The contribution of the Internet of Things and smart systems to agricultural practices: A survey

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Abstract. The growing demand for agriculture products contradicts the challenges associated with the decline in farming land size and labour workforce. Recent literature acknowledges that the Internet of Things (IoT) plays a crucial role in enhancing the smart aspects already deployed in agriculture. Smart farming is an emerging concept because of IoT sensors capable of aggregating information about their agriculture fields under real-life circumstances. The paper aims to survey the recent implementation of IoT based monitoring systems applied in agriculture worldwide. A systematic literature review carried out to investigate the extent of IoT adoption in agriculture industries. The understanding of Reason to adopt IoT, the Scale of adoption and the cost and benefit of IoT adoption were drawn from papers published in SCOPUS, Web of Science, and DOAJ between 2010 up to early 2020. Twenty-eight most relevant articles extracted from the search. This paper recommends strategies to adopt an IoT-based monitoring tool pertinent to irrigation systems implementation in Indonesia.

1. Introduction
With the explosive growth of the human race, which means population growth, conventional or ancient farming methods have become unable to compensate for growth with satisfaction. Therefore, advanced farming methods are needed to approach the food needs of an increasing human population. In recent years, intelligent farming systems based on embedded systems and the Internet of Things (IoT) have gained traction and popularity among people to increase food production for humans [1].

The Internet of Things (IoT) plays an essential role in smart agriculture. Smart agriculture is an emerging concept because IoT sensors can provide information about crop condition [2]. IoT connects agricultural devices and collects data information. It applies in a variety of applications such as farms connectivity, smart environment, water management, measurement tools, crop monitoring, and other agriculture automation systems. The connected devices are capable of analyzing aggregated information and then sending it to the monitoring centre [2].

The functional aspect of IoT is to connect every object in the world for the human to control them through the internet. The concept of IoT proposed a few years ago; perhaps it is not wrong to quote that this term has become a benchmark for establishing communication between objects. In the context of the current IoT position, identification of the most prominent applications in the IoT field has been highlighted, and comprehensive reviews have been carried out accurately in the area of Agriculture [3].
From the emergence of IoT, there are different approaches to interacting objects with each other, also between objects and humans. Based on the context presented, this article surveys the use of IoT in various agricultural settings that do not limit to mobile robots, drones, image extraction and processing. Specific to the proposed works are those related to centralized processing, cost reduction, and maximizing computer power [4]. The work suggested targets the development of low-cost intelligent systems for smart irrigation [5]. The cost of IoT adoption devoted attention [6], as the passage should give farmers an alternative to increase production and limit crop damage. Intelligent or precise farming systems are expected to play an essential role in growing agricultural activities [7]. Several researchers are relevant to the topic of the Internet of Things in Smart Agriculture. By the advent of the IoT [8], it set the new direction for innovative research in agriculture. Therefore, this paper proposes for the strategies to adopt an IoT-based monitoring tool pertinent to irrigation systems implementation in Indonesia.

2. Methods
This paper adopted a systematic literature review [9] to sort, identify and draw knowledge from gathered reference. This method is employed to delve deeper into a specific topic of interest. Recent finding underlined that it is the most effective method in exploring preexisting research topics. This research explored hundreds of articles indexed in SCOPUS, Science Direct, and DOAJ. Published between 2010 and 2020. To scoped down the appropriate knowledge, the research’ agriculture monitoring systems', 'drip irrigation systems', and 'internet of things' as the keywords. Twenty-eight most relevant articles extracted from the search. The articles, then, classified into three categories as depicted in Figure 1.

According to Figure 1, most of the papers argued for the reasons for adopting the Internet of Things were published in 2017 - 2020. Alike, those discussed on the cost and benefits of adopting IoT. It is slightly different from the topic of IoT scale of adoption that mostly published between 2013 - 2016. A matrix of concept was applied to draw a conceptual framework from the overarching literature [10]. The matrices were reorganized according to papers’ publication date, show the longitudinal aspects of the topic, the insight suggested by each article related with research questions, and the description of the each papers’ causal relationship [11].

