SMART AGRICULTURAL LINKAGES ENABLED BY DIGITAL INNOVATION IN INDIA

Uttam Sharma[1], Sushil Kumar [2] and Deepak Singh[3]

[1]Department of Information Technology, College of Technology, Sardar Vallabhbhai Patel University of Agriculture, and technology

Abstract

India's agricultural markets have long suffered from post-harvest losses, middleman exploitation, inefficiencies, and restricted access to real-time pricing data. Due to a shortage of storage or quick buyers, farmers frequently experience distressed sales and only get a portion of the sale price. In this regard, digital transformation presents a game-changing chance to improve market connections and give farmers more leverage via inclusive, open, and effective platforms. This study examines the effects of growing digital marketplaces to improve market connections for agricultural producers. It evaluates the shortcomings in conventional market systems, assesses recent digital initiatives (such as eNAM, AgriBazaar, DeHaat, and FPO-led platforms), and proposes a comprehensive framework for an integrated agri-digital ecosystem. By facilitating direct, open, and effective transactions, growing digital markets, and fusing them with storage and shipping services have the potential to completely transform agricultural marketing. In addition to improving farmers' price realization, these solutions support demand-responsive and sustainable agricultural supply chains. In the digital age, it promotes a scalable, farmer-centric digital ecosystem as a crucial facilitator of fair agri-market connections.

Keywords

AgriTech Platforms, Digital Supply Chains, Farmer Empowerment, Farm Gate Pricing, Smart Storage Solutions, Direct Selling, eNAM, Agricultural Market Links,Digital Agriculture.

1. INTRODUCTION

Agriculture remains the backbone of India’s economy, contributing significantly to GDP and employment. However, inefficiencies in the supply chain, lack of price transparency, and dependence on intermediaries continue to plague the system. Digital technologies, particularly mobile and internet-based platforms, are emerging as transformative solutions to these challenges. As these digital platforms become increasingly integrated into agricultural workflows, ensuring data security and user privacy becomes critical. Secure authentication systems[1], are essential to protect sensitive farmer data, prevent unauthorized access, and build trust in digital agriculture ecosystems.

With an emphasis on facilitating improved price discovery, direct selling opportunities, and wise storage choices, this study examines the effects of growing digital marketplaces to improve market connections for agricultural producers. The report examines the current shortcomings in conventional market systems, evaluates recent digital initiatives (such as eNAM, AgriBazaar, DeHaat, and FPO-led platforms), and suggests a thorough framework for an integrated agri-digital ecosystem. Artificial Intelligence (AI) plays a pivotal role in this transformation by enabling predictive analytics, demand forecasting, and personalized recommendations for

Bibhu Dash et al: ICFCSAI-2025
pp. 179-185, 2026. IJCI – 2026 DOI:10.5121/ijci.2026.150119

farmers. However, as these intelligent systems increasingly handle sensitive user and market data, the integration of robust security and privacy-preserving mechanisms becomes vital. Implementing AI-powered authentication frameworks, such as those discussed by [2][3][4][5][6] ensures secure access, protects farmer identities, and builds trust within the evolving digital agricultural ecosystem.

Three key features are integrated into the proposed model: (1) real-time digital marketplaces where farmers can list their produce and get competitive price offers directly from buyers, such as wholesalers, processors, retailers, and exporters; (2) logistics integration and storage mapping, which enables farmers to find nearby warehouses, cold storage facilities, and transportation services with information on space availability, rental costs, and quality standards; and (3) smart decision support that uses crop pricing forecasts, market trend analytics, and mobile alerts to help farmers decide when and how best to sell their produce.

