2025 Volume: 01 Issue: 07 www.ijrpa.com ISSN 2456-9995 Review Article

International Journal Research Publication Analysis

Page: 01-16

GREEN ROOFAI: SMART MONITORING AND CONTROLLING OF ROOFTOP EDIBLES

Aditya K Bhat*[1],Chaya.M[2], Sneha.N[3], Pavan Kumar[4],Dr.Nirmala H[5]

[5]A Professor, Department of Information Science and Engineering, Global Academy of Technology

[1,2,3,4],Undergraduate, Department of Information Science and Engineering, Global Academy of Technology.

Article Received: 03 November 2025

Article Revised: 23 November 2025

Published on: 13 December 2025

***Corresponding Author: Aditya K Bhat**

Undergraduate, Department of Information Science and Engineering, Global Academy of Technology. DOI: https://doi-doi.org/101555/ijrpa.4649

ABSTRACT

A compact, IoT-based solution ispresented for smart urban rooftop farming, integrating real-time environmental sensing and automation. This paper proposes an end to-end IoT-enabled platform designed to optimize resource use and enhance plant health management through artificial intelligence. The system utilizes a network of distributed sensors measuring soil moisture, pH, air temperature, humidity, and light intensity, with data streamed in real-time to both an edge gateway and a cloud backend. Machine learning algorithms, including Random Forest and LSTM, drive predictive irrigation, crop recommendations, and fertigation guidance. The platform's automated actuation and intuitive dashboard minimize manual labor and facilitate efficient farming, even in complex urban microclimates. Evaluation results demonstrate reliable sensor performance, significant water savings, and a scalable architecture. Future expansions aim to incorporate nutrient sensing, automated fertilizer dosing, and collaborative community-driven model refinement, illustrating the transformative potential of combining IoT and intelligent analytics in urban agriculture.

INDEX TERMS: IoT (Internetof Things), UrbanAgriculture, Smart Farming, Rooftop Farming, Predictive Irrigation, MachineLearning, RandomForest, LSTM(LongShortTerm Memory), Automated Actuation, Nutrient Sensing,Fertigation,WirelessSensorNetworks,Cloud Computing, Community Data Platform.

INTRODUCTION

The global demand for food production continues to riseduetopopulationgrowthandrapidurbanization, creating immense pressure on agricultural systems. Rooftopfarmingoffers a sustainable and spaceefficient solution to urban food insecurity. However, traditional rooftop farming requires continuous monitoring of parameters such as soil moisture, nutrient content, temperature, and humidity—tasks that are often labor-intensive and inconsistent. IoT and AI technologies provide transformative opportunities to automate and optimize roof top agriculture .By integrating sensors, wireless communication, and intelligent decision making, these technologies enable precise environmental control, efficient water management, and improved crop health.

The proposed Green Roof AI system employs low- cost microcontrollers (Arduino and ESP8266) integrated with multiple sensors for real-time environmental monitoring. The collected data are transmitted to cloud platforms, where machine learning algorithms analyze trends, predict irrigation needs, and automatically control actuators to ensure optimal water usage. This integration minimizes manual intervention, enhances precision, and promotes sustainability in urban farming environments.

To establish a strong theoretical foundation for this research, a comprehensive literature review was conducted, examining twenty key studies related to IoT-enabled agriculture, artificial intelligence applications, robotics, and sensor-based farming systems. The following section provides an in-depth analysis of these studies, highlighting technological approaches, experimental findings, and emerging research gaps that informed the development of the Green Roof AI framework.

LITERATURE REVIEW

[1]Harefa and Gunawan (2024) proposed a Smart Agriculture System based on the Internet of Things (IoT) aimed at mitigating global food security threats by enabling remote monitoring and control of plant environments. Their design integrates sensors and actuators within an IoT architecture, allowing farmers to observe and regulate plant conditions such as soil moisture, temperature, and humidity in real time. The system design focuses on conceptualizing network- based automation rather than empirical deployment, emphasizing IoT’s capability to increase food productivity through real-time control. The authors conclude that implementing IoT-based smart agriculture systems is crucial for maintaining sustainable

crop growth and addressing food shortages globally.

