Smart Farming and Internet of Things Platform

Subjects: Agricultural Engineering
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Nepal, a lower-middle-income country in South Asia, predominantly features smallholder farming communities operating on modest land holdings. These smallholders often adhere to traditional farming methods, relying on familial labor, which has become increasingly inefficient in contemporary agricultural landscapes. To enhance their productivity and efficiency, smallholder farmers require affordable and accessible Internet of Things (IoT)-based systems.

Internet of Things (IoT) custom IoT architecture smart agriculture smallholder

1. Introduction

The Internet of Things (IoT) is an emerging technology which has been significantly increasing recently in many application domains such as smart cities, industrial manufacturing, home automation, precision agriculture, the health industry, wearables, etc. The IoT-based system includes a network of different sensors and actuators that can be integrated into the cloud service using the internet. Cloud-based applications and services can be accessed using network-enabled devices like smartphones, laptops, and other digital devices anytime, anywhere. IoT-based systems in agriculture can assist farmers in streamlining their labor and managing their resources efficiently. The information about the weather, soil properties, fertilizer, pests, and other variables can be obtained in real time using an IoT-based system [1][2][3]. Smallholder farmers in many lower-middle-income countries play a crucial role in global food production [4]. However, limited technological resources and access to information are the most challenging issues they often face. With the rising number of industries utilizing IoT, the agriculture sector is also one potential industry that can benefit significantly from IoT. On the other hand, designing a reliable, affordable IoT platform suitable for agricultural farms for smallholder farmers of middle- and lower-income countries with limited resources is always challenging [4][5].

The essential components of IoT-based systems in agriculture include sensor networks, edge computing, and cloud computing. The sensor network collects data on weather conditions, soil moisture, and crop growth and controls irrigation systems. Edge computing processes and analyses sensor data close to the field. Cloud computing can store and analyze data from sensor networks and other IoT-based systems.

2. Challenges and Opportunities of Internet of Things (IoT) in Agriculture for Smallholder Farmers: In Context of Nepal

Most of the farmers in Nepal are smallholder farmers with modest land holdings [6]. Smallholder farmers are also most of the agricultural labor force, accounting for more than 80% of all farm production. Despite being an agrarian country, the majority of the agricultural products are imported. The traditional way of farming solely relying on manual labor has not been productive these days. The rising cost of production, on the other hand, the shortage of manpower severely affects overall agricultural production. This has not only demotivated them to preserve their farming tradition but also significantly impacted their socio-economic status. The departure of the youth for foreign employment, the concept of a lower mindset for agriculture business, and the lack of access to technology and information have led to un-cultivating acres of land.

In this context, the IoT system could revolutionize how smallholder farmers manage their farms. There are, however, challenges to its implementation. One of the main challenges is the cost of deploying and maintaining IoT-based systems. Another challenge is the limited technical capacity of smallholder farmers, who may need more skills or resources to use IoT-based methods [7] effectively. Several factors can make IoT in agriculture for smallholder farmers in Nepal differ from other regions. Nepal's geographical location, topography, and climate can make farming in Nepal challenging. Many smallholder farmers in Nepal may need more access to capital, credit, and technology, which can affect the adoption and use of IoT. The lack of infrastructure, such as reliable electricity and internet connectivity, can limit the potential benefits of IoT in agriculture for smallholder farmers in Nepal. The cost of implementation and deployment of IoT systems is another potential challenge. Technical expertise and know-how of IoT devices and their operation is also a significant challenge. The agricultural practices and crops grown in Nepal may differ from other regions. Despite these challenges, the potential benefits of IoT for smallholder farmers in Nepal are significant, including increased efficiency, improved yield, reduced costs, and access to markets. For many years, the Nepal government has been focusing on improving agricultural production and commercialization by introducing some key plans and strategies. The government's recent initiative is the Prime Minister Agriculture Modernization Project, Agricultural Development Strategy (2015–2035), which aims to implement modern technology to enhance agricultural productivity and commercialization [8]. With these initiatives and motivation, smallholder farmers will gradually start using the technology, familiarizing themselves with its operation and benefits. However, close coordination with the Government, local bodies, and communities is needed to overcome the challenges of understanding their specific needs and to ensure that the system is relevant to their needs.

3. Real Use Case Scenario from Smallholder's Perspective

The proposed IoT platform for smallholder farmers presents compelling real-world applications across various agricultural scenarios. These applications include:

- Mushroom Farming: Mushroom cultivation is a popular endeavor among smallholder farmers in Nepal due to its quick turnaround and profitability. The IoT platform can play a pivotal role in mushroom farming by enabling precise control of environmental factors such as darkness, temperature, and humidity, which are critical for successful mushroom growth.

