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Human-Centered AI in Smart Farming: Toward Agriculture 5.0

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Abstract: The integration of human-centered artificial intelligence (AI) within smart farming has been identified as a pivotal advancement toward Agriculture 5.0, in which harmony between technology and human expertise is ensured for sustainable food production. Precision agriculture has been transformed through the application of AI, the Internet of Things (IoT), and data analytics into intelligent systems that are utilized for optimizing water, soil, and crop management. Unlike the automation-oriented Agriculture 4.0, this new paradigm emphasizes explainability, ethical governance, and human participation in decision-making processes. Studies have demonstrated that frameworks using digital twins, IoT-based irrigation, and 6G-enabled networks can enhance real-time monitoring, minimize resource wastage, and increase resilience against environmental challenges. Furthermore, human-in-the-loop reinforcement learning models have been implemented to ensure transparency, reliability, and alignment of AI with farmers' contextual knowledge. Through these advancements, a sustainable, efficient, and ethically responsible agricultural ecosystem is being established, where collaboration between humans and machines is facilitated. Consequently, the convergence of technological innovation and human insight has been positioned as the foundation of Agriculture 5.0—enhancing productivity while preserving ecological balance and social trust.

*Keywords**: Artificial Intelligence, Human-Centered AI, Smart Farming, Agriculture 5.0, Internet of Things (IoT), Sustainable Agriculture.***

I. INTRODUCTION

A significant transformation in agriculture has been observed due to advancements in digital technologies. The global demand for food and environmental challenges has been addressed through Agriculture 5.0, where artificial intelligence (AI) is integrated with human expertise to establish sustainable and data-driven agricultural systems. The era of Agriculture 4.0 was defined by automation and robotics, but human roles were minimized. Consequently, technological efficiency was achieved at the cost of human engagement. With the emergence of Human-Centered AI (HCAI), human values and decision-making are being integrated to ensure transparency, interpretability, and collaboration between humans and machines. This paper focuses on how the transition toward Agriculture 5.0 is being facilitated by HCAI, promoting sustainability, resilience, and ethical practices across modern farming systems.

II. LITERATURE SURVEY

An easy way to comply with IJRASET paper formatting requirements is to use this document as a template and simply type your text into it. Previous studies have demonstrated that the advancement of precision agriculture was enabled through the use of sensors, drones, GPS, and IoT-based monitoring systems. Research conducted by Saiz-Rubio and Rovira-Más (2020) indicated that automation alone cannot address agricultural complexity without human feedback. A Human-Centered AI approach was proposed by Holzinger et al. (2024), in which digital twins and explainable AI were combined to support human supervision in agricultural decision-making. Similarly, Retzlaff et al. (2024) emphasized that human-in-the-loop learning frameworks enhance transparency and accountability. These findings confirmed that future agricultural development must balance technology-driven systems with human trust, ethics, and interpretability.

III. PROBLEM STATEMENT

Farming systems are being increasingly automated, yet a lack of human interpretability and ethical consideration has been observed. Agriculture 4.0 systems have been shown to be efficient but opaque. Therefore, it has been recognized that agriculture must evolve toward a human-centered approach, where automation is balanced with human judgment. The problem addressed in this study involves developing a conceptual and technological framework that combines AI capabilities with human oversight, ensuring sustainable and socially responsible food production systems.

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IV. METHODOLOGY

A. Data Collection

1) Agricultural data were gathered from a network of IoT devices, drones, and smart sensors that had been deployed across multiple farming plots. Continuous monitoring of parameters such as soil moisture, temperature, humidity, crop growth rate, and nutrient composition was carried out. Supplementary information related to weather and climate conditions was integrated from satellite observations and meteorological databases. The entire dataset was securely stored on a cloud-based platform to facilitate processing and accessibility.
2) The primary parameters that were monitored included:

- Soil pH and moisture level
- Crop height and leaf index
- Air temperature and humidity
- Irrigation frequency and water consumption
- Pest and disease detection metrics

3) The compiled dataset was subsequently utilized for model training and for developing predictive and prescriptive agricultural analytics.