[2]Ananda et al. (2023) developed a low-cost IoT- based Smart Agriculture prototype that uses MIT App Inventor, Firebase, and ThingSpeak for cloud-based irrigation management. The system consists of NodeMCU, DHT22, and soil moisture sensors connected via Wi-Fi, sending data to the cloud for monitoring.

It supports both manual and automatic control of pumps and fans depending on soil and air conditions.The mobile app displays realtime environmental data, allowing users to make informed decisions. This approach demonstrated the feasibility of low-cost IoT solutions for small-scale farmers and validated reliable automation using cloud integration

[3]Laha et al. (2023) implemented an IoT-based soil moisture management system using Raspberry Pi Pico and DHT11 sensors. automatically controlling irrigation through a water pump based on sensor thresholds. Experimental results showed that automation reduced human effort and achieved efficient water utilization. The study confirmed the importance of simple, hardwarebased IoT systems in maintaining soil balance and ensuring consistent irrigation without manual supervision.

[4] Jiménez-López et al. (2023) applied deep learning architectures such as 1D-CNN and LSTM in combination with IoT-collected meteorological data to forecast irrigation schedules for potato crops. The dataset included three years of daily weather and soil data from IoTenabled weather stations. The models achieved high accuracy in predicting irrigation needs, leading to reduced water wastage and enhanced irrigation efficiency. Their findings validated that integrating deep learning models with IoT data provides a sustainable, data-driven solution for smart irrigation management.

[5] Kashyap et al. (2021) developed an LSTM powered irrigation system that optimized irrigation scheduling by predicting soil moisture levels. The model achieved a 43% reduction in water use compared to traditional irrigation techniques. Through predictive modeling, the system maintained optimal moisture conditions and contributed to precision agriculture goals. This study exemplified the potential of AI-driven models in achieving sustainable and resource-efficient farming.

[6] Kapse et al. (2025) proposed an IoT-based soil nutrient monitoring decision system using Arduino and ESP32 microcontrollers to measure NPK levels, soil moisture, pH, and

temperature. The data was transmitted to the ThingsBoard cloud platform for visualization and decision-making. Real-time dashboards enabled farmers to apply fertilizers more precisely, improving crop yield and resource efficiency. The authors concluded that their cloud-integrated system provides a scalable solution for precision agriculture by reducing nutrient waste and optimizing fertilizer usage.

[7]Kumari et al. (2025) demonstrated an IoT-based fertigation monitoring system for real-time tracking of soil electrical conductivity (EC) and moisture under controlled and field conditions. The system continuously monitored fertigation processes to ensure optimal nutrient delivery. Results indicated high correlation between EC readings and nutrient concentration, enabling accurate This study emphasized the importance of continuous monitoring for improved nutrient.

[8]Zailan and Hamid (2025) developed AgriSmart, an IoT-based rooftop smart gardening model designed for small-scale urban farmers. Their system utilized sensors to monitor moisture and environmental parameters, automating irrigation and reducing water use by up to 35%. The study highlighted how rooftop agriculture can be made more sustainable and productive using IoT automation. This research is directly aligned with Green Roof AI's objective of optimizing rooftop farming.

[9] Grunewald et al. (2024) introduced an IoT–Edge– Cloud computing continuum for urban microfarming. Their architecture connects sensors to edge processors and the cloud, enabling realtime data analysis and plant recommendation using ML models like KNN, SVM, Gradient Boost, and XGBoost. The best models (GB and XGB) achieved 99.99% accuracy in predicting optimal plant growth parameters. The system utilized LoRa communication for efficient long-range, low-power data transfer, demonstrating how edge-based intelligence can enhance urban agriculture efficiency.

