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Management Information System for Smart Agriculture (MISSA) Soil Sensing in Initao, Misamis Oriental

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Abstract

The present practice in the Department of Agriculture 10 (DA 10) involved a conventional process of data collection in the farms, relying mainly on the farmer's perception which causes inconsistency. Given the seen gap, this study on the Management Information System for Smart Agriculture (MISSA) Soil Sensing System was conducted. It is an approach to modernize the determination of the nitrogen, phosphorous, and potassium (NPK) quality and pH level of soil samples qualitatively. The main objective of the study was to develop an integrated sensor prototype determining the NPK and pH which has a local database generating a geographical coordinate transmitted to a develop MISSA Portal. Soil samples were collected from selected farms in Tubigan, Initao, Misamis Oriental and analyzed qualitatively using the developed MISSA soil sensing prototype. Obtained results were comparable to the DA standard for soil tests.

***Keywords**:* NPK quality, pH level, sensing device, soil sensing, MISSA

1. Introduction

Soil measurement devices have been developed and described by many researchers such as Loreto and Morgan (1996), Christy (2008), and Adamchuk *et al*. (2005); and soil sampling approaches have been described by others such as Birrell and Hummel (2001), Shibusawa (2003), Sethuramasamyraja *et al.* (2005) and Sethuramasamyraja *et al.* (2008). Macro-nutrients nitrogen (N), phosphorus (P), and potassium (K) are the elements essentially used by plants for relative growth.

Soil testing results are essential inputs to the profitable application of fertilizer, lime, and other soil amendments. When soil test results are combined with information about the nutrients that are available to the various crops, a reliable basis for planning the fertility program can be established (Hoeft *et al.*, 1996). The DA uses the conventional way of determining information about soil quality mapping and land profile. The chemical analyses involve intensive and complex laboratory testing, which makes sampling and evaluation of soil samples over what could be tens to thousands of acres of farmland physically impractical and cost prohibitive (Adamchuk *et al.,* 2004). The process of collecting data is through the visual inspection of the farm technicians about the soil chart. Moreover, this agency still uses the pen-and-paper method for the entry of data regarding farm profiles causing the time delay. Thus, there is a need to develop a system that systematically integrate soil quality data and transmit this information to the server/database.

For any soil sensor to be successful there is a need for the sensing system to perform at least five key functions (Sinfield *et al*., 2009):

1. Initialize system: Prepare the on-the-go system for a measurement, ensuring that all components are ready for use and free of any residual influence from previous measurements.
2. Sample the soil: Permit periodic or continuous contact with the soil and/or repeatedly and reliably obtain soil samples.
3. Derive sample volumes: Reliably derive soil samples and/or extracts of a controlled mass.
4. Present sample: Present known volume/mass of soil/soil extract in an effective range of the sensor.
5. Perform a measurement: Accurately and/or precisely (with calibration) assess ion concentrations.

This study developed an integrated sensor prototype that determines the NPK quality and pH level of the soil, designed a local database in the prototype for access of data, and transmitted data from the prototype to the MISSA Portal's database together with the generated coordinates of the studied farms.

2. Methodology

2.1 Framework of the Study

Figure 1 shows the framework of the soil sensing system. The first stage is the detection of the NPK quality and pH level of the soil and the generation of coordinates. The color sensors detect the color of the sample mixture, and each color is equivalent to a particular value and quality in the color chart. The device that was responsible for generating the coordinates was the Global Positioning System (GPS). Stored in a local database the data can be sent to the MISSA database with good internet accessibility.