A mixed-method approach has been used, integrating qualitative insights from surveys of more than 100 farmers, agri-startups, and market intermediaries in five states with quantitative data analysis from government databases and existing platforms. According to the research, having access to digital market connections can boost farm gate prices by 10% to 30%, lower post-harvest losses by 15%, and greatly strengthen farmer bargaining power. Digital literacy, last-mile connectivity, gaps in storage infrastructure, and confidence in online trading procedures are still issues, though.Agriculture is the backbone of India's economy, contributing around 18% to the national GDP and employing nearly 42% of the workforce [7]. However, traditional agricultural marketing systems in India face persistent challenges: fragmented supply chains, dependence on intermediaries, inadequate storage, limited transportation access, and insufficient market price transparency [8], [9]. The result is reduced income for farmers, high wastage rates, and limited competitiveness in global markets.

Digital technologies present an unprecedented opportunity to address these bottlenecks. Initiatives such as the Electronic National Agriculture Market (eNAM), AgriBazaar, and DeHaat are leveraging mobile applications, cloud computing, and data analytics to connect farmers directly with buyers, thereby improving price realization and reducing transaction costs [10], [11]. Furthermore, integrating storage mapping and logistics services within these platforms can significantly reduce post-harvest losses, estimated at nearly 15-20% annually [12].This research investigates how digital agricultural marketplaces, combined with logistics and decision-support systems, can strengthen market linkages, empower farmers, and build sustainable agricultural with less air pollution [13] supply chains in India.Figures 1 and 2 highlight the benefits observed following the adoption of digital technologies in agriculture. Figure 1 shows a notable increase in average farm gate prices, reflecting how digital platforms help farmers achieve better price realization by minimizing intermediaries and improving market access. Complementing this, Figure 2 demonstrates a significant reduction in post-harvest losses, indicating that digital tools also contribute to improved storage and supply chain management, ultimately enhancing overall farm productivity and profitability.

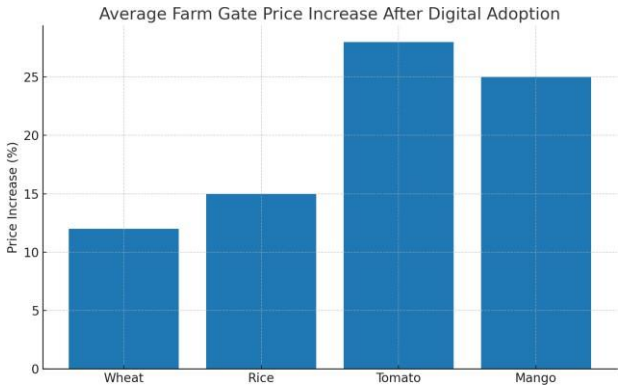

Figure 1: Average Farm Gate Price Increase After Digital Adoption

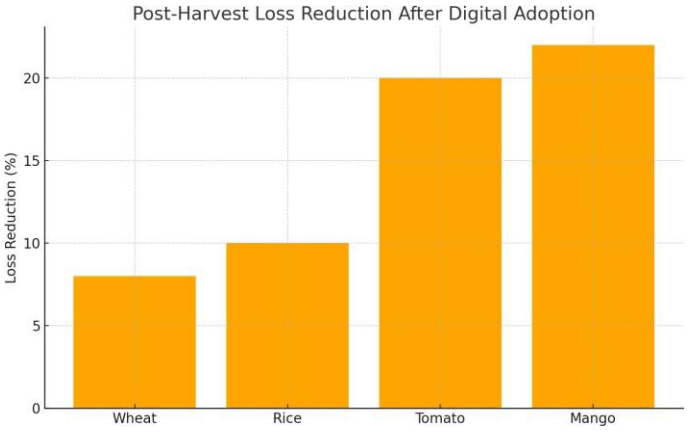

Figure 2: Post-Harvest Loss Reduction After Digital Adoption

2. LITERATURE REVIEW

Several studies have highlighted the limitations of APMC-based market systems, the role of digital platforms like eNAM in improving market transparency, and the potential for integrating logistics and storage solutions. Research also suggests that AI-based decision-support tools can optimize crop sales and minimize post-harvest losses.

