lines: eggs, cheese, milk, salmon. By 2022, the objective is to apply this technology to all FQC food products.[12]

Along with this, Carrefour partnered with IBM Food trust to ensure traceability which means the complete information from the point chicken was in the farms, rearing time, usage of treatments, whether antibiotic-free or not; to the slaughterhouse, transportation, storage, temperature, until the moment it reaches the Carrefour shelves.

Table 2. Benefits of blockchain to different stakeholders [9]

For Producers	For Regulatory agencies	For Consumers
Build reputation and add value to their produce. Increase Competitiveness Producers can identify fraud by intermediaries	Accurate information to carry out informed and efficient regulations	Trustworthy and reliable information about the source and journey of the produce The food safety concern of the consumer is satisfied.

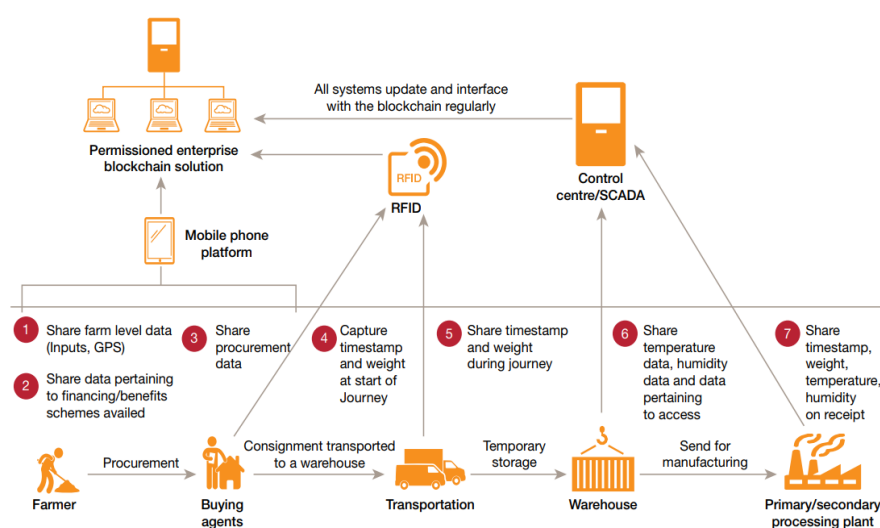


Image Source- PwC and FICCI report - Blockchain: the next innovation to make our cities smarter.[3]

The prominent multinational company in the agriculture sector - Bayer Crop Science, Developed Trace Harvest, which uses a permissioned blockchain ledger (also known as an enterprise blockchain) to track the status of agricultural products. Instead of using cryptocurrency or any open public networks, they work on solidity smart contracts – a unique feature of the Ethereum blockchain protocol-to program and automate business activities and rules into the Trace Harvest network. Importantly, it runs on the BlockApps STRATO blockchain platform, which makes it genuinely enterprise-grade and production-ready [13].

To summarize, as stated by Lalita Garg & Kamal Kumar (2021), scientific research should orient towards a more practical approach for creating pilot applications and platforms combining them with big data, AI, and machine learning techniques, in order to form a better, safer, and well-protected agriculture and allied sector [14].

3.3 Blockchain Technology in Crop insurance [15]

The insurance industry in India is expected to reach USD 280 billion (84 billion in 2017) by the end of 2020. Insurance in agriculture protects against the weather risk - rainfall, drought, etc, which stabilizes the farmer's income, ensuring the continuance in farming.

There are two types of issuance based on the assessment of losses and how the payouts are triggered. They are

1. **Indemnity-based insurance** where payment for the loss of insured items is made after investigation of damage at farm level by the insurance company and Government agency only when it meets the criteria of failure. (most commonly used)

2. **Crop index-based insurance** - Including blockchain technology smart contracts with all stakeholders will trigger the payment when pre-determined and agreed criteria are met.

Example - If the temperature is more than 10% of the 5-year average.

To further explain it - the weather risks as mentioned earlier can be quantified by different parameters. The excess rainfall (if rainfall received is more than 20% or more) leading to flooding, the scanty rainfall (if rainfall received is lower than 60 to 99 %), and the high

temperatures leading to drought are recorded by the regional meteorological stations.

The insurer can build a smart contract with the farmer along with the regional stations, then issuance of claim amount becomes automatic when the threshold is reached.

A Study held by the Global Innovation Lab for Climate Finance and Etherisc showed that only 20% of smallholder farmers in developing countries have access to agricultural insurance. Etherisc offers crop insurance using smart contracts of blockchain, and the claim amount is received as DIP currency (currency of their own). The technology used by them reduces the costs required for policy issuance up to 41%, reducing the premium for farmers by up to 30% [16].

Beacon - Boosting Agriculture insurance based on earth observation data, as the name suggests, issues the insurance based on Earth observation (by Copernicus Sentinel missions), Weather intelligence (data assimilation and seasonal forecasting), and ICT and Blockchain technology (smart contracts). Apart from that, as early warning service mitigation measures and risks related to weather conditions are given [17].

3.4 Blockchain Technology in Microfinance

Dr. Muhammad Yunis popularize microfinance as an alternate source of an institutionalized bank to get micro-loans by financially weaker sections. It is defined as a financial service that enables raising the income and improving the standard of living for the poor in rural, semi-urban, and urban areas, along with thrift credit.

