International Journal of Electrical and Computer Engineering (IJECE)
Vol. 15, No. 1, February 2025, pp. 1123~1131
ISSN: 2088-8708, DOI: 10.11591/ijece.v15i1.pp1123-1131

Context-aware self-powered intelligent soil monitoring system for precise agriculture

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Article Info

Article history:

Received Jul 17, 2024
Revised Aug 20, 2024
Accepted Sep 3, 2024

Keywords:

Context-aware
Internet of things
Self-powered
Smart farming
Soil monitoring

ABSTRACT

The agricultural sector is transforming with advanced technologies such as internet of things (IoT), cloud computing, and machine learning, for increased productivity and sustainability. However, fixed sensor deployments struggle to capture the dynamic and heterogeneous soil properties with irregularities in farming operations, and negatively impacting crop performance and resource utilization. This paper presents a novel context-aware, self-powered intelligent soil monitoring system (ISMS) applied in precision agriculture. By integrating advanced sensors, energy harvesting, real-time data analytics, and context-aware decision support, ISMS provides real-time context insights into soil, energy, and weather conditions. The informed decisions are enabled and tailored to their specific agricultural environment. The system utilizes a multi-parameter soil sensor, photovoltaic (PV) panel, and intelligent context-aware analytics for a sustainable, cost-effective solution powered by solar energy and OpenWeather application program interface (API) for weather data. Field tests over two months demonstrated the system's effectiveness, together with continuous operation without grid power. This research highlights ISMS's potential in enhancing soil nutrient management and decision-making and offering significant economic and environmental benefits for modern agriculture, especially in remote areas.

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1. INTRODUCTION

The agricultural sector contributes significantly to food security and economic stability. As the global population continues to grow rapidly, the demand for food security has put pressure on limited resources and raised significant environmental concerns [1]–[3]. Conventional agricultural methods encounter numerous challenges, namely labor-intensive, time-consuming [4], insufficient information on soil parameters and environmental conditions, as well as resource constraints such as water and energy shortages. Consequently, it leads to environmental degradation due to excessive and inefficient use of water resources and fertilizer and is further exacerbated by climate and soil variations [5].

It is expected that the world population will exceed 9 billion by 2050. Therefore, agricultural sustainability is urgently needed in terms of enhanced efficiency and productivity to satisfy growing demand. More specifically, agriculture in developing countries faces numerous challenges in farming operations such as nutrient deficiencies, pH and humidity imbalance, and water scarcity [6]. Among these challenges, soil pH variations can have a long-term effect on yield and quality [7]. Furthermore, a lack of formal understanding of soil nutrient composition leads to over-reliance on fertilizers, resulting in reduced crop yields and environmental contamination.

To achieve optimal crop growth, a precise balance of soil nutrients and favorable climate conditions are required [8]. Numerous advanced technologies such as the internet of things (IoT), cloud computing, and machine learning have enhanced agricultural productivity, minimized resource wastage, and refined decision-making processes. Indeed, smart farming, or precision agriculture, employs these innovative technologies to optimize farming operations while conserving water, fertilizer, and energy resources [9], [10]. Among the efforts, IoT-based soil monitoring systems have recently gained significant attention. These systems use various sensors for soil conditions and environmental data in real-time [11]–[16]. The acquired data are then uploaded to a central hub for storage and analysis. For instance, studies [17]–[19] have shown the effectiveness of IoT systems with soil moisture and nutrient sensors in real-time soil monitoring, optimizing irrigation schedules, and improving fertilizer applications. However, fixed sensor deployments are limited in capturing soil properties' dynamic and heterogeneous nature across different locations and timeframes. The irregularities in farming operations negatively impact crop performance and resource utilization [20], [21].

To address these limitations, a context-aware self-powered intelligent soil monitoring system (ISMS) is proposed to provide real-time, accurate soil nutrient data and customized recommendations based on current environmental conditions, including soil, energy, and weather data [22]. Context-aware systems can adapt to environmental conditions, increasing the precision and actionability of insights for irrigation, fertilization, and crop management [23]. This research is motivated by the urgent need to improve agricultural practices and reduce the impact of climate and soil variability on crop production. Integrating self-powered and context-aware features in sensing technologies offers a sustainable solution for remote and off-grid monitoring by harnessing solar energy for continuous operation without battery replacements [24], [25].

