

Impact of Artificial Intelligence in Precision Agriculture: Insights from Farmer Surveys and Secondary Market Analysis

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Abstract - Precision agriculture has developed as an important technique for solving global food security concerns while also improving environmental sustainability, resource conservation, and economic prosperity. Precision farming is a scalable and sustainable method to improving agricultural resilience and productivity through data-driven farm management, as agricultural systems confront increasing pressures from population increase, climate change, and depleting natural resources. The incorporation of Artificial Intelligence (AI) into precision agriculture has hastened the shift to intelligent and sustainable farming systems. AI-powered solutions provide real-time monitoring, predictive analytics, and automated decision-making, which improves agricultural efficiency and reduces waste. Among these innovations, smart irrigation systems utilize soil moisture sensors, weather forecasting models, and IoT-enabled monitoring devices to optimize water application, resulting in improved water-use efficiency and enhanced crop productivity. Similarly, unmanned aerial vehicles (UAVs), commonly known as agricultural drones, have become indispensable tools for crop surveillance, disease detection, nutrient assessment, weed identification, and precision pesticide application, enabling farmers to monitor field conditions with high spatial and temporal resolution. This study investigates the role of Artificial Intelligence (AI) in promoting sustainable agricultural practices through precision farming technologies.

Specifically, it examines the adoption of AI-enabled smart irrigation systems and various categories of agricultural drones used for field monitoring, crop health assessment, and resource management. The empirical research is based on 116 primary survey responses from farmers from various sections of Telangana State, providing information about their awareness, adoption, and perceptions of AI-driven precision agriculture. To validate and contextualize these findings, the study compares primary survey responses to secondary market data from 2023 acquired from Market.us. Exploratory Data Analysis (EDA) is used to compare AI-driven precision agriculture against conventional farming approaches. EDA provides a strong analytical framework for detecting hidden patterns, trends, anomalies, and correlations in both primary and secondary datasets. By combining farmer-level data with industry market figures, the study provides a thorough knowledge of AI adoption, field variability, and resource use.

The findings promote evidence-based decision-making, increase operational efficiency, and highlight AI technology'

promise for promoting sustainable, resilient, and data-driven agricultural production systems.

Keywords: Precision Farming, Artificial Intelligence, Exploratory Data Analysis, Analytics

1.INTRODUCTION:

1.1 Overview of AI in Agriculture:

Precision agriculture, also known as precision farming, represents a paradigm shift in modern agricultural systems by integrating advanced digital technologies such as Global Positioning Systems (GPS), Internet of Things (IoT) devices, remote sensors, unmanned aerial vehicles (UAVs), robotics, and data-driven analytics to optimize agricultural operations. This technology-enabled strategy enables site-specific crop management, allowing for precise allocation of vital resources like water, fertilizer, and pesticides while minimizing environmental impact and increasing agricultural production. Precision agriculture, which combines real-time monitoring, geographic mapping, and predictive analytics, promotes informed decision-making, improves crop health assessment, increases resource efficiency, and minimizes output losses. As a result, it addresses various major issues plaguing the agricultural sector, such as rising input costs, climatic variability, resource constraint, and increased need for sustainable food production.

Precision farming, also known as precision agriculture, uses GPS, sensors, and drones to boost crop output while minimizing waste and environmental damage. Integrating these tools allows farmers to carefully manage resources such as water, fertilizer, and insecticides. This technology allows for accurate field mapping, crop health monitoring, and customized input applications based on unique conditions. The benefits include higher yields, resource conservation, sustainability, profitability, and data-driven decision-making. Precision farming represents a contemporary and sustainable agriculture strategy. The use of technology and data to address the pressing issue of feeding a growing population while campaigning for environmental stewardship. Artificial intelligence (AI) is transforming agriculture by enabling data-driven, more effective decision-making.

