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INTERNET OF THINGS BASED IRRIGATION MONITORING SYSTEM

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Abstract

This study aims to monitor the sustainability of the irrigation system through a smartphone application. This research method used primary and secondary data collection methods, supported by quantitative descriptive analysis and prototyping design. The research result is an application design that is easy to understand and use in regular irrigation system monitoring activities. Based on the design, results show that the design of the application display is equipped with information features of water quality, water level, water discharge, and irrigation gate location points. Therefore, this research is examined regarding the constraints when monitoring agricultural irrigation, agricultural irrigation systems, and the needs of farmers in the application design used. The design of this irrigation system application is expected to help farmers increase agricultural production to support the concept of a green economy in the agricultural sector.

Keywords**:** IoT; Irrigation; Monitoring system.

1. Introduction

The green economy is the concept of knowledge-based economic development and technology related to resources and the sustainability of ecosystems to minimize the environmental impact due to economic activity [1]. In addition, to the potential for the sustainability of ecosystems, the concept of the green economy is expected to provide economic development opportunities, especially for all humans' welfare. The urgency of the green economy on achieving sustainable development is as a framework, means, and driver in achieving economic and environmental alignment [2]. The green economy increases sensitivity to preserving natural resources, particularly to reducing emissions and pollutants that create environmental crises [3]. Currently, the application of the green economy has been increasingly stuttered and tested by various parties. It is due to the increasing population, and industrial waste produced every day [4]. Therefore, in its implementation, technology is needed to maximize economic value and maintain the environmental sustainability. One sector that is currently optimized for the use of technology in agriculture.

Comparative studies conducted on China, India, Spain, Germany, Australia, and the U.K. found that applying technology rife in the agricultural sector is Artificial Intelligence (AI). Such technologies are considered to increase investor attractiveness in agricultural products and reduce consumption and use of resources [5]. In addition to the application of A.I. in the agricultural sector, it was found that other countries such as Ireland, France, China, the USA, Thailand, and the Philippines are implementing the Internet of Things (IoT) which is expected to be very promising to assist in decision- making through monitoring of environmental conditions [6]. Instead, they use technology in agricultural supply chain preparation activities in the form of the blockchain. It is because blockchain has revolutionary technological methods to improve the search for agricultural commodities [7].

Similarly, nanotechnology is used to improve nutrient use efficiency, reduce the impact of climate change, increase the effectiveness of pest management, and reduce the environmental impact of agricultural food production activities. Thus, the application of technology as an agricultural innovation becomes an essential factor in improving the welfare of farmers, agricultural productivity, and the economy of the food sector [8, 9]. One example of a region that started to implement technology in agriculture is Sub-Saharan Africa (SSA). SSA is currently experiencing stagnant agricultural productivity and food insecurity in low-income countries [10].

Therefore, with the lack of application of technology to irrigation systems integrated into information systems, this research was conducted to facilitate monitoring of irrigation flows by farmers to increase agricultural production and minimize crop failures. The method used in this study is a method of quantitative descriptive analysis with application design methods in the form of prototyping.

2. Literature Study

2.1. Green economy concept

The green economy has a significant role to play in the context of sustainable development and poverty alleviation. Green Economy has the concept of bringing together ideas from various fields related to sustainable development issues in economics and philosophy (feminist economics, postmodernism, ecological economics, environmental economics, anti-globalization, international relations theory, etc.) [11,12]. The application of the green economy affects technological changes that consider the implementation of environmentally friendly strategies. Indicators that must be considered include the allocation of economic resources, environmental regulations, the creation of subsidies, environmentally friendly activities, and the optimization of the regional planning process [13].

In some countries, one of them in Russia, the concept of the green economy is applied to prepare public policies to achieve economic stability. It is formulated with special considerations, such as analysis of situations, ecological problems, and power [14]. On the other hand, in China, the preparation of green economy policies is still experiencing obstacles, especially in companies engaged in the industry. In industrial companies in China, applying the green economy concept focuses on the application of clean energy policies. Such applications are associated with socioeconomic factors such as population, gross domestic product per capita, educational attainment, sulfur dioxide emissions, and regional economic marketing [15].