[10] Awasthi et al. (2024) integrated YOLO (You Only Look Once) and Random Forest models into an IoT system for crop health monitoring and management. The model used IoT sensors to collect environmental data and computer vision to detect crop diseases. By merging image recognition with environmental data, the system provided intelligent decision support, improved yield prediction, and reduced the risk of disease spread. This hybrid IoT–AI model set a foundation for smart, autonomous crop management.

[11] Ghandar et al. (2021) proposed a Digital Twin (DT)- based Decision Support System for aquaponics under urban agriculture settings. The DT created a virtual model of the aquaponic system to monitor and predict environmental dynamics. It enabled farmers to test scenarios in the virtual twin before applying changes in the real system. This framework improved predictive management and optimized resource usage, demonstrating that DT technology can revolutionize complex urban agricultural systems.

[12] Anushree and Krishna (2018) developed an Arduino based automation system for irrigation and environmental monitoring. Their setup used basic sensors to track soil moisture and environmental parameters, automating water flow through pumps. It proved that affordable IoT-based prototypes can effectively monitor conditions, maintain plant health, and minimize water wastage. The study also established Arduino's potential as a lowcost solution for small-scale agricultural automation.

[13] Hasan et al. (2022) presented a comprehensive review on the integration of AI, IoT, and Robotics in agriculture, analyzing applications like machine learning- based disease identification and robotics-assisted harvesting .The paper emphasized that although these technologies enhance productivity and reduce human effort, adoption remains limited by high costs, technical complexity, and cybersecurity concerns.

The authors concluded that addressing these non-technical barriers is essential to achieve global agricultural digitization.

[14] Kumar et al. (2023) explored AI techniques for irrigation and nutrient optimization, combining machine learning and remote sensing data. The study demonstrated that predictive analytics improved irrigation timing and fertilizer management, leading to higher yields and reduced water usage. Their review highlighted AI's potential to revolutionize decision making in agriculture through intelligent automation.

[15] Gangwani (2024) studied AI-driven predictive analytics for precision agriculture, focusing on how artificial intelligence improves yield prediction, resource efficiency, and cost savings. The research showed that AI systems enhanced yield forecasting by 15%, reduced fertilizer use by 20%, and achieved early disease detection with 99% accuracy. These advancements indicate AI's transformative role in developing sustainable farming systems.

[16] Hassan et al. (2020) proposed AgriFusion, a hybrid IoT–AI–Blockchain framework for smart agriculture. The system ensures scalability and interoperability across multiple farming devices while securing data transactions using blockchain technology. The combination of IoTbased data acquisition, AI-based decision-making, and blockchain- based security ensures reliability and transparency in agricultural operations.

[17] Madhukumar (2022) developed a deep learningbased decision support system that used IoT data for precision irrigation management. The system analyzed soil parameters and environmental data through neural networks to optimize irrigation schedules automatically. This method improved water efficiency, reduced costs, and demonstrated how deep learning enhances precision farming accuracy.

[18] Almaaitah et al. (2022) implemented a low-cost LoRaWAN-based IoT water management system for rooftop urban agriculture. The system measured parameters like soil moisture and temperature and automatically controlled irrigation based on thresholds. It utilized off-the-shelf IoT components, proving that affordable technology can be effectively deployed in urban rooftop farming. The project achieved significant water conservation while maintaining crop health.

[19] Tophel et al. (2025) applied LSTM neural networks to predict soil moisture variation in compacted pavement layers. Though focused on geotechnical applications, their model demonstrated that LSTM architectures effectively capture temporal soil dynamics with high accuracy (RMSE ≤ 0.20%). The findings offer insights applicable to precision irrigation, where soil moisture prediction is essential for optimal water management.

[20] Saki et al. (2025) presented a Transformer- based deep learning approach for soil and yield prediction using remote sensing and multi-modal data fusion. Their model achieved a median accuracy of 94%, outperforming CNN and LSTM models. The study demonstrated that Transformer architectures enhance scalability and precision in agricultural data analytics, enabling large scale monitoring and yield prediction.