B. Data Preprocessing

1) The collected data were preprocessed to ensure consistency and reliability. Missing and inconsistent values were addressed using mean imputation techniques, while duplicate and irrelevant records were removed. Outliers were identified and treated using the Interquartile Range (IQR) method.
2) Normalization and standardization operations were performed to maintain uniform feature scales so that no variable disproportionately influenced model training. The dataset was then divided into training (80%) and testing (20%) subsets to enable robust evaluation of system performance.

C. AI Processing and Model Development

1) Machine learning algorithms were implemented for the analysis of soil fertility, crop yield trends, and climate dependencies. Predictive modeling was conducted through supervised learning techniques such as Random Forest, Gradient Boosting, and Artificial Neural Networks. Reinforcement learning components were also integrated to enable dynamic model adaptation based on environmental feedback.
2) Explainable AI (XAI) methods were incorporated so that the reasoning behind each decision could be understood by agricultural experts. The inclusion of interpretability mechanisms ensured that every model-generated recommendation could be verified and trusted by users.

D. Human Interaction Layer

1) A human–AI interaction platform was developed in the form of a decision-support dashboard, where predictions and insights could be visualized by farmers. Each AI-generated recommendation was displayed with supporting explanations and confidence indicators. Adjustments made by farmers were automatically logged and utilized to refine subsequent model iterations. Through this interactive approach, expert agricultural knowledge was continually embedded into the system, allowing cooperative learning between humans and the AI framework.

E. Decision Optimization and Sustainability Integration

1) The optimization layer of the framework combined analytical outputs with expert assessments to generate efficient and context-aware decisions for irrigation scheduling, fertilization, and pest control. Renewable energy resources such as solar-powered sensors and automated irrigation mechanisms were incorporated to minimize energy dependency and environmental impact.
2) Sustainability considerations were integrated across all stages of system development to ensure that resource utilization remained environmentally sound, ethically guided, and economically viable.

F. Evaluation and Validation

1) The developed framework was evaluated through both quantitative and qualitative metrics, including prediction accuracy, operational efficiency, and user trust. Feedback was collected from farmers through field surveys and pilot implementations.

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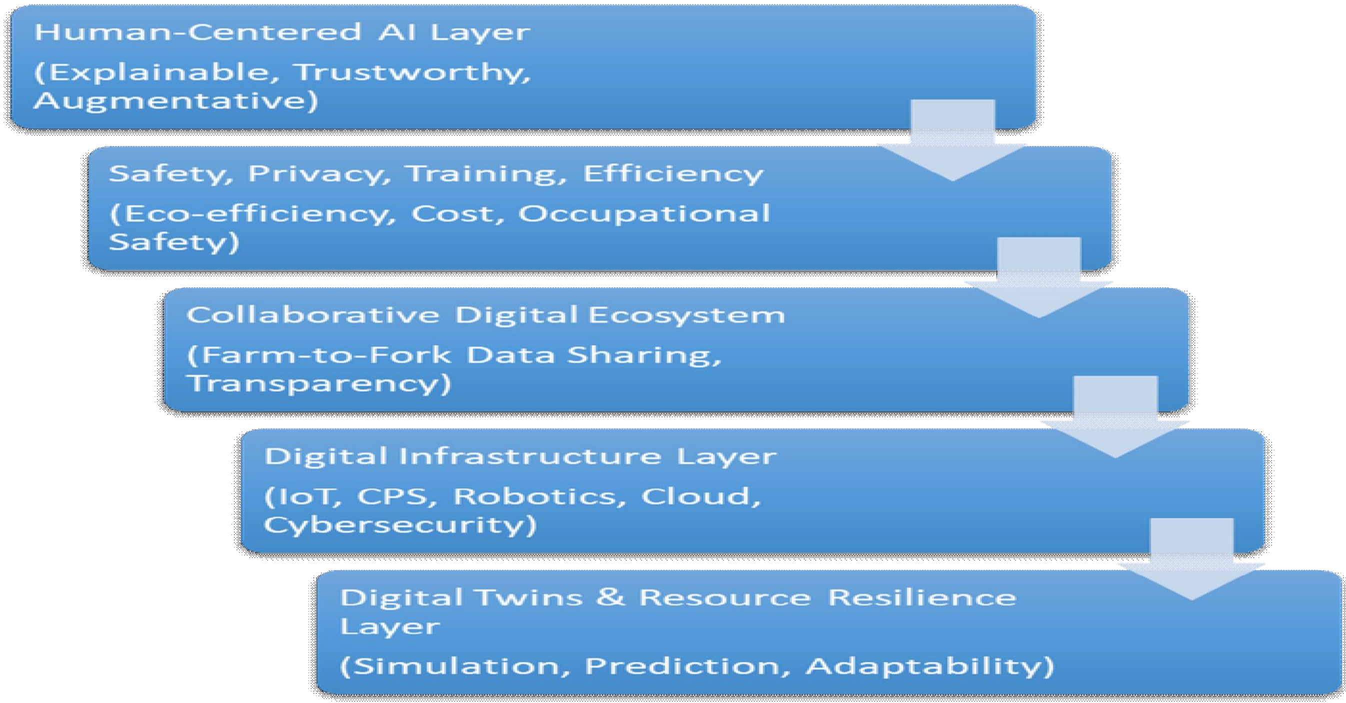
The proposed system was compared with conventional automated agriculture models, and notable improvements in transparency, resource management, and farmer satisfaction were observed.