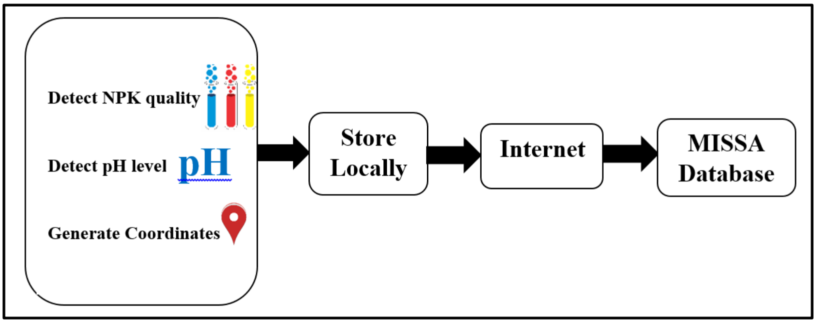


Figure 1. Framework of the soil sensing system

2.2 Conduct of the Study

Table 1 shows the site and coordinates of the chosen farm. The farms were considered due to accessibility to the main road. The location of the farms where the study was conducted was under the same municipality. The sensor was tested in a mango, banana, and tobacco farm located in Purok-3A Tubigan, Initao Misamis Oriental (see Figure 2).

Table 1. Coordinates of the site chosen

Sample Code	Source/ Crop Grown	Site	Coordinates	
			Latitude	Longitude
1	Cardava Banana	Nangkaon Tubigan, Initao, Mis. Or.	8.4716416	124.68117
2	Carabao Mango	Purok-3A Tubigan, Initao, Mis. Or.	8.471665	124.68116
3	Tobacco	Nangkaon Tubigan, Initao, Mis. Or.	8.4716416	124.68116

Mango Farm **Banana Farm**

Tobacco Farm

Figure 2. The farm sites at Initao, Misamis Oriental, where soil sampling was conducted

2.3 Design

The concept of the system was based on the studies of Ramane *et al.* (2015) and Laskar and Mukherjee (2016) with modifications to fit the objectives of the study. Testing the reliability of the sensors was done with the comparison of the laboratory test and DA's soil test kit.

2.3.1 Hardware Design

The development of the sensing module included the use of a color sensor device which provided a digital return of red, green, blue (RGB), and clear light sensing values. An IR blocking filter, integrated on-chip and localized to the color sensing photodiodes, minimize the IR spectral component of the incoming light and allows color measurements to be made accurately. The determination of the quality of the soil then follows an algorithm that makes use of the raw RGB values. Figure 3 shows the hardware design of the prototype.

Further, the communication between the different components and the microcontroller was done through the use of different interface pins of raspberry pi, the tcs34725 used Inter-integrated circuit(I2C) pins, the touchscreen display used serial peripheral interface(SPI) pins, and the GPS module used RS232(Tx and Rx) refer to Figure 4). Integration of this different components requires various libraries, drivers, etc. Thus, the researchers followed the easy installation guide of Adafruit, the designer, and manufacturer of these components.

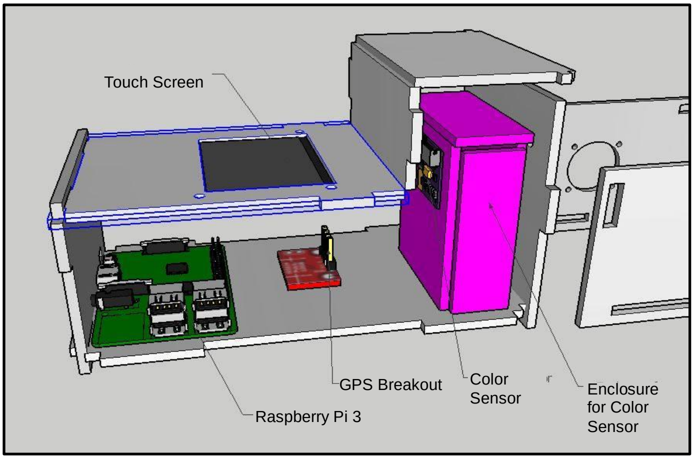


Figure 3. Casing embedded with the color sensor, Raspberry pi 3, touch screen display and GPS

