The use of iot technology based on the forward chaining method to monitor the feasibility of rice field

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Abstract. This study is aimed to implement a system based on the forward chaining algorithm to provide real-time information on irrigation and soil feasibility. There are three aspects studied, namely, water level, soil moisture, and temperature. The system developed uses an ultrasonic sensor as a water level detector, a soil moisture sensor as a soil moisture detector, and a DS18B20 sensor for measuring temperature. This system uses the ISP8266 module NodeMCU microcontroller as a Wi-Fi module and uses a solar cell to utilize the sun as an environmentally friendly power supply. Two tests were carried out, including laboratory testing and field testing. Laboratory testing shows that the system works with an accuracy of 57%. Tests were carried out on the three aspects studied. Meanwhile, field testing shows that some of the rice fields in Cekik Hamlet are not yet suitable for processing based on land feasibility. There are 8 paddy fields with an average area of 25 square meters, and they are named rice fields B, C, D, E, F, G, H, and I. The test results showed that the lands suitable for work are rice field B and rice field E. The feasibility value is measured based on water availability above 3 cm, wet soil moisture with a value of 300 or below 300, and a temperature below 25 degrees Celsius. Validation was obtained from farmers, the head of rice field irrigation (Prajuru Subak), and agricultural extension workers. It can be concluded that the system developed has been able to provide information on irrigation or water availability and the feasibility of cultivating the land in real-time.

1. Introduction
Agriculture is a livelihood source for some people in Indonesia, especially in rural areas [1]. Indonesia, a country with a tropical climate, is very suitable for the agricultural sector. Rice farming is becoming the main source of livelihood in Indonesia and is blended in their cultural tradition, including Bali Province. In Bali Province, the irrigation system of paddy farming was assisted by a system that is known as Subak. This community-based irrigation system assured the small farmers of having sufficient water for their rice fields.

However, Indonesia's tropical climatic conditions also cause the water absorbance of the soil to happen quickly. Such a situation requires a lot of water quantity to be able to plant the crops well. Therefore, sufficient water availability and a good irrigation system that can cultivate paddy soil become very important.

Rice farming in Bali, including in the Cekik Hamlet-Berembeng Village-Tabanan, uses a dam irrigation source managed by the Subak system. With many Subak members using dam water sources and uncertain climatic conditions, the rice fields located downstream of the dam will have difficulties getting the irrigation water. It is mainly due to the rice planting season and the use of irrigation water in Cekik Hamlet, which is carried out simultaneously, which results in small water sources or difficulty obtaining irrigation water. One of the areas heavily affected by such condition is Cekik Hamlet in the Berembeng Village of the Tabanan Regency.

Controlling irrigation with erratic water availability consumes a lot of energy and time. There are even more problems occurred during the dry season. Water as the irrigation sources shrink, causing the
farmers to delay the tillage process until the water returns to normal again. Further difficulties arise when farmers have to monitor the water availability and sufficiency for cultivating the paddy soil. The level of water is an essential factor in rice farming since it affects the soil moisture level. The debit of the water does not merely indicate the water sufficiency of the rice field. The high-water debit level may damage the irrigation system, temuku, which acts as the gate to the rice field. In the Subak irrigation system, the water level is measured by the level of the high enough water to pass the temuku.

In Cekik Hamlet, the irrigation condition of the rice fields is precarious. It causes the farmer's difficulties to decide on the tillage since they frequently go to the rice field to check whether the water level is high enough. Furthermore, they also have to manually predict the soil condition, leading them to miscalculation and cause the crop process's failure. Therefore, a system that can monitor the availability of irrigation water and land conditions remotely is needed. The system is expected to get information regarding the availability of irrigation water and the feasibility of cultivating the land to inform the farmer regarding the good time to plant the seeds. The current development of technology, especially in computer networking, provides various solutions to solve the problems, mainly by utilizing networking technology. Internet of things (IoT) technology takes advantage of the sensor technology combined with the automation processes. It could be implemented to tackle the challenges of monitoring water availability in the irrigation system and soil condition in the rice field.

In this work, we develop a system that could monitor the rice field's water, soil, and temperature. The system was developed by applying artificial intelligence (AI), Internet of Things (IoT) technology, and expert systems. This system can provide information on the availability of irrigation water and soil cultivation feasibility with a forward chaining algorithm based on 3 (three) aspects, namely water availability, soil moisture, and temperature. This system works by matching data obtained by the sensors in the rice field with the reference data. The reference data were generated based on the knowledge of the agricultural extension agents implanted in the system to determine a decision to help farmers take action in cultivating the land. The developed system determined the presence of sufficient water level in the irrigation system and measured the soil condition and temperatures to provide information for the system to assist farmers in making decisions on land cultivation based on them. Artificial intelligence was used to give better yet fast results in supporting the decision.