Precision Agriculture (PA), a modern agricultural practice that uses technology to track, quantify, and respond to crop and field variability, is one of the most important applications of AI in agriculture. The global precision agriculture industry has

expanded dramatically in recent years, indicating the rising usage of digital agricultural technologies. Market sales rose from roughly USD 10.5 billion in 2023 to USD 11.8 billion in 2024, owing to the extensive adoption of automated agricultural machinery, GPS-guided equipment, IoT-enabled sensing systems, and microclimate monitoring technologies. Furthermore, recent advances in artificial intelligence (AI), robotics, cloud computing, and big data analytics have considerably improved precision farming capabilities, allowing for intelligent decision-support systems, predictive crop management, and autonomous agricultural operations.

Growing investments from governments, research institutions, and agricultural organizations, combined with strategic technical alliances, are accelerating the implementation of precision agriculture in crop production and animal management. These advancements establish precision agriculture as a cornerstone of long-term agricultural change, helping to improve productivity, environmental conservation, resource optimization, and food security. Despite challenges such as fluctuating input costs, high initial investment requirements, limited technical expertise, and the complexity of implementing advanced digital technologies, the precision agriculture sector is expected to grow strongly over the next decade, with a compound annual growth rate (CAGR) of approximately 12.2%.

1.2 Importance of Precision Agriculture

Precision agriculture employs cutting-edge technologies such as drones, IoT sensors, satellite imaging, and AI-powered analytics to improve farm management. The objectives are to reduce environmental impact, increase productivity, and improve resource efficiency.

- AI improves productivity by precisely applying inputs to maximize production potential.
- Reducing waste and improving resource use leads to lower production costs.
- AI reduces the usage of water, fertilizers, and pesticides, contributing to environmental sustainability.
- Expert systems offer real-time information for effective agricultural management.
- Expert AI is revolutionizing agriculture by making farming more efficient, sustainable, and profitable.

Precision Agriculture, powered by AI, enables data-driven decision-making that optimizes every aspect of farming, ensuring a balance between productivity and environmental responsibility. As technology continues to advance, AI-driven precision farming will play a critical role in feeding the growing global population while conserving natural resources.

1.3 Objectives of the Study

The objectives of this study are centered on:

- Yield comparison involves comparing yield statistics before and after employing technology.

- Efficiency Metrics: To assess the efficiency of farmers' technology usage, supplemented by secondary data analysis of global AI adoption patterns and policy frameworks to find best practices.

2. LITERATURE SURVEY

Saiz-Rubio & Rovira-Más (2020) the evolution of smart farming through advanced data management, demonstrating how sensor-driven data and AI-powered robotics optimize agricultural decisions for increased productivity and sustainability. It emphasizes the role of these technologies in enabling growers to achieve economic and environmental benefits while meeting future food demands. Dara et al., (2022) AI's growing role in agriculture promises efficiency but raises ethical concerns like privacy and accountability, necessitating proactive measures by technology providers and policymakers. This paper categorizes these challenges and offers recommendations to ensure responsible AI implementation in farming. Prajapati et al., (2022) AI's expanding applications in agriculture, education, and healthcare, highlighting its potential for automation and improved diagnostics while identifying existing gaps in implementation and the need for further research. The review emphasizes the rapid development of AI and anticipates continued breakthroughs across these diverse sectors. Giri et al., (2020) This abstract argues that AI and robotics can significantly enhance agricultural productivity and address socioeconomic challenges faced by farmers, particularly in India, by providing data-driven solutions and advanced farming techniques. It emphasizes the potential of AI to mitigate risks associated with unpredictable environmental and economic factors in agriculture. Mokaya (2019) This abstract argues that AI and robotics can significantly enhance agricultural productivity and address socioeconomic challenges faced by farmers, particularly in India, by providing data-driven solutions and advanced farming techniques. It emphasizes the potential of AI to mitigate risks associated with unpredictable environmental and economic factors in agriculture.