2. IOT 3-LAYERED ARCHITECTURE

The proposed ISMS model adopts an IoT 3-layered architecture comprising a physical layer, an edge and communication layer, and a cloud computing layer [26], [27]. The system integration is accomplished by using hypertext transfer protocol (HTTP) and application program interface (API) to facilitate real-time monitoring and visualization of soil quality parameters, weather conditions, and battery charging and discharging status. Figure 1 depicts the block diagram for the context-aware solar-powered ISMS.

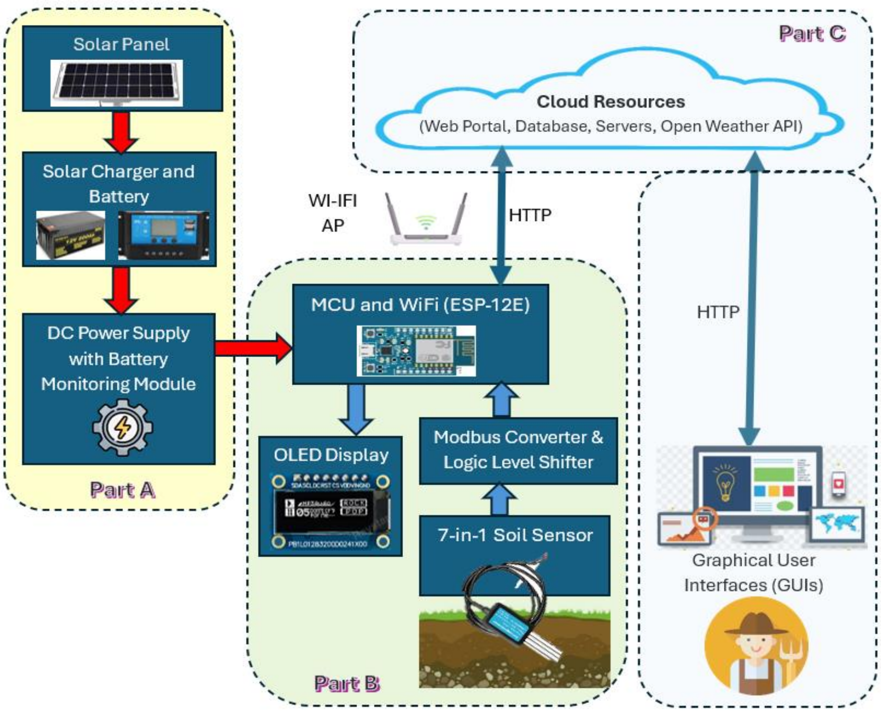


Figure 1. Block diagram of context-aware solar-powered ISMS

ISMS consists of three components: i) regenerative power module, ii) core component module, and iii) cloud computing resources and graphical user interfaces (GUIs). The regenerative power module is a solar-powered direct current (DC) electricity source without connecting to the main grid electricity supply. More specifically, it consists of a solar panel, an 18,650 lithium-ion battery, and power converters that provide constant DC voltages of +5 and +3.3 V. Furthermore, a battery management circuit facilitates real-time monitoring and managing of the battery charging and discharging status. The ease-of-installation design makes it suitable for remote farming that is far from electricity accessibility. Moreover, it provides continuous 24/7 operation by utilizing solar energy and stored battery power rather than relying on fossil fuel-generated power from the main grid.

The core component module is the primary component, which includes an ESP-12E microcontroller unit (MCU) with a built-in Wi-Fi shield, an input data acquisition board, and an output organic light emitting diode (OLED) display. The ESP-12E provides robust computational power and Wi-Fi capabilities, while the JXBS-3001 soil sensor acquires soil quality parameters displayed on the OLED display. As a result, the acquired data is uploaded to the cloud for storage and analysis using common internet transfer protocols such as HTTP. GUIs consist of a web portal, servers, and third-party cloud weather data. Farmers can access them using web browsers or mobile apps. In addition, machine learning algorithms are integrated to optimize fertilizer and irrigation schedules based on soil parameters and open weather data, as well as to predict crop outcomes and provide recommendations.

