# Internet of Things based Automated Irrigation System for Growing Grapes

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## ABSTRACT
Grape growing requires care and diligence in providing nutrients to feed the plants and watering according to the plants' needs to maximized growth. This research develops a system to meet these needs, namely a system for watering according to the needs of the plants, i.e. according to soil moisture. The moisture sensor is used to determine the water requirements of the plants, and when the sensor indicates that the water content in the planting medium is less than the specified value, the system delivers water to the planting medium. To know the nutrients needed by the plants, this system is equipped with an NPK sensor, and based on the readings of the NPK sensor, nutrients that are lacking in the planting medium are added by mixing nutrients with the water for irrigation. In order to monitor the development of the vines, this system has also been equipped with a camera so that the owners of the vines can take pictures of their plants using Android devices connected to the irrigation system using Internet of Thing technology. The results of the tests carried out show that. Based on the results and tests carried out on the irrigation system, several conclusions can be drawn, including the following: the irrigation system has been able to function properly using several sensor components, namely the soil moisture sensor, the NPK sensor and the camera module connected to the ESP8266 microcontroller. The average automatic watering time is ± 6 seconds, the soil moisture is ± 60% and the accuracy of the readings from each sensor is ± 99%. During the 30 days of testing, vine A (manual) experienced a growth of ± 4.3 cm while vine B (automatic) experienced a growth of ± 5.2 cm.

## Keywords
Humidity sensor, NPK sensor, Growth, Watering,

## 1. INTRODUCTION
Some types of grapes are in high demand for fruit snacks because they are sweet and refreshing. However, some grapes are not sweet or sour and their skin is thick, so many people dislike them. The types of grapes that many people like are imported types because it can be grown in various climates around the world [1]–[3] and its advantages have a higher level of sweetness. In addition to having a higher level of sweetness, some types of grapes have other advantages, such as thicker flesh, thin skin, seedless, and crunchier than other types. Another advantage of growing grapes is that this type of fruit has a relatively stable selling value with a fairly high price compared to some fruits when the harvest season has decreased in price. Considering the advantages of growing grapes that will be obtained, many people plant grapes on the lands they have. Problems arise when they realize that it is not easy to grow grapes, there are several activities that must be undertaken to maintain maximum grape plant growth, such as watering should not be missed, there should be no lack of water or excess water [4], [5], the provision of nutrients must be sufficient [6]–[8]. In addition, care for grapes must absolutely be carried out, such as pruning so that the plant can release buds followed by flowers [9].

Some of the stages in grape cultivation that must be carried out include: land preparation [10], [11], making planting holes [12], [13], planting [14], fertilizing [10], irrigating [13], loosening the soil [14], and pruning [9]. The process of fertilization and irrigation is the main key to the success of grape cultivation because it will determine the growth and fruiting of grapes [10], [13]. Watering should be constant, sufficient, and not stagnant. Grapes need water but should not be excessive [4], [5].

This research tries to overcome the problems that arise when cultivating grape plants, namely an automatic watering system by paying attention to the level of soil moisture using a moisture sensor and the nutritional needs needed for plants using an NPK sensor. In order for plant watering to be monitored remotely, the developed system is equipped with Internet of Things technology so that monitoring can be done via an application embedded in an Android device. The camera installed in the system can be used to observe the condition of the plant remotely via an Android device.

## 2. METHOD
This research method consists of several parts, including: system block diagram, hardware setup, system flow diagram, and Android application design.

### 2.1 System Block Diagram
Figure 1 shows the moisture sensor used to detect the soil moisture level, this sensor consists of a probe that passes a current through the soil and reads its capacitance to obtain the moisture level value [15]–[17]. The temperature sensor is used to measure soil temperature, it consists of a waterproof probe that can be inserted into the growing medium [18], [19]. The NPK sensor is used to measure the nutrient content of the soil, the NPK sensor consists of 3 probes that are implanted in the soil to measure the content of nitrogen, phosphorus, potassium in the soil [20], [21]. The camera module is used to photograph plant conditions in real time [22]. The ESP8266 microcontroller acts as a data reader, sending data to Firebase to be read by Android devices [23], [24]. The pump, as the output of the system, functions to drain the solution, namely irrigation water and liquid fertiliser, which is a nutrient for plants [25].

