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REVIEW ARTICLE

The Role of IoT in Agriculture in Sri Lankan Context: A Comprehensive Review

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ABSTRACT

The integration of the Internet of Things (IoT) technologies into Sri Lankan agriculture offers transformative opportunities to improve the resilience, efficiency, and sustainability of predominantly crop production and livestock systems, which are highly vulnerable to climate variability and resource constraints. This review systematically examined the application of IoT in key agricultural domains such as smart irrigation, real-time crop health monitoring, livestock management, and supply chain optimization within the unique agroecological and socio-economic context of Sri Lanka. By enabling continuous data acquisition through sensors and applying advanced analytics, IoT solutions facilitate precise water and nutrient management, early detection of crop diseases and animal health issues, and the minimization of losses during post-harvest and post-production stages. Drawing upon empirical research and pilot initiatives conducted locally, this paper identifies several critical barriers to IoT adoption, including inadequate rural infrastructure, high initial investment costs, and insufficient digital literacy among farmers and livestock keepers. The study further proposed actionable recommendations including the development of supportive policy frameworks, expansion of rural internet connectivity, and the implementation of comprehensive farmer and livestock owner training programs to enhance technology uptake. The findings highlighted that successful scaling of IoT innovations requires collaborative efforts between government agencies, private technology providers, and academic institutions to develop cost-effective, scalable, and context-specific solutions. Future research should prioritize the design of affordable, user-friendly IoT systems that address both crop and livestock production challenges, ultimately advancing sustainable agriculture and strengthening food security in Sri Lanka.

Keywords: *Crop and livestock production, Internet of things, Smart farming, Smart irrigation system, Supply chain and post-harvest*

INTRODUCTION

Agriculture remains a cornerstone of Sri Lanka's economy, contributing approximately 7% to the gross domestic product (GDP) and employing a substantial share of the workforce (Department of Census and Statistics, 2023). To achieve sustainable improvements in agricultural productivity, it is essential to shift from conventional farming practices to smart technologies by transforming agricultural production systems. The Internet of Things (IoT), an emerging innovation in information and communication technology (ICT), involves a network of interconnected devices capable of making and executing decisions autonomously, with minimal human intervention (Malavade and

Akulwar, 2016). IoT applications have demonstrated significant advantages in various areas of agriculture, including greenhouse operations, crop production, livestock monitoring, and agri-food supply chain management (Shenoy and Pingle, 2016).

IoT plays a transformative role in smart and precision agriculture by enabling real-time monitoring of crop growth, optimized fertilizer application, early disease detection, and intelligent irrigation decision-making. These technologies have been widely adopted in developed countries and advanced agricultural markets, leading to significant improvements in efficiency and productivity (Urlagunta *et al.*, 2017). In Sri Lanka, where agriculture remains a vital source of rural livelihoods and food security, the adoption of smart farming technologies is still in its early stages. However, pilot projects in regions such as the North Central Province have shown promising potential for IoT-based systems in water management and pest control, particularly in paddy cultivation (International Water Management Institute, 2021). With the global population continuously increasing and putting pressure on limited arable land and freshwater resources, the integration of smart technologies into Sri Lankan agriculture is becoming increasingly critical. Such integration can support the achievement of both national and global sustainable development goals by promoting efficient resource use and boosting agricultural productivity (FAO, 2018).

A key area often overlooked in discussions on IoT in agriculture is the domain of livestock management. IoT-based systems ranging from wearable health monitors to computer vision tools can monitor animal health, behaviour, and productivity in real time. Recent work by Gunaratnam *et al.*, (2024) demonstrates how computer vision and sensor technologies are revolutionizing livestock monitoring, helping to reduce disease outbreaks and enhance production efficiency. Incorporating livestock into digital agriculture frameworks is essential for a holistic approach, especially in the mixed-farming systems that dominate Sri Lanka's agricultural landscape. On many farms, animal health is still monitored manually, which significantly limits efficiency and productivity. Manual health assessment methods are time-consuming and prone to delays, especially when identifying early signs of illness. This often leads to late diagnoses, which can result in increased treatment costs and reduced animal welfare. In larger farms, manual systems become even more ineffective due to the scale of operations. However, the integration of advanced technologies, such as IoT, has begun to transform livestock management. These tools enable continuous monitoring and support real-time decision-making, thereby enhancing farm productivity, animal well-being, and ultimately, the quality and profitability of farm outputs (Gunasekara *et al.*, 2023).

In Sri Lanka, automated greenhouses equipped with sensors and IoT-enabled control systems are becoming increasingly common in regions such as Badulla, Bandarawela, and other upcountry areas. These greenhouses regulate environmental factors like temperature, humidity, and soil moisture, allowing farmers to optimize crop production while reducing manual labour (Field Instruments, 2023; AiGrow, 2025). Supporting this advancement, several Sri Lankan companies are pioneering IoT applications in agriculture. SenzMate's "SenzAgro" platform offers AIoT-driven smart irrigation and soil monitoring (SenzMate, 2023). ELZIAN AGRO provides real-time agronomy monitoring systems to optimize resource utilization (Elizan Agro, 2022). AiGrow develops intelligent greenhouse solutions with integrated sensors for precision farming (AiGrow, 2025). Field Instruments specializes in automation technologies for climate control in greenhouses (Field Instruments, 2023). Dialog Axiata has introduced affordable IoT sensors and actuators for smart farm management via smartphones (Dialog Axiata, 2023). Suleco (Pvt) Ltd combines drone-based imaging and IoT sensors to deliver precision agriculture services (Suleco, 2024). Together, these innovations are driving more sustainable and efficient agricultural practices across Sri Lanka.