3. METHOD

3.1. Regenerative power module

The ISMS can be sustainably powered by the regenerative power module, which essentially consists of solar-charged 18,650 batteries based on lithium-ion. The module comprises several key components: a solar photovoltaic (PV) panel, a TP4056-based battery charging module, 18,650 lithium-ion battery cells, a boost converter, and a battery monitoring circuit. The 10 W solar PV panel can generate 5 V DC at maximum capacity and charge an 18,650 lithium-ion battery bank at a capacity of 10,000 mAh. The setup allows the 18650-battery charging through the TP4056 battery charger module and produces a regulated 5 V DC output for onboard power supply by the boost converter module. On the other hand, the voltage regulator ICs (AMS1117) deliver both +3.3 and +5 V power supply to the ISMS core module.

In addition, it features a battery monitoring circuit to gauge the charging and discharging status of the 18,650-battery bank. The lithium-ion batteries exhibit a nominal of 3.7 V but reach a maximum voltage of 4.2 V with a tolerance of ±0.5 V when fully charged. Under direct sunlight, the solar panels yield an output ranging between 5 to 6 V. The TP4056 battery charger module facilitates the charging process and prevents overcharging. Upon reaching full charge, the lithium battery outputs 4.2 V. Figure 2 depicts the block diagram of the regenerative power module.

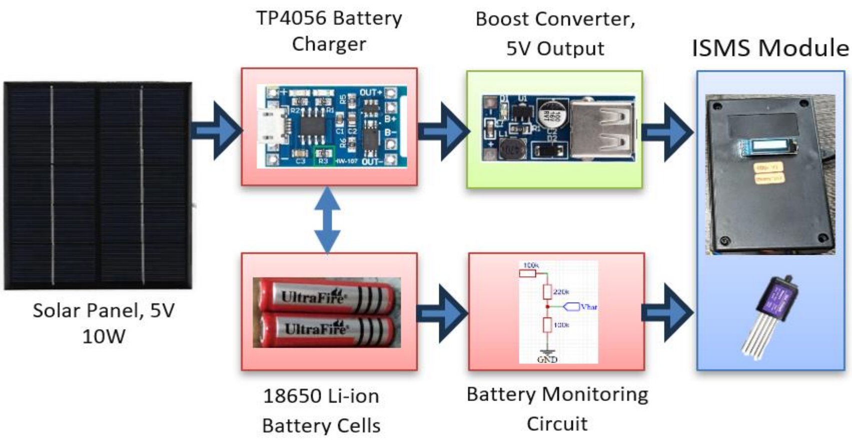


Figure 2. The block diagram of regenerative power module

3.2. JXBS-3001 7-in-1 soil sensor and Modbus interface module

JXBS-3001 sensor is specifically designed for advanced monitoring and measurement of soil parameters. The sensor offers accurate, real-time measurements of soil nitrogen, phosphorus, potassium (NPK) and other soil parameters, which are essential for assessing soil health, nutrient levels, and overall soil conditions. Known for its robust construction, high sensitivity, reliable performance, quick response, and excellent interchange capabilities, the JXBS-3001 sensor is considered a high-precision industrial calibrated agriculture sensor [28] To ensure smooth communication between the JXBS-3001 soil sensor and the ESP-12E MCU, an interfacing module for Modbus communication protocol is essential. It consists of two primary components: i) the RS485-to-TTL Modbus converter, and ii) the transistor-transistor logic (TTL) level shifter, illustrated in Figure 3.

The RS485-to-TTL Modbus converter converts the serial data between the Modbus RS485 and RS-232 standards. On the other hand, the TTL logic level shifter converts the 5 V TTL signal to the 3.3 V signal voltage level. The 3.3 V signal voltage is compatible with the ESP chipset (ESP-12E), facilitating wireless data transmission via Wi-Fi access point (AP) to the cloud platform. In this work, the Interfacing Module enables data communication between the master device (*i.e.*, ESP-12E MCU) and the slave device (*i.e.*, JXBS-3001 soil sensor). RS-485 serial data generated from the JXBS-3001 soil sensor is converted into standard RS-232 serial data, which is recognizable by the host ESP-12E MCU. The Modbus communication setup acquired the relevant measured soil parameters from the JXBS-3001 soil sensor, namely humidity, temperate, pH, conductivity and NPK parameters. The measurement accuracy of the JXBS-3001 sensor is tabulated in Table 1.