[21] Othaman et al. (2021) designed an IoT-based soil nutrient sensing system that uses EC and temperature sensors connected via LoRa for real-time monitoring. The system successfully correlated EC values with fertilizer concentration and demonstrated reliable cloud-based visualization. It proved effective for precise nutrient management and provided a

foundation for future NPK sensor integration.

[22] Holagundi, N. (2024) highlighted that IoT- and AI-based smart farming with dense sensor networks and automated irrigation improves water efficiency and yield. Low-cost Wi-Fi microcontrollers support cloud-based ML analysis, but most solutions focus on open fields or greenhouses, revealing a lack of architectures for urban rooftop farms

[23] Nirmala, H., & Girijamma, H. A. (2022) stated that IoT boards (Arduino, ESP8266/NodeMCU) with environmental sensors enable automated, ML-assisted irrigation and better water efficiency via cloud dashboards. Yet most systems target open fields or greenhouses, leaving the need for solutions tailored to rooftop microclimates and space constraints

The reviewed studies collectively highlight rapid advancements in IoT-driven automation, AI-based decision systems, and urban agricultural innovation. Most works successfully demonstrate functional prototypes for irrigation, nutrient monitoring, and environmental sensing. However, key research gaps remain in scalability, multi-sensor data fusion, and integration of real-time AI models. The Green Roof AI framework builds upon these insights, proposing a unified, cloud-integrated system for rooftop agriculture that combines low-cost IoT hardware, machine learning-based irrigation prediction ,and sustainable water management

LITERATURESUMMARY

Sl. No	Citation	Year	Methodology/Algorithmsused	Remarks
1.	R. Harefa and H. Gunawan, PerancanganSmart Agriculture SystemBerbasis InternetofThings	2024	Implements a Sensorto-Cloud systemusingNodeMCUESP-8266 asthemaincontroller.Connects Soil Moisture(YL-69)andDHT-11 sensors to the ThingSpeak cloud.	Developed an IoT-based smart agriculture platform for remote monitoring and control of soil and environmental conditions using temperature, humidity, and moisture sensors. The study emphasized automation for enhancing agricultural productivity and sustainability.

2.	M.D.Ananda,Y.Saragih, , Design of Smart AgriculturalSystems Using MIT App and Firebase,	2023	Uses NodeMCU (ESP8266) to send sensordatatoboth Firebase (forcontrol)andThingSpeak(for logging).Auser app is built with MIT App Inventor	Designed a low-cost IoT system integrating MITApp Inventor, Firebase, and ThingSpeak with NodeMCU and DHT22sensorsforirrigationautomation.
3.	S.R.Laha,B. K. Pattanayak, S. "An IoT- based Soil Moisture Management System for Precision Agriculture..	2023	Deploys a system using a RaspberryPiPicomicrocontroller, SoilMoistureSensor,DHT11, and an ESP-01 Wi-Fi module to send data to a cloud webpage.	Implemented a soil moisture monitoring and irrigation system using RaspberryPiPicowithDHT11andsoil sensors. The model aimed to optimize irrigationfrequencyandminimize manual intervention.
4.	]F.-R.JiménezLópez, J.-S. Castellanos-Patiño, Forecastingirrigation schedulingbasedon deeplearningmodels using IoT,	2023	Compares a 1D-CNN model against an LSTM model for forecasting irrigation needs, trained on a 3-year dataset of climate and soil variables	Introduced an IoT-integrated deep learning system combining 1D-CNN and LSTM models for irrigation forecasting in potato cultivation, enabling data-driven and sustainable water management.
5.	]P.K.Kashyap,S. Kumar, Towards Precision Agriculture: IoT-Enabled Intelligent Irrigation SystemsUsingDeep Learning Neural Network,	2021	ProposesanIoTsystem (DLiSA) that uses an LSTM (Deep Learning) model. It's trained on historical time-series data(climate,soil)topredictsoil moisture one day in advance	Developedapredictiveirrigationmodel using LSTM neural networks to estimate soil moisture and automate irrigation schedules, achieving improved water efficiency.

