IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Smart Agriculture with Integration of IoT, Renewable Energy and Big Data for Efficient Resource Utilization

Kalaiselvi N (Author)
Information technology
Sri Manakula Vinayagar Engineering College Pondicherry, India

Vijayabaskaran PS (Co-Author)
Tata Consultancy Services London, United Kingdom

Mosikeeran T (Co-Author)
Information technology
Sri Manakula Vinayagar Engineering College Pondicherry, India

Akash P (Co-Author)
Information technology
Sri Manakula Vinayagar Engineering College Pondicherry, India

Harinath P (Co-Author)
Information technology
Sri Manakula Vinayagar Engineering College Pondicherry, India

Rahul R (Co-Author)
Information technology
Sri Manakula Vinayagar Engineering College Pondicherry, India

I. ABSTRACT

Water is a critical resource, and its sustainable management is essential to meet the growing demands of agriculture while preserving the environment. This study explores the integration of smart water metering, autonomous irrigation, renewable energy, and big data analytics to enhance agricultural productivity and conserve resources. A cloud-based Internet of Things (IoT) framework enables real-time monitoring, recording, and analysis of water consumption, water table levels, temperature, humidity, soil moisture, and light sensor data. Big Data Analytics to harness real-time data from sensors monitoring temperature, humidity, soil moisture, and light intensity. By processing and analysing vast datasets, the system derives actionable insights to optimize irrigation schedules, energy consumption, and crop management strategies. The Big Data platform enables predictive modelling and trend analysis, improving longterm planning and resource allocation. Smart water metering ensures precise and efficient water distribution, delivering water only where and when needed. Renewable energy sources, such as solar and wind power, reduce dependence on fossil fuels, making agriculture more energy-efficient and eco-friendly. Autonomous irrigation systems, powered by real-time data, enhance crop quality, productivity, and soil health while mitigating issues such as waterlogging and over-irrigation. Additionally, RFID technology enables seamless replication of the system across lands with similar crop and soil conditions, ensuring scalability and operational consistency. This comprehensive solution safeguards aquifers, maintains the water table, and addresses critical environmental challenges. By integrating these advanced technologies, the study provides a sustainable, scalable framework to balance agricultural productivity with environmental conservation, paving the way for resilient farming systems.

Keywords-Smart Water Metering; Renewable Energy Integration; Water-table Conservation; Energy efficient Agriculture; Soil Health;

II. INTRODUCTION

Water is the foundation of life on Soil and plays a fundamental portion in keeping up organic frameworks and human works out. Individuals depend a allocate on water for a divide of things. With creating populaces and growing provincial demands, beneficial water organization has gotten to be more basic. The screen characteristic factors, such as soil moistness, temperature, and climate, at honest to goodness time, makes Farther Sensor Frameworks, or WSNs, another significant advancement to help in this effort. Th is enables farmers to form taught choices around water system and resource utilization. There's a pressing require for cost-effective and prudent data obtainment systems that facilitated renewable essentialness and progressed Information and Communication Advancements. Resource deficiency and climate change pose significant challenges, which can be addressed by transforming agrarian productivity and improving water viability. In order to help achieve this goal, we developed practical sensors and actuators based on nano-Arduinos, which had minimal taken a toll without compromising performance. Real-time checking and control is feasible much appreciated to the related devices. With this innovative technique, farmers will be able to control their ranges remotely, reduce water waste, and move toward more feasible sharpens.

A. Research Problem

Conventional agrarian frameworks confront a few challenges, counting wasteful water administration, tall vitality utilization, and destitute versatility to shifting natural conditions. Routine water system hones regularly lead to water wastage, soil debasement, and expanded reliance on fossil fills, compounding climate alter concerns. Besides, ranchers need real-time checking and data-driven decision-making instruments, constraining their capacity to optimize asset allotment viably.

B. Research Objectives

This think about points to address the over challenges by creating an IoT-based keen agribusiness system that coordinating renewable vitality sources and huge information analytics. The key targets are:

1. To create a cloud-based IoT framework for real-time observing of soil dampness, temperature, mugginess, and water table levels.
2. To actualize shrewdly water system frameworks that optimize water utilization based on real-time sensor information and prescient analytics.
3. To coordinated renewable vitality sources such as sun powered and wind control for energy-efficient water system and asset administration.
4. To upgrade decision-making through huge information analytics, empowering prescient modeling for effective water and vitality conveyance.
5. To supply observational approval by comparing the proposed framework with ordinary agrarian hones in terms of water proficiency, edit surrender, and vitality investment funds.