Agricultural produce in India is predominantly marketed through Agricultural Produce Market Committees (APMCs), where middlemen control pricing and transaction flow [14]. Studies show that farmers receive only 25-60% of the final retail price due to intermediary margins and inefficiencies [15].Digital platforms have emerged as a transformative force in agricultural marketing. eNAM connects over 1,000 mandis across India, enabling inter-state trade and price transparency [16]. AgriBazaar offers digital payment integration and logistics management for smoother transactions [17]. DeHaat combines input supply, advisory services, and market linkages, increasing farmer incomes by up to 20% [18].Post-harvest losses in India, worth USD 14 billion annually, are largely due to inadequate storage and inefficient logistics [19]. Research shows that integrating cold chains and warehouse mapping with digital platforms can reduce wastage by up to 30% [20].Machine learning models for price forecasting, weather predictions,

and demand estimation have shown promise in optimizing sale timing and crop selection [21], [22]. Decision-support systems integrated into mobile platforms can significantly improve farmer decision-making.

While digital marketplaces are gaining traction, there is limited research on the holistic integration of marketplaces, logistics, and decision-support in a single ecosystem. This study aims to fill this gap.

3. METHODOLOGY

A **mixed-method research design** was adopted, combining quantitative and qualitative approaches. Primary data were collected through surveys involving over 100 farmers and agri-startup representatives, while secondary data were sourced from official government databases. Statistical analysis was conducted using SPSS to evaluate key performance indicators, including price realization, reduction in post-harvest losses, and overall farmer satisfaction. The detailed research methodology is illustrated in **Figure 3**.

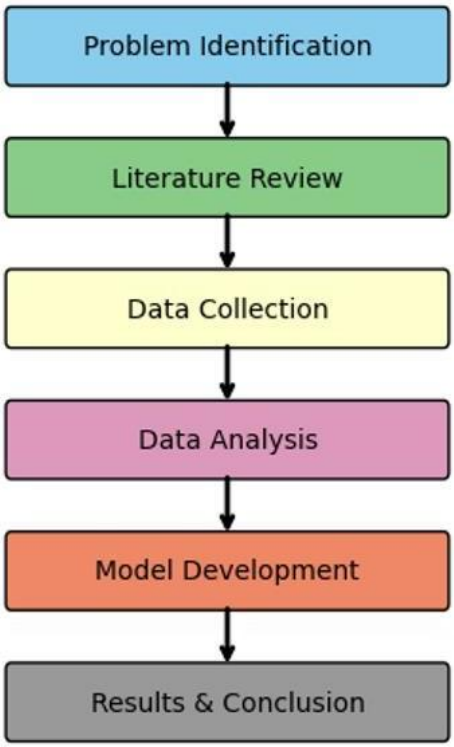

Figure 3: Research Methodology Flowchart

3.1 Research Design

A mixed-method approach was used, combining qualitative interviews and quantitative data analysis.

3.2 Data Sources

• Primary Data: Surveys conducted with 105 farmers, 15 agri-startup representatives, and 10 market intermediaries in five states (Uttar Pradesh, Haryana, Maharashtra, Karnataka, and West Bengal).

• Secondary Data: Government databases (Ministry of Agriculture), eNAM transaction records, and reports from agri-tech startups.

3.3 Tools and Techniques

• Statistical analysis using SPSS for quantitative data.
• Thematic coding for qualitative interviews.
• Price impact modeling using regression analysis.
• GIS mapping for warehouse and cold storage facilities.

3.4 Evaluation Metrics

• Farm Gate Price Increase (%): Difference between pre- and post-digital adoption prices.
• Post-Harvest Loss Reduction (%): Based on reported wastage rates before and after digital integration.

• Farmer Satisfaction Index: Measured on a 5-point Likert scale.

