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Solar-Powered Soil Nutrient Detector for Rice Field

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Abstract:

For almost centuries, Filipino considered rice as one of the most important food. The country was became one of the biggest rice importer not only in the ASEAN country but also across the globe. In the previous year rice farmers had faced crop related issues that heavily affects the rice production rate and resulting for low importation rate. There were several factors that affect the rice production such as biological constraints, soil fertility and not suitable quality rice crop variant for the specific planting field. At present the government are still formulating solutions through science-based agricultural research to address the issue and reduce yield gaps among rice farmers. Several researches were done to provide solutions through collaboration of different fields such as Information technology and agriculture. Development of machines technologies and prototypes to collect, store, process and analyze data to improve rice production. The study focused on the development of a prototype device that will determine the nutrient content of the rice field soil such as Nitrogen, Potassium and Phosphorus elements that should be present in the soil for help plant to grow and other soil characteristics such as soil moisture content, humidity and temperature. The output data from the device will be stored, validate and analyze to become the reference of the Office of Provincial Agriculturist in helping rice farmers in selecting rice crop variant and appropriate fertilizer application resulting for a higher yield.

Keywords *- Soil Nutrient, Rice crop, Solar power, Soil moisture*

I. INTRODUCTION

Agriculturist with their skills in crop production, agricultural technician's years of experience in providing information regarding plants, soil scientist's systematical method in determining the right plant[1] for specific farmland area as well as the technology offered by Information Technology in data gathering, analysing and development of a system are keys to help and support farmers in selecting crops and using the proper fertilizer formulation that would result for high production rate[2]. Maintaining a healthy and fertile ground for planting was also their primary concern. Determining soil nutrient deficiencies that would have a big effect on the crop production is very important[3]. Main nutrients that can be found in the soil such as Nitrogen[4], Phosphorous and Potassium[5] are necessary for the plant to grow. Researches such as soil moisture detector and rice crop height detection are just some very good research project to help in determining different factors affecting the rice production[6]. Most plants require minute amount of substances known as trace elements, which are present in the soil in very small quantities. Nutrients often occur in the soil in compounds that cannot be readily utilized by plants.

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Fertile soil provides essential nutrients to plants. Important physical characteristics of soil-like structures and aggregation allow water and air to infiltrate, roots to explore and biota to thrive. Diverse and active biological communities help soil resist physical degradation and cycle nutrients at rates to meet plant needs. Soil health[7] and soil quality are terms used interchangeably to describe soils that are not only fertile but also possess adequate physical and biological properties to sustain productivity, maintain environmental quality[8] and promote plant and animal health.