3. Results and discussion
Figure 1 summarizes the articles investigated in this study by their categories. Twenty-one articles discussed the application of IoT in agriculture, while twelve of the selected papers addressed the use of IoT-based devices in agricultural activities [12]. The gist of each category is elaborated in the following sections.
3.1. The costs and potential benefits of adoption of Internet of Things

The work proposed here focuses on the adoption of a low-cost system in smart irrigation. Wherein, the system utilizes IoT to create appliance employed in the network communicate with themselves, with capabilities such as user interaction, setting the estimated drip irrigation schedule, controller and remote data monitoring. The proposed system has proven to be adequately intelligent, low cost and portable, making it suitable for greenhouses, agriculture, and so forth [5].

The advantage of an IoT device is that it is cheaper and consumes less power. Intelligent farming systems have been designed and synthesized. This system can be used in greenhouses and plants depending on temperature. It is predicted that future capabilities will be more potent by the addition of modern techniques such as irrigation methods, the use of solar power sources [2].

The following are the main benefit of IoT in agriculture:

- Real-time data benefits cost reduction of decision making in logistic and qualitative traceability of food production.
- Crop monitoring allows the reduction of costs as well as preventing the theft in the farmland.
- The automatic irrigation system [13] works in response to the values of temperature, humidity and soil moisture obtained through sensors.
- Operational efficiency and productivity improvement supported by a large amount of data analysis of the decision support systems [14,15].
- The process for communicating with other devices and services on the internet to carry out the tasks requested by users [16].

Adequate water use and remote monitoring provide smart solutions in areas that lack water and people who are far from their agriculture. The need to conserve natural resources is justified by the use of such automation. Its easy access, cost-effectiveness, and usability make it versatile and thus suitable for a variety of potentials such as adaptability and portability enable it for the deployment in the farmland [5].

3.2. The Reason to adopt Internet of Things in agriculture

Agriculture is the backbone of the country’s economy [17]. Most of the work of the population in our country is agriculture. As we mentioned before, farmers still use the manual method for monitoring plants, and other activities, there are some disadvantages when we apply the manual mode, it consumes much time, we need to be present to monitor the plants, they fail to detect the right situation. Water is the primary agricultural resource, so the government must provide irrigation and proper management of water. Land issues are also one of the reasons for low profits; some farmers do not have land to harvest. Land leasing techniques are adaptable to solve this problem [18]. Alike, a cloud-capable CLAY-MIST (C.M.M.) measurement index based on temperature and relative humidity to assess plant comfort levels [19].

Intelligent or precise farming systems are expected to play an essential role in increasing agricultural activities [7]. Therefore we can use technology in an efficient way to get accurate results and save time. Now we will look at technology in agriculture, there are many technologies, but now all prefer to use IoT for agriculture-related work. With the help of technology, we can monitor the harvest from anywhere, and we can provide water to the fields from a distance from the location, plant detection can also be done without being in the field [19]. Overall the area of the country if we consider the agricultural sector does not receive adequate attention. Nowadays, technology is everywhere, but it is still at an early stage in adopting technology to the farming industry [19].

IoT is potentially applied through an agricultural drone [6] which is a relatively inexpensive drone with a mechanism that provides farmers with an alternative to increase yields and reduce crop damage. IoT also applied as intelligent greenhouses [20] which include aquaponics and small-scale systems [21]. The application of IoT in vertical farming [22] allows the control of moisture and groundwater using computers or cellular devices such as tablets and smartphones. In particular, advances with the Internet of Things, artificial intelligence, and robotics have, among other things, enabled automated
and data-based agriculture [23]. The increasing demand for food, both in quantity and crop quality, has increased the need for intensification and industrialization in the agricultural sector. IoT is an up-and-coming technology family that can offer many solutions to agricultural modernization [24].