C. Research Hypothesis

The speculation of this inquire about is: The integration of IoT, renewable vitality, and enormous information analytics in agribusiness will result in made strides water preservation, diminished vitality utilization, and improved trim efficiency compared to ordinary cultivating strategies.

D. Significance of the Study

This inquire about contributes to maintainable horticulture by creating a versatile and cost-effective keen cultivating framework. By leveraging real-time information, robotization, and renewable vitality, the think about presents a system that adjusts with worldwide endeavors toward resource-efficient and climate-resilient farming.

III. LITERATURE REVIEW

The integration of IoT, renewable vitality, and huge information analytics in agribusiness has picked up critical consideration in later a long time. Different thinks about have investigated how shrewd innovations can improve water preservation, move forward vitality proficiency, and optimize edit administration. This segment basically looks at earlier inquire about, distinguishes crevices, and positions the current think about inside the broader field of feasible farming.

A. IoT and Wireless Sensor Networks in Agriculture

Remote Sensor Systems (WSNs) play a significant part in checking natural parameters such as soil dampness, temperature, and mugginess in genuine time. Ponders by Khan et al. (2018) and Tangle et al. (2020) highlight how WSNs can progress water system planning and edit wellbeing administration. Be that as it may, these thinks about need large-scale arrangement approval and integration with prescient analytics for decision-making. Later headways in AI-powered IoT frameworks have empowered real-time information preparing and mechanized asset administration. Farooq et al. (2022) illustrated an IoT-based choice back framework (DSS) for optimizing water system plans. Whereas promising, this investigate does not completely coordinated renewable vitality sources to decrease the natural affect of agrarian operations.

B. Smart Water Metering and Water-Table Management

Shrewd water metering has risen as a practical arrangement for productive water conveyance and preservation. Qazi et al. (2022) investigated cloud-based IoT arrangements for water metering, giving real-time bits of knowledge into water utilization. Be that as it may, the consider does not address how keen metering can be combined with renewable vitality to attain energy-efficient water system. A basic challenge in existing savvy metering arrangements is information exactness and misfortune discovery. Ponders propose that joining AI-driven inconsistency location can essentially make strides the adequacy of water preservation models. This ponder points to bridge this crevice by joining AI-based prescient analytics into the water metering framework.

C. Automatic Irrigation Systems

Programmed water system frameworks utilize sensor information to analyze trim water needs and trigger water system occasions in like manner. Inquire about by Nalwade and Mote (2022) highlights the potential of hydroponics and aeroponics as water- efficient procedures. Whereas these strategies appear guarantee, they require tall starting speculation costs and need adaptability for conventional cultivating applications.Later considers emphasize the require for machine learning-driven water system models. Tiusanen et al. (2020) presented AI-based water system planning, but their approach needs comparative benchmarking with conventional water system strategies. The current think about looks for to approve the viability of AI-powered water system through experimental case thinks about.

D. Renewable Energy Integration in Agriculture

The move toward renewable vitality in cultivating is basic for diminishing fossil fuel reliance. Investigate by Touati et al. (2022) investigated solar-powered water system frameworks, appearing critical vitality reserve funds. Be that as it may, the ponder does not address the affect of regular varieties on sun oriented vitality accessibility.A key impediment in existing renewable vitality investigate is the nonattendance of cross breed vitality arrangements. This ponder proposes an coordinates show that combines sun powered and wind vitality, guaranteeing ceaseless control supply for IoT-based agrarian operations.

E. Soil Health and Ecosystem Conservation

Soil wellbeing could be a principal calculate affecting long-term agrarian maintainability. Ponders by Li et al. (2022) appear that IoT-based soil checking frameworks can identify supplement insufficiencies and soil corruption in genuine time. In any case, most existing models need prescient capabilities to figure soil wellbeing patterns over amplified periods. By consolidating huge information analytics and AI-driven soil wellbeing forecast, this ponder points to create a more proactive approach to soil preservation.

F. Research Gaps and Contributions

Audit of existing writing highlights the taking after holes:

1. Constrained integration of IoT and renewable vitality – Most ponders center on IoT-based checking or renewable vitality but don't combine both for comprehensive asset administration.
2. Need of experimental approval – Few considers give quantitative benchmarks comparing keen agribusiness frameworks with conventional cultivating strategies.
3. Constrained prescient analytics – Existing thinks about center on real-time checking but need prescient models for water system planning, soil wellbeing estimating, and asset optimization.