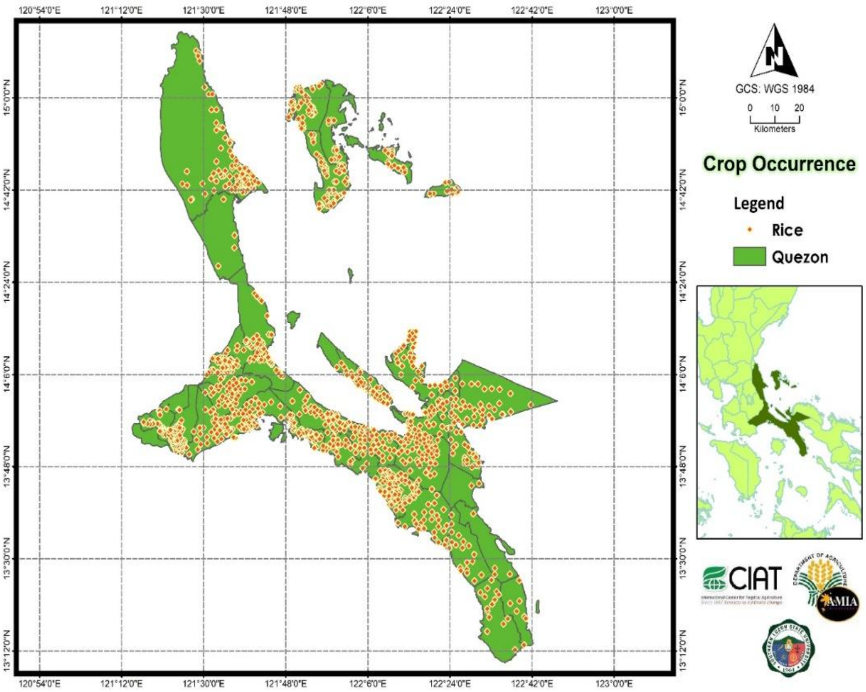

Fig 1. Rice Crop Occurrence in the province of Quezon

As shown in Fig.1 is the province of Quezon Rice Crop occurrence, Quezon was considered as the 8th largest province in the country and biggest agricultural producer in (Cavite, Laguna, Batangas, Rizal and Quezon) CALABARZON region in terms of farm implemented program from its 35 municipalities as revealed from the survey of Philippine Statistics Authority with 513,618 hectares of agricultural land[9] .

In CALABARZON region, Quezon is one of the most important agricultural province in producing staple foods such as corn and rice. Annually the province alone could supply almost 200,000 MT of corn and rice almost 42% or total corn and rice requirement of the CALABARZON region. Yet still, some part of the province are in the less critical state on in terms of rice production some of the reasons are lowering number of agricultural farm areas due to conversion poor quality infrastructure for farming, poor irrigation system, natural calamities resulting to overflowing of river systems, droughts, lack of knowledge in good farming practices, less support for farmers education and more[10]. To improve agricultural outputs and address the above mentioned issues, the government and experts listed numbers of proposals such as climate-resilient farming technology, improvement of irrigation systems and improvement in research and development for higher yield.

This study focusses on the development of Solar-Powered Soil Nutrient detector device to be used in identifying and determining the soil characteristic. The data that gathered by the device will be the basis for best farming practices, proper fertilization, and use other technology-advanced method such as data mining for agriculture[11] that will contributed for having a better yield. Nowadays many type researches

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was been done for the improvement of rice production. Most of the projects and papers presented are combination of Information Technology, Agriculture as well as Engineering field. Examples are Soil nutrient detector using Electrochemical Sensors that can detect different nutrients such as Nitrogen and Potassium, Solar Power Soil Moisture Sensor use to determine the moisture level on the soil that plant roots needed[12] particularly , Automatic Rice Crop Height Measurement Using a Field Server and Digital Image Processing for analysing the length of rice crop linked to yield potential, Predicting Rice Production in the Philippines Using Seasonal Climate Forecasts or using the recorded data of climate and yield rate from the previous years also was been used[13].

The general objective of the study is to design and develop a device that will determine the level of soil nutrients and determine soil characteristics. In line with this, the projects aims to achieve specific objectives such as to design and develop the Solar-powered Soil Nutrient Detector device using Arduino AtMega as its main component and C++ Language for the development of the prototypes system and evaluate the acceptability of the prototype in terms of Efficiency, Functionality, Maintainability, Reliability and Usability.