In the Eurasian Economic Union (EAEU), consisting of Russia, Armenia, Belarus, Kazakhstan, and Kyrgyzstan, the transition to the green economy is carried out to solve environmental and sustainable development problems. Therefore, the concept of a green economy formulated by EAEU is an improvement in the population's quality of life and environmental situation, the renewal of the technology base, and the improvement of production efficiency and competitiveness. The procurement of renewable energy sources is a major factor in economic growth, energy resilience, and sustainable development [16].

2.2. Green economy and technology

Applying the green economy concept by integrating technology is the most critical part that must be applied in running a company. It is because the application of green economy technology and concepts can help maintain the company's competitiveness in the market and provide environmentally friendly products and services at the same time. Kazakhstan is one of the countries whose industrial activities combine the concept of a green economy and technology. It is shown from the number of 30% of the industry that applies the concept to energy production activities, waste management, and other activities [17, 18]. In the Southern African Development Community (SADC), technology plays a role in encouraging the implementation of the green economy. Information technology includes internet penetration, mobile penetration, mobile broadband, and fixed broadband [19]. Similarly, in China, green economy and technology are applied in Green Total Factor Productivity (GTFP). It is done using an econometric model and is measured by GDP per capita [20].

2.3. Technology in agriculture sector

The agricultural sector plays an essential role in food security in a country. Therefore, this sector is focused on sustainable agriculture with the use of technology in every activity. The application of agricultural technology increases added value in agricultural products and assists in product processing and irrigation [21]. Agricultural activities such as supply chain provision, agricultural insurance, smart agriculture, and agricultural commodity transactions can use blockchain technology. Blockchain is a digital record-keeping technology with a high level of security to maintain the confidentiality of consumer data and other agricultural data [7, 22]. On the other hand, in pest detection activities, crop projection, groundwater use calculation, and plant genetics, the technology used is Artificial Intelligence (AI). Some of the productive countries implementing it are China, the United States, and India [23]. In contrast, currently, agricultural fertilizer delivery technology uses nanotechnology. Nanotechnology in the form of Nanofertilizers (NF) technology is beneficial for increasing agricultural production and resistance to the threat of biotic and abiotic environmental components [24].

2.4. Irrigation system

An agricultural irrigation system is a system of conservation of agricultural land to maintain the balance of agricultural development and food security [25]. One of today's sustainable agricultural irrigation systems is to utilize technologies such as Photovoltaic (PV) based solar irrigation pumps. In this irrigation system, PV are linked with high-efficiency irrigation systems such as drip, furrow irrigation methods, bubbler, and sprinkler [21]. In addition to photovoltaic (PV) based, other systems utilize Soil Water Content (SWC), the system uses two irrigation scheduling based on plant growth stages [26].

3. Method

This research was conducted in Cibeusi Tourism Village, West Java, Indonesia. The study used primary and secondary data sources. The primary data was conducted by direct observation of the irrigation system conducted at the research site and discussions with the tourism village managers about irrigation constraints by farmers. Secondary data were obtained from literature studies sourced from journals or agency data related to irrigation and monitoring systems, as for the application's design using prototyping.

The stages in the prototype model include [14]:

i. Identify user needs

At this stage, the process of gathering data regarding the needs of information system users is carried out, generally through direct observation and interviews.

ii. Prototype making

Following the analysis of the needs, a prototype is created directly on the basis of the results of data collection on previous needs. At this stage, it is still in the form of an initial prototype of the information system to be used as material for further discussion with users.

iii. Prototype testing

After the prototype is completed, the developer will consult with users as well as test the results of the early stages of making whether it is appropriate or still needs to be added or there are subtractions.

iv. Prototype fixing

When there is an evaluation or input from the user side, the developer needs to improve according to user requirements.

v. Prototype implementation

If the prototype has been completed and is in accordance with user requirements, the final step is to implement the system that has been designed to be used in accordance with user requirements (see Fig. 1).

