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DIGITAL TRANSFORMATION IN INDIAN AGRICULTURE: THE ROLE OF IOT AND BLOCKCHAIN FOR SUSTAINABLE GROWTH

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ABSTRACT

The agricultural sector in India faces numerous challenges, including increasing demand, evolving crop varieties, declining yields, soil erosion, unpredictable weather conditions, limited automation, and stagnant financial growth. In the modern era, agriculture must transition into a technologically advanced, mechanized, and smart system that ensures high productivity, superior quality, and contamination-free produce. This transformation necessitates the adoption of digital technologies.

This study examines the key barriers to the widespread implementation of digital technology in Indian agriculture, particularly the lack of digital infrastructure, data authenticity, transparency, and network connectivity, especially in remote rural areas. By integrating IoT and Blockchain technology into agriculture, the sector can bridge the gap between production and yield quality and quantity. Furthermore, these technologies can help small-scale farmers become part of the economic system, enabling them to access financial inclusion and sustainable development opportunities. A digitally driven agricultural framework has the potential to enhance productivity, ensure fair market access, and contribute to the eradication of rural poverty in India.

Keyword: Block chain, IoT, Rural Development, Smart Agriculture

I. INTRODUCTION

India is a vast and rapidly growing nation, poised to become the world's most populous country, surpassing China within the next decade. With an estimated current population of 1.37 billion, an additional 273 million people—an increase of approximately 20%—are expected to be added over the next three decades, bringing India's population to around 1.64 billion by 2050 (UN, 2019).

While the Indian economy is experiencing remarkable growth, positioning itself as a global powerhouse in information technology (IT) and manufacturing, significant disparities remain. Despite the rapid expansion of the IT sector, India is home to 25% of the world's poor. Agriculture, which contributes 17% to the country's GDP, provides direct or indirect employment to 60% of the population. In contrast, the IT sector, despite contributing 4% to GDP, employs only about one million people—highlighting the stark rural-urban divide in economic development.

This paper examines the key challenges facing Indian agriculture today and in the coming decades. It explores the necessary measures to make the sector more independent and self-sufficient in order to meet the rising demand driven by population growth. Additionally, it underscores the crucial role of digital technology in transforming agriculture into a more efficient and resilient industry.

While technological advancements in services, manufacturing, and research continue to drive economic growth, India's progress will remain incomplete unless the 60% rural population is integrated into mainstream development. Poverty eradication and improved livelihoods in

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rural areas are essential for sustainable growth.

Currently, the widespread adoption of digital technology in Indian agriculture faces several constraints, including inadequate digital infrastructure, concerns over data authenticity and transparency, and the lack of reliable network support, particularly in remote rural regions. Addressing these challenges is critical to ensuring that digital transformation benefits the agricultural sector and, consequently, the entire nation.

This study employs a secondary research approach to analyze the role of digital technologies, IoT, and Blockchain in transforming India's agricultural sector. The methodology involves gathering, analyzing, and synthesizing existing literature, reports, and case studies to assess the impact of technology-driven agriculture on productivity, sustainability, and rural development. The research follows a descriptive and analytical design, focusing on secondary data sources to explore how digital infrastructure, data-driven decision-making, and advanced agricultural technologies contribute to sustainable farming practices.

This study focuses on research objectives

1. To analyze the impact of digital technologies, IoT, and Blockchain on agricultural productivity and sustainability in India.
2. To examine the role of digital infrastructure in enhancing supply chain transparency and economic inclusiveness for small farmers.
3. To identify the challenges and opportunities in implementing technology-driven agriculture for rural development and poverty eradication.

Also, research questions involves in this study are :

1. How do IoT and Blockchain technologies contribute to improving agricultural productivity, sustainability, and efficiency in India?
2. What are the key benefits of digital infrastructure in ensuring supply chain transparency and fair pricing for small farmers?
3. What are the major challenges in adopting digital technologies in Indian agriculture, and how can they be addressed for long-term rural development?