This study critically examined the current and potential applications of Internet of Things (IoT) technologies in Sri Lankan agriculture, including crop production, livestock management, and post-harvest processes. It explored the barriers to adoption and presents case examples of successful pilot projects. The aim was to identify strategies to enhance IoT adoption at scale, with a focus on smallholder farmers, climate resilience, and supply chain efficiency.

Application of IOT in agriculture

Crop production

Under crop production, recent innovations have focused on automating greenhouse management through integrated robotic systems. A notable example is the autonomous cloud-connected mobile robot developed by Dharmasena *et al*. (2019), designed to monitor and optimize greenhouse conditions. This system uses sensors to measure temperature, soil moisture, humidity, and pH and employs image processing to detect unhealthy crops by analysing leaf texture and colour. The robot autonomously navigates a mapped greenhouse, collects soil samples, and transmits data to the cloud for real-time decision-making using a fuzzy logic controller that manages irrigation, heating, and humidification systems. A study conducted by Jayathilaka *et al.* (2022) investigated the application of an IoT-based micro-climate control system for salad cucumber (*Cucumis sativus*) cultivation in Sri Lanka. It addressed key issues such as high labour costs, poor fruit quality, and increased pest attacks by automating temperature, humidity, and moisture control using digital sensors and actuators. The IoT system effectively reduced internal temperatures by 1.55 to 4.42°C and increased the yield per vine by 41.6% compared to the conventional method (Jayathilaka *et al.*, 2022).

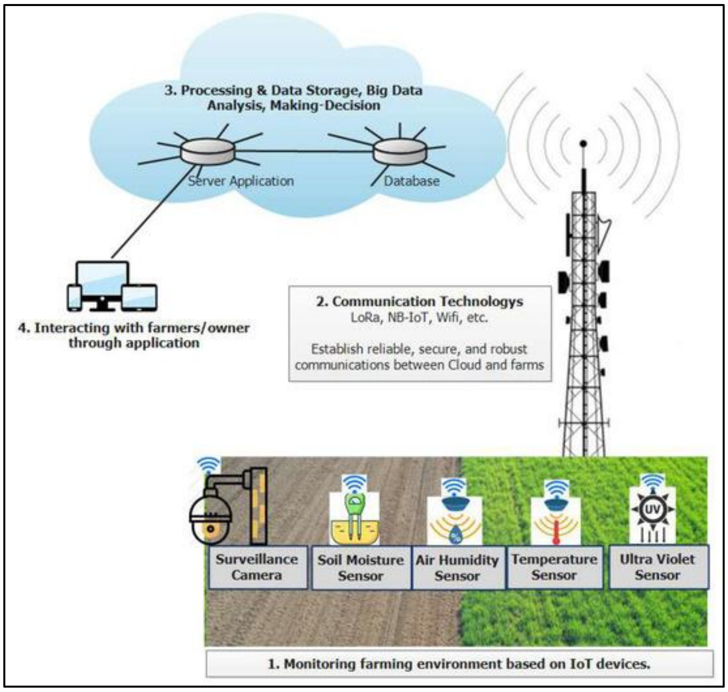

Figure 1: An illustration of the IoT ecosystem architecture for smart agriculture (Dilrukshi *et al.*, 2021)

In addition to improving yield, IoT applications in agriculture have contributed to resource conservation. A study by Wanninayake *et al.* (2023) introduced an IoT-enabled system for rice disease detection and yield prediction, achieving accuracy rates between 89 and 98%. This system enables timely interventions, reducing the need for excessive pesticide use and minimizing environmental impact. By providing data-driven insights, IoT empowers farmers to make informed decisions, leading to more sustainable farming practices.

The International Water Management Institute (IWMI) has played a pivotal role in advancing climate-smart agriculture in Sri Lanka through its GeoGoviya platform, which delivers real-time climate information and agronomic advisories to farmers, thereby empowering vegetable growers to make informed decisions that enhance crop management and increase yields (International Water Management Institute, 2023). In strawberry cultivation, the Department of Agrarian Development has launched an export-oriented project in Nuwara Eliya involving 52 farmers and 40 greenhouses, utilizing modern techniques such as grow bags and drip irrigation to boost productivity and quality. Additionally, smart agriculture monitoring systems like the IoT-based e-crop system have enabled farmers to remotely monitor soil conditions and manage irrigation effectively (Figure 1), proving both cost-efficient and supportive of sustainable agriculture, particularly for vegetable crops (Nowfeek, 2021). Complementing these efforts, the FRESH Initiative, in collaboration with the

ClimBeR initiative, provides Sri Lankan farmers, especially in upcountry regions affected by climate change, with direct mobile access to climate information and agronomic advisories, helping them adapt and improve vegetable production (International Water Management Institute, 2023; World Vegetable Center, 2023).

The integration of smart agriculture technologies in Sri Lanka has shown promising advancements through systems like EcoGrowAdviser and the 'Smart Crop and Fertilizer Prediction System'. The EcoGrowAdviser system leverages IoT technology to monitor nitrogen (N), phosphorus (P), and potassium (K) levels in soil and recommends suitable organic fertilizer combinations based on crop type and age, addressing the environmental and health hazards caused by excessive use of inorganic fertilizers (Perera *et al.*, 2024). Similarly, Wickramasinghe *et al*. (2019) developed a mobile application that utilizes sensor data to predict optimal NPK levels and recommend suitable crops and fertilizer plans, enhancing cultivation efficiency and reducing soil degradation. Their approach integrates machine learning models such as multi-class support vector machine (SVM) to analyse sensor inputs like pH, temperature, and humidity, delivering accurate fertilizer recommendations and crop predictions. These systems demonstrate the potential of combining IoT and AI to support sustainable agriculture, particularly in regions where traditional methods dominate, and farmers often lack access to precise nutrient analysis tools.