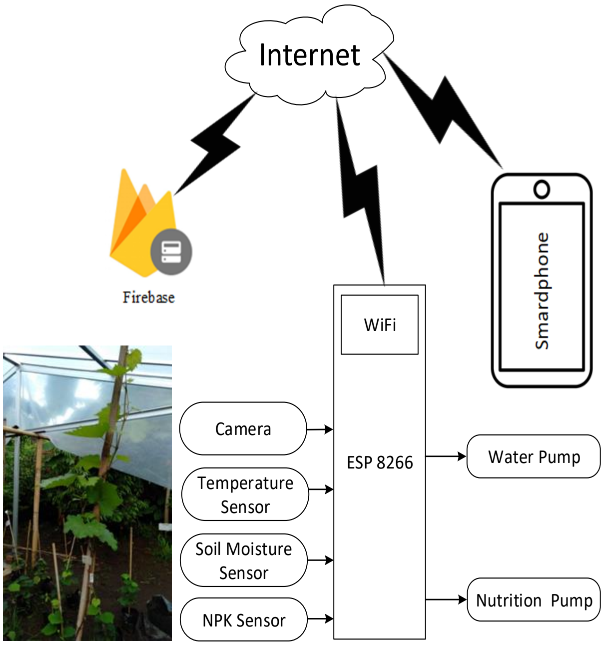


**Figure 1. Block diagram of the irrigation system.**

## 2.2 Hardware Setup

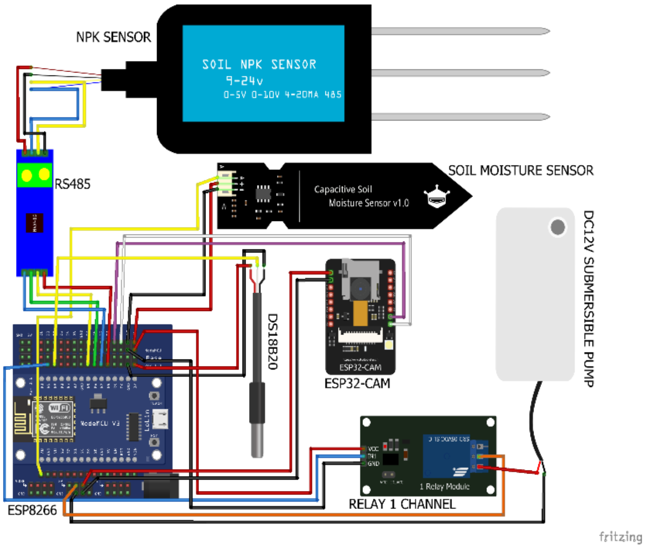


**Figure 2. Hardware Setup**

Figure 2 shows all the components connected to the ESP8266 microcontroller as the center of the data reader, which is sent to Firebase and processed so that it can make a decision to water or not, depending on the state of the humidity sensor readings. The circuit consists of DC submersible pump, DS18B20 temperature sensor, capacitive soil moisture sensor, camera module (ESP32-CAM), NPK sensor, RS485 Modbus module and ESP8266 + expansion board.

## 2.3 System Flow Diagram

Figure 3 shows the steps of the irrigation system, the first step is to install a temperature sensor, a humidity sensor and an NPK sensor in the soil, which is the medium for growing grapes. Then the ESP8266 microcontroller reads the temperature sensor and the humidity sensor is processed to determine the level of water demand, if the soil moisture is less than the specified requirement of 60% then the irrigation pump is activated, otherwise if the soil moisture is sufficient then the irrigation pump is turned off. In addition, the ESP 8266 microcontroller reads the NPK sensor to determine the nutrient needs of the plants, and if nutrients are needed, the nutrient pump is activated to add nutrients to the irrigation water. The sensor readings are sent to Firebase for display on the Android application.