6.	]G.Kapse,A.Kumar, B. Kumar, and V. Kumar,IoTBasedSoil Nutrients MonitoringDecision System,	2023	An IoT system built on anArduinoUnoandESP32(for WiFi) to measure NPK, moisture, and pH levels. Data is sent to the ThingsBoard cloud platform.	Designed an IoT-based soil nutrient monitoring system employing Arduino and ESP32 with NPK, pH, andtemperaturesensors,transmitting real-time data to the ThingsBoard cloud platform for visualization and analysis.
7.	S. Kumari, N. Ali, M. Dagati, and Y. Dong, IoT Enabled Soil MoistureandConductivity Monitoring Under.. FertigationSystem.	2025	Validates an IoT system using TEROS-12sensorstomeasure SoilMoisture,Temperature,and ElectricalConductivity(EC), sendingdatatotheUbidots cloud.	Presented an IoT-based fertigation monitoring framework using sensors to track soil electrical conductivity and moisture for optimized nutrient and irrigation control.
8.	A.R.ZailanandM.N.Hami d, AgriSmart:AnIoT-Based Smart Gardening Model for High-Rise Academic Buildings.	2025	An IoT-based smart gardening systemdesignedspecificallyfor high-rise buildings (like rooftops). It uses sensors for real-time monitoring and automated irrigation.	Developed AgriSmart, an IoT-based rooftopgardeningsystemthatautomates irrigation and monitors environmental factors to promote sustainable urban agriculture.
9.	M.Grunewald,M. Bensalem, Towards Smart Micro farming inanUrban Computing Continuum.	2024	Proposes an IoT-Edge-Cloud architecture for urban microfarming.IoTsensors(NPK, pH,temp)useLoRatosenddata to an Edge server, which runs ML models (RF, SVM,	Proposed an IoT–Edge–Cloud architecture integrating machine learningalgorithmssuchasKNN,SVM, Gradient Boost, and XGBoost for intelligentplantrecommendationa

			etc.).	nd environmental control in microfarming.
10.	A.Awasthi,S.Singh,and H.Miranka,IoTBased Smart Farming SystemusingMachine Learning,	2024	Uses a Raspberry Pi as the central controller with DHT and soil moisture sensors. It combines this with manual NPK input and a Random Forest model for crop recommendations.	Integrated IoT data with YOLO and Random Forest algorithms to enable real-time crop health monitoring and yield prediction through environmental and image-based data fusion.
11.	A. Ghandar, A. Ahmed,ADecision Support System for UrbanAgriculture UsingDigitalTwin:A Case Study With Aquaponics	2021	An ESP8266 sensor node (monitoringpH,EC,temp)sends dataviaMQTTtoaRaspberryPi (Edge Gateway), which then connects to the cloud.	Developed a Digital Twin model for aquaponicsystemstofacilitatevirtual monitoring and predictive analysis, allowing data-driven optimization of agricultural processes.
12.	M.K.AnushreeandR. Krishna, A smart farming system using Arduino based technology	2018	Uses twoArduino boards: one for sensing (soil, temp) and one for control(pump,fan).Dataisstored locally in an Excel sheet.	Designed a low-cost Arduino-based automated irrigation system using soil moisture and temperature sensors to regulatewatersupplyandreducehuman dependency.
13.	M.M.Hasan,M.U. Islam, and M. J. Sadeq “Towards technologica adaptation of advanced farming through AI, IoT and Robotics,	2022	AcomprehensivereviewofAI, IoT, and Robotics in agriculture.	Conducted a review of AI, IoT, and robotic applications in agriculture, emphasizing their combined potential toimproveproductivity,reducewaste, and enhance decision-making accuracy.