The data for this research is obtained from reliable secondary sources, including government reports and policy documents from institutions such as the Ministry of Agriculture & Farmers Welfare, NITI Aayog, and Digital India initiatives. Additionally, academic and scientific journals related to agricultural technology, IoT, Blockchain, and rural development are reviewed, along with industry reports and white papers from organizations like the Food and Agriculture Organization (FAO), World Bank, and International Food Policy Research Institute (IFPRI). Furthermore, case studies and pilot projects on smart agriculture, Blockchain-driven supply chains, and IoT-based farming solutions are examined to understand real-world applications. Insights from news articles and expert opinions of agricultural economists, technology innovators, and policy experts further enrich the analysis.

A qualitative content analysis approach is adopted to examine trends, patterns, and emerging insights related to smart agriculture. The study critically evaluates the effectiveness, challenges, and future potential of IoT and Blockchain in agriculture, assessing their role in improving yield efficiency, supply chain transparency, and economic inclusiveness. However, while this study provides valuable insights into digital technology adoption in agriculture, it is limited by the availability of current and region-specific data. Additionally, as it does not involve primary data collection, it relies solely on secondary sources for

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analysis. Despite this limitation, cross-validation from multiple sources ensures reliability and accuracy.

The expected outcome of this research is to provide a comprehensive understanding of how digital technologies can bridge the gap between subsistence farming and smart agriculture, enhance rural livelihoods, and drive sustainable agricultural development in India. The findings will also offer policy recommendations for better implementation of digital infrastructure and financial inclusion strategies in the agricultural sector.

THE ROLE OF TECHNOLOGY IN AGRICULTURE SECTOR

Modern agricultural policies often fail to address the interconnected nature of crop selection, input costs, and supply chains, contributing to persistent marginal farming. A significant disparity exists between the potential benefits of advanced agricultural technologies and the actual gains realized by smallholder farmers (Mkandawire & Matlosa, 1993). The institutional frameworks and technological solutions promoted by governments play a crucial role in determining agricultural productivity growth (Meinzen-Dick et al., 2004). However, the effectiveness of these technologies depends on their accessibility, affordability, and farmers' willingness to integrate them into their farming practices (Meinzen-Dick et al., 2002).

Technology adoption in agriculture is vital not only for enhancing productivity but also for addressing challenges related to poverty alleviation and environmental sustainability (Ashtankar et al., 2023a; Meinzen-Dick et al., 2004). Emerging digital technologies, such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI), are increasingly being explored to optimize agricultural operations and improve decision-making processes (Jain et al., 2025). The integration of AI-driven analytics can enhance predictive modeling for crop yields, mitigate climate-related risks, and facilitate efficient resource management (Kakade et al., 2024a; Brown, 2015). Additionally, blockchain technology ensures transparency and security in supply chain management by decentralizing data storage, reducing fraud, and improving traceability (Babich & Hilary, 2018; Chod et al., 2019).

A major barrier to widespread adoption of technology in Indian agriculture is the lack of a secure and comprehensive digital infrastructure. Traditional agricultural systems often rely on centralized data management, making them vulnerable to inaccuracies, data distortion, and security breaches (Bidve et al., 2023). To address these challenges, AI-driven solutions and cryptographic methods can enhance cybersecurity and protect sensitive agricultural data from unauthorized access (Mani et al., 2024). Furthermore, improving rural digital connectivity is essential to integrating smart technologies and fostering financial inclusion among smallholder farmers (Ashtankar et al., 2023b).

Enhancing agricultural productivity, increasing technology adoption rates, and improving food security require a multi-faceted approach. This includes promoting technology-driven agricultural practices, expanding rural financial markets, increasing access to capital and equipment, and strengthening research and extension linkages (Von Braun et al., 1999; Ashtankar et al., 2023b). Additionally, implementing robust network security measures, such as the Honeybrid method, can safeguard agricultural databases and IoT-enabled smart farming systems from cyber threats (Mane et al., 2024). By addressing these factors, the agricultural sector can become more efficient, inclusive, and sustainable, ultimately enhancing the livelihoods of smallholder farmers while ensuring long-term food security.

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II. THE ROLE OF TECHNOLOGY IN ERADICATING RURAL POVERTY

The agricultural sector is fundamental to India's economic growth, particularly in achieving rural development and economic inclusiveness by eradicating rural poverty. As one of the key pillars of the Indian economy, agriculture sustains more than half of the country's population.