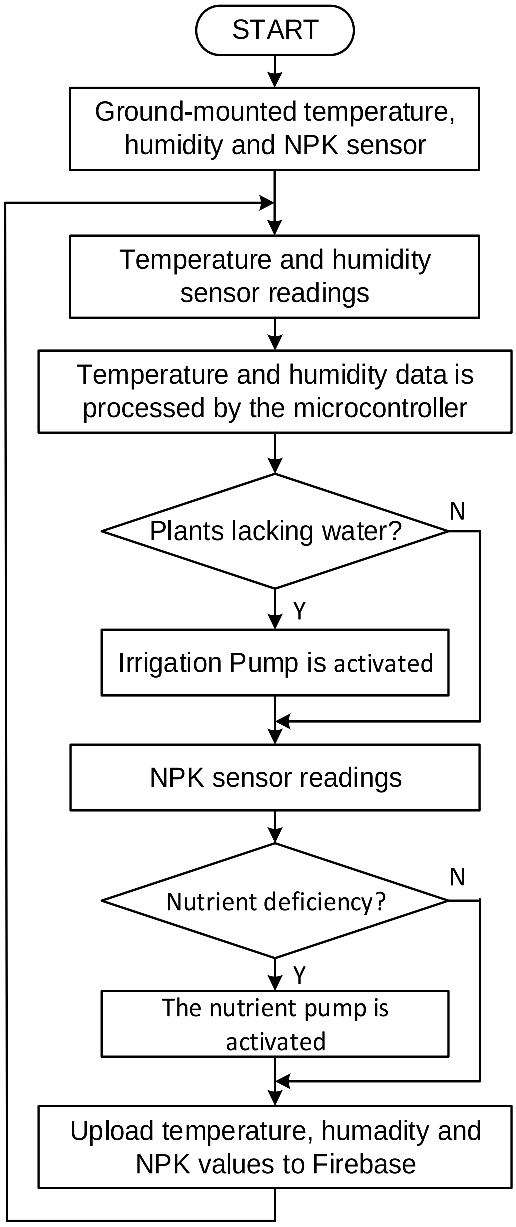


**Figure 3. System Flowchart**

## 2.4 Android application design

Figure 4 shows the application design including the main page, the monitoring page, which contains data from the humidity, temperature and NPK sensor readings. The next page shows images captured by a camera and sent to Firebase. By using the application, the development of the grapevine plants can be monitored remotely using IoT technology, so that the farmer, as the person responsible for the growth of the grapevine plants, does not have to visit his garden every day, as the watering can be done automatically, and the growth monitoring can be observed using images that have been successfully sent to Firebase.

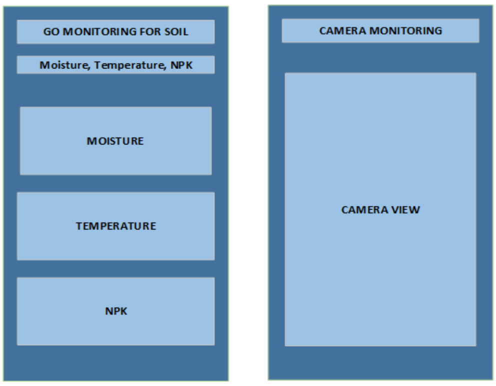


**Figure 4. Android application design**

# 3. RESULTS AND DISCUSSION

This system test starts by providing data from the readings of several sensors, namely NPK sensor, moisture sensor, temperature sensor and irrigation system test results, as well as the display of the application that presents the results of the sensor readings and camera shots with several images that can be viewed using the application on Android devices.

## 3.1 NPK sensor test

Table 1 shows the results of testing the NPK content in the soil of the planting medium by comparing the measurement results using the NPK sensor with the NPK measuring instrument, namely the 2 in 1 Fertilizer + pH Meter. The test results show that the NPK sensor is able to provide empirical values, whereas the 2 in 1 Fertilizer + pH Meter only provides scale limits, namely Too little (0-40%); Ideal (50-70%) and Too much (80-100%).

**Table 1. NPK sensor value test compared to NPK meter**

| No | N (ppm) | P (ppm) | K (ppm) | Measuring Instrument | |
|---|---|---|---|---|---|
| | | | | Counted | Approximate Percentage |
| 1 | 1 | 0 | 0 | Too Little | 0 |
| 2 | 51 | 18 | 25 | Too Little | 20 |
| 3 | 77 | 27 | 38 | Ideal | 50 |
| 4 | 117 | 42 | 58 | Ideal | 60 |
| 5 | 138 | 49 | 69 | Ideal | 65 |
| 6 | 177 | 155 | 217 | Ideal | 70 |
| 7 | 192 | 159 | 223 | Too Much | 85 |
| 8 | 181 | 247 | 90 | Too Much | 90 |

## 3.2 Moisture sensor test

Table 2 shows the test results between the Capacitive Soil Moisture Sensor v1.2 and the soil moisture sensor. From the test results it can be seen that both instruments give almost the same reading, there is an error but it is very small.