Government initiatives have also played a significant role in promoting IoT adoption among farmers. The Information and Communication Technology Agency of Sri Lanka (ICTA) launched the Ag-Tech Innovation program to enhance agricultural productivity through technology adoption. This initiative focuses on integrating IoT, artificial intelligence, and other advanced technologies into farming practices to increase efficiency and improve product quality (Information and Communication Technology Agency of Sri Lanka, 2021). By collaborating with universities and the private sector, ICTA aims to bridge the technological gap and support farmers in adopting modern agricultural practices.

Private sector involvement has further accelerated the adoption of IoT in agriculture. Dialog Axiata PLC, in partnership with local universities, developed an affordable IoT-based smart farming solution tailored to Sri Lankan conditions. This system includes sensors for monitoring temperature, humidity, and soil moisture, and actuators for controlling irrigation and fertigation. Pilot projects have shown that this solution can lead to up to a 50% increase in crop yield by optimizing resource usage and reducing waste (GSMA, 2020). The affordability and customization of this technology make it accessible to smallholder farmers, thereby promoting its widespread adoption.

Smart irrigation systems

The integration of IoT in irrigation management has shown significant promise in Sri Lankan agriculture. A study by Hanees and Godevitharane (2021) introduced a smart irrigation system that utilizes soil moisture sensors, Arduino microcontrollers, and the ATmega328P chip for automated water regulation. The system is powered by solar energy and can operate in both manual and automatic modes, depending on real-time soil moisture data. Designed to minimize water waste and reduce labour dependency, the system is particularly suited for small-scale farming applications. By enabling precise irrigation, it contributes to resource conservation and enhances crop productivity in a cost-effective manner.

The implementation of an automated main sluice gate system plays a critical role in promoting sustainable agriculture by enhancing water use efficiency in paddy cultivation. As highlighted by Kumar and Anand (2023), automating sluice gates enables precise water distribution, reduces waste, and improves crop health through timely irrigation (Figure 2). In this system, a reservoir sluice gate is designed to release water only when necessary, preventing continuous outflow and conserving valuable water resources. The released water flows through a main canal and is regulated at the paddy field level using smaller gates. Within the field, sensor nodes collect real-time data on soil moisture, water level, temperature, and humidity, providing vital input for irrigation decisions (Sanjula *et al.*, 2020). This integration of IoT and automated control systems supports data-driven, efficient, and environmentally sustainable farming practices.

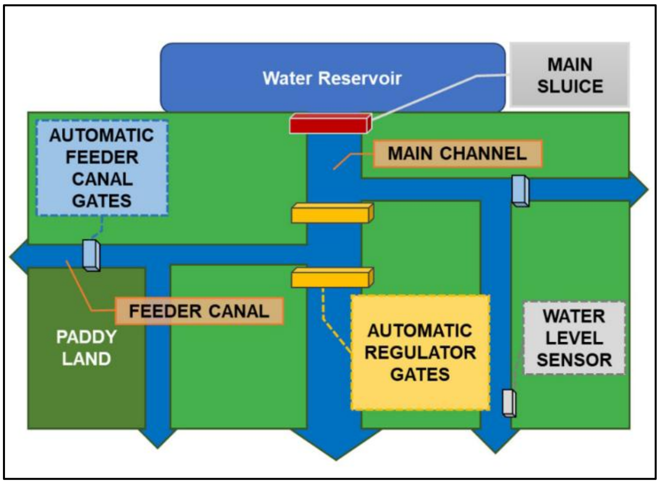

Figure 2: A scheme of automatic gate controlling irrigation network system (Rathnayaka and Park, 2024)

The IoT-based smart irrigation system developed by Laksiri *et al.* (2019) offers a practical and cost-effective solution for optimizing water use in Sri Lankan agriculture. The system combines soil moisture sensors with IoT technology to enable remote monitoring and control of irrigation through an online interface. It integrates weather data, including temperature, humidity, and rainfall, and employs prediction models such as the 'Sliding Window and Hidden Markov

Model' to forecast soil moisture and rainfall, although the accuracy of rainfall prediction still needs improvement. Despite this, the system effectively regulates irrigation valves to supply the required amount of water, minimizing wastage and reducing electricity consumption. This technology promotes sustainable farming by improving irrigation efficiency and conserving vital resources.

Firdhous *et al.* (2020) developed an IoT-powered microclimate management system aimed at improving sustainable agriculture in dry zones by optimizing water use. The experimental system continuously monitors key environmental parameters such as soil moisture and temperature and controls irrigation accordingly to maintain optimal conditions for crop growth. Featuring an open design for easy adaptability, the system utilizes a GPRS communication module to transmit data and send alerts when soil moisture drops below preset levels, prompting timely human intervention. Powered by a rechargeable 12 V Li-ion battery system, the setup demonstrated reliable performance in real-world tests, highlighting the potential of IoT technologies to enhance water management and increase agricultural productivity in water-scarce dry zone regions.

Livestock management and monitoring

Recent advancements in IoT and machine learning technologies have significantly contributed to the improvement of livestock monitoring and health management systems in Sri Lanka. One notable example is the IoT-enabled cattle health and location monitoring system developed by Rajapakse *et al.* (2022), which integrates wearable collars equipped with sensors to track vital signs such as body temperature and heart rate. GPS modules further enhance the system by enabling continuous location tracking of individual cattle. The collected data is transmitted via GSM/GPRS modules to a cloud server, allowing real-time remote monitoring and early detection of health anomalies (Figure 3). This system was found to be both cost-effective and efficient in improving livestock management for small- and medium-scale farmers.

