Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 10 Issue 7 September 2026

Research Article

AgriTradeConnect: A Blockchain-Enabled and AI-Driven Platform for Transparent MSP-Based Agricultural Trade

Ravindra Nath[1], Devraj[2]*, Meenakshi Malik[3], Vibhushit Katiyar[4], Gaurav Sharma[5] and Nikita Singh[6]

[1]Associate Professor, BBAU Central University, Lucknow (U.P.), India

[2]Principal Scientist, ICAR-Indian Institute of Pulses Research, Kanpur (U.P.), India

[3]Scientist, ICAR-National Research Institute for IPM, New Delhi, India

[4]Student, Department of Computer Science, B.Tech. (CS), Lovely Professional University, Jalandhar (Punjab), India

[5]Assistant Professor, School of Computing and Artificial Intelligence, Lovely Professional University, Jalandhar (Punjab), India

[6]Young Professional-II, ICAR-Indian Institute of Pulses Research, Kanpur (U.P.), India

***Corresponding Author:** Devraj, Principal Scientist, ICAR-Indian Institute of Pulses Research, Kanpur (U.P.), India.

DOI: 10.31080/ASAG.2026.10.1570

Received: August 18, 2026

Published: September 28, 2026

Abstract

The Minimum Support Price (MSP) system is essential for safeguarding farmers' income; however, existing agricultural trading mechanisms often suffer from limited transparency, delayed payments, and intermediary-driven inefficiencies. This study presents AgriTradeConnect, a blockchain-enabled and AI-driven digital platform designed to facilitate secure, transparent, and efficient MSP-based agricultural trade. The platform integrates farmers, buyers, procurement agencies, and regulatory authorities through a unified web-based ecosystem. Blockchain technology ensures immutable transaction records and end-to-end traceability, while AI-based analytics provide real-time market insights and decision support. The system supports crop listing, MSP verification, transaction monitoring, and automated payment processing. A prototype implementation demonstrated improved transparency, faster transaction processing, reduced disputes, and enhanced stakeholder trust compared with conventional trading practices. The proposed framework offers a scalable and farmer-centric solution for modernizing MSP procurement, strengthening digital governance, and promoting fair and efficient agricultural marketing.

Keywords: Agriculture; AI-Driven Digital Platform; Minimum Support Price (MSP); Blockchain; Crop Trade; Transparency; Farmers Empowerment

Introduction

Agriculture remains one of the most important sectors of the Indian economy, contributing significantly to national food security, employment, and rural livelihoods. More than half of India's population depends directly or indirectly on agriculture, making the sector vital for sustainable economic development. To

safeguard farmers against market price fluctuations and ensure remunerative prices for agricultural produce, the Government of India introduced the Minimum Support Price (MSP) mechanism for major crops. MSP serves as a price guarantee that protects farmers from distress sales and supports national food procurement policies. However, the effective implementation of MSP continues to face several challenges, including inadequate market access, information asymmetry, delayed payment settlements, fragmented procurement systems, lack of transparency, and the continued dominance of intermediaries in agricultural marketing [1,2].

The rapid advancement of digital technologies has created unprecedented opportunities for modernizing agricultural marketing and supply chain management. Technologies such as blockchain, artificial intelligence (AI), Internet of Things (IoT), cloud computing, and edge computing have demonstrated considerable potential in enhancing transparency, traceability, security, and operational efficiency across agricultural value chains [3-5]. Blockchain technology provides decentralized, immutable, and tamper-resistant transaction records that improve trust among stakeholders and facilitate secure data sharing without reliance on centralized authorities. Similarly, AI-based analytical models support intelligent decision-making by enabling demand forecasting, price prediction, procurement planning, and market trend analysis using historical and real-time agricultural data [6].