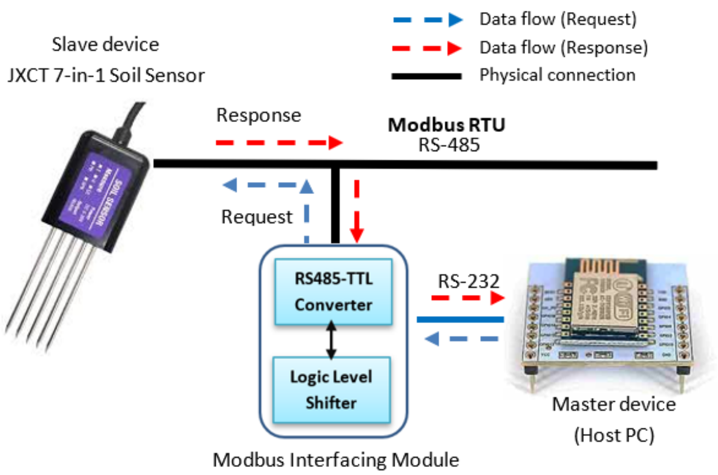


Figure 3. Interfacing module for Modbus RS485 communication protocol

Table 1. Measurement parameters (model JXBS-3001) [28]

Parameter	Range	Accuracy (Error)	Resolution
Moisture	0-100 %	3%	0.1 %
Temperature	-40~80 ℃	±0.5 ℃ (25 ℃)	0.1 ℃
EC	0~20000 us/cm	±3% F.S	10 us/cm
PH	3~9 pH	±0.3 pH	0.1 pH
Nitrogen	1~1999 mg/kg (mg/L)	2% F.S	1 mg/kg (mg/L)
Phosphorus	1~1999 mg/kg (mg/L)	2% F.S	1 mg/kg (mg/L)
Potassium	1~1999 mg/kg (mg/L)	2% F.S	1 mg/kg (mg/L)

3.3. Web-based ISMS portal

The web-based ISMS portal plays a crucial role in the overall functionality of the ISMS system. It serves as a foundation pillar, offering a comprehensive suite of tools for data storage, information retrieval, weather forecasting, remote controlling of irrigation, data trending and visualization. The portal is constructed using hypertext preprocessor (PHP), MySQL database, and incorporates APIs that serve as a communication interface between ISMS and the backend and third-party cloud servers such as open weather and Microsoft Azure. Upon accessing the web-based ISMS portal, the authorized user login to the main menu which serves as an informative gateway and overview of the system's functionality, such as administration of user and site information, holistic viewing of current site information, data analysis, weather forecasting, remote control and automation of farming operations, as depicted in Figure 4.

To acquire the weather information, the portal initiates API calls to the OpenWeather cloud server according to the geographical coordinates of the farming site, such as latitude, longitude, count of future days, and the API key of the connection. The response from this API request comes in JavaScript Object Notation (JSON) format with the values of temperature, precipitation, wind speed, humidity, and many others which were then extracted, stored and interpreted. The weather information acts as complementary data for intelligent soil monitoring system to optimize smart farming operations such as irrigation scheduling, alerting and farming recommendations.

