



## Review Article



# Agri-Tech Revolution in Agribusiness: Harnessing Technology for Sustainable Growth

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## ABSTRACT

The adoption of technological advances is indeed pivotal for the sector's growth and sustainability. Digital transformation brings with it a strong emphasis on sustainability, aligning agribusiness with eco-friendly solutions and practices that reduce waste and optimize resource utilization. The study delves into the complicated landscape of digital transformation in agriculture, covering essential aspects such as defining the paradigm and exploring its landscape in agribusiness. It examines how precision, blockchain, and artificial intelligence are transforming agribusiness. Analysing digital platforms for agri-trade and market access shows that they offer transparency and efficiency, but there are drawbacks as well, like low digital literacy and expensive startup expenses. The study also intends to assess the effects of digital agribusiness on environment sustainability, due diligence is required in its deployment. The study looks into implementation difficulties and suggests solutions. Finally, promising a robust agribusiness ecosystem, future trends indicate a confluence of sustainable practices and technological advances. Thus, this thorough investigation advocates for a responsible and innovative mix that will lead agribusiness into a tech-driven, efficient, and sustainable future.

**Keywords:** Digital Transformation; Agribusiness; Digital Platforms; Agri-Trade; Market Access.

## INTRODUCTION

In India, agriculture plays a pivotal role in the country's Gross Domestic Product (GDP) and provides the majority of income for households living in rural areas (Hubacek *et al.*, 2007). Being the largest employer, it is essential to maintain communities and guarantee food security for the country's expanding population (Lipper *et al.*, 2014). The industry has a significant impact on exports, which boosts economic stability (Pingali, 2007). It also has an impact on rural development, particularly concerning educational facilities and infrastructure. Beyond its influence on the economy, agriculture plays a central role in customs and festivals throughout India's cultural tapestry. Acknowledging these diverse roles highlights how urgently digital transformation is needed to improve productivity, sustainability, and the nation's overall agricultural development.

A paradigm shift in terms of efficacy, optimization of resources (Morales *et al.*, 2020), access to markets, risk management, knowledge sharing, and sustainability is provided by digital transformation in agriculture (Mendes *et al.*, 2022). Digital technologies enable precision farming, which guarantees increased agricultural productivity. In addition to increasing productivity, automation and innovative technologies help farmers obtain larger yields using fewer resources,

which supports sustainable farming practices (Javaid *et al.*, 2022).

One important aspect of the digital revolution is resource optimization (Sharma *et al.*, 2022), wherein tools are used to assist farmers in managing pesticides, fertilizers, and water resources wisely to reduce waste and environmental effects. Through the use of data-driven insights and precision agriculture techniques, resources are deployed precisely where and when they are needed, maximizing effectiveness. Through the elimination of middlemen and the direct connection between farmers and buyers, digital platforms are essential for fair pricing and market access. By ensuring that farmers are fairly compensated for their produce, price transparency; which is made possible by these platforms; promotes economic viability in the agricultural industry.

Digital technologies offer real-time data on market trends, insect outbreaks, and meteorological conditions, which is beneficial for risk management. This gives farmers the ability to manage risks proactively, and the combination of financial technologies and crop insurance further lessens the negative effects of unanticipated events on farmers' earnings. Digital platforms enable the transfer of knowledge and education by providing farmers with information on market trends, new technologies (Fabregas *et al.*, 2019)

and best practices. Farmers who have access to smartphones and online information are better equipped to make educated decisions and adjust to changing farming practices.

Thus, digital transformation places a strong emphasis on sustainability, encouraging eco-friendly solutions, cutting waste, and maximizing resource utilization (Sharma *et al.*, 2022). Data-driven insights make it easier to monitor and manage environmental effects, bringing agriculture into line with more general objectives of ecological harmony and long-term sustainability. To put it simply, the adoption of technological advances is essential to bringing agriculture into a new era of sustainability, efficiency, and precision.

#### Defining Digital Transformation in Agriculture

The term "digital transformation" in agriculture describes how various facets of agricultural and agribusiness operations are fully integrated with technological advances, analytics of data, and smart devices. It represents a change from more manual, traditional processes to automated, driven by data and technologically sophisticated ones. Digital transformation in agriculture refers to a broad spectrum of tools and procedures. Precision farming, the application of the Internet of Things (IoT), devices for real-time tracking, the use of analytical tools for making decisions, and the integration of intelligent gear and equipment are a few examples of how this might be done. The objectives include increasing output, maximizing efficiency, and advancing sustainability in agricultural techniques. The essential components for defining digital transformation in the agricultural sector are listed below.