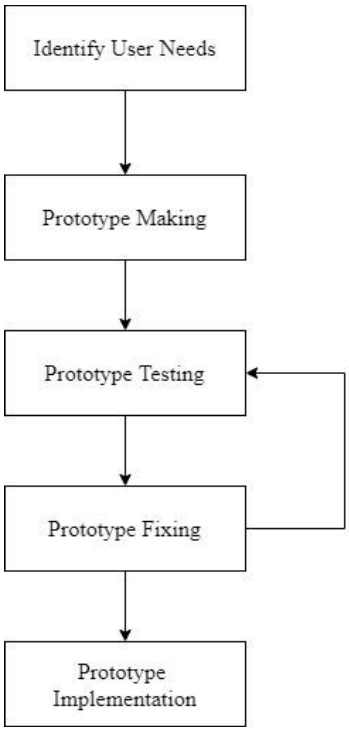


Fig. 1. Stages of the prototype model.

4. Results and Discussion

4.1. Green economy in Cibeusi tourist village

Cibeusi Tourism Village is one of the villages in West Java whose majority population have livelihoods as farmers. In addition to relying on agricultural products, people also rely on the tourism sector. Cibeusi Tourism Village has natural tourism potential in beautiful village conditions, village areas, and Cibareubuy waterfall. The potential of natural tourism helps the community's economy through trade in the form of the provision of restaurants. It is in line with research conducted by Astawa et al. [27], which said that the development of tourist villages, especially in Indonesia, aims to help rural communities in advancing villages and the economy about economic, cultural, and environmental balance. As for the application of the concept of the green economy in tourist villages, it must pay attention to the region's location, socio- economic, environmental conditions, and the availability of rural infrastructure [28, 29].

In Cibeusi tourism village, the application of green economy in the form of greening agriculture and greening tourism. Greening agriculture and greening tourism Cibeusi tourist village are combined and applied simultaneously. It is shown from the percentage of land use in the village which is about 80% used as agricultural land and tourist attractions. Cibeusi tourist village uses traditional concepts in irrigation systems and utilization of water sources.

The irrigation system in this village is managed by the village community with the help of the government. The village water source comes from three springs located in the village of Cibeusi Tourism. These water sources have different pH, temperature, ppm, and electroconductivity (ms/cm) qualities. The three springs are used based on the needs of the community, including Location 1 (to support the needs of the village water supply around it), Location 2 (for the daily life of the community), and Location 3 (for the consumption of mineral water villagers) (See Table 1).

Table 1. Water quality in Cibeusi tourist village.

No.	Location	Ph	Temperature (^oC)	Ppm	Electro Conductivity (Ms/Cm)
1	Location 1	6.70	26.2	33	**62**
2	Location 2	5.48	27.0	36	**74**
3	**Location 3**	**6.54**	**28.0**	**30**	**58**

Based on the water quality measurement indicator (Table 1), the water quality of the three sources is classified as alkaline and for locations 1 and 3 classified as a category worthy of consumption (pH drinking water standard based on the Regulation of the Minister of Health of the Republic of Indonesia on Drinking Water Quality Requirements No. 492 / MENKES / PER / IV / 2010, ranging from 6.5 - 8.5). Conversely, if viewed based on the total content of solids in the water, the three springs can be used as drinking water containing inorganic minerals, so it requires treatment to be consumed every day [30].

The irrigation system used in Cibeusi Tourism Village for agriculture is a surface irrigation system (for agriculture) with a method of providing water in the form of flooding. Conversely, in meeting household needs, clean water needs are met using a connection method without a water meter with galvanized pipe and PVC types. In addition to utilizing this type of pipe traditionally by utilizing natural resources, the type of pipe used is bamboo.

4.2. Irrigation monitoring system

In this study, an irrigation monitoring system called ASPIRASI was designed to provide real-time data for decision-making information. The data sent by the tool will be stored in a cloud database to be then presented in applications accessed by officers. The main components of real-time water irrigation monitoring stations consist of (i) cloud and database technologies, (ii) automated sampling and on-site sensors, and (iii) laboratory analysis of representative water samples [31]. The system designed in this research is based on a mobile application to be accessible to the relevant officers and the public. Irrigation in Cibeusi tourist village is divided into 3 locations with different functions. The first location point serves as a source of water that flows throughout the river flow and irrigation. The second point serves as a flow of water for the daily needs of Cibeusi village. Meanwhile, the third point is irrigation that distributes water from Cibeusi village to the surrounding area. The following is the design of the irrigation monitoring system in Cibeusi Tourism Village (Fig. 2).