However, Indian agriculture faces several challenges, including rising demand, the need for newer crop varieties, declining yields, soil erosion, unpredictable weather conditions, a lack of automation, and financial stagnation. Farmers also struggle with inadequate infrastructure, low productivity, marketing constraints, land diversion, insufficient advisory and support services, and evolving consumer preferences for nutrient-rich and healthy foods.

In the 21st century, agriculture must evolve into a mechanized, technology-driven, and high-quality sector that ensures contamination-free produce. This transformation necessitates the adoption of digital technologies in agriculture.

Technology serves as a powerful catalyst for change in multiple dimensions of the agricultural sector. The primary objectives of new agricultural technologies include increasing productivity, boosting adoption rates among small farmers, enhancing household incomes, and ensuring food security and nutrition. These goals can be achieved through improved agricultural practices, the expansion of digitalized rural financial markets, and greater access to capital and modern equipment. However, a significant gap remains between the potential of available technology and the actual benefits smallholder farmers receive. Agricultural technology development must not only contribute to the national economy but also uplift the livelihoods of small farmers. As a result, the need for digital transformation in agriculture is growing at an unprecedented pace.

The future of Indian agriculture will be shaped by advanced technologies such as quantum computing, quantum machine learning, cloud computing, blockchain, artificial intelligence (AI), autonomous IoT (AIoT), big data analytics, and augmented/virtual reality, all supported by 5G-enhanced broadband and secure, low-latency wireless connectivity. With the introduction of 5G, agricultural operations will reach new levels of efficiency, operating at the speed of light.

These emerging technologies are attracting innovators in agriculture, including those working on quantum computing, AI, blockchain, biotech, robotics, drones, photonics, and advanced materials. Their application in agriculture promises to revolutionize the sector, transforming it into a smart, data-driven industry.

Smart agriculture aims not only to enhance productivity and produce higher-quality yields at lower costs but also to promote financial inclusion and social-economic development. Under the Digital India initiative, the government has already launched several programs to drive this transformation. However, significant challenges remain in translating the power of digital technologies into a farmer-friendly revolution that benefits India's 156 million rural households. Overcoming these challenges will be crucial for the future of Indian agriculture.

III. APPLICATION OF TECHNOLOGY IN SMART AGRICULTURE

The agricultural sector must evolve into a mechanized, technology-driven industry characterized by high-quality, contamination-free production. Agricultural computerization is a crucial and efficient approach to achieving these goals, enabling precision farming, resource optimization, and sustainable agricultural practices.

This transformation necessitates the digitalization of all agricultural processes, including crop

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production, livestock management, aquaculture, and forestry, through the integration of Information and Communication Technologies (ICT) (Yan-e, 2011).

The Future of Agricultural Science and Technology in India

Over the next 50 years, India's agricultural science and technology sector should focus on ensuring the sustainable development of natural resources, environmental conservation, and socio-economic stability. Achieving this will require the implementation of innovative technologies and security systems that support agricultural production and cater to the evolving demand—both traditional and non-traditional—of human society.

The Role of Smart Agriculture in Sustainable Development

Smart agriculture is designed to increase yields, enhance quality, and reduce costs while ensuring environmental sustainability and financial inclusion. It integrates connected devices and innovative technologies into agricultural practices, creating a high-tech, efficient system for food production.

Smart agriculture is a broad term encompassing agricultural and food production practices powered by the Internet of Things (IoT), big data, and advanced analytics. IoT, in particular, is transforming conventional agriculture by turning physical assets into data-driven, intelligent systems. Practically any agricultural component can be equipped with sensors and made "smart," improving efficiency, accuracy, and productivity.

Key IoT Applications in Smart Agriculture

1. **Sensor-based monitoring systems** – Tracking crops, soil conditions, fields, livestock, and storage facilities to optimize production.
2. **Smart agricultural vehicles, drones, and autonomous robots** – Enhancing efficiency in farming operations.
3. **Connected agricultural environments** – Smart greenhouses and hydroponic systems that optimize resource use.
4. **Data analytics, visualization, and management systems** – Enabling real-time decision-making for better farm management.

By leveraging IoT, modern agricultural solutions bridge the gap between production efficiency and yield quality. Sensors collect real-time data, enabling swift action and minimizing crop damage.