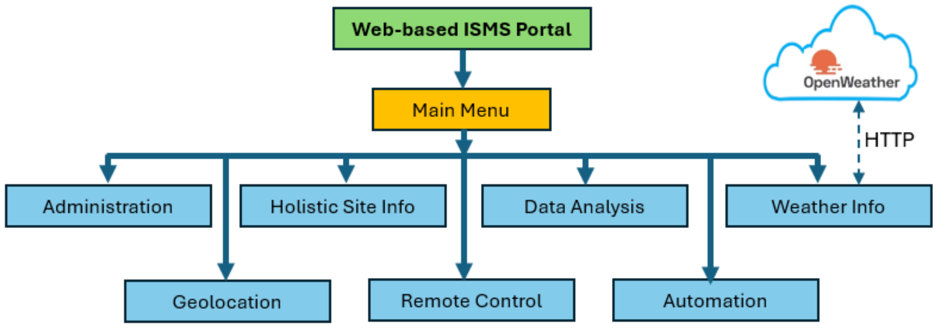


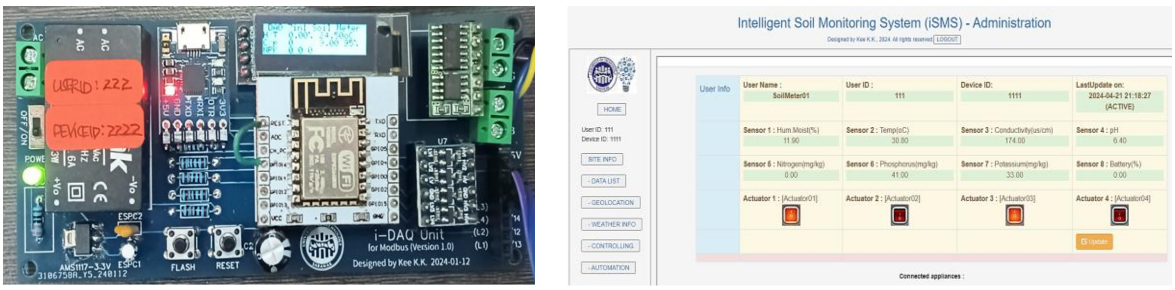
Figure 4. Web-based ISMS portal structure

4. RESULTS AND DISCUSSION

In this section, the outcomes achieved in the study are explained. This includes a web-based portal, battery charging and discharging profile, runtime duration study, and validation of ISMS deployment. Figure 5(a) shows the complete hardware prototype for the proposed ISMS system. The system acquires and updates the monitored data at 5-minute intervals. Both data on soil conditions and battery charging status are uploaded to the ISMS web-based portal. Users can access information using any web browser.

4.1. Web-based ISMS portal

The web-based ISMS Portal is designed using a simplified IoT model. It includes scripts in PHP, hypertext markup language (HTML), and APIs hosted on cloud computing machines for scalable storage and computing resources. The ISMS unit connects the physical site to the cloud web portal by acquiring, streamlining, and uploading data for storage and analysis. Several modules are available, including current data overview, historical data analysis, OpenWeather API and remote control and automation of actuators for irrigation and fertilizer schedules. Figure 5(b) depicts a holistic view of ISMS data on the web portal.



(a) (b)

Figure 5. System deployment of ISMS: (a) prototype of ISMS system and (b) holistic view of ISMS data on the web portal

4.2. Battery charging and discharging profile

The regenerative power module has been experimentally tested for its charging and discharge capabilities. The input voltage from the DC converter is 5 V. The charger starts charging the 18,650 lithium-ion battery when its voltage drops below 2.8 V. A study was conducted to theoretically and experimentally analyze the battery operation (ISMS runtime). A 10,000 mAh 18,650 lithium-ion battery stores up to 37.0 Wh of energy (*i.e.*, 10.0 Ah×3.7 V). The ISMS unit consumes an average of 0.51 A at 5.0 V, equating to

2.55 W of power consumption. The run-time duration is calculated using (1). Thus, theoretically, it takes 14.51 hours to drain the battery fully.

$$Device\ runtime = \frac{Battery\ Capacity\ (Wh)}{Device\ Power\ Rating\ (W)} \tag{1}$$

This runtime duration was verified through a field experiment of battery discharging during the absence of solar energy. A fully charged 18,650 lithium-ion battery bank was connected to the ISMS module at 6:00 pm on May 13, 2024, and discharged until 8:15 am the next day, as shown in Figure 6, confirming a runtime of 14:15 hours or 2.48% in variation. Based on the field experiment result, a 10,000 mAh 18,650 lithium-ion battery is capable of achieving the self-powered and sustainable design of ISMS. During the daytime period, the ISMS is powered by solar PV and 18,650 lithium-ion battery banks are fully charged. During the nighttime, the energy from the 18,650-battery bank is used to power up the ISMS module, achieving 24/7 runtime operation without using a power supply from the main grid.

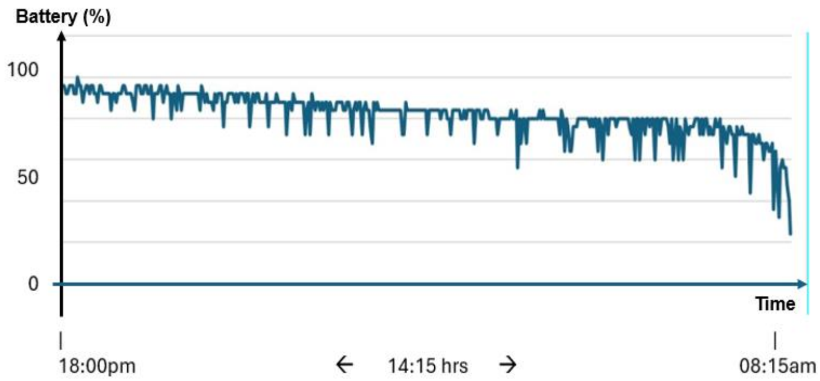


Figure 6. Discharging pattern and battery remaining in percentage (%)

4.3. Validation results from the selected site for system deployment

Validation results were obtained from several designated sites following the deployment of the ISMS to assess its functionality and efficiency in smart farming operations. One of these sites was situated along Jalan Teku in the Sibu district of Sarawak, Malaysia. It was a pineapple farm covering an area of 100.0×50.0 m as the experiment plot, as depicted in Figure 7(a).