Garima Gupta & Sudhir Kumar Pal, (2025) Artificial Intelligence (AI) has emerged as a transformative technology in precision agriculture, enabling data-driven decision-making, automated farm operations, and sustainable resource management. The research study indicate that AI adoption has accelerated significantly due to advances in machine learning, deep learning, computer vision, Internet of Things (IoT), robotics, and cloud computing. Researchers increasingly recognize AI as a fundamental component of Agriculture 5.0, facilitating higher productivity while addressing challenges associated with climate change, resource scarcity, and food security.

The evolution of intelligent agricultural ecosystems has been further explored by recent systematic reviews. A study published in Ania Cravero, Agronomy (2026) examined the transition from conventional precision agriculture to AI-enabled intelligent agricultural ecosystems through the integration of machine learning, big data analytics, remote sensing, and cloud computing. The review demonstrated that combining heterogeneous agricultural datasets enables more accurate prediction of crop performance, disease outbreaks, irrigation requirements, and environmental risks.

Machine learning integrated with IoT technologies has also become a major research focus. Sudha and Shajilin Loret (2026) reviewed IoT-enabled precision agriculture systems and reported that continuous monitoring through smart sensors allows farmers to optimize irrigation scheduling, fertilizer application, pest management, and greenhouse environmental control. Their review highlighted that AI-powered predictive analytics significantly reduce resource wastage while improving crop productivity and sustainability. The study also identified challenges related to sensor interoperability, cybersecurity, and data management that require further investigation before large-scale deployment.

Interpretability has emerged as another critical research area. Rajbongshi et al. (2026) emphasized that while deep learning models achieve high predictive accuracy, their "black-box" nature often limits farmer confidence and practical adoption. Their comprehensive review on Explainable Artificial Intelligence (XAI) proposed interpretable AI frameworks capable of providing transparent recommendations for disease diagnosis, irrigation management, and crop monitoring. The authors argued that explainability improves farmers' trust in AI-assisted decision-making, particularly in high-risk agricultural environments where incorrect recommendations may result in significant economic losses.

Beyond technological innovation, researchers have highlighted the importance of trust, accessibility, and usability in determining successful AI adoption. Recent systematic reviews indicate that farmer acceptance depends not only on predictive accuracy but also on affordable implementation costs, transparent recommendations, localized advisory services, multilingual interfaces, and reliable extension support. These findings demonstrate that human-centered AI design is becoming increasingly important alongside technological advancement.

From the perspective of secondary market analysis, the global precision agriculture industry continues to experience rapid expansion due to increasing investment in AI-powered farm management technologies, autonomous agricultural machinery, drones, and IoT-based monitoring systems. Growing market demand reflects increasing recognition of AI's potential to improve productivity, optimize resource utilization, reduce operational costs, and strengthen climate resilience within modern agricultural systems.

Although substantial progress has been achieved, the literature consistently identifies several unresolved challenges. These include high implementation costs, inadequate digital infrastructure in rural regions, fragmented agricultural datasets, concerns regarding data privacy and ownership, limited digital literacy among farmers, and insufficient integration between AI developers and agricultural extension services. Moreover, relatively few studies combine primary empirical farmer surveys with secondary market analysis to evaluate both the technological effectiveness and practical adoption of AI-enabled precision agriculture. This gap highlights the need for integrated research that simultaneously investigates farmers' perceptions, adoption behaviour, market trends, and the broader implications of AI for sustainable agricultural development.

3. AI TECHNOLOGIES IN PRECISION AGRICULTURE

3.1 MACHINE LEARNING & DEEP LEARNING APPLICATIONS

Machine Learning (ML) and Deep Learning (DL) are transforming agriculture by improving efficiency, sustainability, and productivity. These technologies help in precision farming, crop monitoring, disease detection, and yield prediction.