In a similar effort, Chandrarathna *et al.* (2023) developed a mobile application named 'The Taurus', which uses machine learning to identify cattle breeds and diagnose diseases based on image recognition. The application incorporates a MobileNet V2 model trained on Sri Lankan datasets, enabling accurate predictions for common cattle diseases. Furthermore, it estimates the weight and age of the cattle to recommend appropriate medication doses, offering a more precise and informed approach to animal care. Trial results demonstrated high accuracy in breed identification and disease classification, indicating strong potential for practical implementation among local farmers and veterinary officers.

Another initiative by Rajapakse *et al.* (2022) proposed an IoT-based architectural framework for remote animal health monitoring. This architecture includes wearable sensors and GSM communication modules, offering scalable solutions tailored to the Sri Lankan context. Preliminary testing showed that the system could successfully capture and transmit real-time health data to a central server, issuing alerts when abnormalities were detected. This significantly reduces the need for manual surveillance while enhancing the ability to respond quickly to health issues, thus reducing mortality rates and improving productivity.

Gunaratnam *et al*. (2024) further explored the use of computer vision technologies for livestock disease management. Their study examined various imaging systems such as infrared and RGB cameras, which can be deployed to identify visual signs of diseases like mastitis and foot-and-mouth disease. Their findings emphasize the practicality of incorporating non-invasive computer vision tools into existing livestock systems in Sri Lanka to increase efficiency and early disease detection. Together, these research efforts represent a growing body of evidence demonstrating how IoT and AI-driven technologies can transform traditional livestock farming into more sustainable and productive operations in the country.

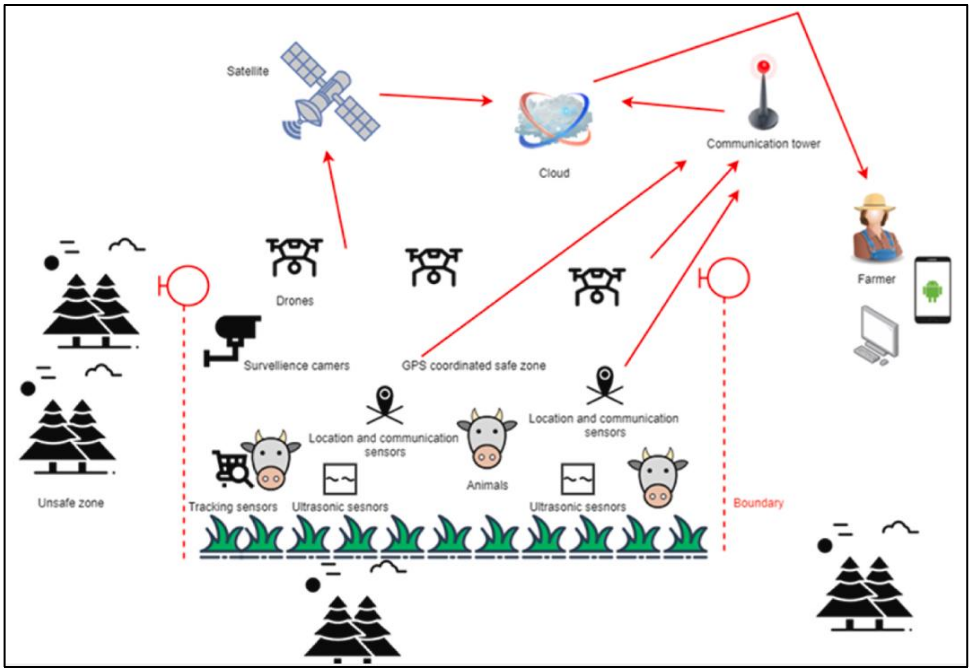

Figure 3: IoT based Livestock tracking and monitoring (Thilakarathne *et al*., 2025)

Pest and disease management

Several studies have demonstrated the potential of IoT and digital technologies for enhancing pest and disease identification in Sri Lankan crop production. Gunathilaka *et al*. (2019) developed an efficient agricultural sensor network that continuously monitors environmental factors such as temperature, humidity, and soil moisture to detect early signs of crop diseases. Their system enables timely disease identification by analysing sensor data in real time, thereby helping farmers take prompt action to mitigate yield losses. This sensor network approach provides a scalable and cost-effective solution suitable for smallholder farmers in Sri Lanka.

In another approach, Sivagnanasundaram *et al.* (2019) introduced a crowdsensing platform that empowers farmers to report pest incidences directly via mobile applications. This platform aggregates data from multiple farmers across regions, facilitating the creation of dynamic pest incidence maps. By leveraging real-time farmer inputs, the system improves the accuracy and timeliness of pest outbreak detection, enabling agricultural authorities and farmers to coordinate effective pest control measures. This participatory model addresses the limitations of conventional pest surveillance methods, which often suffer from delays and limited data coverage.

Wijekoon *et al.* (2022) utilized transfer learning with convolutional neural networks (CNNs) to develop an intelligent system capable of both identifying crop diseases and forecasting their spatial dispersion. The model was trained on a dataset of diseased plant images specific to Sri Lankan crops, achieving high classification accuracy. Additionally, the system predicts the potential spread of disease outbreaks, allowing farmers to implement preventive strategies proactively. This machine learning-based method represents a significant advancement in digital agriculture, offering scalable disease monitoring and early warning capabilities.

Furthermore, Buhary *et al.* (2021) proposed a digitally enabled crop disorder management system that integrates direct farmer observations with contextual environmental data to diagnose crop disorders, including pest and disease issues. The system provides farmers with tailored recommendations for control measures based on symptoms and local conditions. This approach enhances decision-making by combining indigenous knowledge with scientific data, resulting in more effective and timely pest and disease management.