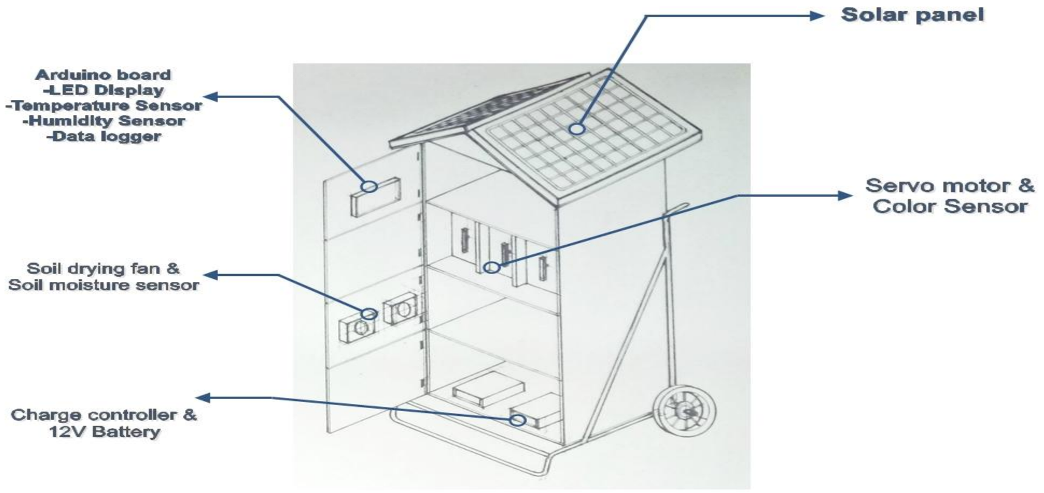

Fig 2. Isometric projection and design

As shown in Figure 2 is the Isometric projection of Solar-powered soil nutrient detector which will be utilized by the researcher in conducting soil testing.

II. MATERIALS AND METHODOLOGIES

A. Study Area

The study is conducted in the selected municipalities in Quezon. Soil sampling and testing procedure was done in the actual rice field in selected barangay with high rice crop occurrence see Fig.1.

B. General Description of the designed system

The researcher designed the Solar-powered Soil Nutrient Detector consist of several electronic components: Touchscreen LED monitor that will serve as the main

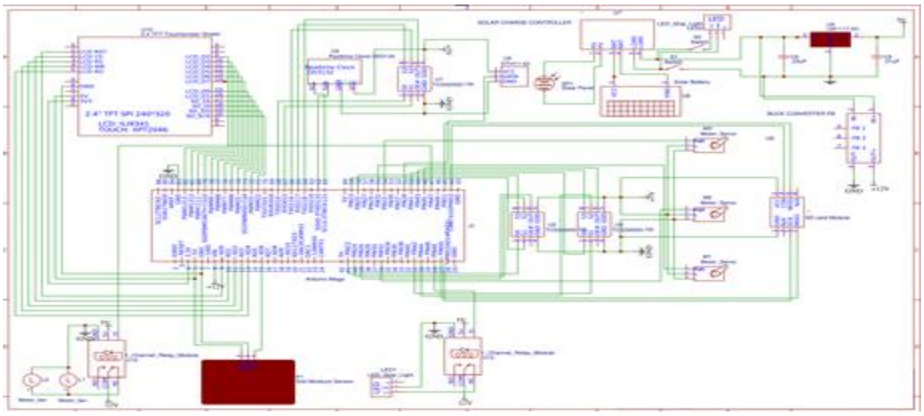

Fig 3. Schematic Diagram of Solar-powered Soil Nutrient Detector

Interface to operate the device. Soil moisture sensor used in determining the moisture content that influences the chemical, physical, and biological characteristics of the soil[14][15]. Utilize to estimates soil volumetric water content based on the dielectric constant. Color sensor based on reflectance of light[15] on the test tubes containing the mixed soil and reagent for analyzing the nutrient level through colorimetric method. Humidity sensor and temperature sensor that determines the humidity and temperature of the rice field, factors that affects the rice production. Various components of the device are all attached to Arduino ATmega 2560, a microprocessor board with microcontroller chip act as the main central controller of the Solar-powered Soil Nutrient Detector device as shown in Figure 3. Photovoltaic solar panels that harness power from the sun to become electricity will be utilized to energized all the components of the device. It will be used to collect and record the characteristic of the soil and the rice field.

Fig 5. Soil Testing and data collection

As shown in figure 4 is the soil testing procedure conducted in 2-month period right after the rice harvesting season and before the field preparation for planting from different locations in the province of Quezon. Figure 5 shows the Phosphorus level using the soil testing kit and the result from the soil nutrient detector device. The soil test data will be analyzed and compared with the actual lab test result for validation.