The ISMS unit was housed within an IP65 enclosure measuring 15.0×15.0×10.0 cm. All electronic components were accommodated within this enclosure, excluding the soil moisture sensor and solar PV panels. Additionally, a hole was drilled in the enclosure to facilitate the passage of wires connected to the soil moisture sensor and solar panels. The IP65 enclosure was then affixed to a polyvinyl chloride (PVC) pipe. The assembled ISMS system, integrated within a plant box, is illustrated in Figures 7(b) and 7(c). The results from the web-based ISMS portal are depicted in Figure 8.

(a) (b) (c)

Figure 7. Deployed site location of ISMS for validation (a) site location, (b) system deployment, and (c) placement of sensor

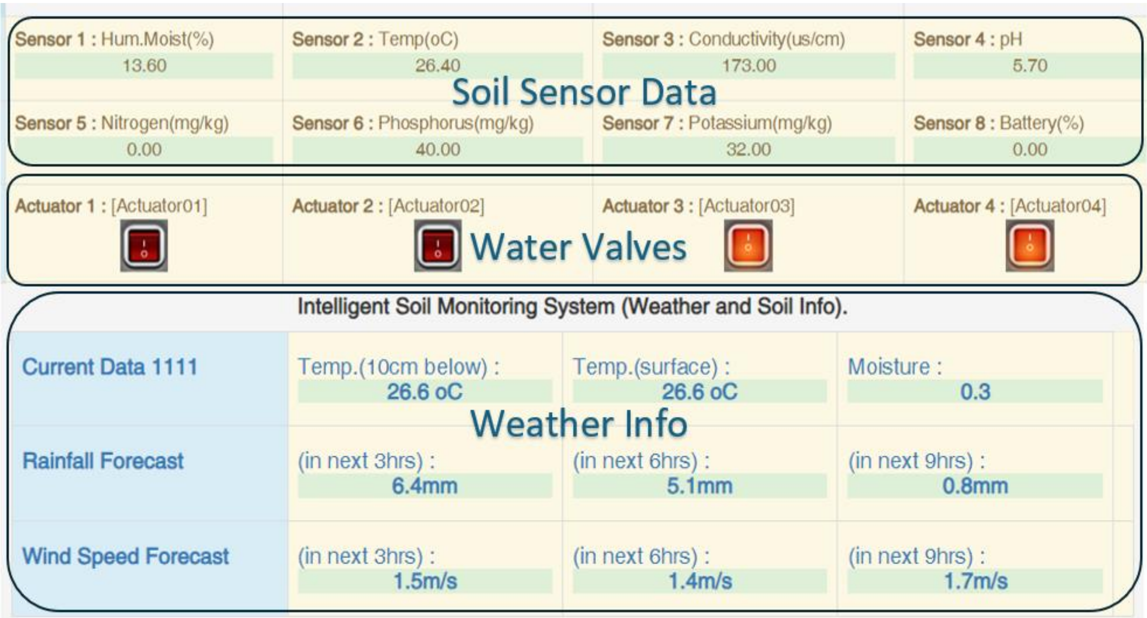


Figure 8. Field collected soil information with open weather data

5. CONCLUSION

This study introduces the context-aware self-powered ISMS, leveraging advanced technologies for modern agriculture. ISMS offers precise soil management by integrating sensors, energy harvesting, real-time analytics, and context-aware decision support. Field tests confirm ISMS's efficiency, sustainability, and cost-effectiveness, with 24/7 continuous runtime operation independent of grid power. However, several limitations such as internet dependency, data security and privacy issues, need to be addressed. Furthermore, future research aims to enhance scalability and usability, integrating machine learning, satellite imagery, and weather data for comprehensive insights.