Supply chain and post-harvest management

The use of IoT technologies in Sri Lanka's agricultural supply chains has been demonstrated to enhance monitoring and management, particularly for perishable goods. Chandrasiri *et al.* (2022) implemented a novel supply chain configuration integrated with IoT sensors to simulate the banana supply chain. Their system collected real-time data on environmental factors such as temperature and humidity, allowing for better control of post-harvest conditions. The results showed a significant reduction in spoilage and waste, leading to improved sustainability and economic benefits within the supply chain.

In the dairy sector, Madhunamali and Jayasena (2023) developed an integrated blockchain and IoT system to maintain traceability and quality control during the COVID-19 pandemic. Their implementation involved IoT sensors to monitor milk temperature and quality parameters throughout the supply chain, combined with blockchain for secure data logging. The results indicated enhanced transparency and product safety, enabling dairy producers to adapt quickly to disruptions and maintain consumer confidence during the pandemic period.

Similarly, Madhunamali and Jayasena (2023) designed and implemented a blockchain-IoT-based dairy supply chain management system tailored for Sri Lankan conditions. This system utilized IoT devices for real-time monitoring of cattle health and milk production metrics, with blockchain ensuring data integrity and traceability. The results demonstrated improvements in operational efficiency, fraud reduction, and strengthened stakeholder trust due to increased visibility across the supply chain.

Fernando *et al.* (2024) focused on digitalizing smallholder farmer agri-food supply chains through IoT-enabled data collection and decision-support tools. Their case study implemented sensors and mobile platforms to track crop and post-harvest parameters, improving coordination between farmers, traders, and buyers. The results revealed increased income for farmers, reducing post-harvest losses, and better alignment of supply with market demand, highlighting IoT's role in empowering smallholders.

Lastly, Karunanayaka *et al.* (2020) conducted a literature review analysing barriers and opportunities for technology adoption in Sri Lankan agricultural supply chains. They highlighted that although infrastructure and awareness challenges exist, successful implementations of IoT have led to measurable gains in supply chain efficiency and post-harvest management. Their synthesis underscored the critical role of stakeholder collaboration and policy support in scaling IoT solutions, with documented improvements in real-time data sharing and decision-making across pilot projects.

Challenges and limitations

While the integration of IoT technologies in Sri Lankan agriculture offers significant potential to enhance productivity, sustainability, and resource management, the adoption process is not without its challenges. Various technical, economic, infrastructural, and social factors act as barriers, slowing down widespread implementation. These challenges range from the lack of reliable internet connectivity in rural areas to the high initial costs of IoT devices, as well as limited technical expertise among farmers. Furthermore, issues related to data privacy, maintenance, and scalability also contribute to the complexity of deploying IoT solutions in the agricultural sector. Understanding these limitations is crucial for developing strategies that ensure effective and sustainable adoption of IoT in Sri Lanka's agricultural landscape. Table 1 gives a summary of system results reported across selected studies.

High initial investment cost: The adoption of IoT technologies in Sri Lankan agriculture faces significant financial and infrastructural challenges. One of the primary issues is the high initial cost of IoT devices, such as sensors and cloud-based systems, which is often unaffordable for small- and medium-scale farmers. These systems, including smart irrigation and soil monitoring setups, are

typically more expensive than traditional farming methods, making cost a major barrier (Table 2).
Moreover, the lack of financial assistance, such as government subsidies or affordable credit schemes, further discourages farmers from investing in these modern technologies. As a result, despite the potential benefits, many farmers remain hesitant or unable to adopt IoT-based agricultural solutions.

Limited Internet and power infrastructure: Rural areas lack stable Internet access and electricity, which hinders the functionality of IoT systems. Many agricultural regions still rely on outdated telecommunication networks with poor connectivity, reducing the effectiveness of real-time monitoring and automation. A study conducted in the Eastern Province of Sri Lanka highlighted that farming villages have inconsistent internet access, making remote IoT management difficult. Furthermore, unreliable electricity grids lead to frequent power disruptions, impacting the continuous operation of IoT-enabled devices.

Knowledge and skill gaps: Farmers require training and technical support to adopt and manage IoT technologies effectively. A significant proportion of Sri Lankan farmers have limited exposure to digital tools, creating resistance to adopting advanced agricultural technologies. Research has shown that smallholder farmers lack basic digital literacy, further limiting their ability to leverage IoT solutions for productivity enhancement. Government-led initiatives and agricultural extension services must prioritize education programs and hands-on training to bridge this knowledge gap.

Data security: The risk of data breaches and cyberattacks poses a significant challenge in IoT-enabled farming. As IoT devices collect and transmit vast amounts of agricultural data, farmers and agribusinesses face potential threats related to hacking, unauthorized data access, and misuse of confidential farm information. Research has shown that IoT-driven agricultural systems globally have reported vulnerabilities to cyber threats, highlighting the need for stronger security protocols and encrypted data storage solutions. Implementing robust cybersecurity frameworks, promoting farmer awareness, and ensuring regulatory compliance are essential to mitigating these risks.

Lack of government and private sector support: Institutional support is essential for the successful diffusion of emerging technologies like IoT. However, in Sri Lanka, there is currently limited coordinated effort from the government to promote IoT adoption in agriculture through policy incentives, funding schemes, or regulatory frameworks. Similarly, the private sector has yet to invest substantially in scalable, farmer-friendly IoT services. In contrast, countries like China, the Netherlands, and Israel have demonstrated that public-private partnerships and innovation ecosystems can drive the widespread adoption of precision agriculture.