**Precision agriculture:** It refers to the application of technology to accurately control resources like pesticides, fertilizers, and water using real-time data

from sensors, satellite photography, and other sources (Pierce and Novak, 1999). Precision farming reduces waste and increases input efficiency.

**IoT and Sensor Technologies:** Setting up a network of connected gadgets and sensors to gather and send data from the farm. These could include equipment trackers, weather stations, and soil sensors, which can give farmers useful information to help them make better decisions (Lima *et al.*, 2021).

**Data-driven decision-making:** Using data analytics technologies (Mandinach, 2006) to process massive amounts of agricultural data "data-driven decision-making." With this information, farmers can plan their entire farm strategy, allocate resources, and manage their crops with knowledge.

**Digital Platforms for Farm Management:** Using software and digital platforms to help with planning, organizing, and general farm management (Agyekumhene *et al.*, 2020). These systems frequently give farmers access to centralized dashboards where they may track and manage many areas of their business.

Thus, the concept of digital transformation in agriculture refers to the various ways in which digital technology is incorporated to modify conventional farming methods. It seeks to develop more data-driven, sustainable, and effective farming practices that can handle issues like resource scarcity, changes in the climate, and the world's rising food demand.

#### Exploring the Landscape of Digital Transformation in Agribusiness

Digital transformation in agriculture has a broad reach and offers numerous chances to improve productivity, sustainability, and general performance along the whole value chain. Table 1 showcases the wide-ranging impact of technological advancement in agribusiness which are listed below.

**Table 1.** Technological Advancements with Related Significance

Technological Advancements	Significance
Precision Farming for Optimal Resource Use	Farmers can now administer inputs (such as water, fertilizer, and herbicides) precisely thanks to technologies like drones and GPS-guided tractors. With this focused strategy, waste is reduced, resource utilization is maximized, and crop yields are increased.
Data-Driven Decision-Making	Real-time data on crop performance, soil health, and weather conditions is provided by technology. Based on this information, farmers can make well-informed decisions that will increase planning accuracy and decision-making processes overall.
Supply Chain Optimization	Blockchain technology improves supply chain traceability and transparency. Ensuring the reliability and efficacy of agricultural products during their manufacturing and distribution process is of utmost importance for the agricultural industry.
Innovation for Sustainable Practices	Using technology to its full potential promotes the use of sustainable farming methods. Innovations that support long-term sustainability and environmental stewardship include renewable energy applications, smart irrigation systems, and organic farming technologies.

Global Competitiveness	Technology-savvy agribusinesses have the advantage to compete internationally. They may now comply with international standards, satisfy the expectations of a market that is changing quickly, and take part in a global agriculture supply chain thanks to technological improvements.
Rural Development and Economic Growth	Technology integration in agriculture promotes rural development and economic expansion. Improved farmer lives result from higher production and profitability, which has a beneficial knock-on effect on regional economies.
Agricultural Understanding and Education Accessibility	Technology makes it easier to share best practices and agricultural expertise. Farmers can access educational materials through digital platforms, mobile applications, and internet resources, enabling them to make well-informed decisions.
E-commerce for Agri-Outputs and Inputs:	Using online marketplaces to buy and sell agricultural products and inputs (such as seeds, fertilizer, etc.). This improves market efficiency and simplifies transactions.
Agri-FinTech and Crop Insurance	FinTech, or financial technologies, are integrated into agriculture to facilitate credit access, crop insurance, and efficient financial transactions. For farmers, this guarantees financial stability and helps reduce risks.
Mobile Applications	Creating mobile applications and internet resources to give farmers access to agricultural expertise, best practices, and instructional materials. This enables farmers to enhance their farming methods and make well-informed judgments.
Automation and Robotics	Planting, harvesting, and sorting are just a few of the agricultural processes that can be automated and roboticized. This lessens labour-intensive jobs, boosts productivity, and helps certain places that are experiencing a labour shortage

Thus, the extent of digital advancement in agriculture is dynamic and changes in tandem with technological breakthroughs. Agriculture will benefit from digital solutions in terms of production, sustainability, and resistance to different problems. By integrating these technologies, agriculture is modernized and becomes more productive, sustainable, and favourable to the environment.