Fig 4. Device deployment on the rice field

Table 1 Categorical rating scale of commercial soil test kits (low, medium, high)

Analysis[z]	Low	Medium	High
NO_3-N (mg·kg^{-1})[y]	<25	25–60	>60
P_2O_5 (mg·kg^{-1})	<6	6–10	>10
K_2O (mg·kg^{-1})	<50	50–80	>80

[z]NO_3-N, P_2O_5, and K_2O are nitrate–nitrogen, Olsen-phosphorus, and exchangeable potassium, respectively.
[y]1 mg·kg^{-1} = 1 ppm.

Table 1 shows the Conversion of Low, Medium and High categories of laboratories analytical result and comparison with commercialized test kit values based on Reisenauer(1978) interpretative guide which was used for determining the level of soil nutrient applied for the device.

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III. RESULTS

Through this machine, determination of commonly monitored parameters such as Nitrogen, Phosphorus and Potassium in soil testing will come in handy. It would easily determine and measured some most important elements in the soil that the plants needed to grow such as Nitrogen, Phosphorus, and Potassium. It could also identify the soil characteristics like soil moisture, humidity and temperature, factors that influence plant growth.

3.1 Structure of the device

The developer made use of soil moisture sensor to determine the soil moisture content, LM35 Temperature sensor for identifying the temperature of the area or field where the soil testing was conducted, DHT11 used to identify the humidity level of the rice field, TCS3200 color sensor was used to determine the present nutrient level in the soil, SRC
Real-time clock to provide the exact time/date when the testing was conducted, Card Reader where all the data from soil test will be stored, Touch screen LCD display as the medium where the control operation and testing data will be displayed, as shown in Figure 6 all the electronic components attached to the Arduino Atmega and lastly the Solar panel and battery as the main source of electricity to energized all the electronic components of the device.

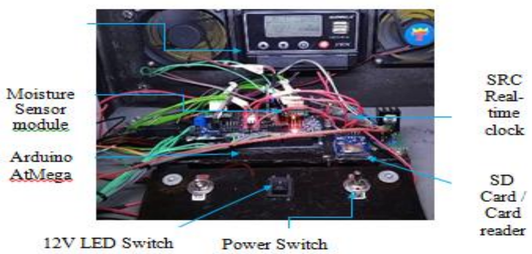

Fig. 6 Main Controller

3.2 Optical Unit

Color analyzer is utilized to capture sample color data that can transform three primary color into electrical frequencies and digital signal output. TCS3200 color sensor is a programmable color light-to-frequency converter launched by TAOS[16]. A simple Complementary Metal-Oxide Semiconductor circuit consists of red, blue and green (RGB) filters with silicon photodiode and current-frequency converter. The color analyzer consists of the lighting module that uses LED with high brightness light hitting directly the test tube containing the soil mixture to be determined its nutrient level by the color recognition module. After color recognition of the soil mixture from the test tube, the color information measured will be sent to the main processing unit for display and stored in the SD card.

3.3 Software Development of detector

The functions required by the Soil Nutrient Detector's control software are as follows:
(1) Device collection of data function. It obtained the color information measured by the TCS3200, which was reflected by the photodiode.
(2) Device processing of data function. It processed the obtained measured color data by the color sensor and convert the soil value to equivalent level (Trace, Low, Medium, High).
(3) Device displaying of data function. All the data collected such as Temperature, Humidity and soil moisture level and converted color data into information will be display in the LCD.
(4) Device storing data function. A text file will be created to store all the acquired information to the SD card through SD card module.