Table 1: Summary of system results reported across selected studies

No	Topic	System type	Technology integration	Key features	Limitations/Notes	References
1	Autonomous cloud robotic system for smart agriculture	Cloud-connected mobile robotic monitoring and control system	IoT, Cloud robotics, Image processing, Fuzzy Logic Control	Automated climate and irrigation control, mobile robot navigation, unhealthy plant detection via leaf analysis, soil and environmental data collection	Limited to greenhouse environment, depends on the predefined navigation map, may have challenges in real-time adaptability and outdoor scalability	(Dharmasena *et al.*, 2019)
2	Smart irrigation system using IoT	IoT-based smart irrigation system	IoT, Wireless Sensor Network, Arduino (ATmega328P), Solar power	Soil moisture-based water flow control, solar-powered pump, manual and automatic operation modes, water and labour efficiency	Limited sensing scope, basic decision-making logic, dependency on solar energy availability, and scalability not addressed	(Hanees and Godevitharane, 2021)
3	Automatic gate controlling system for sustainable agriculture water management in Sri Lanka: A review	Automated irrigation gate control system	Smart sensors, Intelligent control systems, Real-time analytics	Real-time data collection (soil, weather, crop), automated gate control, reduced labour, optimized water use for paddy cultivation	Specific to paddy fields, infrastructure setup complexity, dependent on accurate sensor data, cost implications for rural farmers	(Rathnayaka and Park, 2024)
4	Investigation of the potential to introduce internet of things (IoT) based micro-climate controlling system for salad cucumber (*Cucumis sativus*) in conventional protected houses	IoT-enabled microclimate control system for protected agriculture	IoT sensors (DHT21, capacitance), Automated foggers, Exhaust fans, Drip irrigation	Real-time monitoring and control of temperature, humidity, substrate moisture; 41.6% yield increase; labour reduction	Limited to protected house environment, initial setup costs, specific crop focus, requires sensor maintenance	(Jayathilaka *et al.*, 2022)

5	Transforming agriculture supply chain with technology adoption-: a critical review of literature	Technology adoption in the agricultural supply chain	IoT, Big data, Blockchain, digital transformation	Review of technology applications, focus on digital transformation to improve supply chain efficiency and resilience	Literature review only, no experimental results, broad scope without specific system implementation	(Karunanayaka *et al*., 2020)
6	E-AGRO: Intelligent chat-bot. IoT and artificial intelligence to enhance farming industry	Cloud-based AI chat-bot and chat room platform	AI (AIML), Cloud computing, IoT	AI-powered intent recognition, cloud hosting for low client resource needs, interactive chat platform for farmer support	Dependent on predefined intents and examples, limited to text-based interaction, no integration with physical farming devices	(Ekanayake and Saputhanthri, 2020)
7	Ecogrowadviser: organic fertilizer recommendation system to enhance organic fertilization process - a case from Sri Lankan farming industry	IoT-based soil nutrient monitoring and fertilizer recommendation system	IoT Sensors (N, P, K), Case-based recommendation system	Real-time soil nutrient monitoring, crop and age-based fertilizer advice, tested with local farmers	Limited crop coverage, restricted natural source options, requires farmer education, lacks integrated pH, humidity, and moisture sensors	(Perera *et al*., 2024)
8	Precision agricultural technologies for enhancing crop productivity: away forward to Sri Lankan agriculture	Precision agriculture technologies review	IoT, GPS, WSN, VRA, Robotics, satellite systems	Low-cost, scalable precision farming tech, real-time fertilizer/pesticide application, small-scale farm suitability, global adoption trends	Limited adoption in developing countries, economic and social constraints, lack of infrastructure and awareness	(Dilrukshi *et al*., 2021)
9	A review of innovative fertilization strategies in precision agriculture	Review of precision fertilization techniques	IoT, GPS, WSN, Blockchain, Data analytics	Site-specific fertilizer application, advanced fertilizers (Nano, coated), VRT, fertigation for precise nutrient delivery	Implementation cost, technology adoption barriers in developing regions, need for technical knowledge	(Polwaththa *et al*., 2024)

10	Farming through technology driven solutions for agriculture industry	Mobile application	AI (CNN, NLP, VGG19), IoT, API, SMS	Pest and disease solutions for maize, fire threat detection, farmer-buyer connection, price forecasting, soil moisture monitoring	Focus on maize only; limited geographic scope	(Imalka *et al.*, 2022)
11	Drone-based Internet of Things for smart agriculture: A review	Review paper	Drones, IoT	Soil quality evaluation, seed spreading, crop monitoring, pest detection, fruit ripeness assessment	High adoption cost; emerging technology; user familiarity	(Rathnayake and Hettige, 2023)
12	Efficient agricultural sensor network with disease detection	Wireless Sensor Network (WSN)	IoT, Machine learning, Image processing, Energy harvesting (MPPT)	Real-time disease detection and crop environment monitoring; battery-free operation via supercapacitors	Tested mainly on pineapple; scalability challenges	(Gunathilaka *et al.*, 2019)
13	Optimizing the coconut supply chain: Blockchain and IoT integration	Supply chain management system	Blockchain, IoT sensors, RFID	Transparent real-time data monitoring; smart contracts for transaction automation; waste reduction	Limited to coconut supply chain; adoption barriers	(Dissanayaka, 2024)
14	Internet of Things enabled smart agriculture: current status, latest advancements, challenges and countermeasures	Review paper	IoT, AI, Cloud computing, Big data	Automation and optimization of agriculture operations; increased efficiency, yield, and reduced waste	Infrastructure, cost, and knowledge barriers	(Thilakarathne *et al.*, 2025)
15	IoT Based E-crop: Smart agriculture monitoring system for Sri Lanka	Automated irrigation system	Wireless Sensor Networks, Wi-Fi, GPRS/GSM	Monitors soil moisture, temperature, pH; automates irrigation; sends SMS alerts to farmers	Dependent on wireless network coverage; sensor calibration and maintenance required	(Razeed and Nowfeek, 2021)