ACKNOWLEDGEMENTS

This work is fully funded by the University of Technology Sarawak Research Grant (Project ID: $UTS/RESEARCH/< 3/20s23/07 > (01)$) of the University of Technology Sarawak. The authors would like to thank the Centre of Research and Development (CRD) of UTS for its support. Special thanks to Zinpine Farm Sdn. Bhd. and Mr. Siaw Ai Kin for supporting this project.

REFERENCES

[1] V. P. Kour and S. Arora, "Recent developments of the internet of things in agriculture: a survey," *IEEE Access*, vol. 8, pp. 129924–129957, 2020, doi: 10.1109/ACCESS.2020.3009298.
[2] A. Chehri, H. Chaibi, R. Saadane, N. Hakem, and M. Wahbi, "A framework of optimizing the deployment of IoT for precision agriculture industry," *Procedia Computer Science*, vol. 176, pp. 2414–2422, 2020, doi: 10.1016/j.procs.2020.09.312.
[3] G. S. Malhi, M. Kaur, and P. Kaushik, "Impact of climate change on agriculture and its mitigation strategies: a review," *Sustainability (Switzerland)*, vol. 13, no. 3, pp. 1–21, 2021, doi: 10.3390/su13031318.
[4] T. Paepae, P. N. Bokoro, and K. Kyamakya, "From fully physical to virtual sensing for water quality assessment: A comprehensive review of the relevant state-of-the-art," *Sensors*, vol. 21, no. 21, 2021, doi: 10.3390/s21216971.
[5] L. Delgado and J. J. Stoorvogel, "Role of soil perception and soil variability by smallholder farmers in the low adoption rates of extension packages in Central America," *Journal of Rural Studies*, vol. 93, pp. 92–103, 2022, doi: 10.1016/j.jrurstud.2022.05.009.
[6] M. Dhanaraju, P. Chenniappan, K. Ramalingam, S. Pazhanivelan, and R. Kaliaperumal, "Smart farming: internet of things (IoT)-based sustainable agriculture," *Agriculture*, vol. 12, no. 10, Oct. 2022, doi: 10.3390/agriculture12101745.
[7] A. H. Gondal, Q. Farooq, I. Hussain, and M. D. Toor, "Role of microbes in plant growth and food preservation," *Agrinula: Jurnal Agroteknologi dan Perkebunan*, vol. 4, no. 2, pp. 106–121, 2021, doi: 10.36490/agri.v4i2.158.
[8] FAO, *Soils for nutrition: state of the art*. Rome: Food and Agriculture Organization of the United Nations, 2022.
[9] M. Kuradusenge *et al.*, "Crop yield prediction using machine learning models: case of Irish potato and maize," *Agriculture (Switzerland)*, vol. 13, no. 1, p. 225, 2023, doi: 10.3390/agriculture13010225.
[10] V. K. Quy *et al.*, "IoT-enabled smart agriculture: architecture, applications, and challenges," *Applied Sciences (Switzerland)*, vol. 12, no. 7, 2022, doi: 10.3390/app12073396.
[11] N. Ananthi, J. Divya, M. Divya, and V. Janani, "IoT based smart soil monitoring system for agricultural production," *Proceedings - 2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development, TIAR 2017*, vol. 2018-Janua, pp. 209–214, 2017, doi: 10.1109/TIAR.2017.8273717.