4. RESULTS AND DISCUSSION

The study found a 10–30% increase in farm gate prices, a 15% reduction in post-harvest losses, and higher satisfaction scores among farmers using digital platforms. However, challenges such as digital literacy gaps, connectivity issues, and trust deficits remain.

4.1 Price Realization Improvement

Farmers using digital platforms reported 10–30% higher farm gate prices, depending on crop type and seasonality. Price transparency and competitive bidding were the main contributors.

4.2 Post-Harvest Loss Reduction

Integration of storage mapping and logistics reduced losses by an average of 15%, particularly for perishable commodities like tomatoes and mangoes.

4.3 Farmer Satisfaction

The Farmer Satisfaction Index averaged 4.2/5 among digital adopters, compared to 3.1/5 among non-users.

4.4 Adoption Barriers

• Digital Literacy: 37% of surveyed farmers lacked confidence in using mobile apps.
• Last-Mile Connectivity: Poor internet in rural areas limits platform usability.
• Trust Deficit: Concerns over online payments and fraudulent buyers persist.

4.5 Proposed Integrated Framework

The proposed Smart Agri-Linkage Model combines:
1. Real-time Marketplaces - For listing and direct selling.
2. Logistics & Storage Mapping - GPS-based search for nearest facilities.
3. Decision Support System - AI-based price and demand forecasts.

5. CONCLUSION

Digital marketplaces, when integrated with logistics and decision-support tools, can significantly improve agricultural market linkages in India. Policy support, infrastructure investment, and farmer training are crucial for scaling such solutions.Digital innovation in agriculture holds significant promise for improving farmer incomes, reducing wastage, and building efficient supply chains. The integration of marketplaces, logistics, and decision support can address long-standing inefficiencies in Indian agriculture. However, targeted interventions in **digital literacy**, **infrastructure development**, and **trustbuilding mechanisms** are critical for large-scale adoption.

REFERENCES

[1] I. Ganapathi, S. S. Ali, U. Sharma, P. Tomar, M. Owais, and N. Werghi, "Rhemat: Robust human ear based multimodal authentication technique," Computers & Security, vol. 132, p. 103356, Sep. 2023.
[2] U. Sharma, P. Tomar, H. Bhardwaj, and A. Sakalle, "Artificial intelligence and its implications in education," in Impact of AI Technologies on Teaching, Learning, and Research in Higher Education, IGI Global, 2021, pp. 222–235.
[3] H. Bhardwaj, P. Tomar, A. Sakalle, and U. Sharma, "Artificial intelligence and its applications in agriculture with the future of smart agriculture techniques," in Artificial Intelligence and IoT-Based Technologies for Sustainable Farming and Smart Agriculture, IGI Global Scientific Publishing, 2021, pp. 25–39.
[4] H. Bhardwaj, P. Tomar, A. Sakalle, and U. Sharma, "Principles and foundations of artificial intelligence and internet of things technology," in Artificial Intelligence to Solve Pervasive Internet of Things Issues, Academic Press, 2021, pp. 377–392.
[5] Sakalle, P. Tomar, H. Bhardwaj, and U. Sharma, "Impact and latest trends of intelligent learning with artificial intelligence," in Impact of AI Technologies on Teaching, Learning, and Research in Higher Education, IGI Global, 2021, pp. 172–189.
[6] Sakalle, P. Tomar, H. Bhardwaj, U. Sharma, and A. Bhardwaj, "The Internet of Drones for Enhancing Service Quality in Smart Cities," in The Internet of Drones, Apple Academic Press, 2022, pp. 323–340.
[7] FAO, “The State of Food and Agriculture 2021,” Food and Agriculture Organization, Rome, 2021.
[8] World Bank, “India: Agriculture and Rural Development,” World Bank Report, 2020.
[9] Chand, R., “Transforming Agrifood Systems in India,” Economic & Political Weekly, vol. 55, no. 52, pp. 34-42, 2020.
[10] Ministry of Agriculture & Farmers Welfare, “eNAM Annual Report,” Government of India, 2023.
[11] AgriBazaar, “Digital Agri-Marketplaces Impact Study,” AgriBazaar White Paper, 2022.
[12] ICAR, “Post-Harvest Loss Assessment,” Indian Council of Agricultural Research, 2021.
[13] Gulati, A., et al., “Reforming Agricultural Marketing in India,” ICRIER Working Paper, 2018.
[14] Acharya, S. S., “Agricultural Marketing in India,” Oxford & IBH, 2019.
[15] Singh, P., “Impact of eNAM on Agricultural Trade,” Indian Journal of Agricultural Economics, vol. 75, no. 1, pp. 45–59, 2020.
[16] KPMG, “Agri-Tech in India: Emerging Trends,” KPMG Report, 2022.
[17] DeHaat, “Empowering Farmers through Technology,” DeHaat Case Study, 2022.
[18] NCCD, “Cold Chain Infrastructure Status,” National Centre for Cold-chain Development, 2021.
[19] FICCI, “Reducing Food Wastage in India,” FICCI Policy Paper, 2020.