- Polyhouse Tunnel Agriculture: The adoption of polyhouse tunnels for tomato cultivation is on the rise. Within these controlled environments, the IoT platform offers effective management of climatic conditions and irrigation, ultimately leading to increased productivity and higher profits for farmers.

- Nursery Operations (Fruit and Flower Plants): Grafting fruit and flower plants in a nursery demands meticulous internal microclimate control. The IoT platform provides an ideal solution for managing these conditions, ensuring optimal growth and development of plants.

- Poultry Farming: A significant number of smallholder farmers in Nepal operate small-scale poultry farms. The IoT platform facilitates real-time remote monitoring of crucial parameters within the poultry farm, including temperature, humidity, and air quality. It can also be employed to automate feed and water systems. Additionally, real-time heating, cooling, and lighting systems can be automated to optimize energy consumption.

- Farm Security and Access Control: Ensuring security and controlled access to a farmer's premises is of paramount importance. The IoT platform can be harnessed for this purpose, integrating sensors and actuators such as motion sensors and alarms. These elements provide early intrusion detection and facilitate prompt responses to safeguard the farm.

Incorporating the IoT platform into these agricultural contexts not only enhances the precision and efficiency of farming practices, but also empowers smallholder farmers in Nepal to achieve better yields, improved profitability, and enhanced security measures, ultimately contributing to the sustainable growth of their agricultural endeavors. In essence, this research not only identifies the unique demands and challenges faced by smallholder farmers in resource-constrained developing countries, but also offers a tangible solution in the form of a deployable, cost-efficient, and reliable IoT platform. By rigorously evaluating its features and performance, this research contributes to the advancement of agricultural technology, particularly in contexts where smallholder farmers play a pivotal role in sustaining local and national food production.

4. Related Work

Doshi et al. developed a smart farming prototype using a third-party cloud application that connects various agriculture sensors and displays sensor data on the farmer's smartphone [9]. Ayaz et al., in their article, highlighted the potential use and challenges of wireless sensors and IoT in agriculture. Authors have also analyzed the IoT devices and communication techniques associated with agriculture applications [10]. Nigussie et al. propose an "IoT-based irrigation management for smallholder farmers in rural sub-Saharan Africa" and found that an IoT-based irrigation management system can significantly improve the efficiency and effectiveness of irrigation for smallholder farmers in rural sub-Saharan Africa. The study conducted in Ethiopia showed that the system was able to reduce water use by 60% while maintaining or increasing crop yields. The design provided farmers with real-time information on soil moisture levels and weather conditions, allowing them to make informed decisions about when and how much to irrigate [11]. Dahane et al. present low-cost smart farming for enhancing the irrigation efficiency of smallholder farmers. The study conducted in Algeria showed that the system using low-cost sensors and a mobile application provided real-time data and feedback to farmers, reducing water consumption by up to 50% while maintaining or increasing crop yields. The authors suggest that IoT-based smart farming systems can significantly enhance irrigation efficiency but require careful attention to affordability, accessibility, local context, and collaboration between stakeholders [12]. Bayih et al. describe a case study in Ethiopia where an IoT and wireless sensor network (WSN)-based system was implemented for smallholder farmers to monitor and control their irrigation and fertilization practices. The system used low-cost sensors and a web-based platform to provide real-time data and feedback to farmers. The study found that the system could significantly improve crop yields, reduce water usage, and increase fertilizer efficiency while reducing labor costs and minimizing environmental impact [13].

Maraveas et al. review studies on IoT-based greenhouse monitoring and control systems which use sensors and actuators to collect and adjust environmental factors. These systems can improve crop growth and quality, energy efficiency, and resource management. The authors suggest that these systems can enhance the sustainability and profitability of greenhouse agriculture, but implementation requires careful attention to issues such as affordability, reliability, scalability, and collaboration between stakeholders [14]. Lufyagila et al. discuss using an IoT-powered system to monitor environmental conditions in a poultry house in Tanzania. The study deployed a low-cost system with sensors to monitor temperature, humidity, and air quality and a cloud-based data storage and analysis platform. The results showed that the system effectively improved animal health and productivity, was user friendly and accessible, and highlighted the importance of sustainable technologies in developing countries agricultural sectors [15]. Quayson et al. introduce a framework for technology for good social foundations in sustainable supply chains, emphasizing the importance of a supportive environment for smallholder farmers, including access to technology, training, and market incentives. The research highlights the potential for technology-based interventions to improve social and environmental outcomes and calls for future research to ensure inclusivity for smallholder farmers in developing countries [16]. Cheng et al. present a study on the development and implementation of an intelligent agriculture system that utilizes IoT technology in Taiwan. The system includes environmental monitoring sensors and a cloud-based data analysis platform. The study results showed that the system improved crop yields and resource management while being user friendly and accessible. The researchers suggest that the system has the potential to improve sustainability and profitability in agriculture by reducing resource use and increasing productivity. Further system development could include automated irrigation and fertilization [17].