To address these crevices, this consider contributes by:

- Creating a half breed renewable energy-powered IoT system for feasible horticulture.
- Applying machine learning for prescient water system planning and soil wellbeing examination.
- Giving experimental approval through comparative benchmarking with routine cultivating frameworks.

IV. EXISTING SYSTEM

A. State of the Present System

The current system makes use of one piece parcel farmland in fields that is using a cloud and IoT technology for monitoring and control. Although data can be garnered on environmental variables such as temperature and soil moisture, the existing system is rather rigid and unadaptable to handle any number of operations for multiple crops at a mass scale. Though there is so much progress, it still faces many scaling challenges for wider applications. Further building the system to handle more than one plot. It assists in handling AI and predictive analytics in more agile and resource-effective decision-making.

B. Limitations

1) The current model seems mainly tailored toward management within a single plot and crop type, making it cumbersome for farmers with many crop varieties. This limitation complicates efficient resource allocation to numerous plots, resulting in waste and less than optimal productivity. Farmers that grow crops at the same time might have difficulty optimizing irrigation and energy usage. Further development of the model could make it work at multiple plots or crop levels improving efficiency and resource management and improving overall farm productivity.

2) Resource Wasteful practices: Poor asset allocation across various fields often results in either over- or under-irrigation, resulting in waste or reduced abdicate. There are higher running costs and variable yields with regard to the plantation of crops due to inadequate oversight on larger farms. These will result in spent resources and an expectation of rewards. Taut control of water and energy use is achieved by using modern resource management systems. This increases the level of rural surrender, reduces wastage, and energizes sustainable farming practices.

3) The current model cannot scale effectively, making it inadequate for farmers to manage multiple farms. The design restricts the ability to expand operations across different plots. Resource mismanagement is caused by this limitation that prevents seamless integration with diverse farming needs. Enhancing the model to support scaling would enable broader application, improve resource allocation and benefit farmers with larger or more complex operations.

V. DRAWBACKS OF THE EXISTING SYSTEM

A. Inefficient Multiples Plot Monitoring

The device in place has been limited only to monitoring one plot of the land, posing enormous challenges in its application with respect to farms working on a multitude of different fields or various types of crop. This challenge bars green irrigation across various regions, thereby causing unbalanced water supply. As an end result, some plants may even acquire excess water whilst others will face shortages. This inefficiency not only wastes valuable resources but also decreases general crop productiveness. For enhancing agricultural output and sustainability, a machine that can cater for multiple plots is very important.

B. Resource Management Issues

The system, even though it uses renewable energy for irrigation, has no effective ways to maintain the usage and consumption of water and energy between the different crops or plots. So far, farmers have been using their resources in an inefficient way, particularly large-scale farms, which involve various needs. It gives some areas more resource consumption and others less with no accountability. These can cause higher operational costs and lower efficiency. There should be wiser regulation for better usage of resources, thus making the farm more productive.

C. Limited Capability of Decision-Making

Nowadays, most of the irrigation systems depend on heuristics to manage soil moisture control or very simple analog monitoring, but it doesn't incorporate any machine learning aspect of predicted yield. That prevents them from taking actions concerning immediate changes in environment and the actual needs of crops. As a consequence, irrigation scheduling may not become optimized, thereby water is inappropriately consumed and lower productivity is obtained Predictive models would be employed to make an accurate and fact-based irrigation activities. Such a development would further help us reap maximum productivity in minimum resource usage.

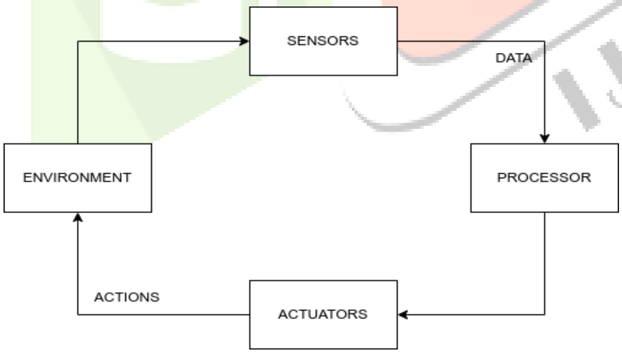

Fig. 1. General Architecture

VI. PROPOSED SYSTEM

A. System Architecture

The proposed framework coordinates remote sensors and actuators with a cloud-based IoT stage to screen different cultivate plots in real-time. The sensors capture natural information such as soil dampness, temperature, and mugginess, whereas actuators oversee water system and other rural exercises. This framework is outlined for adaptability, empowering ranchers to oversee numerous crops over diverse plots with moved forward effectiveness.

