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Assessing the Prospects of Artificial Intelligence (AI) and Internet of Things (IoT) Technologies in Improving Crop Production in Eastern Uttar Pradesh

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Abstract

The agricultural sector in Eastern Uttar Pradesh is currently undergoing a profound transformation, yet it remains hindered by long-standing structural challenges such as fragmented landholdings, frequent climate variability, and limited access to real-time agricultural intelligence. This study assesses the prospects of Artificial Intelligence (AI) and the Internet of Things (IoT) in improving crop production in the selected districts of Ambedkar Nagar, Sultanpur, and Ayodhya. Using a multistage sampling method, primary data were collected from 150 small and marginal farmers distributed across 12 villages. The findings reveal a significant awareness gap regarding digital agriculture; while awareness is slowly growing, 63.3% of the respondents remain entirely unacquainted with AI and IoT technologies. Currently, only 14.2% of the surveyed farmers actively utilize digital tools in their operations. Among the adopters, the predominantly utilized technologies are AI-powered weather forecasting tools (8.0%) and IoT-enabled soil moisture sensors (6.0%). Farmers who adopted these technologies reported substantial benefits, most notably higher crop yields (76.2%), better irrigation efficiency (68.4%), and reduced input costs (55.1%). However, widespread adoption is heavily constrained by several critical barriers. The high initial cost of technology emerged as the most significant constraint (Garrett Mean Score of 78.12), followed closely by a lack of awareness and technical training (71.85), and poor internet connectivity (66.43) in rural areas. The study concludes that while AI and IoT possess high potential to optimize resource use, boost farm productivity, and foster sustainable agriculture, their widespread adoption requires robust, targeted policy interventions. Financial subsidies, the enhancement of rural digital infrastructure, and comprehensive digital literacy programs are critical imperatives to facilitate inclusive agricultural growth for smallholder farmers in the region.

Keywords: Artificial Intelligence, Internet of Things, Smart Farming, Technology Adoption, Precision Agriculture, Eastern Uttar Pradesh

Introduction

Agriculture has historically been the foundational pillar of India's economic and social structure, functioning as the primary source of livelihood for a substantial segment of the population. According to the World Bank (2022), nearly 50% of the Indian workforce is engaged in agriculture, which contributes significantly to the country's Gross Domestic Product (GDP). In Eastern Uttar Pradesh particularly within the districts of Ambedkar Nagar, Sultanpur, and Ayodhya agriculture remains the dominant occupation. The region is endowed with fertile alluvial soil and favourable Agro-climatic conditions that support the cultivation of key crops like rice, wheat, sugarcane, pulses, and various vegetables (Gupta et al., 2021) [5]. However, despite these natural advantages, the agricultural sector in these districts is plagued by numerous structural and environmental challenges that severely hamper overall productivity and income generation for farming communities. Some of the most pressing issues in this agrarian landscape include highly fragmented landholdings, traditionally low levels of farm mechanization, outdated and inefficient irrigation systems, and a critical lack of access to real-time agricultural intelligence. Moreover, the unpredictability of climate patterns manifested through irregular rainfall, prolonged droughts, and sudden floods frequently disrupts farming cycles, thereby

increasing the economic vulnerability of small and marginal farmers. These structural issues are further exacerbated by inadequate modern infrastructure, limited institutional support, and low levels of awareness concerning innovative, modern farming techniques. To address these multifaceted challenges and pivot towards a more resilient, sustainable agricultural model, the integration of emerging digital technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) is increasingly recognized as an essential intervention. Artificial Intelligence, encompassing machine learning, predictive data analytics, and computer vision, has demonstrated significant potential in transforming traditional agricultural practices globally. AI-powered systems can analyse vast amounts of historical and real-time data to assist farmers in making highly accurate decisions regarding sowing windows, irrigation scheduling, fertilization, pest control, and harvesting (Mishra and Sharma, 2020)^[8]. Complementing AI, the Internet of Things (IoT) facilitates continuous real-time data collection through interconnected field devices like soil moisture sensors, micro-weather stations, and automated irrigation controllers. The convergence of AI and IoT technologies has given rise to the paradigm of precision agriculture, which aims to optimize agricultural inputs and maximize output through data-driven methodologies. While national-level initiatives under Digital India are paving the way for smart farming, their reach in rural regions like Eastern Uttar Pradesh remains limited due to infrastructural and socio-economic constraints (Government of India, 2018). Therefore, the present study is undertaken to meticulously assess the prospects of AI and IoT technologies in improving crop production in this region, focusing specifically on the awareness, adoption, perceived benefits, and operational constraints faced by small and marginal farmers (World Bank, 2022).