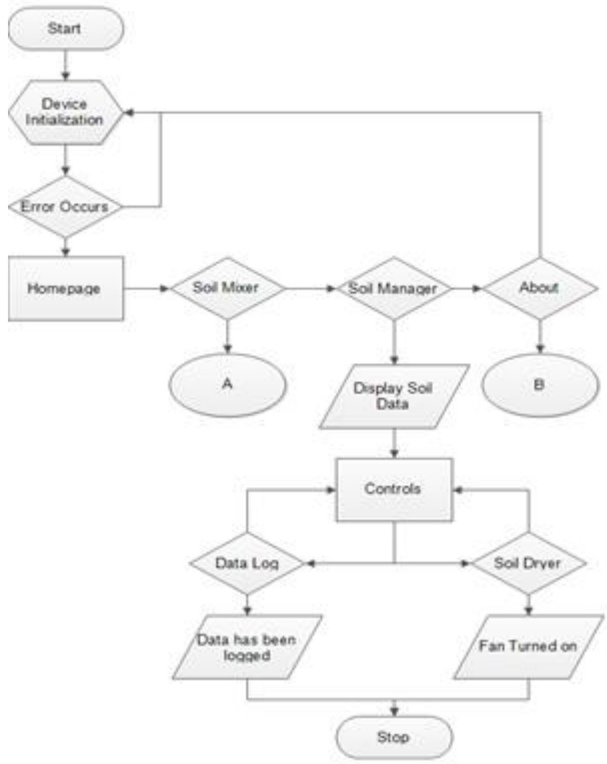

Fig. 7 Temperature, humidity and soil moisture data collection process

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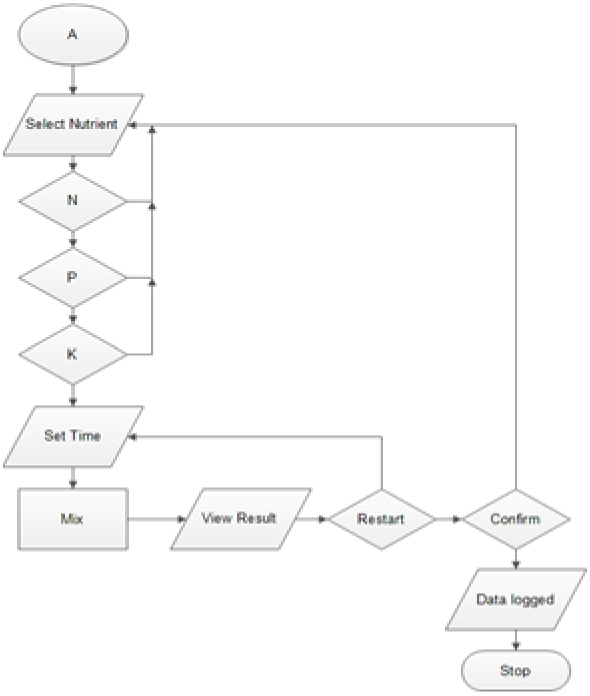

Fig. 8 Soil nutrient level detection process

The software was programmed in the for the device interruption way to ensure that each task was handled in a timely manner. After the system starts, the machine will initialize itself and proceed to the main menu displaying Soil Analyser and Environment Factor as shown in Figure 7 and 8. To perform soil nutrient detection, selecting Soil Analyser button, choose the nutrient to be measured and set the time for shaking the soil mixture. There will be a 30 seconds delay letting the mixture to stand still before the color sensor determine the color and appeared on the LCD screen. Storage module main task is to save the data acquired by the device to SD card. Environment Factor button function is to display the humidity, temperature and soil moisture level the rice field. It also has the data logging button for storing of data to the SD card. Experiments and trials have been made to produce the color comparisons to have a combination of the specific colors used in the actual soil test kit. An expert checked all color references to ensure the proper use of existing color references.