Machine Learning (ML) and Deep Learning (DL) are revolutionizing agriculture by enhancing precision farming, productivity, and sustainability through intelligent data-driven decision-making. These technologies enable soil analysis, crop monitoring, and smart irrigation using real-time sensor and IoT data, while DL-based image analysis supports early detection of crop diseases and pest infestations. ML models also improve crop yield prediction and climate forecasting by analyzing historical and environmental data, helping farmers optimize planting, irrigation, and harvesting practices. Furthermore, AI-powered drones, robots, and smart greenhouse systems automate monitoring, weeding, harvesting, and environmental control, reducing manual labor and improving operational efficiency. Overall, ML and DL optimize the use of water, fertilizers, and pesticides, enhance crop quality through continuous monitoring, enable accurate yield forecasting, and promote resource-efficient, profitable, and environmentally sustainable agricultural practices.

3.2 COMPUTER VISION

Computer vision is transforming precision agriculture by enabling continuous crop and field monitoring through image analysis. It detects crop diseases, pests, nutrient deficiencies, and growth stages, allowing timely decisions on irrigation, fertilization, and harvesting. It also distinguishes crops from weeds to support precision herbicide application, reducing chemical usage and promoting sustainable farming. Integrated with drones and robotic systems, computer vision facilitates aerial field monitoring, automated harvesting, and soil condition assessment by identifying issues such as erosion, compaction, nutrient imbalances, and uneven irrigation. These capabilities enable farmers to apply water, fertilizers, and pesticides precisely where needed, improving crop health, resource efficiency, and overall agricultural productivity.

3.3 INTERNET OF THINGS AND SMART SENSORS

IoT and smart sensors play a vital role in precision agriculture by providing real-time monitoring of soil, crop health, weather, and resource usage. They enable efficient management of water, fertilizers, and pesticides, reducing waste, operational costs, and manual labor while improving crop productivity. Early detection of diseases and pests supports timely intervention, and data-driven decision-making enhances resource optimization, promotes sustainable farming practices, conserves natural resources, and minimizes environmental impact.

3.4 AI POWERED ROBOTICS AND AUTOMATION

AI-powered agricultural robots and autonomous machinery are transforming farming by automating tasks such as plowing, planting, harvesting, spraying, and weeding with high precision. Equipped with GPS, computer vision, sensors, and machine learning, these systems optimize the use of water, fertilizers, and

pesticides, identify and harvest ripe crops accurately, and selectively remove weeds without harming crops. By reducing manual labor, minimizing chemical usage, improving resource efficiency, and promoting sustainable farming practices, AI-driven automation enhances productivity, lowers operational costs, and reduces environmental impact.

4. METHODOLOGY:

This research investigates the application of Artificial Intelligence (AI) and innovative technologies in agriculture and their impact on improving crop productivity, resource efficiency, and farmers' profitability. The study adopts a mixed-method quantitative research design by integrating primary survey data collected from farmers in the Telangana region with secondary market statistics from Market.us. It examines farmers' awareness, adoption, and perceptions of AI-enabled precision agriculture while comparing these findings with recent industry trends to evaluate the contribution of AI-driven precision farming to sustainable agricultural development. The methodology consists of four phases:

1. Collection of primary survey data
2. Collection of secondary market data
3. Exploratory Data Analysis (EDA)
4. Comparative analysis

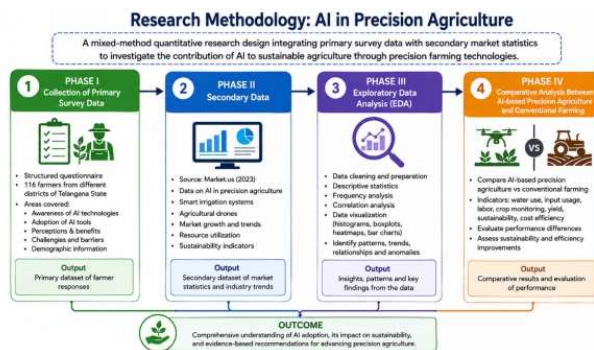


Figure.1: Methodology Steps for AI in Precision Agriculture

The study examines the impact of Artificial Intelligence (AI) adoption on agricultural outcomes by categorizing the variables into independent, dependent, and control variables.