3.3. The scale of the relevant research adoption

Research related to the topic of the Internet of Things in Smart Gardening. Analysis by Ray [8], for example, explains the advent of the Internet of Things (IoT) as a new direction for innovative research in agriculture. Low cost, autonomous, energy-efficient and robust solutions with features like artificial intelligence and much-needed maintenance. Overall, various aspects of IoT must be met in such a way that agriculture becomes intelligent and thriving.

Prathibha, Hongal [2] report in IoT-based Monitoring Systems in Smart Gardening underscore the vital role of IoT in smart agriculture. The concept of smart farming arises since IoT sensors are capable of providing information about the farm's real-time condition. The research aims to take advantage of developing technologies, namely IoT and Intelligent Agriculture, using automation. Automation monitoring can reduce human strength and be more natural.

Gondhawar and Kawitkar [25] propose to enrich agricultural activities by utilizing automation and IoT technology. The system comprises an intelligent application-based remote controller that monitors soil moisture and executes watering automation based on accurate real-time field data. Included in the systems is an irrigation mechanism equipped with smart control and decision making based on real-life agricultural data.

Rajalakshmi and Mahalakshmi [26] argue for crop-fields monitoring systems using soil moisture, temperature, humidity, and light sensors. Data from sensors will be conveyed wirelessly to the webserver under encrypted JSON format. Notifications will be sent to mobile farmers regularly, and farmers can monitor the condition of the field from virtually anywhere. The system will be beneficial in water-scarce areas and 92% more efficient than conventional approaches.

Baranwal and Pateriya [27]’s project focused on the safety and protection of agricultural products from insect attacks in the fields. The security provides real-time notifications once it detects an intrusion. Python scripts integrate sensors and electronic devices adopted in the systems.

Sales, Remédios [28] explain that wireless sensor networks performance in a three-node network, including the acquisition, collection, and analysis of data such as temperature and soil moisture. While the benefits of irrigation in agriculture are reducing water consumption and the environment, the Cloud Computing capabilities offer a large amount of data for high watering supported by wireless sensors and network actuators. This work is aimed at agriculture, greenhouses, and landscapes. Monitoring soil moisture to assess the plant's needs for water and conservation consideration.

Kassim and Mat [29] describe a wireless sensor network as the best way to solve agricultural problems such as optimizing agricultural resources, decision-making support, and land monitoring. The approach provides real-time information about land and plants that help farmers to make the right decision. IoT based precision farming systems comprise hardware and network architecture, and the process control software for precision irrigation systems. The software collects data from current sensors that optimize the use of water fertilizers through irrigation and also maximizes the yield of crops.

Modern agriculture requires a better irrigation management system to conserve water use in agriculture and related activities [30]. Four prevalent factors adopted in smart irrigation systems are real-time integration of weather forecast data, farmers’ control systems from anywhere, activating WiFi and Ethernet connections, increasing synchronization with humidity sensors installed on the farmer's yard, and reducing monthly farmer bills that help conserve resources limited water power. IoT continues to gain popularity in systems related to irrigation management around the world.

Controlled use of pesticides and fertilizers helps improve crop quality while minimizing agricultural costs. The predictor of pesticide uses in the farmland requires the monitoring of probability and occurrence of pests in plants. The need to collect disease and insect pest information
using sensor nodes, data processing, and mining, are enabled with the help of the IoT infrastructure [31].

4. Conclusion
Various studies have been carried out in adopting IoT technology. There are several aspects examined, namely the reason for taking IoT, the scale of adoption, and the costs and benefits of IoT adoption. Intelligent farming systems have been designed and integrated. The system is developed more efficiently and is beneficial for farmers. It provides information on temperature, humidity and soil moisture. Researchers propose and need to build an intelligent agriculture system based on IoT. The application of such a system in the field will be able to help advance crop harvests and global production. In the future, this system can be improved by adding some modern techniques such as the use of solar power sources.

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