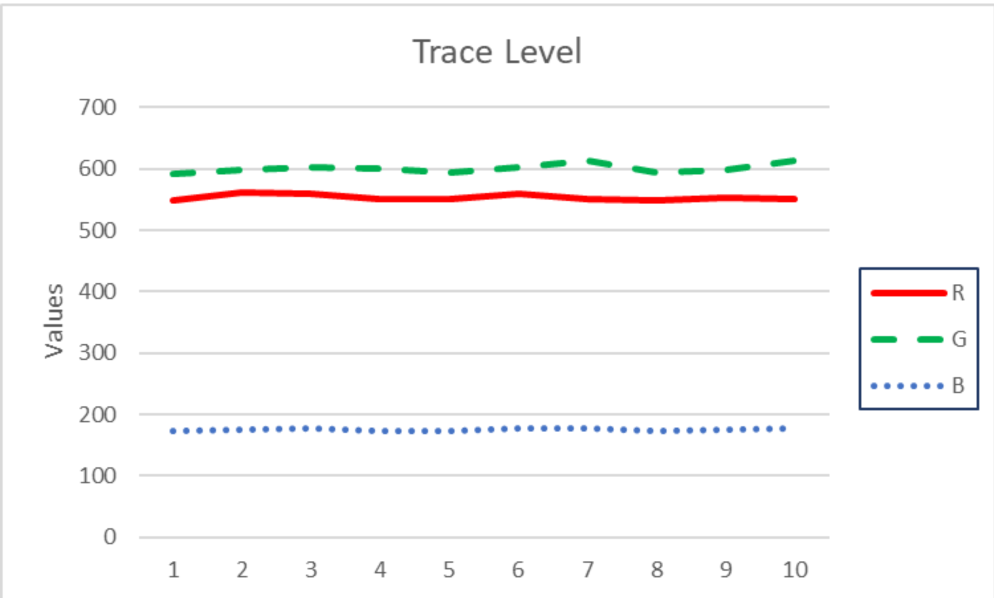

Fig. 9 Nitrogen trace level values

As shown in Figure 9, red values showed a good response for the Nitrogen trace rate, which was perfect for the color of the threshold using the LDR color sensor. The sensor's numerical output shows good response for getting the threshold for color red from 549 to 562, for green color 592 to 614 and for blue color 172 to 178. The x-axis is the number of instances and on the y-axis is the converted output form 10-bit analog to digital numerical value.

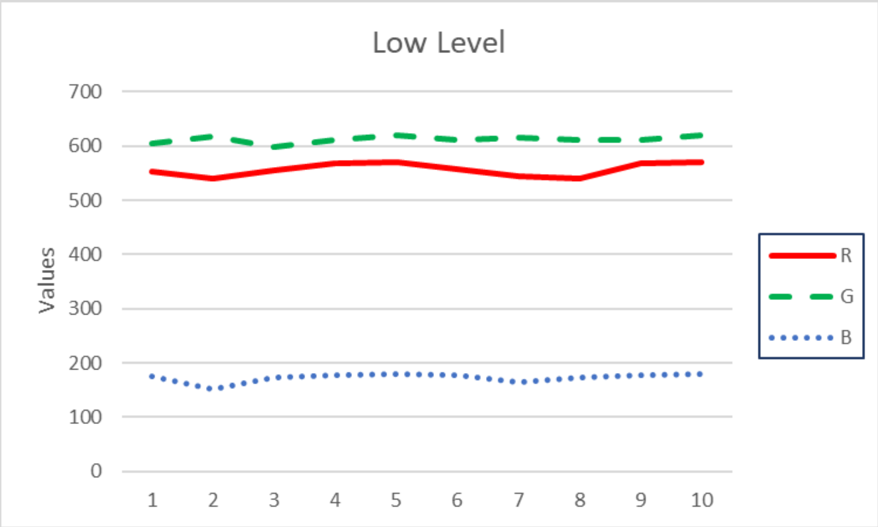

Fig. 10 Nitrogen low level values

TCS3200 was used and shows a good response for red values for the Nitrogen low level, which was good for the color of the threshold using the LDR color sensor as shown in Figure 9. The sensor's numerical output shows good response for getting the threshold for color red from 539 to 570, for green color 599 to 619 and for blue color 151 to 179. The x-axis is the number of instances and on the y-axis is the converted output form 10-bit analog to digital numerical value.