IoT in Agricultural Operations

The current IoT-driven system operates across three major agricultural domains:

1. **Inventory Management & Warehouse Operations**
    - Crop production route optimization and elimination of in-process inefficiencies.
    - Cost-efficient, flexible inventory management.
    - Improved handling of hard-to-reach or perishable crops.
    - Real-time visibility of stock levels and prevention of shortages.
    - Fast response to inventory misplacements and quality threats.

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2. **Production & Manufacturing Operations**
    - Real-time monitoring of soil health, weather, fertilizers, and water supply.
    - Remote and automated crop production management.
    - Predictive maintenance to detect stress levels, prevent failures, and uphold quality standards.
    - Enhanced machine-to-machine and machine-to-human interactions for operational efficiency.
3. **Transportation & Supply Chain Management**
    - Continuous tracking of agricultural products across the supply chain.
    - Remote sensing of environmental factors (temperature, humidity, vibrations) to prevent contamination and disease spread.
    - Optimized transport routes, fuel efficiency, and driver safety.
    - Real-time food traceability for improved supply chain transparency.
    - Minimization of bottlenecks to enhance logistics and service delivery.

Despite the potential of smart agriculture, challenges such as data authenticity, seamless data sharing, and technological accessibility must be addressed. Under initiatives like Digital India, the government has already taken steps to integrate technology into farming. However, significant efforts are needed to ensure these innovations are farmer-friendly and accessible to India's 156 million rural households.

By embracing smart agriculture, India can revolutionize its agricultural sector, making it more resilient, efficient, and sustainable. The integration of advanced technologies like IoT, AI, blockchain, and big data analytics will not only enhance productivity but also contribute to economic inclusiveness and environmental conservation.

IV. THE EVOLUTION OF IOT IN AGRICULTURE: FROM CLOUD COMPUTING TO BLOCKCHAIN & 5G

In current technology frameworks, the Internet of Things (IoT) relies on cloud-based platforms for data storage and exchange. This enables digital information to be processed and accessed from virtually anywhere.

Shifting IoT Paradigms: From Cloud Computing to Blockchain

With the advent of cloud computing, the definition of IoT has evolved:
IoT = Cloud Computing + Ubiquitous Network + Intelligent Sensing Network

While cloud computing provides centralized data management, it comes with inherent challenges:

- **Centralized Control:** Cloud providers retain full control over stored data.
- **Data Integrity Risks:** Vulnerability to unauthorized alterations and cyber threats.
- **Lack of Transparency:** Users cannot always verify the authenticity of transactions.
- **Data Traceability Issues:** Difficulty in tracking data modifications and ensuring reliability.

To overcome these limitations, a combination of Artificial Intelligence (AI) and Blockchain can be integrated to enhance data transparency, security, and traceability.

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The Future of IoT: Blockchain & 5G Integration

A **decentralized network structure** using blockchain technology ensures:

- **Tamper-proof Data:** Protection against unauthorized alterations.
- **Transparent Transactions:** All exchanges are verifiable and traceable.
- **Cost Efficiency:** A more affordable alternative to traditional cloud platforms.
- **Seamless IoT Compatibility:** Designed to integrate with existing IoT networks.

With the rise of **Blockchain and 5G technology**, the definition of IoT is now redefined as:

IoT = Blockchain + Ubiquitous Network (5G) + Intelligent Sensing Network

Blockchain-Enabled Smart Agriculture Model

The proposed **blockchain-supported IoT-based smart agriculture model** will revolutionize the sector by establishing a **decentralized agricultural information system**. This model integrates:

- **Artificial Intelligence (AI)** for predictive analytics and automation.
- **IoT sensors** for real-time monitoring of crops, weather, and soil conditions.
- **Blockchain technology** to ensure transparency in transactions and data security.

This combination will enable dynamic resource distribution, optimized resource utilization, and enhanced efficiency in agricultural operations.

Empowering Small Farmers Through Financial Inclusion

The **blockchain-based smart agriculture model** will bring small farmers into the formal economic system, ensuring financial inclusion through:

1. **Fair Pricing Mechanisms:**
    - Transparent financial contracts between farmers and distributors.
    - Elimination of price exploitation in traditional commodity markets (mandis).
    - Expanded selling options for farmers, reducing dependency on intermediaries.
2. **Farm-to-Fork Food Traceability:**
    - A direct, secure link between **farmers (producers)** and **consumers (end-users)**.
    - Reduced interference from unnecessary intermediaries, ensuring efficiency in the supply chain.