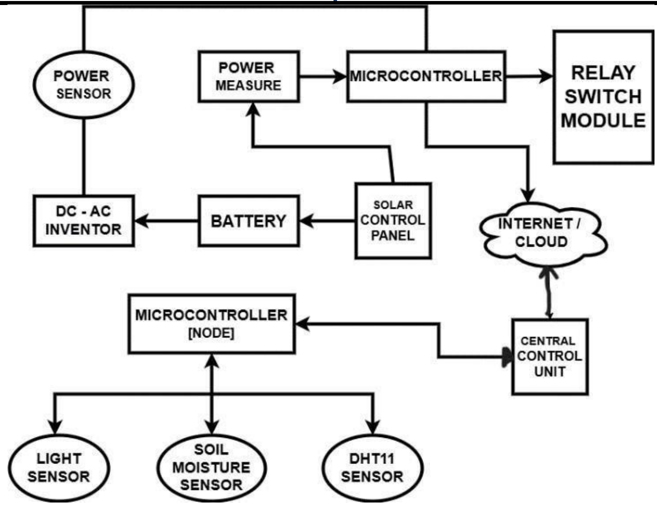

Fig. 2. System Architecture

B. Machine Learning for Resource Management

Real-time data collected from sensors is evaluated using a machine learning illustration. The appear wanders water framework requires agreement to information concerning soil moistness, climate figures, and essentialness generation. With regards to particular alter needs, the system optimizes the use of resources like water and imperativeness. By using its prescient features, the illustration helps prevalent choice making, which builds alter resign.

C. Methods and Methodology

This segment diagrams the inquire about strategy, information sources, computational models, and approval procedures utilized to create the proposed IoT-based savvy horticulture system. The technique guarantees reproducibility, adaptability, and experimental approval of the system's viability in water preservation, vitality productivity, and trim administration.

The consider takes after an test inquire about plan, joining IoT sensors, renewable vitality sources, and machine learning models to optimize water system and vitality utilization. The technique comprises of the taking after key stages Information Collection – Sensor arrangement for real-time natural observing Computational Show Improvement – AI-driven investigation for water system planning and asset administration Framework Usage – Cloud-based IoT engineering for inaccessible observing and computerization Approval and Comparative Examination – Benchmarking with customary cultivating strategies.

D. Data Sources and Collection Methods

The framework accumulates real-time natural information utilizing IoT sensors sent in rural areas, counting soil dampness sensors (capacitive & resistive) for measuring water substance, temperature and mugginess sensors (DHT11, DHT22) for following natural conditions, water stream meters for observing water system utilization and recognizing peculiarities, and light sensors (LDR, photodiodes) for surveying sun oriented introduction. Also, renewable vitality information is collected to degree sun based board yield and wind turbine proficiency. The collected sensor information is transmitted to a cloud-based IoT stage (Firebase, AWS, or Sky blue IoT Center), where it is handled utilizing enormous information analytics devices (Apache Start, Google BigQuery) to infer experiences. AI models at that point analyze designs within the information and prescribe ideal water system plans, guaranteeing effective asset utilization and maintainability.

E. Computational Models and Validation Techniques

To improve framework exactness and execution, the think about coordinating machine learning calculations for decision- making and prescient analytics. For shrewd water system, relapse models (direct & polynomial relapse) foresee soil dampness levels based on climate conditions, whereas Arbitrary Timberland & XGBoost optimize water system planning by analyzing verifiable information and real-time sensor inputs. Furthermore, LSTM neural systems estimate future soil dampness patterns to progress water administration. For renewable vitality optimization, sun based irradiance forecast (time-series examination) guarantees proficient vitality utilization for water system frameworks, whereas a cross breed vitality administration demonstrate powerfully switches between sun based and wind control based on accessibility. To approve framework viability, measurable strategies such as Root Cruel Square Blunder (RMSE) assess dampness level expectation exactness, Cruel Outright Rate Blunder (MAPE) measures vitality effectiveness in renewable vitality integration, and matched t-test investigation compares trim abdicate and water utilization between conventional and keen cultivating

Comparative Analysis with Existing Methods

To assess the performance of the proposed framework, a comparative study is conducted against conventional farming techniques.