2. Review of literature

The transition toward digital agriculture has been the subject of extensive academic and policy-oriented research in recent years. The Government of India (2018), in its National Strategy on Artificial Intelligence released by NITI Aayog, explicitly outlined a vision for AI adoption across critical sectors, identifying agriculture as a primary beneficiary. The strategy emphasized public-private partnerships and rural innovation hubs, positing AI as a key enabler for doubling farmers' incomes and fortifying national food security. Furthermore, Reddy and Rao (2018)^[12] conducted a comprehensive examination of AI-powered weather forecasting tools in Indian agriculture. Their empirical study demonstrated how predictive analytics empowered farmers with localized, highly accurate weather forecasts, thereby supporting optimized decision-making for sowing and irrigation, while significantly mitigating climate-induced risks. Expanding on the predictive capabilities of digital tools, Patel et al. (2019)^[11] investigated machine learning algorithms for predicting crop yields and executing early detection of plant diseases. Their research underscored that AI models could rapidly analyze extensive datasets to generate precise, timely agricultural insights. The study emphasized that early stress detection using AI heavily reduced post-harvest losses, making it an exceptionally cost-effective solution for resource-poor farming communities. In a parallel context, Bendre and Sawant (2020)^[1] explored the synergistic integration of AI and IoT in precision agriculture. Their findings detailed how real-time monitoring systems facilitated timely field interventions, optimizing irrigation and fertilization, ultimately lowering operational costs and promoting climate-

resilient farming practices. Focusing geographically on the context of this study, a World Bank (2022) report assessed various AI and IoT interventions in Indian agriculture, placing a distinct focus on Eastern Uttar Pradesh. The report documented several pilot programs driven by startups and agencies aimed at improving regional productivity and market connectivity. While recognizing that connected devices drastically reduce supply chain inefficiencies, the World Bank flagged that adoption remained heavily skewed and uneven. Pervasive infrastructure gaps, notably unreliable electricity and a severe lack of high-speed internet in rural belts, were identified as primary impediments. The literature collectively indicates an urgent need to localize digital agricultural solutions and address socio-economic barriers to facilitate inclusive adoption among smallholder farmers.

3. Materials and methods

This study adopts a comprehensive mixed-method research approach to systematically examine the prospects and role of AI and IoT in agriculture across Eastern Uttar Pradesh. The methodology integrates both quantitative and qualitative techniques to assess the levels of technological awareness, current usage patterns, perceived productivity impacts, and structural barriers to adoption among farmers. The state of Uttar Pradesh was selected due to its massive agrarian base and the increasing relevance of digital interventions required to overcome plateauing crop yields. Within Eastern Uttar Pradesh, three districts Ambedkar Nagar, Sultanpur, and Ayodhya were purposively chosen based on their high agricultural activity, large populations of small and marginal farmers, and emerging exposure to technology-driven agricultural initiatives. rigorous multistage sampling design was employed to select a highly representative sample. In the first stage, the three aforementioned districts were selected. In the second stage, two blocks from each district were purposively chosen based on their agricultural prominence (e.g., Akbarpur and Jalalpur in Ambedkar Nagar; Lambhua and Dhanpatganj in Sultanpur; Sohawal and Milkipur in Ayodhya). In the third stage, two villages from each block were selected, ensuring varied representation of cropping patterns and technological exposure, yielding a total of 12 study villages. Finally, a sample of 150 respondents (comprising 45 from Ambedkar Nagar, 55 from Sultanpur, and 50 from Ayodhya) was purposively drawn, focusing exclusively on small and marginal farmers who are the primary stakeholders in the context of inclusive AI and IoT adoption. Data collection occurred over a defined temporal framework extending from July 2025 to April 2026, capturing variations across both the Kharif and Rabi agricultural seasons. Primary data were procured through direct field surveys utilizing a meticulously structured interview schedule. The collected data encompassed demographic profiles, agricultural awareness parameters, and farmers' perceptions regarding technology utility and constraints. Secondary data were sourced from NITI Aayog reports, District Statistical Handbooks, and literature from Krishi Vigyan Kendras (KVKs). Analytically, the study utilized descriptive statistics (percentages, means) to summarize adoption metrics. Crucially, Garrett's Ranking Technique was applied to systematically rank the constraints and opportunities perceived by the farmers, transforming qualitative ranks into quantifiable scores for objective comparison.