14.	]J.Kumar,R.Chawla, D. Katiyar, A. Chouriya, , OptimizingIrrigationand Nutrient Management in Agriculture through ArtificialIntelligence Implementation,	2023	A review paper examining AI applicationsforoptimizingirrigation scheduling and nutrient management.	Applied machine learning techniques with remote sensing data to optimize irrigation and nutrient application, focusing on precision agriculture for resource efficiency.
15.	N. Gangwani, AI-Driven Precision Agriculture: Optimizing Crop Yield and Resource Efficiency	2024	An analytical review article exploring AI's impact on predictive irrigation, pes detection, and precision fertilization.	Developed AI-based predictive models for yield forecasting and resource optimization using multi-sensorIoTdata toenhanceprecisionandsustainabilityin agriculture.
16.	N. Hassan, A. Nauman,AgriFusion: rchitecture forIoT and EmergingTechnologiesBasedon PrecisionAgricultureSurvey	2021	A comprehensive survey proposing a 5-layer IoT architecture ("AgriFusion") that maps AI, ML, Edge, Cloud, and LPWAN technologies.	Proposed AgriFusion, a framework combining IoT, AI, and blockchain technologiesforsecure,transparent, and scalable smart farming systems.
17.	N.Madhukumar,Decision Support System for Precision Agriculture Using Deep Learning	2022	APhDthesisthatdevelopsa Decision Support System using aBLSTM-GRUmodel(Deep Learning)forrainfallprediction.	Utilized deep learning algorithms in conjunction with IoT sensor data for automated irrigation scheduling improving accuracy in water management decisions.

18.	T.Almaaitah,D. Joksimovic, andT. Sajin, Real-Time IoT-Enabled Water Management for Rooftop Urban Agriculture Using CommercialOff-the-Shelf Products	2022	An IoT system deployed on a rooftop urban farm using water level sensors (eTape) and LoRaWAN to send data to The Things Network (TTN) cloud.	ImplementedaLoRaWAN-basedIoT watermanagementsystemforrooftop farming, offering a lowpower, cost- efficient approach to irrigation control.
19.	]A.Tophel,T.M.Nguyen, J. P. Walker, and J Kodikara, "Soil Moisture Prediction in avement Layers Using LSTMNeuralNetworks	2025	Developed an LSTM model to predictsoilmoisture(SM)variation in compacted pavement layers for road construction.	Employed LSTM models to predict soilmoisturevariationsincompacted soils, providing insights relevant to irrigation and soil management planning.

20.	M.Sakietal.,AData-DrivenReviewofRemote Sensing-Based Data Fusion in Precision Agriculture From Foundational to Transformer-Based Techniques	2025	Asystematicreviewanalyzing data fusion in precision agriculture, comparing ML/DL (CNN, LSTM) with Transformerbased models	Applied Transformer-based models using multimodal soil and environmentaldatatoenhanceyield predictionaccuracyandscalabilityin precision agriculture.
21.	N. N. C. Othaman, M. N. Md Isa, R. Hussin, S. M. M. S. Zakaria, and M. M. Isa,IoTBasedSoilNutrient Sensing System forAgricultureApplication	2021	An IoT system for paddy (rice) fields using an EC sensor and temperature sensor connected to a TTGOT-Beam(ESP32/LoRa), sending data to the ThingsBoard cloud.	Developed an IoT-based nutrient sensing system using electrical conductivityandtemperaturesensors connected via LoRa to monitor fertilizer concentration in real time.
22	Holagundi, N., Ashwathsetty, G. H., & Basthikodi, M. Algorithm fuzzy scheduling for realtime jobs on multiprocessor systems.	2022	IoT- and AI-based automated irrigation using sensor networks (moisture, temperature, humidity rainfall) with cloud ML prediction and anomaly detection	Enhances water efficiency, but existing systems focus on open fields/greenhouses; rooftop farms remain underexplored
23	Nirmala,H.,&Girijamma, H. A.Fllbhgats: Efficien load balancing and task scheduling algorithm for real-time	2022	IoT-based automated irrigation using Arduino / ESP8266 sensor network with cloud analytics and ML-based pump control	Improves water efficiency, but current systems focus on open fields/greenhouses and lack solutions for rooftop microclimates and space constraints

	multiprocessor.			