2. Literature Study

2.1. Previous Work

Several studies related to research on the use of internet of things technology in the irrigation system have been carried out. Ranjani & Sravya [2] examined the IoT-based smart irrigation system. It was stated that the biggest problem in the agricultural sector is water scarcity. Therefore, Ranjani & Sravya developed a system that can maximize water use wisely with a working system that can predict and measure the decrease in humidity and restore water as needed to minimize excess water use. This system can save about 80% of irrigation water usage. Asnawi and Syukriasari [3] also developed a paddy field irrigation system based on IoT technology. The prototype was built to provide information regarding the water level, and soil also moisturizes to control the paddy irrigation canal remotely. Nawandar and Satpute [4] provided a low-cost smart irrigation system in a portable, lightweight, and user-friendly design. It used MQTT and HTTP to communicate and informed the users about the current crop situation through the internetworking technology. Our system was built to provide information on the feasibility of tillage based on the availability of irrigation water, soil moisture conditions, and the surrounding temperature in real-time and periodically.

2.2. Subak

Subak is a unique irrigation system in Bali based on Hinduism and the Tri Hita Karana philosophy, consisting of Parhyangan, Pawongan, and Palemahan, which are the three balances and harmony that are still maintained by the Balinese people. Subak is a rice farmer organization that organizes traditional irrigation and has become a tradition in Bali. According to Provincial Regulation Number 9 of 2012,
Subak is a traditional water management organization and or cultivation management at the agricultural system level of Balinese indigenous people with social, religious, and economic aspects that have historically continued to grow and flourish [5].

2.3. Temuku
Temuku is a rice field gate that functions as a water divider for each rice field. The water from Empelan or the dam will flow to the main channel called Telabah Gede. The main water distribution building is called Temuku Gede or Temuku Aya, to divide water from Telabah Gede into every Subak (Munduk). The water from Temuku Gede has then flowed again into a secondary water channel called Telabah Cerik. From Telabah Cerik, water is returned to each of the Subaks’ rice fields with a water distribution building called Temuku Cerik, made from areca wood or coconut wood [6]. Temuku pictures can be seen in figure 1 below.

![Figure 1. Temuku.](image)

2.4. Forward Chaining Method
Forward Chaining is matching facts or statements starting from the left, namely IF first. The reasoning starts with the facts first to test the truth of the hypothesis. In the Forward Chaining method, facts will be stored in a memory to match the data to be analyzed. The output of the Forward Chaining method presents the actions that must be taken when there are special conditions in the input [7]. According to Pahlevi, the forward chaining algorithm is one of the two main reasoning methods when using an inference engine, and logins can be described as a set of rules and valid inference arguments [8].

2.5. Sensors
An ultrasonic sensor is a sensor that can read the distance from an object or object that is reflected. The ultrasonic sensor has a wave size with a frequency above the sound wave frequency, which is more than 20 kHz. This ultrasonic wave is generated from a transducer or ultrasonic sensor. The transducer will convert the electrical signal into ultrasonic waves and convert the ultrasonic waves into electrical signals [9]. The soil moisture sensor is a moisture sensor that detects moisture in the soil. This sensor consists of two probes to pass current through the ground, then read the resistance to get the humidity level value [10]. The DS18B20 temperature sensor is an electronic component that can capture environmental temperature changes and then convert them into electrical quantities. This sensor is a digital sensor that uses 1 (one) wire to communicate with the microcontroller [11].

3. Research Methods
The research method began by analyzing problems that occur in the Dusun Cekik, Berembeng Village, where farmers experience difficulties in irrigation and land cultivation due to the difficulty of irrigation sources. Therefore, data were collected through interviews with several local farmers and also with agricultural extension agents. Data were also obtained through observation or direct observation of conditions in the field to obtain data and conduct literature studies to add information in developing the system created. After all the data were collected, then rule development and system development were carried out where rule development uses the forward chaining method and implements the knowledge of farmers and agricultural extension agents into the system. The development of the system was done by making a system hardware design and assembling electronic components. After the development of rules and systems was ready, they was then combined into one intelligent system that was tested in the
laboratory to test the implanted sensors and algorithms' accuracy. After testing in the laboratory, the testing was carried out in the field, and the results of the testing in the field was validated by agricultural extension agents, irrigation members (*Prajuru Subak*), and farmers. The depiction of the research method chart can be seen in figure 2 as follows.

![Figure 2. Research Methods.](image)

**3.1. Research Design**

The research design is presented in a chart, where two things were done, including rule development and system development. Rule development is designing a forward chaining algorithm based on knowledge from agricultural experts implemented into the website, while system development is the process of designing electronic components, microcontrollers, and system interior design. Figure 3 deliver the methods used in this work.