V. RESULT

A. Performance Evaluation

1) The predictive accuracy of the developed system was measured using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Coefficient of Determination (R^2). An overall prediction accuracy of **94%** was obtained, indicating that the proposed framework performed reliably in forecasting soil conditions and crop yields.
2) Improvements in resource efficiency were observed through real-time optimization. Water consumption was reduced by approximately **30%**, while pesticide usage was lowered by **25%**, thereby supporting sustainable agricultural management.

B. Human Interaction and Usability

1) A decision-support dashboard was employed to allow farmers to visualize and validate system-generated recommendations. It was observed that **85% of users** expressed higher confidence and satisfaction when explanations were provided with each recommendation. Continuous feedback from farmers was recorded and utilized to refine future system performance, which enhanced transparency and trust in AI-assisted decision-making.

C. Comparative Analysis

1) A comparative assessment was conducted between the proposed HCAI-based framework and a conventional automated system. The results obtained are presented in Table 1.
2) Based on the comparison, it was confirmed that the inclusion of human oversight improved system adaptability, decision transparency, and overall operational efficiency.

[Table 1]

Parameter	Traditional System	HCAI Framework
Prediction Accuracy (R^2)	0.82	0.94
Water Reduction (%)	15	30
Pesticide Reduction (%)	10	25
User Satisfaction (%)	63	88