**Table 2. Comparison of Soil Moisture Sensor and Moisture Meter readings.**

| No | Sensor | Meter | Difference (Meter - Sensor) | Error (%) |
|---|---|---|---|---|
| 1 | 10 | 10 | 0 | 0.00 |
| 2 | 19 | 19 | 0 | 0.00 |
| 3 | 29 | 30 | 1 | 3.33 |
| 4 | 40 | 40 | 0 | 0.00 |
| 5 | 50 | 50 | 0 | 0.00 |
| 6 | 60 | 60 | 0 | 0.00 |
| 7 | 70 | 70 | 0 | 0.00 |
| 8 | 80 | 80 | 0 | 0.00 |
| 9 | 90 | 90 | 0 | 0.00 |
| 10 | 100 | 100 | 0 | 0.00 |
| | | Average error value | | 0.33 |

## 3.3 Temperature sensor test

Table 3 shows the test results of the temperature sensor compared to the sensor named DS18B20. Calibration is performed by comparing the measurement of the temperature meter using a hygrometer with the measurement of the temperature sensor. Table 3 shows the results of the temperature sensor comparison,

**Table 3. Results of Temperature Sensor and Instrument Comparison**

| No | Sensor | Meter | Difference (Meter - Sensor) | Error (%) |
|---|---|---|---|---|
| 1 | 32.25 | 32.2 | 0.05 | 0.15 |
| 2 | 31.62 | 31.6 | 0.02 | 0.06 |
| 3 | 31.56 | 31.5 | 0.06 | 0.19 |
| 4 | 31.37 | 31.4 | 0.03 | 0.09 |
| 5 | 30.87 | 30.1 | 0.77 | 2.55 |
| 6 | 30.31 | 30.2 | 0.11 | 0.34 |
| 7 | 29.81 | 29.5 | 0.31 | 1.05 |
| 8 | 29.56 | 29.4 | 0.16 | 0.54 |
| 9 | 24.56 | 24.5 | 0.06 | 0.24 |
| 10 | 23.81 | 23.8 | 0.01 | 0.04 |
| | | Average error value | | 0.53 |

## 3.4 Watering system test

Table 4 shows the results of the watering duration test from 30 trials in varying temperature conditions with humidity at 60%, the data shows that the average duration is 6 seconds.

**Table 4. Watering system test**

| No | Temperature (°C) | Humidity (%) | Duration (Seconds) |
|---|---|---|---|
| 1 | 27.23 | 60 | 6.61 |
| 2 | 30.23 | 60 | 6.61 |
| 3 | 30.06 | 60 | 6.61 |
| 4 | 30.33 | 60 | 6.61 |
| 5 | 31.47 | 61 | 6.00 |
| 6 | 29.40 | 60 | 6.59 |
| 7 | 30.45 | 60 | 6.61 |
| 8 | 31.50 | 60 | 6.61 |
| 9 | 29.45 | 60 | 6.59 |
| 10 | 32.47 | 60 | 6.61 |
| 11 | 32.10 | 59 | 6.62 |
| 12 | 30.45 | 60 | 6.61 |
| 13 | 31.25 | 58 | 6.63 |
| 14 | 30.56 | 59 | 6.62 |
| 15 | 27.50 | 60 | 6.61 |
| 16 | 27.69 | 60 | 6.61 |
| 17 | 27.13 | 60 | 6.61 |
| 18 | 28.44 | 60 | 6.61 |
| 19 | 27.56 | 60 | 6.61 |
| 20 | 26.75 | 55 | 6.65 |
| 21 | 25.81 | 54 | 6.64 |

Table 5 shows a comparison when observing two vines that were given different watering treatments, vine A was watered manually and vine B was watered automatically using an automatic watering system. In this test, it was found that manual watering gave an increase in plant height of 3 cm, while automatic watering gave an increase in height of 5.2 cm over 21 days of observation, so that automatic watering gave a better growth rate for the grape plants.