Parameter	Traditional Farming	Proposed IoT-Based System
Water Usage Efficiency	Low (Manual Irrigation)	High (Automated Smart Irrigation)
Energy Consumption	High (Fossil Fuels)	Low (Renewable Energy)
Crop Yield Improvement	Unoptimized	Optimized with Data-Driven Insights
Monitoring & Control	Manual	Real-time, Remote IoT-based

F. Advantages of the Proposed System

1) The system's ability to collect and analyze data from various plots can make improvements in the control of water and energy use. This promotes better farming practices. Balanced irrigation and energy distribution can be ensured through monitoring of different plots. It supports long-term sustainable use of resources. Effective management reduces costs.

2) Improved Security: The system relies on cloud resources and maintains strict information processing standards that ensure that agriculture information is correctly stored and accessed only by registered users. This prevents unauthorized people from accessing or controlling information thereby protecting sensitive data. CBIT. Information Security and Encryption Information Security and Encryption Classes are key in understanding how to use encryption as a form of securing information.

3) Advantages of the New Wireless Sensors in Agriculture | Real-Time Processing | The integration of wireless sensors with cloud computing allows direct, real-time data collection and instant analysis via the internet, making it possible for farmers to respond quickly in terms of irrigation and energy consumption. Such real-time feedback helps farmers avoid over or underutilization of resources. This allows a farmer to actually respond quickly enough to changing environments, such that crop health and productivity is significantly improved. Improving decisions because of quicker information processing enhances agricultural efficiency, makes farming much sustainable, and generally increases agriculture competitiveness.

4) High Scalability and Flexibility: The framework is developed in a manner where it can support large-scale farming activities. Moreover, being open-source, it is easily customizable. It can be changed based on crop and farm size and is therefore used by small scale and large scale farmers.

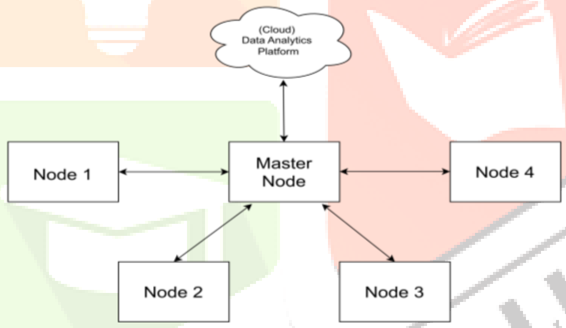

Fig. 3. Network Architecture

VII. CONCLUSION

This proposed system offers a practical, low-cost solution to enhance agricultural routines through the continuous gathering and advanced interpretation of data. The use of IoT, smart water metering, renewable energy, and automatic irrigation systems helps elevate water and energy efficiency, raises crop yields, and encourages sustainable farming. Also, the cloud-based IoT system delivers a solid and effective platform for tracking weather conditions, which meets particular agricultural needs. This opens the door to vast adoption of smart agriculture in deprived and arid regions, promote eco-friendly, resource-aware farming practices that can at the same time bridge the gap between resource exploitation and environmental conservation.

Future Work and Directions

Future research will focus on the following areas to further enhance the proposed system

1) Optimization of Sensor Networks: Map/Exploration of Sensor Networks: The type of sensors and the best places for their placement should come under the horizon of future research to probe if the data collected from the field plots is of good quality and accurate. You may enhance monitoring and optimize resource usage by strategically positioning sensors. Using specialized sensor layouts based on crop and environmental parameters can enhance performance. The adaptive sensor networks could pave the way to precise insights which could be the amenity for efficient harvesting/ agriculture. That leads to smarter farming and more efficient products.

2) Scalability of Cloud and IoT Integration: Our implementation of an IoT intelligent monitoring system is successful, but we believe that more research is needed to explore how to scale it up for large-scale farming. Such scenarios would still have potential bottlenecks in processing and transmitting data. More flexible cloud solutions would, therefore, solve the aforementioned challenges. A hybrid solution of both edge and cloud computing may be more effective. More work needs to be made to these approaches scalable.

3) Advanced Predictive Models: The authors also suggest that more advanced or hybrid machine learning algorithms could be incorporated to enhance the computational irrigation and resource forecast. Techniques such as deep learning and reinforcement learning (RL) are potential areas for further research. Such methods are also likely to improve comprehensive system performance under any agricultural conditions. Algorithmic diversity may optimize niche requirements and efficiency.