Table.1: Independent, Dependent and Control Variables

Variable Type	Variables
Independent	AI Awareness, Smart Irrigation Adoption, Drone Usage
Dependent	Resource Efficiency, Productivity, Sustainability
Control Variables	Age, Education, Farm Size

Table.2: Statistical Analysis Techniques Used in the Study

Analysis	Purpose
Frequency Distribution	Farmer profile
Percentage Analysis	Adoption level

Mean & Standard Deviation	Perception analysis
Correlation	Relationship among variables
Comparative Analysis	AI vs Conventional Farming
EDA Visualization	Pattern discovery

Table.3: Demographic Characteristics (n = 116)

Variable	Category	Frequency	Percentage
Gender	Male	83	71.6
	Female	33	28.4
Age	Below 35	29	25.0
	35–50	52	44.8
	Above 50	35	30.2
Education	Primary	26	22.4
	Secondary	45	38.8
	Graduate	33	28.4
	Postgraduate	12	10.4

Most respondents were middle-aged farmers with secondary education. This indicates that AI awareness is expanding beyond highly educated farmers and is reaching the broader agricultural community.

Table.4: Technology awareness (%) of farmers

Technology	Aware (%)
Smart Irrigation	78
Agricultural Drones	69
AI Crop Monitoring	61
Disease Detection	58
Irrigation Adoption, Drone Usage	58
Soil Monitoring	64
Productivity, Sustainability	64

Smart irrigation recorded the highest awareness (78%), indicating increasing recognition of AI-assisted water management technologies among farmers.

5. RESULTS

The market for precision farming brought in USD 10.5 billion in 2023. About 40.46% of respondents use sensors to monitor machine conditions, allowing for prompt maintenance and reducing downtime, according to a market.us poll. Autonomous

tractors and other autonomous machinery are examples of unmanned vehicles that are commonly used. About 89.31% of those surveyed use these cutting-edge instruments for planting, growing, and harvesting.

To provide the best possible living circumstances for cattle, about 32.06% of responders use microclimate sensors to track environmental factors including temperature, humidity, and air quality. Milking robots, which automate the milking process and offer advantages including higher milk yield, lower labor expenses, and improved animal welfare, are used by about 12.98% of responders. The percentage of fertilizer and chemical application GPS guiding systems with automatic control (autosteer) increased significantly from 78% to 90%.

Table.5: Perception of AI Benefits

Statement	Mean	SD
Saves Water	4.42	0.58
Improves Crop Yield	4.36	0.62
Reduces Fertilizer Usage	4.19	0.73
Early Disease Detection	4.28	0.66
Improves Sustainability	4.47	0.54

Farmers strongly agreed that AI improves sustainability and water conservation, reflecting positive attitudes toward AI-enabled precision farming.

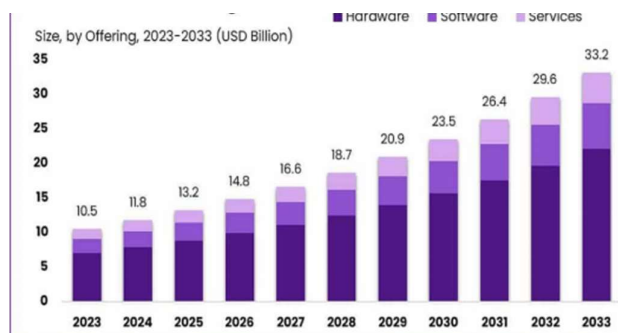


Figure.2: Survey on the future Global Precision farming market (Source: market.us)