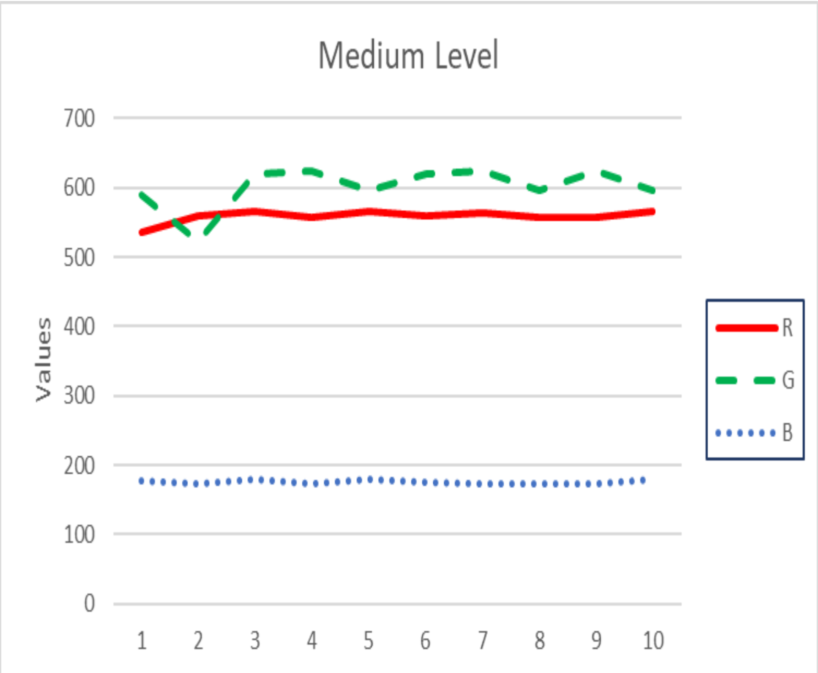

Fig. 11 Nitrogen medium level values

For Nitrogen Medium level as shown in Figure 10, LDR color sensor was tried and showed little difference but still shows a good response for red values for the Nitrogen low level, which was good for the color of the threshold using the LDR color sensor. The sensor's numerical output shows good response for getting the threshold for color red from 536 to 566, for green color 523 to 624 and for blue color 172 to 179. The x-axis is the number of instances and on the y-axis is the converted output form 10-bit analog to digital numerical value.

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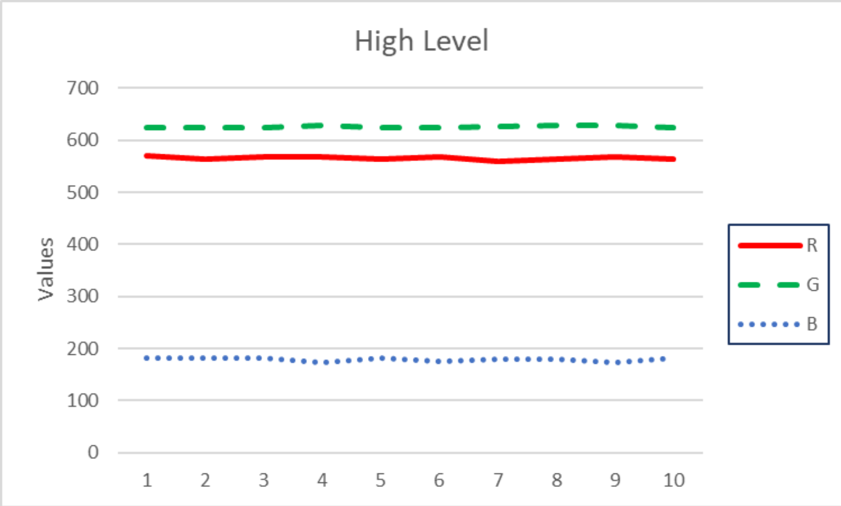