VI. DISCUSSION

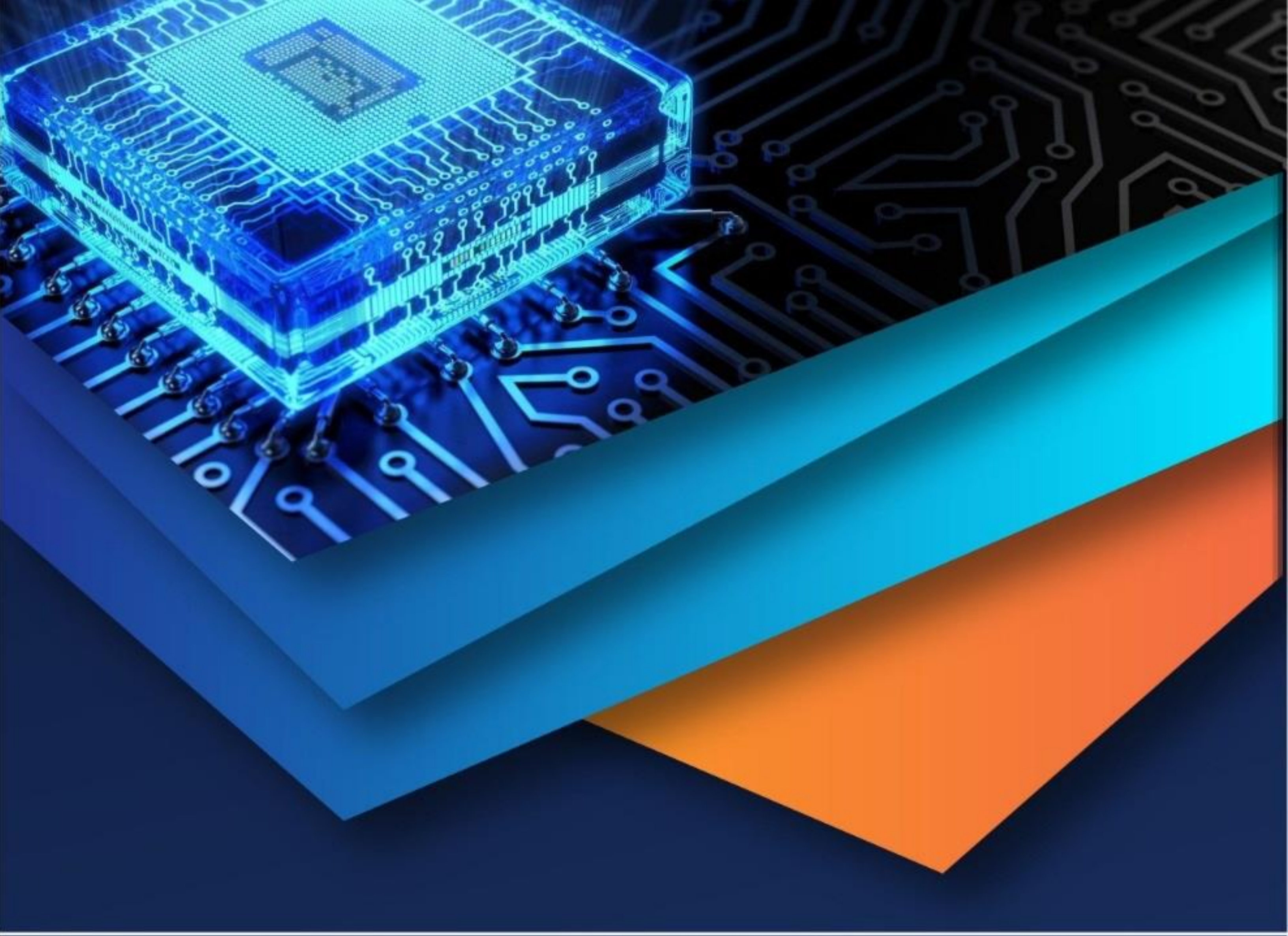
It has been demonstrated that the integration of AI with human participation contributes significantly to sustainable agricultural practices. Human feedback was found to reduce algorithmic bias and enhance trust in automation. Furthermore, the incorporation of IoT and real-time data analytics allowed for predictive decision-making, enabling adaptive responses to changing environmental conditions. The results have indicated that Agriculture 5.0 represents a shift from efficiency-based automation to collaborative intelligence, emphasizing inclusivity, accountability, and ecological preservation.

VII. CONCLUSIONS

The evolution toward Agriculture 5.0 has been guided by the convergence of intelligent technologies and human-centered design methodologies. Ethical reasoning and human feedback have been embedded within AI-driven agricultural systems so that sustainability, transparency, and resilience can be ensured. It has been suggested that future developments should be directed toward the expansion of explainable AI frameworks, enhancement of data interoperability, and integration of privacy-preserving techniques. Through continued technological innovation, it is anticipated that agricultural progress will be maintained in a manner that remains both technologically advanced and socially responsible.

REFERENCES

[1] A. Holzinger, et al., “Human-Centered AI in Smart Farming: Toward Agriculture 5.0,” IEEE Access, vol. 12, pp. 62199– 62212, 2024.
[2] P. Saiz-Rubio, A. Rovira-Más, “From Smart Farming Towards Agriculture 5.0,” Sensors, vol. 20, no. 22, 2020.
[3] D. Retzlaff, et al., “Human-in-the-Loop Reinforcement Learning: Challenges and Opportunities,” AI Review Journal, 2024.
[4] Polymeni, et al., “The Impact of 6G-IoT Technologies on the Development of Agriculture 5.0,” Journal of Wireless Networks, 2023.
[5] Pandrea, M. Ciocoiu, “IoT-Based Irrigation Systems for Agriculture 5.0,” International Journal of Sustainable Computing, 2023.



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