According to Masha Sandeep (2021), microfinance in India is dominated by the Self-help groups (SHG's) - Bank Linkage Programme. SHG is a voluntary association of a group of people (less than 20) of similar socio-economic conditions who save a fixed amount of money stored in a bank [18]. The linkage of the banks, assisted by NABARD, helps the members to acquire small loans for income-generating activities. The borrowers of the SHG face problems obtaining loans from the formal financial sector because of a lack of information on borrowers' creditworthiness or access to the risk profile.

Addressing this issue, the Government of Telangana is using a trail of tamper-proof transactions on a decentralized blockchain platform, which gives a credit rating for Self Help Groups (SHGs). Stree Nidhi is a Credit cooperative Federation limited acting as a supplement credit flow from banks which gives affordable credit to poor SHG's, as a part of SERP (Society for the elimination of rural poverty) [19].

- It has implemented *B-PoS*T (Blockchain Protection for StreeNidhi transactions) working with Cognitochain Technologies Private Limited, for which it banked the Indian Express Technology Sabha Award 2020
- The Loan disbursement and repayments of StreeNidhi for all the 1.5 lakh members (*pilot project –Sircilla District of Telangana*) will be recorded on the blockchain platform.
- The SelfHelp Group (SHG) Member, level credit rating, will be derived from these Blockchain transactions and leverage other financial instruments from banks and other institutions.

3.5 Blockchain Technology in Land Records Maintenance

Digitization is a process of converting analog/paper-based data to digital for easy processing, storage, and transmission. Several projects are laid down in Karnataka (BHOOMI), Andhra Pradesh (CARDS), Tamilnadu started in the early 2000s to computerize the village property records.

Even efficient digitization cannot curb the land-related litigations, difficulties in tracking the double selling of the same land, tiresome paperwork, Delay in obtaining documents from government institutions. [20]

Including blockchain technology is the process of digital transformation to keep documents secure. The immutability makes it challenging to manipulate the data of the true owner, provenance helps in tracing back the entire history of ownership all this in a transparent way making the Government implement it.

Andhra Pradesh government, in December 2017, began registrations in association with Zebl, blockchain-based solutions to store this information using cryptography.

A total of 58 attributes—names, Aadhaar numbers, mobile numbers, boundaries marked with latitude and longitude coordinates, neighboring plots, roads, and so on—are linked to each property in the database [20].

Globally, the Republic of Georgia started the National Agency of Public registry for land title registration in 2016 using blockchain technology. They observed a decrease in the operational cost by 90 percent, ranking the country as the fourth easiest country to register property (ibidem) by the World Bank.

3.6 Sahyadri farms - Farmer Producer Company implemented Blockchain Technology [21]

Sahyadri farm is India's largest Farmer Producer Company, established in 2010, Maharashtra, and has the highest share in grape exports from India compared to any other. They aimed to create a sustainable income for small and marginal farmers by creating crop-specific value chains with transparency for efficient management. They partnered with Emertech Innovations Pvt Ltd to on board the value-chain allied activities on a Blockchain platform named AgroTrust.

Agro trust's vision aligns with the Sahyadri farms in helping smallholder farmers, strengthening the ecosystem of farmer collectives by extensive usages of emerging technologies like Blockchain, AI, and IoT. Also, support the creation of sustainable farmer collectives by providing transparency of cost across the supply chain entities by providing real-time produce traceability. All these activities decrease small-landholding farmers' economic vulnerability by enabling access to the market, providing *FinTech solutions* like fair insurance & credit facilities, and providing trusted certifications of yield, quality, and practices.

To create a smoother end-to-end process, Mr. Vilas Shinde (Sahyadri farms) began the blockchain technology initiative in collaboration with Gaurav Somwanshi's (Agro Trust) team.

Amid the Covid-19 situation, four crores worth of produce is sold by 8000 farmers directly to the consumer using the new app. AgroTrust is a secure cloud-based ledger that can store supply chain information securely to ensure transparency for farmers and traceability for consumers. By reducing the layers in between, they can provide better facilities to farmers for

storing their produce and selling at a sustainable price, with assured quality to consumers.

3.7 Other Potential Areas - [22,23,24]

The lack of transparency in the certification of organic produce hinders exports to developed countries. Using BCT will increase Transparency and traceability, which helps the farmers to achieve the price deserved by the produce. Similarly, this can be extended to allied sectors of agriculture (Dairy). The energy sector is another potential area that is now centralized in production, which is the primary source of power production and consumption disparities. Using BCT enabled with smart microgrids, smart Purchase Power Agreement makes it Community driven (distributed).

4. CONCLUSION

Blockchain technology acts as a solution for different sustainable goals [25] - Zero hunger (2), Decent Work and Economic growth (8), Innovation and infrastructure (9), Responsible consumption and production (12), Partnership for goals (17). Right now, even though it is an efficient solution for prevailing transparency problems, the barriers associated with it reduce the practice/ uptake –

- Technology maturity
- Limited Education and Training in BCT.
- The digital divide between developing and developed countries
- Consensus algorithm (Pros and Cons) - Energy cost, Privacy, and transparency issues.
- 51% attack (where a group of participants gains control of more than half the network's mining computing power chances of data tampering increases). As it is mainly public and distributed technology, increased responsibility on users in entering valid data into these immutable blocks.
- The Government policies rules and regulations will decide the extension/perishment of the BCT.

The application of blockchain technology needs broad participation and collaboration of involving parties in the food supply chain, which is significant to play its full role.

DISCLAIMER

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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