4) Farmer Access and Education: The interface could also be much more intuitive and guidance/information should be available in layman's terms for the farmers. Or upcoming applications should work off multilingual, user-friendly mobile applications. Farmers also need to be cognizant on high planned systems used. That will enable them to utilize the technology for the best results in their crop cycles.

5) Health and Renewable Energy Improvement: Sufficient energy can be generated from these sources to be used in homes and hospitals; this would be not only a technically challenging feat but a significant achievement for the hospitals because they have always relied on the grid. Future research should strive to improve energy storage methods and look to add new renewable resources, such as wind energy and biogas, to facilitate proper energy generation from them. Using this approach to run a power generation plant this way could keep the energy efficiency at the highest level and hence it will improve sustainability as well.

6) Real-field Testing and Implementation: Only in the real field of implementation and application would the efficiency of this proposed system be authenticated. The prescriptions given above can be made to undergo real-life testing by extension of collaborations with agricultural research institutes and large-scale farms.

REFERENCES

[1] K. Chatterjee and A. Singh, ''A blockchain-enabled security framework for smart agriculture,'' *Comput. Electr. Eng.*, vol. 106, Mar. 2023, Art. no. 108594.

[2] G. Kaur and M. Bhattacharya, ''Intelligent fault diagnosis for AIT-based smart farming applications,'' *IEEE Sensors J.*, vol. 23, no. 22, pp. 28261–28269, Nov. 2023.

[3] A. K. Koshariya, D. Kalaiyarasi, A. A. Jovith, T. Sivakami, D. S. Hasan, and S. Boopathi, ''AI-enabled IoT and WSN-integrated smart agriculture system,'' *Artificial Intelligence Tools and Technologies for Smart Farming and Agriculture Practices*, Hershey, PA, USA: IGI Global, 2023, pp. 200–218.

[4] M. M. Hossain et al., ''Smart-agri: A smart agricultural management with IoT-ML-blockchain integrated framework,'' *Int. J. Adv. Comput. Sci. Appl.*, vol. 14, no. 7, pp. 1–12, 2023.

[5] T. Alahmad, M. Neményi, and A. Nyéki, ''Applying IoT sensors and big data to improve precision crop production: A review,'' *Agronomy*, vol. 13, no. 10, p. 2603, Oct. 2023.

[6] R. Sitharthan et al., ''A novel autonomous irrigation system for smart agriculture using AI and 6G-enabled IoT network,'' *Microprocessors Microsyst.*, vol. 101, Sep. 2023, Art. no. 104905.

[7] Et-Taibi Bouali et al., "Renewable Energy Integration Into Cloud & IoT-Based Smart Agriculture," *IEEE Access*, vol. 10, pp. 1–10, Jan. 2022, doi: 10.1109/ACCESS.2021.3138160.

[8] A. Din et al., ''A deep reinforcement learning-based multi-agent area coverage control for smart agriculture,'' *Comput. Electr. Eng.*, vol. 101, Jul. 2022, Art. no. 108089.

[9] G. Valecce et al., "NB-IoT for smart agriculture: Experiments from the field," in *Proc. 7th Int. Conf. Control, Decis. Inf. Technol. (CoDIT)*, vol. 1, 2022, pp. 71–75.

[10] Node Red User Guide. Accessed: Jun. 29, 2021. [Online]. Available: https://nodered.org/docs/user-guide/.

[11] *B. Et-taibi et al., ''Smart agriculture as a cyber-physical system: A real-world deployment,'' in Proc. 4th Int. Conf. Intell. Comput. Data Sci. (ICDS), Oct. 2020, pp. 1–7, doi:10.1109/ICDS50568.2020.9268734.*

[12] *S. Sadowski and P. Spachos, ''Wireless technologies for smart agricultural monitoring using IoT devices with energy harvesting capabilities,'' Comput. Electron. Agricult., vol. 172, May 2020, Art. no. 105338, doi: 10.1016/j.compag.2020.105338.*

[13] *H. A. O. Zhang, "IoT-based precision irrigation with LoRaWAN technology applied to high tunnel vegetable production," in Proc. ASABE Annu. Int. Virtual Meeting, 2020, p. 1.*