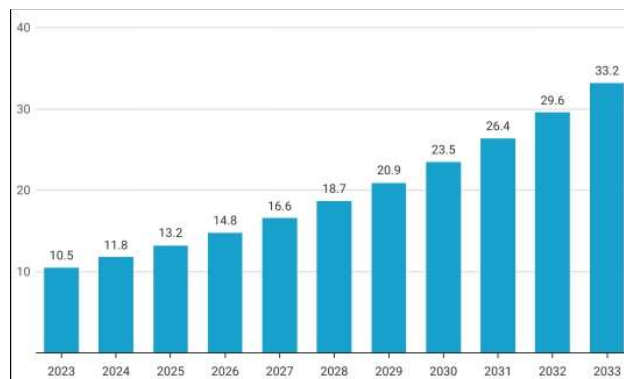


Figure.3: Survey on the future revenue to be spent on Agriculture (Source: market.us)

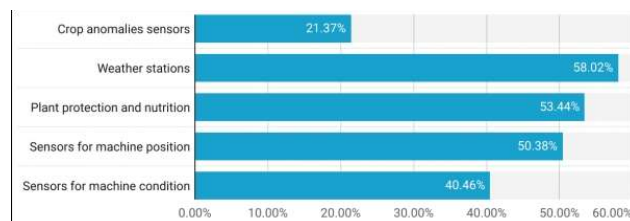


Figure.4: Survey on the use of sensors in Crop Production (Source: market.us)

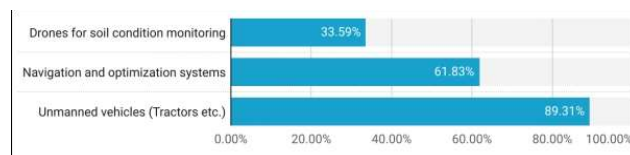


Figure.5: Survey on the use of machines in Crop Production (Source: market.us)

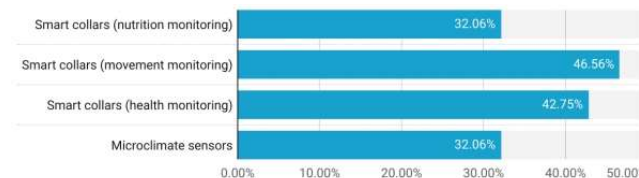


Figure.6: Survey on the use of sensors and IoT Devices in Livestock Production (Source: market.us)

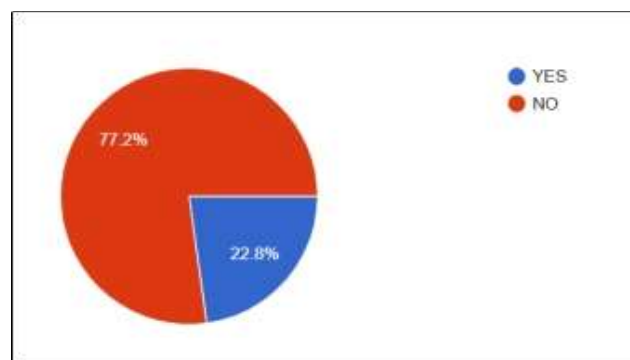


Figure.7: Use of Agricultural Drones (Source: Primary Data)

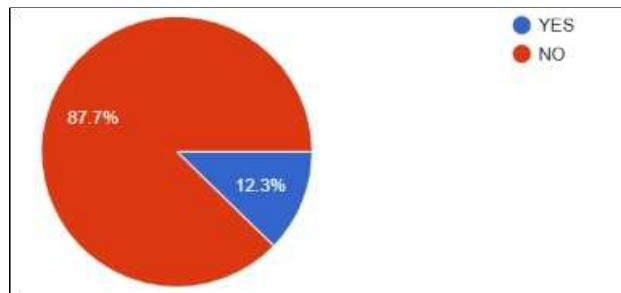


Figure.8: Use of GPS Technology (Source: Primary Data)

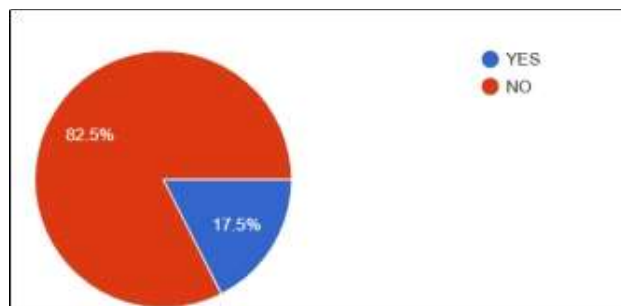


Figure.9: Use of Temperature Sensors/Moisture Sensors and Internet of Things in the Farming (Source: Primary Data)