16	Internet of Things (IoT) for smart agriculture: polytunnels	Low-cost IoT monitoring system	IoT devices, sensors	Converts polytunnels into semi-controlled environments; real-time monitoring; data generation	Limited training data; system performance varies with environmental factors	(Jaliyagoda *et al.*, 2023)
17	Design and optimization of IoT based smart irrigation system in Sri Lanka	Smart irrigation system	IoT sensors, Weather sensors, Remote database	Automates drip irrigation based on soil moisture; remote monitoring and manual control; weather prediction integration	Weather prediction accuracy impacts irrigation efficiency; sensor costs	(Laksiri *et al.*, 2019)
18	IoT-powered sustainable dry zone agriculture: Experimental implementation	Microclimate management system	IoT sensors, Communication module	Continuous environmental monitoring; automated pot irrigation; alert notifications	Requires reliable power and network; may need human intervention despite automation	(Fazil *et al.*, 2018)
19	IoT Based greenhouse system for tropical countries	IoT-integrated greenhouse	IoT sensors, Automation	Automates greenhouse environmental control; improves productivity in tropical climates	Initial setup complexity; cost and technical skills needed; environmental variability challenges	(Priyadarshana *et al.*, 2020)
20	Internet of Things (IoT) enabled food technologies: A systematic review approach	Review / Analysis study	IoT devices, Cloud computing	Reviews IoT use in food safety, transport, packaging; identifies privacy/security issues; suggests cloud-based solutions	Lack of IoT food tech studies in Sri Lanka; data privacy concerns	(Cader *et al.*, 2021)
21	Investigation of benefits and challenges of using IoT to enhance coconut irrigation in Sri Lanka	Qualitative study / IoT adoption	IoT sensors, Interviews, Smart irrigation	Shows improved ROI, yield, water/electricity savings after IoT adoption; highlights adoption challenges; recommends wider use	Challenges include tech knowledge gap and poor internet connectivity	(Sarathchandra, 2021)

22	Use of IoT for smart security management in agriculture	IoT-based security system	IoT sensors, Monitoring devices	Proposes IoT devices for real-time agricultural area monitoring; aims to improve security and productivity	Security system complexity; dependency on technology infrastructure	(Samarasinghe *et al.*, 2021)
23	Smart crop and fertilizer prediction system	Sensor-based decision support	Soil nutrient sensors, Cross-platform Mobile app	Measures soil fertility (N, P, K), recommends best crops and fertilizer plans; sensor validation against lab tests	Relies on sensor accuracy and farmer adoption	(Wickramasinghe *et al.*, 2019)
24	Computer vision in livestock management and production	Computer vision for animal monitoring and food quality	Computer vision, Infrared Thermography (IRT), Biometric identification	Enables early disease detection in animals (via IRT), monitors lameness/activity, identifies individual animals through biometric features	IRT not disease-specific; requires standard confirmation. Image capture is challenging for fast animals. High data demand for accurate predictions.	(Gunaratnam *et al.*, 2024)
25	Soil quality monitoring system for smart farming	IoT-based soil monitoring system	IoT sensors (DHT11, pH, Soil moisture, NPK), Arduino, GSM for SMS alerts	Monitors soil moisture, temperature, humidity, pH, nutrients; real-time display on LCD; sends SMS alerts to farmers	Requires hardware deployment; dependent on GSM network	(Jayathilaka *et al.*, 2022)

IoT=Internet of Things, ML=Machine Learning, AI=Artificial Intelligence, AIML=Artificial Intelligence Markup Language, API= Application Programming Interface, CNN = Convolutional Neural Network, DHT11=Digital Humidity and Temperature Sensor 11, DHT21=Digital Humidity and Temperature Sensor 21, GPRS=General Packet Radio Service, GPS=Global Positioning System, GSM=Global System for Mobile Communications, ICT = Information and Communication Technology, IRT=Infrared Thermography, LCD=Liquid Crystal Display, MPPT=Maximum Power Point Tracking, NLP=Natural Language Processing, NPK=Nitrogen, Phosphorus, Potassium, RFID=Radio Frequency Identification, ROI=Return on Investment, SMS=Short Message Service, VGG19=Visual Geometry Group 19-layer Neural Network, VRA=Variable Rate Application, VRT=Variable Rate Technology, WSN=Wireless Sensor Network, Wi-Fi=Wireless Fidelity

Table 2: Estimated cost categories of common IoT sensors used in agriculture (In Sri Lankan rupees: LKR)

Sensor type	Price range (LKR)	Cost category	Usage
Soil moisture sensor	150 – 1,000	Cheap	Monitors soil water content
Temperature sensor	200 – 2,500	Cheap to moderate	Measures ambient or soil temperature
Humidity sensor	350 – 2,300	Cheap to moderate	Tracks air moisture levels
Light / UV sensor	140 – 2,800	Cheap to moderate	Monitors sunlight exposure
pH sensor	3,500 – 30,950	High	Measures soil or water pH level
NPK sensor	8,900 – 30,950	High	Measures soil nutrient levels (N, P, K)
Gas sensor	330 – 11,500	Cheap to high	Detects gases from livestock or compost
Water quality sensor	1,890 – 3,350	Moderate	Analyzes parameters in irrigation water

The price ranges listed above are approximate values based on publicly available data from local and online electronic component suppliers in Sri Lanka. These prices reflect general market trends and may fluctuate due to import taxes, currency changes, and supplier availability. Sensor selection should consider both accuracy requirements and long-term durability for field applications. [Sources: daraz.lk; www.tronic.lk; www.duino.lk]

Insufficient research and development (R&D) infrastructure: Sri Lanka's R&D capacity in agricultural IoT remains underdeveloped. Universities and research institutions face funding limitations, outdated equipment, and a shortage of specialized expertise in AI, data science, and sensor engineering. This lack of local innovation forces dependency on foreign technologies, which may not be customized for Sri Lanka's specific climatic, soil, and crop conditions. Building a strong R&D base is essential for developing affordable, locally appropriate IoT tools.