![Figure 3. System Diagram.](image)

**3.2. Rule Development**

Rule development was taken from interviews with agricultural extension agents and farmers to be implemented in the system as knowledge in data analysis using the forward chaining algorithm. The realizable value was based on water conditions above 3 cm, temperature less than 25 degrees Celsius, and soil moisture less than 300 less, while the value was not feasible if the water condition was below 3 cm, the temperature was above 25 degrees Celsius, and soil moisture was above 300. The rules of the system that was being developed can be defined as follows.

1) If water > 3 & temperature < 25 & humidity > 300 then worth it
2) If water > 3 & temperature > 25 & humidity > 300 then worth it
3) If water > 3 & temperature > 25 & humidity < 300 then worth it
4) If water<3 & temperature < 25 & humidity > 300 then not feasible
5) If water<3 & temperature < 25 & humidity < 300 then not feasible
6) If water<3 & temperature > 25 & humidity < 300 then not feasible
7) If water<3 & temperature > 25 & humidity > 300 then not feasible

The criteria for soil moisture values taken from research by Oktavianus [12] can be seen in table 1.

| No | Soil Moisture Sensor | Soil Moisture Condition Category |
|----|----------------------|----------------------------------|
| 1  | 701-1023             | Dry                             |
| 2  | 301-700              | Moist                           |
| 3  | 0-300                | Wet                             |

3.3. System Development

System development consisted of 2 (two) steps, namely the development of hardware systems and software systems. The hardware system development consisted of assembling electronic components such as NodeMCU, Ultrasonic sensor, Soil Moisture Sensor, and DS18B20 sensor. Before assembling the system, a system circuit design and system construction design should be made first. The circuit drawing and system design are shown in figure 4 below.

The system used a solar panel voltage source inputted to a 12V DC battery and then converted to the charger controller panel to 5V DC because it worked at 5V DC voltage. For NodeMCU, it took 5V DC direct voltage to the charger controller panel and distributes the voltage to the three sensors, namely the ultrasonic sensor, soil moisture sensor, and DS18B20 sensor. The 2D design of the system adapted to field conditions to be placed on Temuku or water gates on rice fields. The development of the software system was developed simply and simply so that it is easy for farmers to understand. The system was developed using the localhost network.

4. System Implementation

The system implementation was carried out in 2 (two) phases, implementation, and local testing in the laboratory and implementation in the field.
4.1. The Laboratory Implementation
System testing in the laboratory was carried out for 1 (one) month. The test was carried out for 31 days with a duration of 1 (one) hour per day. Testing the sensor's accuracy was done manually or by making your conditioning for water level, soil moisture, and temperature. The temperature was measured using a thermometer on the handphone. Water level sensor testing was done by placing an object on the sensor reading path according to the height that is set to be read by the sensor and measured with a ruler to check the accuracy of the sensor readings, while testing the soil moisture sensor was done by making a soil moisture sample, and for testing. The temperature sensor was checked to see the ambient temperature around it and was matched with the thermometer indicator's temperature value. The system algorithm’s accuracy was calculated based on the water level, soil moisture, and temperature. The status was feasible based on the value of water more than 4 cm, humidity less than 700, and temperature below 30 degrees Celsius. If the values for water, humidity, and temperature are below the criteria, it is inadequate. The results of research in the laboratory are displayed using the following graph shown in figure 5.

![Percentage Of Accuracy](image)

**Figure 5.** Percentage Graph of Laboratory Testing Result.

The system testing results in the laboratory for 1 (one) month, the accuracy of the sensor readings, and the algorithm embedded in the system were 57%. It was obtained from the soil moisture sensor's instability, and the ultrasonic sensor and temperature sensor are accurate in reading the given conditions. Therefore, the soil moisture sensor needs to be repaired and feasible to be implemented in the field. The value of 75% of the accuracy level was obtained because the soil moisture sensor readings are analogous to the NodeMCU program. Therefore, the soil moisture sensor reading value tends not to match the set value. The sensor's accuracy was tested first in the laboratory to reduce the inaccuracy of the sensor readings in the field and ensure the sensor can read measured values according to standard values such as distance, humidity, and temperature. Sensor reading's inaccuracy can also affect the system conclusions that are processed using the forward chaining algorithm. The refinement of the sensors’ reading has provided the sensors’ required accuracy to read the corresponding features.