4. Results and discussion

This section evaluates the current status, practical applications, and future potential of Artificial Intelligence (AI) and the

Internet of Things (IoT) technologies in enhancing crop production across Eastern Uttar Pradesh. The analysis delineates farmers' awareness levels, the spectrum of adopted technologies, the diverse benefits experienced, and the foremost constraints impeding widespread technological integration.

4.1 Awareness and Exposure to AI/IoT Technologies

Awareness serves as the foundational precursor to technology adoption. The study evaluated the familiarity of the 150 sampled farmers with AI and IoT concepts. As detailed in Table 1, the data highlight a profound awareness deficit. A substantial majority of the respondents, comprising 63.3%, remain entirely unaware of AI/IoT technologies. Only 14.2% of the farmers reported being aware and actively utilizing these technologies in their fields, signifying that digital penetration is still confined to early-stage adopters. Interestingly, 22.5% of the respondents indicated awareness but had not yet transitioned to usage. This segment represents an immediate, ready market that could be mobilized if fundamental access, affordability, and training bottlenecks are resolved.

Awareness Level	Number of Respondents	Percentage (%)
Aware and using	21	14.2
Aware but Not Using	34	22.5
Not Aware	95	63.3

Source: Field Survey, 2025-26.

4.2 Types of AI/IoT Technologies Adopted

Investigating the specific tools integrated into farming operations provides insight into the practical priorities of the adopters. As presented in Table 2, AI-powered weather forecasting tools exhibit the highest adoption rate, utilized by 8.0% of the total respondents (12 users). This high reliance reflects the critical need for robust climate information to mitigate the risks of erratic monsoons. IoT soil moisture sensors (6.0%) and mobile-based pest/disease detection applications (4.7%) follow, demonstrating farmers' initial steps toward precision water management and crop surveillance. Conversely, capital-intensive and highly technical solutions such as smart automated irrigation systems (4.0%) and drone-based monitoring and spraying (2.0%) register the lowest adoption rates. The negligible adoption of drones highlights systemic infrastructural and financial barriers that smallholders cannot independently surpass.

Technology Type	Number of Users	Percentage of Total Respondents (%)
AI Weather Forecasting Tools	12	8.0
IoT Soil Moisture Sensors	9	6.0
Smart Irrigation (Automated Systems)	6	4.0
Mobile-Based Pest/Disease Detection Apps	7	4.7
Drone Monitoring and Spraying	3	2.0

Source: Field Survey, 2025-26.

4.3 Perceived Benefits from Using AI and IoT Tools

For those farmers who successfully integrated digital tools into their operations, the empirical benefits proved substantial. Table 3 captures the primary advantages reported by the technology users. An overwhelming 76.2% of adopters cited a higher crop yield as a direct outcome of utilizing AI/IoT tools. Furthermore, 68.4% of users experienced significantly better irrigation efficiency, a benefit closely tied to the deployment of soil moisture sensors which prevent over-irrigation. Reduced input costs, stemming from the optimized application of fertilizers and

pesticides, were acknowledged by 55.1% of the users. The capability for early detection of crop diseases and pests (49.3%) enabled farmers to take swift remedial actions, thereby minimizing potential crop loss. Finally, 37.6% of users noted considerable time saved in routine crop monitoring. Collectively, these reported benefits strongly align with the core objectives of precision agriculture: maximizing output while systematically minimizing resource expenditure.

Benefit Experienced	Percentage of AI/IoT Users (%)
Higher Crop Yield	76.2
Better Irrigation Efficiency	68.4
Reduced Input Costs	55.1
Early Detection of Crop Diseases/Pests	49.3
Time Saved in Crop Monitoring	37.6

Source: Field Survey, 2025-26.