By leveraging blockchain, 5G, AI, and IoT, India's agricultural sector can transition toward a smarter, more efficient, and inclusive ecosystem. This transformation will not only boost productivity but also empower farmers by providing them with fair market access, enhanced data security, and financial stability.

Crop waste management will get control effectively along with contamination trace;

movement of crops will be convenient with effective storage capacity. Crop quality and soil conditions with nutrients ratios will be maintained and monitored effectively and all crop related data will be transparent among all agriculture stakeholders with data authenticity.

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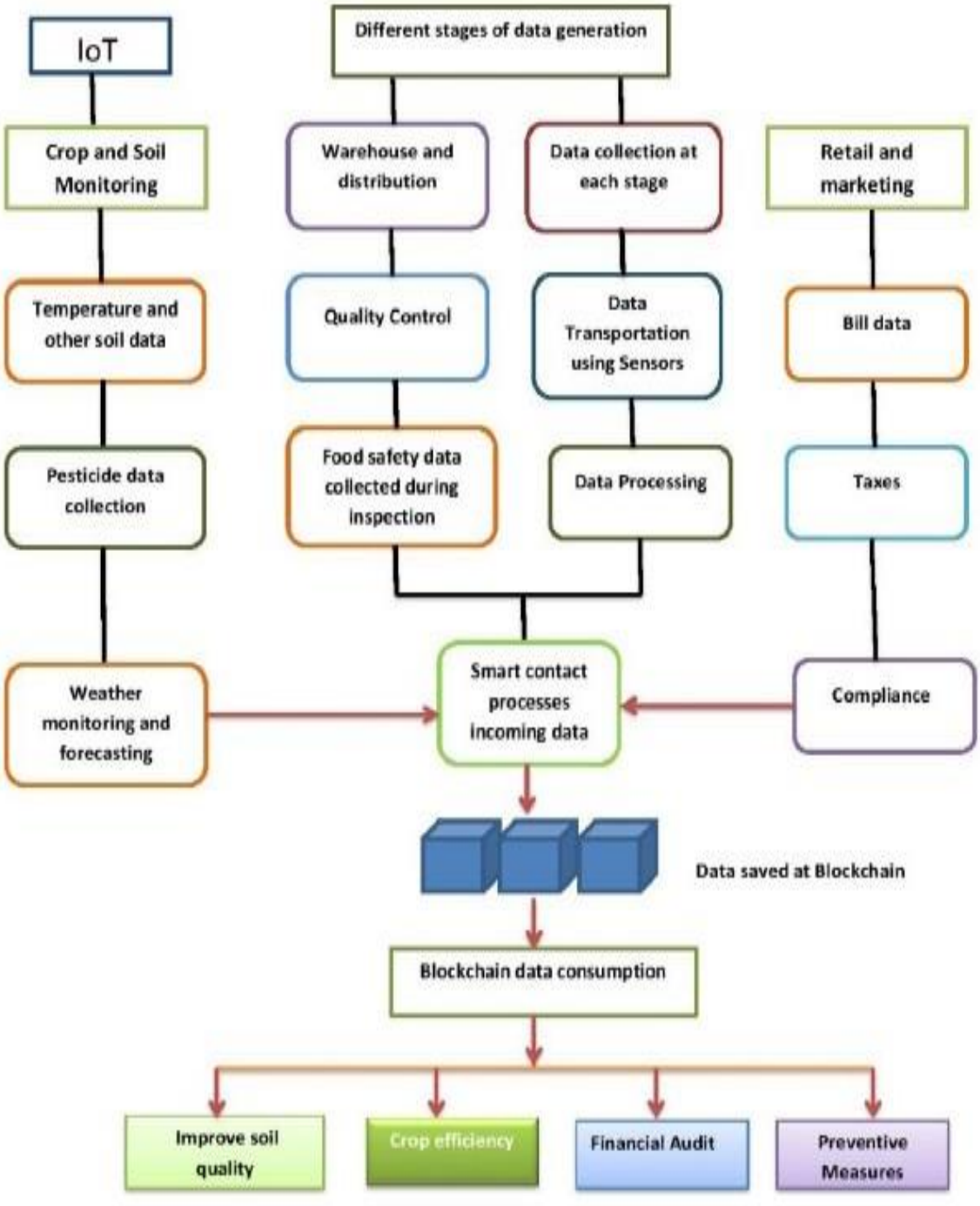
Image 1: IoT with Block-Chain Smart Agriculture Model