Fig. 12 Nitrogen high level values

Lastly for Nitrogen High level as shown in Figure 12, TCS 3200 color sensor was used and resulting a good response for red values for the Nitrogen low level, which was good for the color of the threshold using the LDR color sensor. The sensor's numerical output shows good response for getting the threshold for color red from 560 to 569, for green color 624 to 628 and for blue color 174 to 181. The x-axis is the number of instances and on the y-axis is the converted output form 10-bit analog to digital numerical value.

3.4 Performance test

The device was able to acquire data such as temperature, humidity and soil moisture content of the rice field using the sensors attached to the Arduino board such as DHT11, soil moisture sensor and LM35. All the data collected by the device are directly stored in the SD card thru data logging device which is also attached to the Arduino board.

Table 2 Device testing

Soil Nutrient from Selected Municipalities	**Device reading**	**Human**	**Total**
Nitrogen (Lucban) Medium	10	10	20
Nitrogen (Tayabas) Low	10	10	20
Nitrogen (Catanauan) Trace	10	10	20
Nitrogen (Mauban) Trace	10	10	20
Potassium (Lucban) Trace	10	10	20
Potassium (Tayabas) Low	10	10	20
Potassium (Catanauan) Trace	10	10	20
Potassium (Mauban) Low	10	10	20
Phosphorus (Lucban) Low	10	10	20
Phosphorus (Tayabas) Medium	10	10	20
Phosphorus (Catanauan) Medium	10	10	20
Phosphorus (Mauban) Medium	10	10	20

Table 3 Expectancy table for Table 2

Soil Nutrient from Selected Municipalities	**Device reading**	**Human**
Nitrogen (Lucban) Medium	10	10
Nitrogen (Tayabas) Low	10	10
Nitrogen (Catanauan) Trace	10	10
Nitrogen (Mauban) Trace	10	10
Potassium (Lucban) Trace	10	10
Potassium (Tayabas) Low	10	10
Potassium (Catanauan) Trace	10	10
Potassium (Mauban) Low	10	10
Phosphorus (Lucban) Low	10	10
Phosphorus (Tayabas)	10	10

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Medium		
Phosphorus (Catanauan) Medium	10	10
Phosphorus (Mauban) Medium	10	10

$$\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Eq. 1 Chi Square formula

As shown in table 2 and 3 was the data collected during device testing compared to the human resource person's verdict. To have 95 percent level of confidence, a benchmark value of 0.05 was used. Chi-Square's calculated value was equal to O. Using the table corresponded to the critical value of 3.841 for the critical values 0.05. Calculated value was therefore less than the critical value which can be inferred that there was no significant difference between the reading of the machine and the reading of the human resource.

IV. CONCLUSION

The performance of the device was examined by selected individuals from IT and agricultural institution capable of conducting tests and laboratory experiments on soil. The device was proven useful in acquiring soil and rice field data needed by farmers and agricultural technicians and could be as basis on selecting the suitable rice crop variety for the rice field. With the collaboration of different field such as Agriculture, Information Technology and Engineering, addressing and providing solution in many agricultural issues became into reality through technological advancement. Determining the amount of water or moisture content of the soil that would have a great effect for the rice plant to grow, climate forecasting in identifying the season when to plant rice, nutrient detection that soil contains to which plants needed not only to grow but also to produce better yield. Those are just examples on how rice crop issues can be resolved through the aid of different product of researches. Those product of technology become very useful in the agricultural field most specifically in rice crop production, but still most of them are not yet implemented in the Philippines and it requires to go down deeper, think new ideas that could lead to make all the previous researches become more cost-efficient, portable and more reliable.

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