4.4 Major Constraints in the Adoption of AI/IoT Technologies

Despite the profound benefits demonstrated by early adopters, scaling these technologies across Eastern Uttar Pradesh encounters severe socio-economic and technical impediments. To systematically identify and prioritize these barriers, Garrett's Ranking Technique was applied to the responses of the surveyed farmers. Table 4 delineates the ranked constraints. The high initial cost of technology procurement emerged as the most formidable barrier, registering the highest Garrett Mean Score of 78.12. For small and marginal farmers operating on razor-thin profit margins, capital-intensive investments in sensors or drones are economically unfeasible without heavy subsidies. The second most critical barrier is the lack of awareness and training (Score: 71.85). The inherent complexity of AI applications and IoT dashboards requires a baseline level of digital literacy, which remains strikingly low in the study region. Infrastructural deficiencies also drastically impede adoption. Poor internet connectivity in rural villages (Score: 66.43) was ranked third, highlighting a systemic failure; IoT devices rely heavily on seamless, real-time data transmission to centralized cloud servers to function effectively. A lack of connectivity renders these devices virtually useless. Furthermore, inadequate after-sales technical support (Score: 58.74) and an underlying lack of trust in new technology (Score: 55.92) round out the top five constraints. Farmers frequently express anxiety that if an expensive smart device malfunctions, the absence of local repair technicians will result in a total loss of investment. These aggregated constraints underscore that technology transfer in agriculture cannot be limited to mere device provision; it requires an encompassing ecosystem of financial, technical, and infrastructural support.

Constraint	Garrett Mean Score	Rank
High Initial Cost of Technology	78.12	1
Lack of Awareness and Training	71.85	2
Poor Internet Connectivity	66.43	3
Inadequate After-Sales/Technical Support	58.74	4
Lack of Trust in New Technology	55.92	5

Source: Computed from Field Data using Garrett's Ranking Method, 2025-26.

5. Summary, conclusion, and policy implications

The present study systematically evaluated the prospects, applications, and challenges surrounding the adoption of Artificial Intelligence and Internet of Things technologies among small and marginal farmers in Eastern Uttar Pradesh. The

empirical findings confirm that while the technological penetration of AI and IoT remains in its nascent stages evidenced by a high unawareness rate of 63.3% and an adoption rate of merely 14.2% the tools possess a highly transformative capacity. Farmers utilizing digital platforms, such as AI-driven weather forecasting and IoT-based soil moisture sensors, reported substantial and tangible benefits. These include superior crop yields, vastly improved irrigation efficiency, and significant reductions in input expenditure. These technologies empirically optimize resource allocation and foster sustainable agronomic practices, directly addressing the core inefficiencies of traditional farming in the region. However, the pathway to achieving widespread digital agricultural transformation is currently obstructed by formidable structural and socio-economic bottlenecks. The Garrett Ranking analysis decisively highlights that the high upfront costs of technology, an acute deficit in digital training, and poor rural internet infrastructure constitute the primary barriers to adoption. Small and marginal farmers lack both the financial liquidity to absorb high capital costs and the digital literacy to independently navigate complex software interfaces. Additionally, apprehensions regarding poor after-sales service and technology failures exacerbate the hesitancy to modernize farming operations. Based on these empirical insights, multiple targeted policy interventions are imperative to unlock the potential of AI and IoT in Eastern Uttar Pradesh. Firstly, the government must design and implement specific financial subsidy schemes or micro-credit facilities geared toward subsidizing the cost of agri-tech devices for marginal farmers. Secondly, strengthening rural digital infrastructure is non-negotiable; reliable high-speed internet and uninterrupted electricity are fundamental prerequisites for IoT functionality. Thirdly, a robust institutional framework involving Krishi Vigyan Kendras (KVKs) and Farmer Producer Organizations (FPOs) must be mobilized to conduct grassroots-level digital literacy and capacity-building programs. These hubs could also pioneer shared-equipment models, allowing farmer collectives to rent expensive tools like drones and advanced sensors, thereby mitigating individual financial risk. Through collaborative, multi-stakeholder efforts, the agricultural sector in Eastern Uttar Pradesh can successfully transition into a digitized, resilient, and highly productive ecosystem.

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