**Table 5: Test results of watering treatments for grapevines**

| No | Test Time | Plan Height (cm) | | Number of Leaves (strands) | |
|---|---|---|---|---|---|
| | | Manual (A) | Automatic (B) | Manual (A) | Automatic (B) |
| 1 | 2023-02-01 | 45 | 45 | 15 | 8 |
| 2 | 2023-02-02 | 45.2 | 45.5 | 15 | 8 |
| 3 | 2023-02-03 | 45.4 | 45.7 | 15 | 8 |
| 4 | 2023-02-04 | 45.6 | 47 | 15.25 | 8.5 |
| 5 | 2023-02-05 | 45.7 | 47.2 | 15.25 | 8.5 |
| 6 | 2023-02-06 | 46 | 47.5 | 15.35 | 8.6 |
| 7 | 2023-02-07 | 46 | 47.7 | 15.45 | 8.7 |
| 8 | 2023-02-08 | 46.1 | 47.8 | 15.55 | 8.8 |
| 9 | 2023-02-09 | 46.2 | 48 | 16 | 9.25 |
| 10 | 2023-02-10 | 46.2 | 48.3 | 16.05 | 9.35 |
| 11 | 2023-02-11 | 46.3 | 48.5 | 16.15 | 9.45 |
| 12 | 2023-02-12 | 46.5 | 48.6 | 16:25 | 9.55 |
| 13 | 2023-02-13 | 46.6 | 48.8 | 16.27 | 9.65 |
| 14 | 2023-02-14 | 46.6 | 48.8 | 16.35 | 9.85 |
| 15 | 2023-02-15 | 46.7 | 49 | 16.45 | 10 |
| 16 | 2023-02-16 | 46.9 | 49.2 | 16.65 | 10.2 |
| 17 | 2023-02-17 | 47 | 49.5 | 17 | 10.5 |
| 18 | 2023-02-18 | 47.2 | 50 | 17.5 | 10.8 |
| 19 | 2023-02-19 | 47.4 | 50.2 | 18 | 11 |
| 20 | 2023-02-20 | 47.5 | 50.3 | 18 | 11 |
| 21 | 2023-02-21 | 48 | 50.5 | 18.2 | 11.2 |

The results of the tests carried out show that the system has been able to carry out automatic irrigation according to soil moisture conditions. The installed camera has also provided a report in the form of images sent to Firebase, so that it can be observed using the application embedded in Android, using Internet of Things technology.

### 3.5 Display of application on Android devices

Below are several pages that appear in the Android application as a report on the results of monitoring the irrigation system using Internet of Things technology. Figure 5 shows the sensor readings and Figure 6 shows the images captured by the camera.

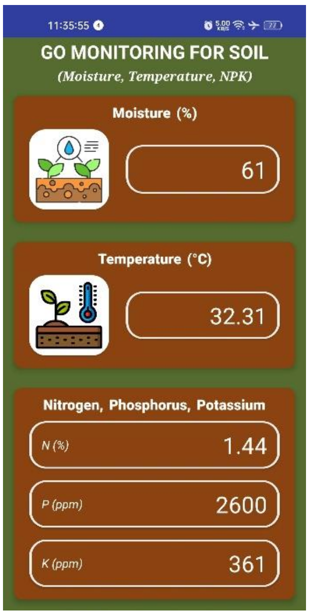


**Figure 5. Sensor Reading Result**


**Figure 6. The camera's image recording function.**

## 4. CONCLUSION

The tests of the developed system have shown that the automatic irrigation of the vines is carried out in an average time of ± 6 seconds, when the temperature is ± 25-32ºC and the soil humidity is in the range of 60%. Tests were carried out comparing manual and automatic irrigation for 21 days, with the result that vine A (manual irrigation) experienced a growth of ± 3 cm, while vine B (automatic irrigation) experienced a growth of ± 5.2 cm. This proves that vines that receive the right amount of nutrients according to the plant's needs have better growth results with a faster increase in plant length. The accuracy of each sensor is also tested against similar sensors, for example the DS18B20 temperature sensor has an accuracy of 99.44%, the soil moisture sensor has an accuracy of 99.874% against the capacitive soil moisture sensor. The same applies to the NPK sensor, which gives better readings after testing the soil with urea fertiliser for the N element, SP-36 fertiliser for the P element and KCl fertiliser for the K element.

The images taken by the camera and sent to Firebase can be viewed using the application embedded in the Android device. The data obtained can be further used to identify diseases or grape varieties by adding image processing algorithms and artificial intelligence, which is still a big question for grape lovers.

## 5. ACKNOWLEDGMENTS

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