Source: J. Mech. Cont.& Math. Sci., Vol.-14, No.-5, September-October (2019) pp 170-188

V. IOT AND BLOCK CHAIN TECHNOLOGY IMPACT ON DATA AND INFORMATION FLOW

An Agri-food system generates critical data and information on natural and economic resources, serving as the foundation for both economic and rural development.

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Data Flow in Agri-Food Systems

As illustrated in the process, an **Agri-food system** operates through multiple interconnected flows:

- **Data & Information Flow:** Moves across various stages, capturing key insights on inputs, production, processing, and distribution.
- **Agri-Food Product Flow:** Transitions from raw inputs to final outputs through multiple value-adding stages.
- **Financial Flow:** Moves in the reverse direction, from consumer purchases back to input providers, ensuring economic sustainability.

Different stakeholders—**farmers, suppliers, distributors, policymakers, and consumers**—generate and manage data based on their specific needs and operational capacities.

The Role of Smart Agriculture

Smart agriculture leverages **Information & Communication Technologies (ICT), Internet of Things (IoT), and advanced data analytics** to enhance efficiency. Key technological components include:

- **Unmanned Aerial Vehicles (UAVs):** Enabling remote monitoring of crops and soil health.
- **IoT Sensors:** Tracking real-time environmental conditions.
- **Machine Learning & AI:** Analyzing agricultural patterns for better decision-making.

Enhancing Data Security with Blockchain

A **major challenge in smart agriculture** is ensuring a **secure, reliable, and transparent data management system**. Traditional agricultural data systems rely on **centralized databases**, which are vulnerable to:

- **Inaccurate Data Inputs**
- **Data Manipulation & Distortion**
- **Unauthorized Access & Misuse**

These vulnerabilities can significantly impact **decision-making in the agricultural sector**, leading to inefficiencies and financial risks.

By **integrating Blockchain technology**, the system can transition to a **decentralized, tamper-proof, and transparent framework**, ensuring:

- **Authenticity & Accuracy:** Preventing data alterations and distortions.
- **Secure Transactions:** Enhancing trust in financial exchanges across the value chain.
- **Efficient Data Management:** Providing all stakeholders with verifiable and real-time access to agricultural insights.

The integration of Blockchain with Smart Agriculture will revolutionize the Agri-food system by enhancing data security, improving decision-making, and creating a more transparent value chain. This transformation will empower farmers, optimize resource utilization, and drive economic growth in rural areas.

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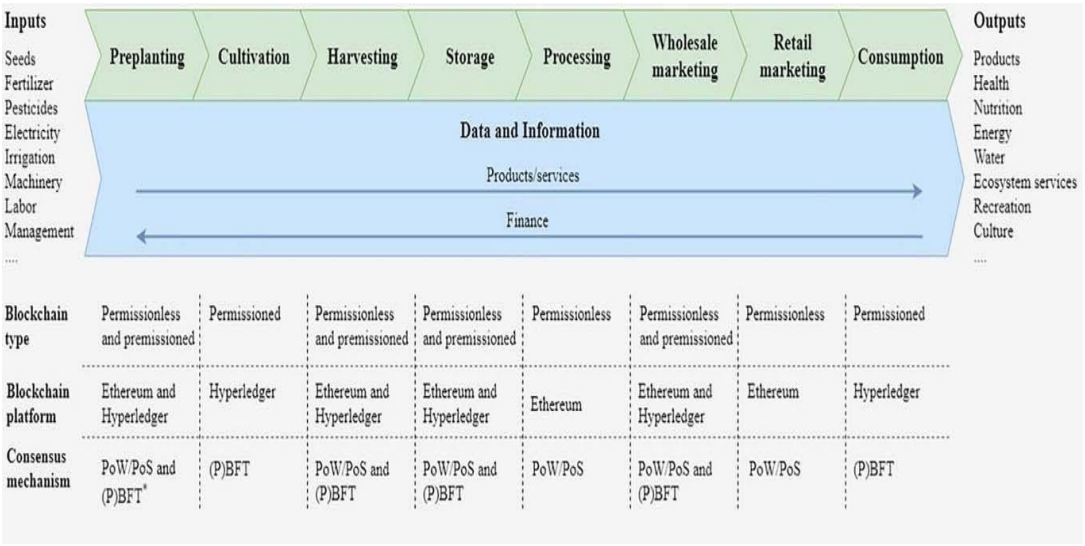
Image 2: Block Chain base Data and information flow in Agriculture Sector