Poor maintenance and after-sales support: Even when IoT devices are available, maintenance services are often lacking in rural areas. Once a sensor fails or a connectivity module malfunctions, farmers have limited access to skilled technicians or replacement parts. This leads to system downtime and discourages continued use. Unlike urban-based users, rural farmers need long-term support systems, including local repair centres, technical helplines, and user-friendly manuals in Sinhala and Tamil.

Lack of interoperability among devices and platforms: In Sri Lanka, IoT solutions are often developed in isolation, using different communication protocols, sensor types, and data formats. This fragmentation limits the integration of various IoT systems into a single, comprehensive platform. For instance, a farmer using separate systems for soil monitoring, irrigation, and pest detection might face difficulties synchronizing data across devices. Without standardized platforms and APIs (Application Programming Interfaces), it becomes costly and technically challenging to scale IoT across multiple farms or regions.

Future prospects and recommendations

The future of IoT in agriculture holds tremendous potential, both globally and in Sri Lanka. For the technology to realize its full impact, a holistic approach involving financial, technical, and institutional support is essential. The following recommendations highlight key areas that must be prioritized to enable widespread and effective IoT integration in Sri Lankan agriculture.

Government subsidies and incentives: Providing targeted financial support, such as subsidies, low-interest loans, or tax relief, can significantly lower the entry barriers for farmers. These incentives will encourage smallholder farmers to adopt IoT-based solutions, thereby improving productivity and long-term sustainability.

Infrastructure development: Strengthening rural internet connectivity and ensuring access to reliable electricity are foundational steps. Investments in renewable energy sources like solar power can provide decentralized solutions for powering IoT devices. Additionally, improving mobile and broadband coverage in remote regions will support the deployment of real-time data systems.

Capacity-building programs: Effective training programs must be developed to improve farmers' understanding of digital technologies. These can include hands-on workshops, field demonstrations, mobile learning apps, and the integration of digital agriculture into agricultural extension services. Special focus should be given to ensuring content is delivered in local languages.

Policy and regulatory frameworks: Establishing clear guidelines and legal frameworks on data ownership, privacy, cybersecurity, and ethical use of AI is essential. This will ensure that farmers' data is protected and used responsibly by service providers, government agencies, and private companies.

Promotion of public-private partnerships (PPP): Collaboration between government, research institutions, technology companies, and agribusinesses can accelerate innovation and lower costs. PPP models can be used to pilot new technologies, create rural tech hubs, and develop affordable solutions tailored to Sri Lankan agroecological conditions.

Development of localized IoT solutions: Technologies should be adapted to local soil types, crop varieties, and climatic conditions. Supporting local startups and research centres to innovate with locally available resources can ensure that IoT solutions are relevant, cost-effective, and easy to maintain.

Establishment of open data platforms: Creating centralized platforms that share weather, soil, pest, and market data can enhance decision-making for farmers. Such platforms can be integrated with mobile applications, helping farmers access valuable insights in real-time.

Integration with climate-smart agriculture (CSA): IoT can support climate resilience by optimizing water use, predicting weather anomalies, and improving fertilizer application. Promoting its use as part of broader climate-smart strategies will support long-term food security and environmental sustainability.

Inclusion of women and youth in digital farming: Special efforts should be made to involve women and young farmers in digital agriculture initiatives. They often bring fresh perspectives and are more receptive to adopting technology. Tailored training and entrepreneurship programs can increase their participation and innovation capacity.

Creation of pilot and demonstration farms: Establishing model farms where IoT technologies are actively used and demonstrated can help build trust among rural farmers. These pilot sites serve as real-world examples of how data-driven agriculture leads to better yields and resource efficiency.

CONCLUSION

The integration of IoT in agriculture holds transformative potential for advancing productivity, optimizing resource utilization, and promoting long-term sustainability. In the context of Sri Lanka, IoT-driven solutions ranging from precision agriculture and smart irrigation to livestock monitoring, pest and disease control, and supply chain management have showcased considerable promise in addressing key agricultural challenges. Despite this potential, widespread adoption remains constrained by several barriers, including high initial costs, insufficient digital infrastructure, limited technical knowledge among farmers, and concerns surrounding data privacy and security. To effectively address these challenges, a multifaceted approach is required. Strategic interventions such as targeted government subsidies, investment in rural infrastructure, farmer capacity-building programs, and the establishment of clear regulatory frameworks are critical. Insights from global leaders in smart agriculture such as the European Union, the United States, China, and India underscore the importance of cohesive policy direction, public-private partnerships, and innovation ecosystems in facilitating successful IoT integration. By adopting and adapting these global best practices, Sri Lanka can build a resilient and future-ready agricultural sector. Moving forward, sustained collaboration between policymakers, research institutions, industry stakeholders, and the farming community will be vital to ensure that IoT technologies are both accessible and impactful. With the right support mechanisms in place, IoT can serve as a cornerstone for transforming Sri Lanka's agricultural landscape, enhancing food security, increasing rural livelihoods, and driving inclusive economic growth.

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