#### **Key technologies driving agribusiness transformation**

The "Key Technologies Driving Agribusiness Transformation" highlights the critical impact that certain technology developments have had in restructuring and streamlining several facets of the agriculture industry. The main technologies that help in the transformation of agribusiness are listed below.

#### **Using IoT and sensor technologies for precision agriculture**

Precision farming is the application of sensor technologies and Internet of Things (IoT) devices to highly accurate farming techniques optimization (Ceron Munoz *et al.*, 2019). Real-time data on a range of aspects, including crop health, nutrient levels, and soil moisture, is collected via the Internet of Things devices, including GPS-guided tractors, drones, and soil sensors. After that, this data is examined to help with resource allocation, fertilization, irrigation, and pest management decisions. With the use of precision agriculture, farmers can tailor their methods to the unique conditions of each section of their fields, saving resources and increasing crop yields (Kovalev *et al.*, 2020).

#### **Supply Chain Management with Blockchain Applications**

A decentralized, open ledger made possible by blockchain technology has the potential to completely transform supply chain operations in the agricultural industry (Mukherjee *et al.*, 2021). Every stage of the agriculture supply chain, from field to market, can be securely and irrevocably documented on the blockchain. This guarantees the agricultural goods' authenticity, traceability, and transparency. Customers can, for instance, ascertain a product's provenance, confirm its quality, and guarantee farmers are fairly compensated. Blockchain lowers the possibility of fraud, diminishes supply chain inefficiencies, and fosters stakeholder confidence.

#### **Machine Learning and Artificial Intelligence in Crop Management**

Technologies related to artificial intelligence (AI) and machine learning (ML) are essential for improving crop management techniques (Javaid *et al.*, 2023). Large databases, including historical and current data on crop performance, soil conditions, and weather patterns, are analysed by these systems. Insights from AI and ML systems can be used to optimize planting dates, forecast crop diseases, and suggest exact dosages of inputs like pesticides and fertilizers. By limiting its negative effects on the environment, this data-driven strategy lowers costs, increases the accuracy of decisions made, and supports sustainable farming methods.

Thus, by improving accuracy, transparency, and efficiency along the whole agricultural value chain, these

revolutionary technologies are propelling a revolution in the agribusiness sector. They improve the overall resilience and sustainability of the agriculture industry, provide farmers with practical information, and optimize supply chain operations.

#### **Digital platforms for market access and Agri-trade**

Due to their ability to offer creative solutions that improve market access, expedite transactions, and foster transparency, digital platforms are crucial in revolutionizing traditional agri-trade practices. The essential elements are listed below.

##### **Farmers' Online Marketplace**

**Virtual Market Places:** Farmers can exhibit and market their agricultural products on online markets, which are digital platforms.

**Direct-to-Consumer Connection:** By doing away with the need for middlemen, these platforms allow farmers to connect directly with customers, retailers, and even other enterprises.

**Product Variety:** By offering a wide variety of agricultural goods on these platforms, farmers can reach a wider audience and possibly grow their clientele.

##### **Payments and Agri-Finance with Blockchain**

**Secure and Transparent Financial Transactions:** To guarantee safe and transparent financial transactions throughout the agricultural supply chain, agri-finance uses blockchain technology.

**Smart Contracts:** Using the blockchain to automate and enforce contracts, smart contracts make sure that payments are made automatically when certain criteria are satisfied.

**Preventing Fraud:** Blockchain's tamper-resistant and decentralized design greatly lowers the possibility of fraud in financial transactions, making it a dependable and trustworthy system.

##### **Platforms for Agribusiness E-Commerce**

**Digital Storefronts:** Agribusinesses can display and sell their goods and services online with the help of digital storefronts provided by e-commerce platforms.

**Global Market Reach:** By giving agribusinesses access to customers outside of their region or local borders, these platforms give them a worldwide market reach.

**Efficient Transactions:** Online payments, order monitoring, and logistics coordination are just a few of the features that e-commerce integrates to make buying and selling easier.

Thus, the expanded market access, less reliance on middlemen, and increased trust and openness are recurring themes that together tell the story of agri-trade's revolutionary transformation. These digital platforms support the advancement and sustainability of the whole agricultural value chain in addition to empowering farmers and agribusinesses.

Therefore, these digital platforms essentially transform the agricultural industry by using technology to make trade routes for farmers and agribusinesses more transparent, efficient, and easily accessible. They improve the accessibility of agricultural products,

empower stakeholders, and help modernize the agri-trade ecosystem.