Oliveira-Jr et al. discuss a case study on developing and deploying an IoT-based sensing platform for e-Agriculture in Mozambique. The platform included environmental monitoring sensors and a cloud-based data analysis platform. The study showed that the platform was effective in improving crop yields and resource management and being user friendly and accessible. The researchers suggest that the platform could be further developed to include weather forecasting and crop disease management, which could reduce crop losses. The study highlights the potential of IoT technology for e-Agriculture in Africa and provides insights for future research and development in other regions and for other crops [18]. Sekaran et al. developed a smart agricultural management system using IoT. This method gathers agriculture data from sensors from the fields. It creates results for ranchers, is essential for observing harvest development, and diminishes their time and energy. The information gathered from the field is stored in the cloud and field control is achieved by using IoT gadgets. The idea introduced in the paper could expand the efficiency of the harvests by decreasing the wastage of assets used in agribusiness fields [19]. Agricultural IoT solutions can help the sector improve operational efficiency, save costs, minimize waste, and enhance product quality.

Haque et al. developed secure IoT devices for the smart agriculture system. Smart agriculture based on the IoT is a system that uses sensors to monitor irrigation activities and automate crop production in the agricultural field. Farmers may monitor the state of their land from any location [20]. Bera et al. presented an intelligent precession Agriculture, where drones can be used to collect the sensor data and send to a ground server station. The data are secured using block chain-based authentication [21].

Jiang et al. described the deep learning approaches for apple fruit detection in agriculture. Deep learning, which demonstrates its ability in fruit handling and grouping, is utilized to arrange apples. The profound neural organization with various convolution layers and individual neurons is analyzed and assessed [22]. Bu et al. introduced a smart IoT agriculture system with deep learning reinforcement integrated in the cloud server for smart decisions, like how much water is required for the better growth of the crop [23]. Parvathi et al. proposed an intelligent agriculture management system to improve agricultural benefits and crop production. The goal is to use IoT and automate the task. It is intended to perform weeding, water system, detecting mugginess, endeavoring to alarm birds and animals, keeping up with reconnaissance, and so forth, to control the geolocation of gadgets from a distance [24]. Katanga et al. proposed an IoT-based, cost-effective hardware solution using voice-activated technology, centered around the ESP8266 NodeMCU micro-controller. It enables home automation via voice commands through Google Assistant and IFTTT integration and offers agricultural monitoring with soil moisture, temperature, and humidity analysis. The system efficiently manages water flow based on soil conditions and utilizes Wi-Fi for data transfer to cloud storage (Thingspeak) and the Blynk IoT platform [25][26].

Most of the work mentioned above has been concentrated on applications that either use more complicated systems or depend on third-party applications unsuitable for smallholder farmers. Smallholder farmers in low- and middle-income countries face multiple challenges in adopting the existing IoT architecture, including high costs, inadequate infrastructure, technical complexity, limited customization, and difficulties in maintenance and support. Consequently, a more affordable, user friendly, and customized IoT solution is required to cater to their unique needs and boost their productivity and livelihoods.

References

1. Stolojescu-Crisan, C.; Crisan, C.; Butunoi, B.-P. Access Control and Surveillance in a Smart Home. High-Confid. Comput. 2022, 2, 100036.
2. Schomakers, E.M.; Biermann, H.; Ziefle, M. Users’ Preferences for Smart Home Automation—Investigating Aspects of Privacy and Trust. Telemat. Inform. 2021, 64, 101689.