Source: https://www.frontiersin.org/articles/10.3389/fbloc.2020.00007/full

Blockchain technology ensures transparency, security, and immutability of data for all involved stakeholders. Unlike traditional centralized systems that rely on "security through obscurity," Blockchain leverages decentralization to enhance security and prevent unauthorized alterations.

By distributing data across multiple stakeholders, Blockchain significantly reduces the risks of data loss, manipulation, and distortion compared to centrally managed databases.

Optimizing Agriculture Through Data-Driven Decisions

A well-structured agriculture database plays a crucial role in enabling data-driven decision-making, allowing farmers and policymakers to:

- **Optimize production strategies** based on real-time insights.
- **Improve supply chain efficiency** by tracking demand and distribution patterns.
- **Enhance resource allocation** to maximize productivity and minimize waste.

Blockchain as a Secure Infrastructure for Smart Agriculture

Blockchain technology addresses the challenge of securing IoT-based smart agriculture by creating a robust, tamper-proof framework. It seamlessly integrates with various ICT-driven technologies, ensuring:

- **Trustworthy data management** for farmers, suppliers, and consumers.
- **Secure and transparent transactions** across the agricultural value chain.
- **Scalability for future innovations** in smart agriculture.

By integrating Blockchain into ICT-based agriculture, the sector can achieve greater efficiency, sustainability, and financial inclusivity, driving a digital revolution in farming.

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VI. CONCLUSION

India's rapidly growing population necessitates a significant increase in agricultural productivity while ensuring pollution-free and environmentally sustainable farming practices. Achieving this goal requires the integration of advanced, eco-friendly, and user-centric technologies that optimize resource allocation and promote sustainable agricultural development. However, despite technological advancements in various sectors, Indian agriculture still largely relies on subsistence farming methods rather than technology-driven solutions. To transition toward a modernized agricultural ecosystem, the sector needs a robust digital infrastructure to support technology adoption, enhanced digital connectivity to integrate all stakeholders, and efficient resource management systems to improve operational effectiveness and ensure higher returns.

As Information and Communication Technology (ICT), Blockchain, and IoT continue to revolutionize industries, it is imperative to assess and implement these technologies in agriculture and rural development. Smart agriculture powered by Blockchain and IoT offers numerous benefits, such as data-driven decision-making to enhance productivity, improved supply chain transparency through decentralized digital records, and employment generation that empowers rural communities, ultimately reducing poverty. By leveraging digital inclusion and embracing technology-driven agriculture, India can increase yields with minimal inputs, create efficient stakeholder networks, and drive sustainable rural development, shaping a future-ready agricultural sector.

VII. REFERENCES

1. Ashtankar, O., Kakade, K. S., Kale, S. K., Rajak, R., Brahmane, J., & Nigadkar, M. P. (2023). Industry 4.0: Analysing readiness of Indian MSMEs. *2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS)*, Chennai, India, 1–9. https://doi.org/10.1109/ICCEBS58601.2023.10449224
2. Ashtankar, O., Kakade, K. S., Kale, S., Brahmane, J., Nigadkar, M. P., & Kulkarni, A. M. (2023). Plastic ban policy: A sustainable development initiative of India. *2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS)*, Chennai, India, 1–7. https://doi.org/10.1109/ICCEBS58601.2023.10448617
3. Ashtankar, O., Kakade, K. S., Srivastava, S., Nigadkar, M. P., Brahmane, J., & Dayma, B. (2023). Sustainable development: Green marketing perspective. *2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS)*, Chennai, India, 1–11. https://doi.org/10.1109/ICCEBS58601.2023.10448664
4. Babich, V., and Hilary, G. (2018). Distributed ledgers and operations: what operations management researchers should know about blockchain technology.Manuf. Serv. Oper. Manag. (forthcoming) (in press). doi: 10.2139/ssrn.3131250
5. Bidve, V., Kakade, K. S., Sarasu, P., Kediya, S., Tamkhade, P., & Nair, S. S. (2023). Patient data management using blockchain technology. *Indonesian Journal of Electrical Engineering and Computer Science, 32*(3), 1746–1754. https://doi.org/10.11591/ijeecs.v32.i3.pp1746-1754
6. Brown, M. E. (2015). Satellite remote sensing in agriculture and food security assessment. Procedia Environ. Sci. 29:307. doi: 10.1016/j.proenv.2015.07.278
7. businesses. In S. Dixit, M. Maurya, V. Jain, & G. Subramaniam (Eds.), *Artificial intelligence-enabled businesses*. Wiley. https://doi.org/10.1002/9781394234028.ch12