Fig. 2. Irrigation monitoring system application design (ASPIRASI).

The system can help users monitor their irrigation, from agriculture to plantations to community consumption. For agriculture, for example, the system can display the temperature and slowness around the water level without going to the place directly. Using the Internet of Things (IoT) concept, how it works can be more time- efficient. This monitoring system contains wireless sensor units placed in each location ranging from locations 1 to 3. Each location contains a temperature sensor, water level sensor, and water flow sensor that detects water discharge. In real-time, each sensor will send the latest data to the Cloud Server to be stored in the database and displayed on the application.

This monitoring system concept uses the workings of the Internet of Things (IoT) by installing specific sensors on objects that can transmit signals [32, 33]. Then the data is stored in the Cloud Server to be displayed on the application. In the application, the user can give commands to open irrigation canals or close as needed. This IoT architecture uses sensors and wireless networks connected to the IoT Gateway to store them on Cloud Server. The sensor circuit is based on the Wireless Sensor Network (WSN) with five components: Transceiver, Microcontroller, Power Supply, Memory, and Sensor [34]. The transceiver has a function as the sender or receiver of the signal of the object. The microcontroller has a task to regulate data communication between sensors installed on the object, so if one object has more than one sensor, then the microcontroller will arrange for the data transmission to function correctly. The power supply becomes the overall electric power for the WSN to function properly, usually using a battery. Memory will store temporary data that is part of the microcontroller. Sensors, which are responsible for converting from one energy to another, can be processed and transmitted to a microcontroller into data. Here is the design of the WSN constituent components (Fig. 3).

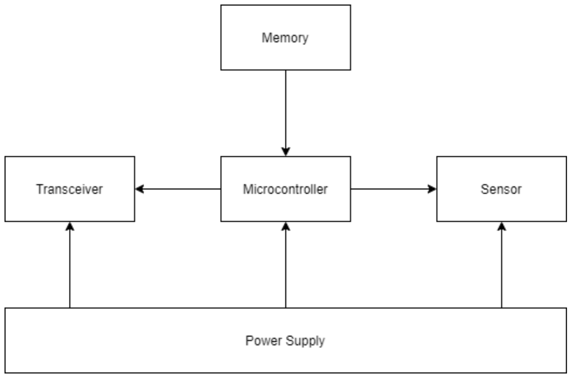
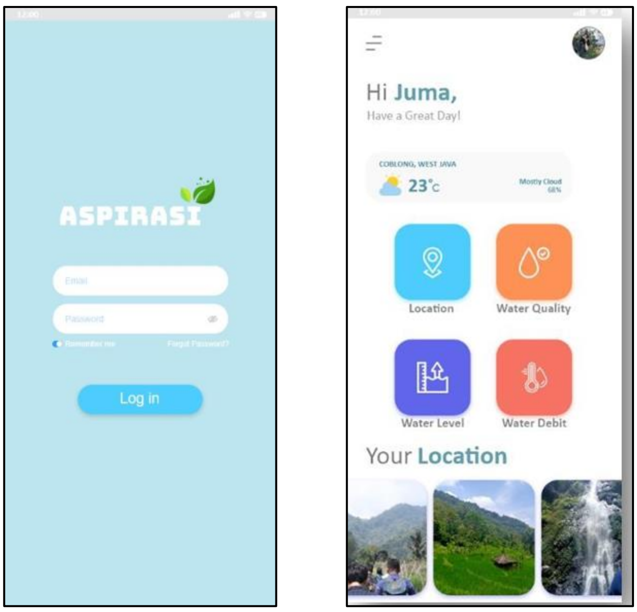


Fig 3. Wireless sensor network (WSN) component design.