Recent research has demonstrated the effectiveness of blockchain-enabled agricultural supply chains in improving product traceability, reducing fraudulent practices, automating smart contracts, and enhancing transaction security [7,8]. Likewise, digital agricultural initiatives, including the National Agriculture Market (e-NAM) and the Digital Agriculture Mission, have strengthened electronic trading and digital service delivery. Nevertheless, these platforms primarily focus on market integration and online trading and do not provide comprehensive mechanisms for automated MSP validation, blockchain-enabled payment settlement, AI-assisted market intelligence, and transparent farmer–buyer interaction within a unified framework.

Motivated by these limitations, this study proposes AgriTradeConnect**,** a blockchain-enabled and AI-driven digital platform for transparent MSP-based agricultural trade. The proposed system integrates automated MSP verification, secure blockchain-based transaction management, AI-powered analytics, and a digital marketplace to establish direct interaction between farmers, buyers, and procurement agencies. By ensuring regulatory compliance, transparent procurement, secure payment processing, and real-time market intelligence, AgriTradeConnect aims to improve transaction efficiency, strengthen farmer confidence, reduce dependence on intermediaries, and contribute to a more transparent and sustainable agricultural marketing ecosystem [9,10].

Literature Review

The digital transformation of agricultural markets has attracted significant research attention due to its potential to improve efficiency, transparency, and farmer welfare. Various technological interventions have been proposed to address challenges associated with traditional agricultural trading systems [11,12].

One of the most notable initiatives in India is the National Agriculture Market (e-NAM), launched to integrate agricultural markets across states through a unified electronic trading platform. Studies indicate that e-NAM has improved market accessibility and transparency; however, its effectiveness is often limited by inadequate digital literacy, infrastructural constraints, and the continued influence of commission agents. These challenges have restricted the full realization of a transparent and farmer-centric marketing ecosystem [13,14].

Blockchain technology has emerged as a promising solution for enhancing trust and traceability in agricultural supply chains. Researchers have demonstrated that blockchain-based systems can maintain immutable transaction records, reduce fraudulent practices, improve price transparency, and facilitate automated payment settlements through smart contracts. Despite these advantages, large-scale adoption remains constrained by implementation costs, technical complexity, and limited stakeholder awareness.

Artificial intelligence and machine learning techniques have also gained prominence in agricultural decision-support systems. Recent studies have shown that predictive models can effectively forecast commodity prices, estimate market demand, and assist farmers in identifying optimal selling periods. Such intelligent systems can reduce market uncertainty and improve profitability; however, their performance depends on the availability of reliable and large-scale datasets.

Digital trading portals and online agricultural marketplaces have further contributed to reducing dependency on intermediaries by enabling direct farmer-to-buyer transactions. Existing platforms have demonstrated improvements in market efficiency and price discovery. Nevertheless, most of these solutions primarily support open-market trading and do not explicitly incorporate MSP enforcement mechanisms, thereby limiting their effectiveness in protecting farmers from unfavorable market conditions.

Researchers have also explored the integration of Internet of Things (IoT) devices and satellite-based monitoring systems for crop assessment and procurement planning. IoT sensors provide real-time field-level information, while remote sensing technologies assist in crop monitoring and yield estimation. Although these technologies can enhance agricultural intelligence and procurement planning, their deployment is often hindered by infrastructure requirements and operational costs.

At the global level, digital agricultural marketplaces such as those implemented in China and several African countries have demonstrated the scalability of technology-enabled trading ecosystems. These platforms successfully connect producers with buyers and improve market efficiency; however, they generally operate under market-driven pricing mechanisms and do not address government-supported procurement frameworks such as MSP.

Existing studies predominantly address traceability, supply-chain security, knowledge management, or general digital agricultural trading. Limited research has addressed an integrated decision-support architecture that combines automated MSP compliance, blockchain-based transaction verification, AI-assisted market intelligence, and quantitative evaluation of procurement performance within an Indian agricultural marketing context. The proposed AgriTradeConnect platform seeks to address this research gap by integrating these technologies into a unified framework for transparent and efficient MSP-based agricultural trade.