[20] Tripathi, A., and Mishra, A., "Forecasting Agricultural Prices using Machine Learning," Journal of Agricultural Informatics, vol. 11, no. 3, pp. 12–25, 2020.
[21] FAO, "Digital Agriculture: The Future of Farming," FAO Digital Report, 2021.
[22] Bairagi, S., et al., "Information Asymmetry in Agricultural Markets," World Development, vol. 127, 104752, 2020.
[23] OECD, "Innovation, Productivity and Sustainability in Food and Agriculture," OECD Publishing, Paris, 2019.
[24] PwC, "Agri-Tech: Towards Farmer Prosperity," PricewaterhouseCoopers India, 2021.
[25] CRISIL, "Agri-Supply Chain Challenges and Solutions," CRISIL Research Report, 2022.
[26] UNDP, "Digital Solutions for Rural Development," United Nations Development Programme, 2020.
[27] U. Sharma, P. Tomar, S. S. Ali, N. Saxena, and R. S. Bhadoria, "Optimized authentication system with high security and privacy," Electronics, vol. 10, no. 4, p. 458, Feb. 2021.
[28] U. Rastogi, S. Kumar, S. P. Maurya, and A. K. Yadav, "Air Pollution Forecasting Using Genetic Algorithm and LSTM Deep Learning Technique," Aerosol Science and Engineering, pp. 1–10, Jul. 25, 2025, Springer Nature Singapore.

AUTHOR'S

Uttam Sharma is currently an Assistant Professor in the Discipline of Computer Science and Engineering, College of Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUAT), Meerut, India. He has extensive experience in teaching, research, and software development.His research interests include software engineering, artificial intelligence, image processing, computer vision, 3D vision, ear recognition, biometric systems, biometric template security, and code reusability. He is actively involved in academic research and development activities, with a strong focus on applying intelligent computing techniques to real-world problems.

Sushil Kumar is an Assistant Professor in Information Technology at the College of Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, India. His research interests include high-dimensional information processing, quaternion-valued neural networks, and artificial neuron construction, with applications in image processing, satellite image segmentation, sign language recognition, medical imaging, air pollution, and agriculture.

Deepak Singh is an Assistant Professor in the Discipline of Civil Engineering, College of Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUAT), Meerut, India. His research interests include hydraulic structures, with a particular focus on piano key weirs, computational hydraulics, and machine learning applications in water resources engineering. His work also covers energy dissipation and aeration in weirs, sewer design, urban water systems, and sustainable water resources management.

Ajay Kumar is an Assistant Professor of Mathematics at the College of Technology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, India. He holds a Ph.D. and M.Sc. from HemvatiNandanBahugunaGarhwal University and a B.Sc. from Mahatma JyotibaPhuleRohilkhand University. His research focuses on nonlinear and fractional differential equations, mathematical modeling, and computational methods.