ISSN No: 2349-059X
Peer Reviewed & Refereed Journal
National Research Journal

8. Chen, W. (2018). Administrative Rules and Regulations for the Introduction of Food
9. Chod, J., Trichakis, N., Tsoukalas, G., Aspegren, H., and Weber, M. (2019). On the financing benefits of supply chain transparency and blockchain adoption. Manag. Sci. (forthcoming) (in press). doi: 10.2139/ssrn.3078945
10. Feng Tian. 2016. An agri-food supply chain traceability system for China based on RFID & blockchain technology. In Proceeding of the 13th International Conference on Service Systems and Service Management (ICSSSM'16), 1–6. DOI: https://doi.org/ 10.1109/ICSSSM.2016.7538424
11. Information Traceability in Blockchain. Ph.D. thesis, Shanghai Normal University, Shanghai.
12. Jain, A., Kakade, K. S., & Vispute, S. A. (2025). The role of artificial intelligence (AI) in the transformation of small- and medium-sized
13. Kakade, K. S., Kale, S. K., Vispute, S. A., & Mane, S. B. (2024). Revamping internal customer experience (ICX) with AI. In *Augmenting customer retention through big data analytics* (pp. 209–223).
14. Mane, S. B., Kakade, K. S., Ukarande, A. H., Saoji, B. P., & Joshi, K. (2024). Honeybrid method for network security in a software-defined network system. *International Journal of Electronic Security and Digital Forensics, 16*(6).
15. Mani, A., Kakade, K. S., Therasa, P. R., & Vanitha, M. (2024). Cryptography in the cloud: Securing cloud data with encryption. *International Journal of Electronic Security and Digital Forensics, 16*(5), 577–589. https://doi.org/10.1504/IJESDF.2024.140744
16. Meinzen-Dick, R., Adato, M., Haddad, L., & Hazell, P. (2004). Science and Poverty: An Interdisciplinary Assessment of the Impact of Agricultural Research.
17. Meinzen-Dick, R., Knox, A., Place, F., & Swallow, B. (2002). Innovation in Natural Resources Management: The Role of Property Rights and Collective Action in Developing Countries.
18. Mkandawire, R., & Matlosa, K. (1993). Food Policy and Agriculture in Southern Africa.
19. Raut, R., Bidve, V., Sarasu, P., Kakade, K. S., Shaikh, A., Kediya, S., Borde, S., & Pakle, G. (2024). Transfer learning-based leaf disease detection model using convolutional neural networks. *Indonesian Journal of Electrical Engineering and Computer Science*, *36*(3), 1857–1865.
20. Von Braun, J., & Pandya-Lorch, R. (2005). Food Policy for the Poor: Expanding the Research Frontiers.
21. Von Braun, J., Teklu, T., & Webb, P. (1999). Famine in Africa: Causes, Responses, and Prevention.
22. W. Zhao, S. Lin, J. Han, R. Xu, and L. Hou. 2017. Design and Implementation of Smart Irrigation System Based on LoRa. 2017 IEEE Globecom Workshops (GC Wkshps'17), 1–6.
23. Yan-e, D. (2011). Design of Intelligent Agriculture Management Information System Based on IoT. In 2011 Fourth International Conference on Intelligent Computation Technology and Automation (pp. 1045–1049). IEEE. https://doi.org/10.1109/ ICICTA.2011.262