[14] *Food and Agricultural Organization of the United Nations. AQUASTAT—FAO's Global Information System on Water and Agriculture. Accessed: Nov. 13, 2020. [Online]. Available: http://www.fao.org/aquastat/en/overview/methodology/water-use*

[15] *B. Et-taibi, M. R. Abid, I. Boumhidi, and D. Benhaddou, ''Smart agriculture as a cyber-physical system: A real-world deployment,'' in Proc. 4th Int. Conf. Intell. Comput. Data Sci. (ICDS), Oct. 2020, pp. 1–7, doi:10.1109/ICDS50568.2020.9268734.*

[16] *Z. X. A. O. Yuan, "Irrigation* remote control system based on LoRa intelligence," in *Proc. J. Phys. Conf. Series*, 2020, Art. no. 12067.

[17]M. Emharraf et al., "Intelligent agriculture platform based on low energy and wireless sensors for efficient water irrigation," in *Proc. Int. Conf. Smart Inf. Commun. Technol.*, 2019, pp. 460–469.

[18]I. Mat et al., ''Smart agriculture using IoT,'' in *Proc. IEEE Conf. Open Syst. (ICOS)*, Apr. 2018, pp. 54–59, doi: 10.1109/ICOS.2018.8632817.

[19]E. J. Yafuso and P. R. Fisher, ''Oxygenation of irrigation water during propagation and container production of bedding plants,'' *HortScience*, vol. 52, no. 11, pp. 1608–1614, 2017, doi: 10.21273/HORTSCI12181-17.

[20]K. L. Krishna et al., "IoT application for implementation of a smart agriculture system," in *Proc. Int. Conf. I-SMAC (IoT Social, Mobile, Analytics Cloud) (ISMAC)*, 2017, pp. 54–59.

[21]W. Zhao et al., "Design and implementation of smart irrigation system based on LoRa," in *Proc. IEEE Globecom Workshops*, 2017, pp. 1–6.

[22]P. P. Ray, ''Internet of Things for smart agriculture: Technologies, practices, and future direction,'' *J. Ambient Intell. Smart Environ.*, vol. 9, no. 4, pp. 395–420, Jun. 2017, doi: 10.3233/AIS-170440.

[23]S. Rodríguez, T. Gualotuña, and C. Grilo, ''A system for monitoring and predicting data in precision agriculture in a rose greenhouse based on wireless sensor networks,'' *Procedia Comput. Sci.*, vol. 121, pp. 306–313, Dec. 2017.

[24]A. A. Babayo, M. H. Anisi, and I. Ali, ''A review on energy management schemes in energy harvesting wireless sensor networks,'' *Renew. Sustain. Energy Rev.*, vol. 76, pp. 1176–1184, Sep. 2017.

[25]H. M. Jawad et al., ''Energy-efficient wireless sensor networks for precision agriculture: A review,'' *Sensors*, vol. 17, no. 8, p. 1781, Aug. 2017, doi: 10.3390/s17081781.

[26]M. Jutila, ''An adaptive edge router enabling IoT,'' *IEEE Internet Things J.*, vol. 3, no. 6, pp. 1061–1069, Dec. 2016, doi: 10.1109/JIOT.2016.2550561.

[27]S. P. Singh and S. C. Sharma, ''A survey on cluster-based routing protocols in wireless sensor networks,'' *Procedia Comput. Sci.*, vol. 45, pp. 687–695, Jan. 2015.

[28]M. A. Mahmood et al., ''Reliability in wireless sensor networks: A survey and challenges ahead,'' *Comput. Netw.*, vol. 79, pp. 166–187, Mar. 2015.

[29]F. Touati et al., ''A fuzzy logic-based irrigation management system in arid regions applied to the state of Qatar,'' *WIT Trans. Ecol. Environ.*, vol. 168, no. Nov., pp. 189–199, 2012, doi: 10.2495/SI120161.

[30]M. Dursun and S. Ozden, ''A wireless application of drip irrigation automation supported by soil moisture sensors,'' *Sci. Res. Essays*, vol. 6, no. 7, pp. 1573–1582, 2011.

[31]N. Kotamäki et al., ''Wireless in-situ sensor network for agriculture and water monitoring on a river basin scale in Southern Finland: Evaluation from a data user's perspective,'' *Sensors*, vol. 9, no. 4, pp. 2862–2883, 2009.

[32]A. Pardossi et al., ''Root zone sensors for irrigation management in agriculture,'' *Sensors*, vol. 9, no. 4, pp. 2809–2835, 2009.