[12] G. B. Loganathan, E. Mohan, and R. S. Kumar, "IoT based water and soil quality monitoring system," *International Journal of Mechanical Engineering and Technology*, vol. 10, no. 2, pp. 537–541, 2019.
[13] S. V Gaikwad, A. D. Vibhute, K. V Kale, and S. C. Mehrotra, "An innovative IoT based system for precision farming," *Computers and Electronics in Agriculture*, vol. 187, 2021, doi: 10.1016/j.compag.2021.106291.
[14] L. García, L. Parra, J. M. Jimenez, J. Lloret, and P. Lorenz, "IoT-based smart irrigation systems: an overview on the recent trends on sensors and iot systems for irrigation in precision agriculture," *Sensors (Switzerland)*, vol. 20, no. 4, 2020, doi: 10.3390/s20041042.
[15] S. R. J. Ramson *et al.*, "A self-powered, real-time, LoRaWAN IoT-based soil health monitoring system," *IEEE Internet of Things Journal*, vol. 8, no. 11, pp. 9278–9293, 2021, doi: 10.1109/JIOT.2021.3056586.
[16] B. M. Zerihun, T. O. Olwal, and M. R. Hassen, "Design and analysis of IoT-based modern agriculture monitoring system for real-time data collection," *Computer Vision and Machine Learning in Agriculture*, vol. 2, pp. 73–82, 2022, doi: 10.1007/978-981-16-9991-7_5.
[17] V. Bhatnagar and R. Chandra, "IoT-based soil health monitoring and recommendation system," *Internet of Things and Analytics for Agriculture, Springer*, Singapore. vol. 2, pp. 1–21, 2020, doi: 10.1007/978-981-15-0663-5_1.
[18] V. Shukla, S. Dixit, and P. Dixit, "An IoT based user authenticated soil monitoring system," *Ad-Hoc and Sensor Wireless Networks*, vol. 53, no. 3–4, pp. 269–283, 2022, doi: 10.32908/ahswn.v53.9453.
[19] X. Zhang, J. Zhang, L. Li, Y. Zhang, and G. Yang, "Monitoring citrus soil moisture and nutrients using an IoT based system," *Sensors (Switzerland)*, vol. 17, no. 3, 2017, doi: 10.3390/s17030447.
[20] M. I. Abdulraheem, W. Zhang, S. Li, A. J. Moshayedi, A. A. Farooque, and J. Hu, "Advancement of remote sensing for soil measurements and applications: a comprehensive review," *Sustainability (Switzerland)*, vol. 15, no. 21, 2023, doi: 10.3390/su152115444.
[21] FAO, *The impact of disasters on agriculture and food security 2023*. Rome: Food and Agriculture Organization of the United Nations, 2023.
[22] M. R. Islam, K. Oliullah, M. M. Kabir, M. Alom, and M. F. Mridha, "Machine learning enabled IoT system for soil nutrients monitoring and crop recommendation," *Journal of Agriculture and Food Research*, vol. 14, Dec. 2023, doi: 10.1016/j.jafr.2023.100880.
[23] E. Symeonaki, K. Arvanitis, and D. Piromalis, "A context-aware middleware cloud approach for integrating precision farming facilities into the IoT toward agriculture 4.0," *Applied Sciences (Switzerland)*, vol. 10, no. 3, p. 813, 2020, doi: 10.3390/app10030813.
[24] Aliyu Sabo *et al.*, "Development of a solar-powered system for soil monitoring with an automated irrigation feature," *World Journal of Advanced Engineering Technology and Sciences*, vol. 10, no. 2, pp. 18–29, 2023, doi: 10.30574/wjaets.2023.10.2.0281.
[25] A. M. Chana, B. Batchakui, and B. B. Nges, "Real-time crop prediction based on soil fertility and weather forecast using IoT and a machine learning algorithm," *Agricultural Sciences*, vol. 14, no. 05, pp. 645–664, 2023, doi: 10.4236/as.2023.145044.
[26] G. Mokhtari, A. Anvari-Moghaddam, and Q. Zhang, "A new layered architecture for future big data-driven smart homes," *IEEE Access*, vol. 7, pp. 19002–19012, 2019, doi: 10.1109/ACCESS.2019.2896403.
[27] K.-K. Kee, S. Lau Boung Yew, Y. S. Lim, Y. P. Ting, and R. Rashidi, "Universal cyber physical system, a prototype for predictive maintenance," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 1, pp. 42–49, Feb. 2022, doi: 10.11591/eei.v11i1.3216.
[28] JXCT, "IoT soil monitoring moisture, temperature, EC, PH, NPK," *Weihai JXCT*, http://www.jxct-iot.com/product/product.php?class2=118&gclid=Cj0KCQjw0IGnBhDUARIsAMwFDLnU5u1MxjN_VpTTMVtla2mYzmzKPVEzeZbyOKBTapapr7oECnfe2HUaAn46EALw_wcB (accessed May 14, 2024).

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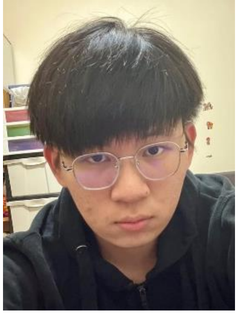

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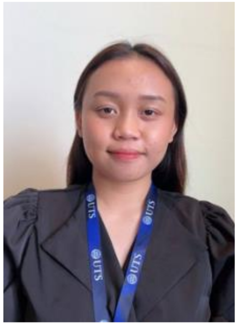

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