Proposed methodology

System architecture

The proposed AgriTradeConnect platform is designed as a blockchain-enabled and AI-driven digital ecosystem that facilitates transparent MSP-based agricultural trade. The architecture integrates farmers, buyers, government procurement agencies, and regulatory authorities through a secure and scalable web platform. The system comprises five functional modules that collectively ensure transparency, security, and efficient transaction management. Figure 1 illustrates the architecture of the proposed AgriTradeConnect platform.

User management module

This module manages the registration and authentication of stakeholders, including farmers, buyers, procurement agencies, and government officials. User profiles are created using verified identity credentials and are linked to crop, landholding, and banking information. Role-based access control is implemented to ensure secure platform access and transaction authorization.

MSP validation engine

The MSP Validation Engine acts as the core regulatory component of the platform. It automatically compares submitted buyer bids with the officially declared Minimum Support Price (MSP) for the respective crop. Any bid below the MSP threshold is automatically rejected, thereby safeguarding farmers against unfair pricing and ensuring compliance with government procurement policies [15].

Digital marketplace module

The Digital Marketplace enables farmers to list their produce and buyers to submit procurement bids. The platform supports real-time crop discovery, bid submission, bid evaluation, and buyer–seller matching. The marketplace promotes direct interaction between farmers and buyers, thereby reducing dependency on intermediaries and improving market efficiency.

Blockchain transaction ledger

All approved transactions are recorded on a permissioned blockchain network. The blockchain ledger maintains immutable and tamper-proof records of crop listings, bid approvals, payment settlements, and ownership transfers. This mechanism enhances transparency, traceability, and stakeholder trust throughout the procurement lifecycle.

AI-Based analytics dashboard

The analytics module utilizes historical transaction records and market information to generate demand forecasts, procurement trends, and price intelligence reports. The dashboard assists farmers, procurement agencies, and policymakers in making data-driven decisions and improving market planning.

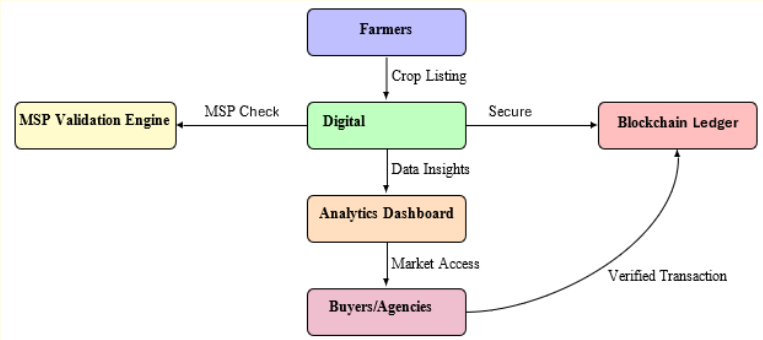

Figure 1: AgriTradeConnect System Architecture with data flow.

MSP validation and buyer matching algorithm

The proposed algorithm ensures that only MSP-compliant bids are considered during the buyer selection process. The system first validates all submitted bids against the MSP value and then identifies the most beneficial bid for the farmer.

Algorithm: MSP Validation and Buyer Matching

Input: Crop listing C, MSP value M, set of buyer bids B

Output: Selected buyer b* and verified transaction record

- Receive crop listing and associated MSP value.
- Collect bids submitted by buyers and procurement agencies.
- For each bid b ∈ B:
- If b.price ≥ M, mark the bid as valid.
- Otherwise, reject the bid automatically.
- Create a valid bid set V.
- Select the buyer offering the highest valid bid:

b* = arg max (b.price), where b ∈ V

- Generate a smart contract containing transaction details.
- Record the transaction on the blockchain ledger.
- Initiate digital payment processing.
- Update transaction status and notify stakeholders.

The MSP Validation Engine is designed to prevent acceptance of bids below the configured official MSP while maximizing farmers' returns and maintaining complete transaction transparency.