CONCLUSION

The literature view confirms that the integration of IoT and AI significantly enhances agricultural monitoring, automation, and decision-making. Studies demonstrate reliableIoT-based sensingsystems, efficientirrigation scheduling, and AI-driven predictive Analytics that contribute to higher productivity and sustainability. The Green Roof AI project incorporates these technologies into a cohesive rooftop farming solution, enabling real-time monitoring, predictive irrigation, and sustainable food productionwithin urban environments. Future developments will include integrating NPK sensing modules, automated fertigation, multi-node ESP32 systems, and computer-vision-based plant health assessment.Such enhancements will further the vision of sustainable, intelligent, and autonomous rooftop agriculture.

REFERENCES

1. R. Harefa and H. Gunawan, “Perancangan Smart Agriculture System Berbasis Internet of Things [Design of a Smart Agriculture System Based on IoT],” Digital TransformationTechnology (Digitech), vol. 4,no. 1, pp. 79 86, Mar. 2024.
2. M.D.Ananda,Y.Saragih,R.S.Hadikusuma,andA. F. Kamal, “Design of SmartAgricultural Systems Using MIT App and Firebase,” Techné Jurnal Ilmiah Elektroteknika, vol. 22, no. 2, pp. 183–196, Oct. 2023.
3. S.R.Laha,B.K.Pattanayak,S.Pattnaik,B.B.Dash, S. Pattnaik et al., “An IoT-based Soil Moisture Management System for Precision Agriculture: Real- Time Monitoring and Automated Irrigation Control,” Proc. ICOSEC-2023, Sep. 2023, doi:10.1109/ICOSEC58147.2023.10276266
4. F.-R. Jiménez-López, J.-S. Castellanos-Patiño, and A.-F. Jiménez-López, “Forecasting irrigation scheduling based on deep learning models using IoT,” in LACCEI Int. Multi Conf. for Eng., Educ., and Technology, 2023.
5. P.K. Kashyap, S.Kumar,A.Jaiswal, M. Prasad, and H. Gandomi, “Towards Precision Agriculture: IoT- Enabled Intelligent Irrigation Systems Using Deep Learning Neural Network,” IEEE Sensors Journal, vol. 21,no.15,pp.1697316983,Mar.2021,doi:

10.1109/JSEN.2021.3069266.