#### **Environmental and sustainability impacts of digital agribusiness**

The emergence of digital agriculture has significant environmental sustainability responsibilities in addition to potential prospects (Hrustek, 2010). It is crucial to strike a balance between the adoption of sophisticated technologies by farmers and agribusinesses to increase productivity and efficiency, and environmental responsibility. The energy usage of data centres, the manufacturing of electronics, and the total carbon footprint of farming techniques aided by technology can all influence the environment as a result of digital agriculture. Maintaining equilibrium necessitates careful consideration of technologies that integrate renewable energy sources and give priority to energy efficiency. Furthermore, in the context of digital agribusiness, sustainable practices are essential. Digital tools make precision agriculture possible, which reduces waste and its negative effects on the environment by allowing focused and optimized resource utilization.

Therefore, adopting organic agricultural methods, putting intelligent irrigation systems into place, and encouraging sustainable supply chain management all help to further the overall objective of ecological sustainability in agribusiness. Adhering to accountable and environmentally friendly techniques is crucial for managing the digital evolution of agribusiness as it guarantees a peaceful coexistence between technology advancement and environmental conservation.

#### **Challenges and solutions in implementing digital transformation**

There are obstacles to overcome while executing digital transformation in every industry, including agriculture. For the integration of digital technology to be successful, these issues must be resolved. The common challenges and possible solutions for the same are listed below in Table 2.

Thus, to effectively navigate these obstacles, a thorough and cooperative strategy is needed. An environment that is favourable to the successful adoption of the digital revolution in agribusiness is created by governments, private sector organizations, non-governmental organizations, and local communities.

##### **Future trends in digital agribusiness**

Emerging developments in digital agribusiness will be defined by the persistent incorporation of cutting-edge technologies to tackle novel obstacles and prospects inside the agricultural industry. The major trends anticipated to influence how digital agribusiness develops in the future are listed below.

**6.1 Artificial Intelligence (AI) and Machine Learning (ML) in Decision Support:** With the ability to provide advanced decision support systems, agribusiness will increasingly embrace AI and ML. Large-scale datasets will be analysed by these technologies to produce useful information on risk assessment, resource optimization, and crop management.

**Table 2.** Challenges and Solutions in Implementing Digital Transformation

Challenges	Solution
Limited Digital Literacy	The adoption of modern technology may be hampered by the low digital literacy of farmers and stakeholders (Barbosa <i>et al.</i> , 2021). <i>Solution:</i> Funding digital literacy projects and training programs to equip farmers with the required knowledge and abilities. Education initiatives and user-friendly interfaces can help deconstruct technology and make it easier to use.
Connectivity Issues in Rural Areas	A lot of agricultural areas don't have enough internet access, which makes it difficult to share data in real-time. <i>Solution:</i> Looking into alternate connectivity options including low-power wide-area networks or satellite-based internet. Expanding connectivity to rural locations can be made possible through public-private partnerships.
Interoperability Problems	A smooth integration process may be impeded by incompatibilities between various digital platforms and technologies. <i>Solution:</i> Encouraging industry-wide norms and interoperability protocols guarantees efficient communication between various systems. Compatibility can be promoted by technology companies working together to provide open-source solutions.
High Initial Costs	Smaller farms and enterprises may find it difficult to adopt digital technologies due to the hefty upfront costs. <i>Solution:</i> To lessen the financial burden, governments, non-governmental organizations, and partners in the corporate sector can provide financial incentives, assistance, or adaptable financing solutions. Cutting-edge technologies can become more accessible to a wider variety of stakeholders through collaborative efforts.
Infrastructure Limitations	Inadequate infrastructure might make it more difficult to implement digital solutions smoothly, especially in isolated or rural places. <i>Solution:</i> Investments in enhancing digital infrastructure, such as dependable power supply and internet access, can come from both the public and commercial sectors. In situations when traditional infrastructure is absent, mobile-based solutions can be utilized.
Data Security Issues	Data safety and confidentiality are issues that are brought up by the gathering and use of confidential information in digital agriculture. <i>Solution:</i> It's critical to put strong cybersecurity safeguards in place, such as encryption and secure storage. Having well-defined policies for data governance and adhering to pertinent regulations fosters confidence among stakeholders.
Integration and Scalability Difficulties	Ensuring compatibility with current systems and integrating technology on a broad scale can be challenging. <i>Solution:</i> Phased deployment is possible with the use of scalable and modular solutions. A more seamless transition can be guaranteed by working with technology suppliers who supply adaptable and integrable solutions.
Opposing to Change	Farmers' or current stakeholders' unwillingness to accept new technologies and alter long-standing customs. <i>Solution:</i> One way to overcome resistance is to involve stakeholders at the beginning of the process, communicate the benefits clearly, and show concrete results. A sense of ownership is fostered when end users are included in the development and decision-making process.