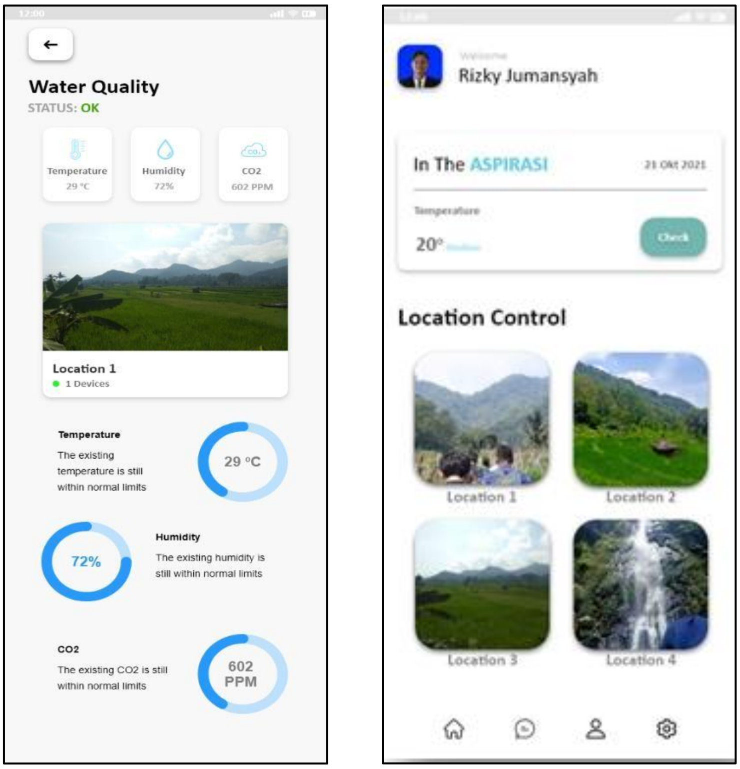
The monitoring system interface here is created in the form of a display of information obtained from several sensors marketed in irrigation. The irrigation monitoring system consists of four sensors. The first sensor is a water level sensor that provides information about the level of water. The second is a temperature sensor that detects the temperature around irrigation. Third, the water flow sensor will detect the discharge of water flowing in the irrigation. Lastly, the air humidity sensor is around. ASPIRASI allows village officials to monitor and be notified if there is dangerous information related to the irrigation of Cibeusi village. People can also access this information by accessing apps only through smartphones [35, 36]. Users of this monitoring system are broadly reserved for admins who are officers from the local village. Admin has a monitoring function to get information obtained from the WSN sensor [37,38]. Figure 4 is the ASPIRASI Mobile Application Interface Design.



(a) **(b)**

Fig. 4. Login page interface design and home ASPIRASI app.

To access the app, admins require signing in with a previously account. After logging in, the app will redirect to the Home page. There are four main menus of the application on this home page, namely Location, Water Quality, Water Level, and Water Debit. The Location menu will display several locations that serve as irrigation points. The water quality menu will display water quality data obtained from sensors at downstream irrigation points. Water level will display water level data if the water exceeds the maximum limit. It will provide notifications on this application. Water debit will display a real-time graph of irrigation flow water discharge. Each menu presents detailed information about irrigation parameters as a consideration in planting seedlings by the conditions presented by the sensor. Then to see the water condition at each point of the location is presented on the location menu. Here is the interface design of the irrigation data detail page (Fig. 5).



(a) **(b)**

Fig. 5. Location control page interface design and water quality ASPIRASI app.

On the Location control, the admin page will be presented several locations of irrigation points that have been marketed by the previous sensor (Figure 4(a)). When the admin chooses one of the locations, it will appear data in numbers that provide information about several things, starting from the temperature, humidity, and carbon dioxide content at the irrigation point. This data can be used as an information consideration for agriculture residents, such as soil moisture, water discharge, and temperature. It could be the consideration of the type of plant suitable for environmental conditions to get more satisfactory results for the surrounding residents. This study is in line with previous reports [39-42].

5. Conclusion

ASPIRASI application presents water and soil quality sensor information at the irrigation point in real-time but based on periodic to get actual data. In addition, this application is easy to use because users only need to access it through a smartphone anytime and anywhere, without monitoring it in a certain place. Another capability of the system built is the ability of the system to send data wirelessly and periodically between sensor devices to applications with a relatively fast time of only a matter of minutes. The data presented in the application is expected to be a consideration for the majority of the surrounding communities as farmers to maximize their agricultural results with data on humidity, temperature, and carbon dioxide content to get maximum agricultural results. However, this research is still limited to one area. Further studies might cover more areas and adopt other technologies in irrigation monitoring systems.

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