3. Nižetić, S.; Šolić, P.; López-de-Ipiña González-de-Artaza, D.; Patrono, L. Internet of Things (IoT): Opportunities, Issues and Challenges towards a Smart and Sustainable Future. J. Clean. Prod. 2020, 274, 122877.
4. Fan, S.; Rue, C. The Role of Smallholder Farms in a Changing World. In The Role of Smallholder Farms in Food and Nutrition Security; Gomez y Paloma, S., Riesgo, L., Louhichi, K., Eds.; Springer: Cham, Germany, 2020; pp. 19–35.
5. Antony, A.P.; Leith, K.; Jolley, C.; Lu, J.; Sweeney, D.J. A Review of Practice and Implementation of the Internet of Things (IoT) for Smallholder Agriculture. Sustainability 2020, 12, 3750.
6. GC, R.K.; Hall, R.P. The Commercialization of Smallholder Farming—A Case Study from the Rural Western Middle Hills of Nepal. Agriculture 2020, 10, 143.
7. Antony, A.P.; Lu, J.; Sweeney, D.J. Seeds of Silicon: Internet of Things for Smallholder Agriculture. MIT D-Lab. 2019. Available online: https://d-lab.mit.edu/resources/publications/seeds-silicon-internet-things-smallholder-agriculture (accessed on 28 February 2023).
8. Thapa, G.; Kumar, A.; Joshi, P. Agricultural Transformation in Nepal; Springer: Berlin, Germany, 2019; ISBN 9813296488.
9. Doshi, J.; Patel, T.; Bharti, S.K. Smart Farming Using IoT, a Solution for Optimally Monitoring Farming Conditions. Procedia Comput. Sci. 2019, 60, 746–751.
10. Ayaz, M.; Ammad-Uddin, M.; Sharif, Z.; Mansour, A.; Aggoune, E.-H.M. Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk. IEEE Access 2019, 7, 129551–129583.
11. Nigussie, E.; Olwal, T.; Musumba, G.; Tegegne, T.; Lemma, A.; Mekuria, F. IoT-Based Irrigation Management for Smallholder Farmers in Rural Sub-Saharan Africa. Procedia Comput. Sci. 2020, 177, 86–93.
12. Dahane, A.; Benameur, R.; Kechar, B. An IoT Low-Cost Smart Farming for Enhancing Irrigation Efficiency of Smallholders Farmers. Wirel. Pers. Commun. 2022, 127, 3173–3210.
13. Bayih, A.Z.; Morales, J.; Assabie, Y.; de By, R.A. Utilization of Internet of Things and Wireless Sensor Networks for Sustainable Smallholder Agriculture. Sensors 2022, 22, 3273.
14. Maraveas, C.; Bartzanas, T. Application of Internet of Things (IoT) for Optimized Greenhouse Environments. AgriEngineering 2021, 3, 954–970.
15. Lufyagila, B.; Machuve, D.; Clemen, T. IoT-Powered System for Environmental Conditions Monitoring in Poultry House: A Case of Tanzania. Afr. J. Sci. Technol. Innov. Dev. 2022, 14, 1020–1031.
16. Quayson, M.; Bai, C.; Sarkis, J. Technology for Social Good Foundations: A Perspective from the Smallholder Farmer in Sustainable Supply Chains. IEEE Trans. Eng. Manag. 2020, 68, 894–898.

17. Cheng, W.M.; Liu, H.J.; Chen, R.; Chang, W.C.; Yuan, J.J.; Chen, J.; Jiang, J. A Real and Novel Smart Agriculture Implementation with IoT Technology. In Proceedings of the 2021 9th International Conference on Orange Technology (ICOT), Tainan, Taiwan, 16–17 December 2021; pp. 1–4.
18. Oliveira-Jr, A.; Resende, C.; Gonçalves, J.; Soares, F.; Moreira, W. IoT Sensing Platform for e-Agriculture in Africa. In Proceedings of the 2020 IST-Africa Conference (IST-Africa), Kampala, Uganda, 18–22 May 2020; pp. 1–8.
19. Sekaran, K.; Meqdad, M.N.; Kumar, P.; Rajan, S.; Kadry, S. Smart Agriculture Management System Using Internet of Things. Telkomnika 2020, 18, 1275–1284.
20. Haque, M.A.; Haque, S.; Sonal, D.; Kumar, K.; Shakeb, E. Security Enhancement for IoT Enabled Agriculture. Mater. Today Proc. 2021, 49, 232–237.
21. Basudeb, B.; Das, V.A.; Kumar, A.; Pascal, L.; Khurram, K. Private blockchain-envisioned drones-assisted authentication scheme in IoT-enabled agricultural environment. Comput. Stand. Interfaces 2021, 80, 103567.
22. Jiang, H.; Li, X.; Safara, F. IoT-based Agriculture: Deep Learning in Detecting Apple Fruit Diseases. Microprocess. Microsyst. 2021, 104321.
23. Bu, F.; Wang, X. A Smart Agriculture IoT System Based on Deep Reinforcement Learning. Futur. Gener. Comput. Syst. 2019, 99, 500–507.
24. Parvathi Sangeetha, S.B.; Kumar, N.; Ambalgi, A.P. IOT Based Smart Irrigation Management System for Environmental Sustainability in India. Sustain. Energy Technol. Assess. 2022, 52, 101973.
25. Katangle, S.; Kharade, M.; Deosarkar, S.B.; Kale, G.M.; Nalbalwar, S.L. Smart Home Automation-cum Agriculture System. In Proceedings of the 2020 International Conference on Industry 4.0 Technology (I4Tech), Pune, India, 13–15 February 2020; pp. 121–125.
26. García-García, L.; Jiménez, J.M.; Abdullah, M.T.A.; Lloret, J. Wireless technologies for IoT in smart cities. Netw. Protoc. Algorithms 2018, 10, 23–64.