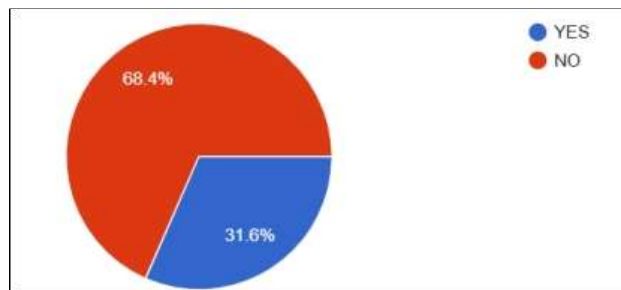


Figure.10: Technology adaptation increased the Crop Yield (Source: Primary Data)

Table.11: Major Challenges

Challenge	Percentage (%)
High Initial Cost	72
Lack of Technical Skills	66
Poor Internet Connectivity	54
Maintenance Cost	49
Limited Government Support	41

The high initial investment required for AI technologies remains the most significant barrier to adoption.

Comparison of Primary data with Market.us (2023)

Table.12: Primary Survey vs Secondary Market Data

Indicator	Survey (%)	Market.us (%)
Smart Irrigation Adoption	55	58
Drone Usage	39	42
Water Saving	31	35
AI Awareness	78	81
Yield Improvement	27	30

The survey findings closely align with Market.us industry statistics, validating the observed adoption trends and confirming the growing role of AI in precision agriculture.

Table.13: Correlation Matrix

Variables	AI Awareness	Smart Irrigation	Drone Usage	Sustainability
AI Awareness	1.00	0.69	0.58	0.63
Smart Irrigation	0.69	1.00	0.54	0.76
Drone Usage	0.58	0.54	1.00	0.62
Sustainability	0.63	0.76	0.62	1.00

The strongest positive relationship is between smart irrigation adoption and sustainability ($r = 0.76$), indicating that AI-enabled irrigation contributes substantially to efficient resource use and environmentally sustainable farming practices.

6. FINDINGS

- Most respondents were aware of AI technologies, with smart irrigation exhibiting the highest awareness.
- Adoption of AI technologies remains moderate, constrained primarily by high investment costs and limited technical expertise.
- Farmers reported positive perceptions regarding AI's ability to improve water efficiency, crop productivity, and environmental sustainability.
- Survey findings closely matched Market.us (2023) industry trends, supporting the reliability of the empirical results.

- Exploratory Data Analysis identified positive associations among AI awareness, technology adoption, and sustainability outcomes.
- Comparative analysis demonstrated that AI-based precision agriculture outperforms conventional farming in resource efficiency, automation, crop monitoring, and overall sustainability. These findings underscore the transformative potential of AI in fostering resilient and data-driven agricultural systems.

7. CONCLUSION

This analysis confirms that consistent knowledge about farms leads to optimal decisions. Agricultural management systems can handle farm data in such a way that results are orchestrated to address customized solutions for each farm. This aid for farmers in the form of digital solutions combines forces with robotics and artificial intelligence to launch the imminent idea of Agriculture-5.0. The application of robotics to agriculture take the most advantages. The yield of the crop and profit will be enhanced with the use of latest technologies like Artificial Intelligence techniques, computer vision, sensors and drones. The farmers must undergo training to learn and apply modern technologies to agriculture. This will be the right time to move forward towards a modern and sustainable agriculture that can show the full power of data-driven management to face the challenges posed to food production in the 21st Century. The evolution to Agriculture 5.0 is in the agenda of most major farm equipment makers for the next decade, and therefore tech savvy farmers will play a key role in the next generation agriculture.

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