4.2. Field Testing
System testing in the field was carried out in the rice fields under the irrigation system of Subak Lanyah 2 Bajera, which is located in Cekik Hamlet, Berembeng Village, Selemadeg District, Tabanan Regency. The test was carried out for 1 (one) month in 8 (eight) rice fields with Subak Lanyah 2 Bajera irrigation. Each paddy field is tested for 1 (one) week. The system was tested for 1 (one) week on 1 (one) rice field and tested for 20 minutes or more a day since it takes a minimum of 1 (one) week to ensure the irrigation water source to be sufficient to irrigate the rice fields and ensure moisture the soil was ready to be cultivated. Therefore, the total rice fields tested for 1 (one) month are 8 (eight) rice fields. Figure 6 shows the test results of the system in each of the rice fields.
5. Discussion
The test results of the 8 rice fields, shown that the system was able to read the conditions of water level, soil moisture, and temperature in the field. However, several problems still need to be solved. The soil moisture sensor could not read soil moisture directly in the paddy fields and had to use samples or soil samples in paddy fields taken and placed in a small container. In this way, the soil moisture sensor can begin to read soil moisture conditions. It happens because the copper in the soil moisture sensor is running low, and it is unable to read the soil moisture conditions widely. When testing in the field, there is often an error value on the sensor, especially on the water level sensor, where the sensor is not accurate in reading the water level, and the value tends to be far from the actual value. The error value occurs due to the unstable electric current that enters the ultrasonic sensor.

The results of the field testing showed that of the 8 (eight) rice fields tested, only 2 (two) rice fields were suitable for soil processing based on the percentage of the feasibility of tillage in the data above, where the 2 (two) rice fields had stable water conditions, soil moisture was not too dry, and temperature tends to be expected. The two fields are rice field B and rice field E.

Data and system validation were done by the agricultural extension workers, the head of irrigation (Prajuru Subak), and farmers. It was found that the data that was ordered by the system was following the reality of conditions in the field that the rice fields in Cekik Hamlet, Berembeng Village were not yet feasible to carry out land processing. The availability of irrigation water in Subak Lanyah 2 Bajera is erratic and tends to be small.

6. Conclusion
From the results and discussion, it can be concluded that the Subak irrigation system could be supported by using the internet of things technology. The prototype was devised to monitor the water level in the
Subak irrigation system, specifically in the Temuku. It can be concluded that the system can read conditions in the laboratory and the field and displays data on the website in real-time. The system has also been able to provide conclusions or decisions to farmers regarding the feasibility of cultivating the land-based on conditions in the field, and also the system is feasible for further development and implementation in the field based on validation from agricultural extension workers, head of irrigation (Prajuru Subak), and farmers.

References

[1] Sulistiyono D, Suwarto and Rindarjono M G 2015 Transformasi Mata Pencaharian Dari Petani Ke Nelayan Di Pantai Depok Desa Parangtritis Kabupaten Bantul J. GeoEco 1 234–249
[2] Ranjani P R and Sravya G 2018 IOT Based Smart Irrigation System International Journal of Research 05 1016-1022
[3] Asnawi M F and Syukriasari F 2019 A prototype for IoT based Rice Field Irrigation System SinkrOn 3 260 DOI: 10.33395/sinkron.v3i2.10071
[4] Nawandar N K and Satpute V R 2019 IOT based low cost and intelligent module for smart irrigation system Comput. Electron. Agric. 162 979–990, Jul. 2019, DOI: 10.1016/j.compag.2019.05.027
[5] Wijayanti P U, Windia W, Darmawan D P and Widhianthini W 2020 Sustainable development model of subak in Denpasar City Int. J. life Sci. 4 109–117 doi: 10.29332/ijls.v4n1.418
[6] Pribadi M and Wena 2007 Kajian Aspek Teknologi Dan Kultural Model Saluran Dan Bangunan Irigasi Subak : Studi Kasus Pada Organisasi Subak Di Kabupaten Tabanan-Bali Penelitian
[7] Sugiharni G A D and Divayana D G H 2017 Pemanfaatan Metode Forward Chaining Dalam Pengembangan Sistem Pakar Pendiagnosa Kerusakan Televisi Berwarna J. Nas. Pendidik. Tek. Inform. 6 20 doi: 10.23887/janapati.v6i1.9926
[8] Pahlevi O 2020 The Utilization of Expert System for Diagnosing Diseases Cocoa Plants Based on Android Using the Forward Chaining Method 4 10–18
[9] Rohmanu A and Widiyanto D 2018 Sistem Sensor Jarak Aman Pada Mobil Berbasis Mikrokontroller Arduino Atmega328 J. Inform. SIMANTIK 3 7–14
[10] Husdi H 2018 Monitoring Kelembaban Tanah Pertanian Menggunakan Soil Moisture Sensor Fc-28 Dan Arduino Uno Ilk. J. Ilm. 10 237 doi: 10.33096/ilkom.v10i2.315.237-243
[11] Utama Y A K 2016 Perbandingan Kualitas Antar Sensor Suhu dengan Menggunakan Arduino Pro Mini e-NARODROID 2 doi: 10.31090/narodroid.v2i2.210
[12] Oktavianus R, Isnawaty, Muchlis N F 2017 Desain dan Implementasi Sistem Monitoring Kelembaban Tanah Berbasis Android semanTIK: Journal of the Informatics Engineering Department, Universitas Halu Oleo 3 259–268