**5G Connectivity for Precision Agriculture:** By bringing 5G technology to rural regions, connectivity will be greatly improved, allowing for faster and more dependable data transmission. This will facilitate real-time farming operation monitoring and control, thus bolstering the growth of precision agriculture.

**Automation and Robotics:** These two trends will become more prevalent in agriculture, especially in labour-intensive operations like planting, harvesting, and sorting. Drones, robotic systems, and autonomous cars will all boost production and efficiency.

**Crop Simulation with Digital Twins:** Using digital twin technology, actual assets or processes may be virtually modelled (Dayioglu and Turker, 2021). The use

of digital twins will be in agribusiness to simulate and monitor crop growth, giving farmers the ability to plan and optimize their farming methods using virtual versions of their farms.

**Blockchain for Supply Chain Transparency:** The agricultural supply chain will continue to use blockchain technology to improve traceability and transparency. Customers will then have access to verified data regarding the provenance, calibre, and sustainability of agricultural goods.

**Edge Computing in Field Operations:** Instead of depending exclusively on centralized cloud computing, edge computing processes data closer to the source (such as on-field sensors). Edge computing in agribusiness will

speed up decision-making, particularly for time-sensitive procedures like pest control and irrigation.

**Agri-Fintech for Financial Inclusion:** As agricultural fintech, or Agri-Fintech, solutions proliferate, they will tackle agribusiness's financial difficulties. To promote financial inclusion, these solutions can include creative financing schemes, digital payment systems, and insurance plans designed specifically with farmers' requirements in mind.

**Climate-smart agriculture technologies:** These technologies are expected to become more and more prominent. This includes resilient crop varieties, cutting-edge weather forecasting algorithms, and adaptive farming techniques that assist farmers in reducing the negative effects of changing climates on agricultural output (Aisenberg, 2017).

**Vertical farming as well as controlled environment agriculture:** When urbanization persists, vertical farming and agriculture in controlled environments will become more significant. These technologies, which are frequently aided by automation and the Internet of Things, allow for year-round production in constrained metropolitan settings.

**Augmented Reality (AR) for Field Aid:** By superimposing digital data on the real world, AR applications will help farmers with activities they must complete on the field. Real-time information on the health of crops, soil conditions, or machinery maintenance guidelines for agriculture could fall under this category.

Thus, the upcoming trends point to agribusiness's ongoing digital transformation, which is being fuelled by the industry's growing demand for efficiency, resilience, and sustainability in the face of changing challenges. It is anticipated that the integration of these technologies will result in an increasingly technologically sophisticated, data-driven, and networked agricultural ecosystem.

## CONCLUSION

When it comes to imagining a tech-driven and sustainable agribusiness future, our investigation into the digital transformation of agriculture has shown a vibrant field that is ready for major change. The three transformational pillars of AI, blockchain, and precision are altering conventional practices. Though not without difficulties, digital platforms for agri-trade and market access offer efficiency and transparency. For adoption to become widely accepted, obstacles including low digital literacy and expensive initial fees must be addressed. Future trends point to the integration of sustainable practices and cutting-edge technologies, guaranteeing a robust agricultural environment. Thus, achieving a tech-driven, sustainable agricultural future necessitates a steadfast dedication to ecological stewardship, diversity, and innovation. A robust, effective, and sustainable agricultural ecosystem will be made possible by proactive research and smart implementation, which stand at the intersection of tradition and technology.

## RECOMMENDATIONS

To further advance this transformative journey, recommendations for ongoing research and implementation are essential. Our understanding will grow as the social, economic, and environmental effects of digital agriculture are further investigated. Financial constraints can be addressed by conducting more research on creative financing methods and inclusive Agri-Fintech solutions. Adoption of technology will increase if regulations protecting privacy and data security are put into place and digital literacy is encouraged. It is essential to adopt comprehensive strategies for sustainability, such as eco-friendly supply chains and precision agriculture.

## CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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