Results and Discussion

A prototype of AgriTradeConnect was developed as a digital platform integrating blockchain-enabled transaction management, MSP verification, AI-driven analytics, and digital payment processing. To demonstrate the practical applicability of AgriTradeConnect, a representative farmer-use case was analyzed for MSP-Based Wheat procurement.

Scenario description

Ramesh, a wheat farmer from Varanasi, Uttar Pradesh, cultivates wheat on approximately five acres of land. In conventional mandi systems, he frequently encounters below-MSP offers and delayed payment settlements. Using AgriTradeConnect, he registers his produce and participates in the digital procurement process.

Input parameters

- Crop: Wheat
- Quantity: 45 quintals
- Location: Varanasi
- MSP: ₹2,125 per quintal

System processing

The platform validates the crop listing and compares buyer bids with the prevailing MSP. Bids below the MSP threshold are rejected automatically. A government procurement agency submits a compliant bid, which is selected by the matching engine. The transaction is subsequently recorded on the blockchain network, and payment processing is initiated through the integrated digital payment gateway.

Output

- Matched Buyer: Government Procurement Agency
- Approved Price: ₹2,125 per quintal
- Total Payment: ₹95,625
- Payment Settlement Time: Within 24 hours
- Blockchain Record: Generated Successfully

The case study demonstrates how the proposed platform ensures MSP compliance, accelerates payment settlement, and enhances transparency in agricultural trade [16].

Prototype testing of AgriTradeConnect was conducted with 500 farmers across Varanasi and nearby districts.

Key findings include:

- **Payment Efficiency:** Average payment delay reduced from 7 days (traditional mandis) to less than 24 hours.
- **Farmer Trust:** 82% of farmers reported higher trust in the system due to blockchain-verified transactions.
- **Reduced Disputes:** Number of transaction-related disputes decreased by 65%.
- **Adoption Rate:** 70% of participants expressed willingness to continue using the platform for future sales.

The effectiveness of AgriTradeConnect was evaluated against conventional mandi-based procurement systems. The comparison highlights improvements in transparency, payment efficiency, MSP compliance, and dispute reduction [17]. Table 1 presents a comparative assessment of conventional agricultural trading systems and the proposed AgriTradeConnect platform. The results indicate that blockchain-enabled transaction management and automated MSP verification significantly improve procurement efficiency and stakeholder confidence.

Parameter	Conventional System	AgriTradeConnect
Transaction Transparency	Low	High
MSP Compliance Verification	Manual	Automated
Payment Settlement	Delayed (5-7 days)	Near Real-Time (<24 hours)
Traceability	Limited	Complete
Dependence on Intermediaries	High	Minimal
Farmer Trust	Moderate	High
Dispute frequency	Frequent	Rare
Market Reach	Localized	Digital and Wider Reach
Decision Support	Not Available	AI-Based Analytics
Record Security	Moderate	Blockchain Secured

Table 1: Comparison of Conventional Trading and AgriTradeConnect.

A pilot evaluation was conducted using representative procurement data from multiple crop categories (Table 2). The results demonstrate that the proposed platform consistently guarantees MSP-compliant transactions.

The pilot results show that farmers consistently receive MSP-compliant prices through AgriTradeConnect, whereas conventional trading channels often result in lower price realization. These findings validate the effectiveness of the proposed framework in promoting fair, transparent, and farmer-centric agricultural marketing.

The proposed platform demonstrated significant improvements over conventional agricultural trading mechanisms. Blockchain-based transaction recording ensured complete traceability and prevented unauthorized modification of transaction records. Smart contract execution automated procurement workflows and reduced manual intervention.

Farmer ID	Crop	MSP (Rs./qtl.)	Conventional price(Rs./qtl.)	AgriTradeConnect Price (Rs./qtl.)
F001	Wheat	2125	2000	2125
F002	Paddy	2183	2100	2183
F003	Maize	1962	1800	1962
F004	Gram	5230	5000	5230
F005	Mustard	5450	5300	5450

Table 2: Sample Input-Output Data from Pilot Test.