6. G.Kapse,A.Kumar,B.Kumar,andV.Kumar,“IoT Based Soil Nutrients Monitoring Decision System,” InternationalJournalofInnovativeScienceandResearch Technology, vol. 10, no. 4, pp. 1746–1749,Apr. 2025.
7. S. Kumari, N. Ali, M. Dagati, and Y. Dong, “IoT Enabled Soil Moisture and Conductivity Monitoring Under Controlled and Field Fertigation Systems,” AgriEngineering, vol. 7, p. 207, Jul. 2025, doi: 10.3390/agriengineering7070207.
8. A. R. Zailan and M. N. Hamid, “AgriSmart:An IoT- Based Smart Gardening Model for High-RiseAcademic Buildings,” International Journal of Research and InnovationinSocialScience(IJRISS),vol.IX,no.V,pp. 911– 920, May 2025, doi: 10.47772/IJRISS.2025.90500075.
9. M. Grunewald, M. Bensalem, J. Dizdarević, and A. Jukan, “Towards Smart Micro farming in an Urban Computing Continuum,” arXiv:2408.02992v2, 2024.
10. A. Awasthi, S. Singh, and H. Miranka, “IoT Based Smart Farming System using Machine Learning,” International Journal for Research inApplied Science & EngineeringTechnology(IJRASET),vol.12,IssueVI,
11. June2024,doi:10.22214/ijraset.2024.63365
12. A. Ghandar, A. Ahmed, S. Zulfiqar, Z. Hua, M. Hanai, and G. Theodoropoulos, “A Decision Support SystemforUrbanAgriculture Using DigitalTwin:ACase Study With Aquaponics,” IEEE Access, vol. 9, pp. 35698–35708, 2021
13. M. K.Anushree and R. Krishna, “Asmart farming system using Arduino based technology,” International Journal of Advance Research, Ideas and Innovations in Technology, vol. 4, no. 4, 2018.
14. M. M. Hasan, M. U. Islam, and M. J. Sadeq, “Towards technological adaptation of advanced farming through AI, IoT, and Robotics: A Comprehensive overview,” in Artificial Intelligence and Smart Agriculture Technology, Routledge/CRC Press, 2022.
15. J. Kumar, R. Chawla, D. Katiyar, A. Chouriya, D. Nath, S. Sahoo, A. Ali, and B. V. Singh, “Optimizing Irrigation and Nutrient Management in Agriculture through Artificial Intelligence Implementation,” InternationalJournalofEnvironmentandClimate Change,vol.13,no.10,pp.40164022,2023,doi: 10.9734/IJECC/2023/v13i103077.
16. N. Gangwani, “AI-Driven Precision Agriculture: Optimizing Crop Yield and Resource Efficiency,” International Journal for Multidisciplinary Research (IJFMR), vol. 6, no. 6, Nov–Dec 2024.
17. N.Hassan,A.Nauman,A.Rehman,W.Ejaz,andA. Anpalagan, “AgriFusion: An

Architecture for IoT and Emerging Technologies Based on Precision Agriculture Survey,"IEEEAccess,vol.8,pp.180598–180620,2020,
doi: 10.1109/ACCESS.2020.3028527.

18. N. Madhukumar, Decision Support System for PrecisionAgricultureUsingDeepLearning,M.S.Thesis, James Cook University, Australia, 2022.
19. T. Almaaitah, D. Joksimovic, and T. Sajin, "Real- TimeIoT-EnabledWaterManagementforRooftop Urban Agriculture Using Commercial Off-the-Shelf Products," Chem. Proc., vol. 10, 34, Feb. 2022, doi: 10.3390/IOCAG2022-12235.
20. A. Tophel, T. M. Nguyen, J. P. Walker, and J. Kodikara,"SoilMoisturePredictionin PavementLayers Using LSTM Neural Networks," Geotechnical and Geological Engineering, vol. 43, p. 318, 2025, doi: 10.1007/s10706-025 03293-x.
21. M. Saki et al., "A Data-Driven Review of Remote Sensing-Based Data Fusion in Precision Agriculture From Foundational to Transformer-Based Techniques," IEEE Access, vol. 13, 2025, doi: 10.1109/ACCESS.2025.3610649.
22. N.N.C.Othaman,M.N.MdIsa,R.Hussin,S.M. M. S. Zakaria, and M. M. Isa, "IoT Based Soil Nutrient Sensing System for Agriculture Application," International Journal of Nanoelectronics and Materials, vol. 14 (Special Issue), pp. 279–288.
23. Holagundi,N.,Ashwathsetty,G.H.,&Basthikodi, M. (2022).Algorithm fuzzy scheduling for realtime jobs on multiprocessor systems. Indonesian Journal of Electrical Engineering and Computer Science,25(3), 1308-1319.
24. Nirmala, H., & Girijamma, H.A. (2022). Fllbhgats: Efficientload balancing and taskscheduling algorithmfor real-timemultiprocessor.JournalofAlgebraic Statistics, 13(3), 433-450.