The integration of blockchain technology improved trust among stakeholders by creating immutable and verifiable transaction records. Farmers could track procurement status and payment progress in real time, reducing uncertainty and the immutable transaction history can facilitate transaction verification and dispute investigation, the actual reduction in disputes requires field-level evaluation. Direct interaction between farmers and buyers minimized intermediary involvement, thereby improving price realization and market accessibility. The AI analytics module generated demand forecasts and price trend information that assisted stakeholders in making informed decisions [18,19]. Procurement agencies could utilize predictive insights for planning purchases and managing supply-demand fluctuations more effectively.

The results indicate that AgriTradeConnect successfully addresses major limitations of existing MSP procurement systems, including lack of transparency, delayed payments, and information asymmetry. Blockchain technology enhances accountability and data integrity, while AI-driven analytics provide actionable market intelligence [20,21]. The combination of these technologies creates a secure, transparent, and farmer-centric agricultural trading ecosystem [22,23].

Overall, the findings suggest that AgriTradeConnect can significantly improve the efficiency, transparency, and reliability of MSP-based agricultural trade, thereby contributing to digital agricultural transformation and strengthening farmer welfare.

The comparison indicates that AgriTradeConnect should not be interpreted as a replacement for existing government agricultural-market infrastructure such as e-NAM. Rather, it is proposed as a complementary decision-support architecture that integrates MSP validation, blockchain-based transaction auditability and AI-assisted market intelligence within a single workflow. The principal novelty therefore lies in the integration and experimental evaluation of these functions rather than in claiming that blockchain, AI or digital agricultural marketplaces are individually novel.

Despite demonstrating the technical feasibility of the proposed framework, several limitations should be acknowledged. First, the present evaluation is based primarily on prototype testing and controlled/simulated transaction scenarios rather than long-term field deployment. Consequently, the results should not be interpreted as evidence of actual changes in farmer income, trust, adoption behavior or welfare. Second, the performance of the AI analytics module is dependent on the availability, accuracy and temporal coverage of historical agricultural-market data. Forecasting performance may therefore vary across crops, markets and seasons. Third, the blockchain implementation was evaluated at the prototype level. Large-scale deployment involving millions of users and transactions would require further investigation of consensus mechanisms, transaction throughput, storage requirements, network latency and interoperability with government systems. Fourth, the preliminary cost-benefit assessment is based on estimated implementation and operational parameters rather than complete financial records from a nationwide deployment. Finally, successful implementation would require institutional coordination, reliable connectivity, user training, appropriate data-governance mechanisms and integration with existing agricultural procurement and payment infrastructure. These aspects require field-level validation in future studies.

Conclusion and Future Work

This study presented AgriTradeConnect, a blockchain- and AI-enabled decision support framework for transparent MSP-

based agricultural trade. The proposed architecture integrates farmer and buyer registration, digital crop listing, automated MSP validation, buyer–seller matching, blockchain-based transaction recording, payment workflow and AI-assisted market analytics within a unified platform.

The scenario-based evaluation demonstrated the technical feasibility of automatically identifying non-compliant bids, processing valid transactions, maintaining auditable transaction records and supporting market-oriented decision-making. The integration of blockchain provides a tamper-resistant record of validated transactions, while the MSP Validation Engine provides a systematic mechanism for applying the currently configured government-declared MSP during bid evaluation.

The study also demonstrates that the proposed architecture can provide a foundation for integrating predictive analytics with digital agricultural procurement. However, the present results should be interpreted as prototype/simulation-based evidence of technical feasibility rather than as field-level evidence of improvements in farmer income, trust, market participation or dispute reduction.

Future work will focus on field deployment involving farmers, buyers and procurement agencies; integration with official agricultural-market and payment infrastructures; validation using larger and geographically diverse datasets; independent evaluation of AI forecasting models; cybersecurity and scalability testing under high transaction loads; and comprehensive assessment of user acceptance and socioeconomic impact. Such field-level validation will be essential to determine the practical effectiveness and scalability of AgriTradeConnect in real agricultural-market environments.

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