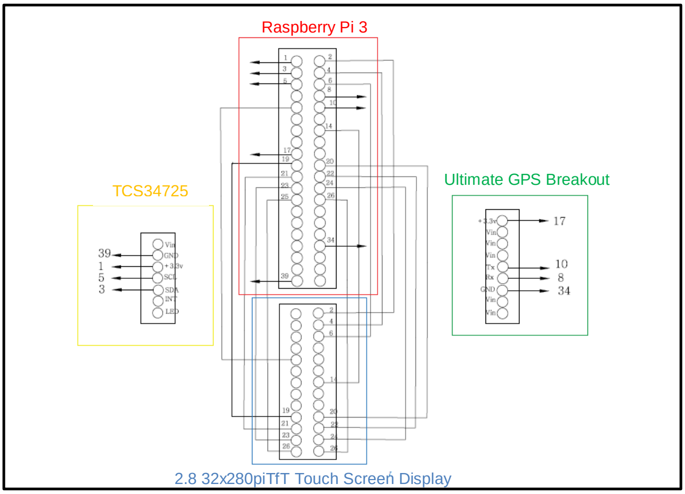


Figure 4. System schematic diagram

2.3.2 Software Design

The researchers created a flowchart based on the interview with the DA (refer to Figure 5). Initially, the main screen displays the buttons N, P, K and pH. When the button is clicked, the system then starts to detect the quality of the soil that corresponds to the button. After this, the detection user can either save or discard the result into the local database.

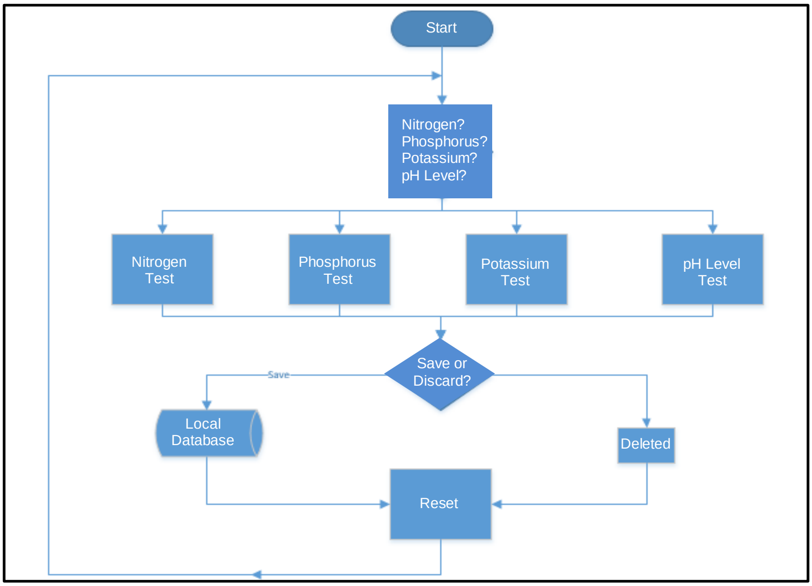


Figure 5. Flowchart of the software

2.4 Data Gathering

The data was gathered through sampling soil samples from the selected farm. The collected soil samples were analyzed for Rapitest soil test kit (STK), and STK forms the DA. The sensors were used to measure the color intensity from the result using the Rapitest soil test kit. Precision and accuracy have been used as the primary quantitative assessments of sensor performance (Vaughan, 1999).

2.5 Data Analysis

This study compared the DA STK and Rapitest STK to test its reliability. The program was set to display a specific reading of the RGB values that follow a procedure or a simple algorithm.

3. Results and Discussion

3.1 Actual Hardware Output

Figure 6 presents the actual connection and set-up of the different modules, namely, touchscreen, sensor, and GPS for Raspberry pi 3. These modules were integrated into the raspberry pi 3 for the MISSA-Soil Sensing system to process obtained data. The concepts on the development of the hardware were based on the studies of Ramane *et al.* (2015) and Laskar and Mukherjee (2016) with modifications to fit the objectives of the study.

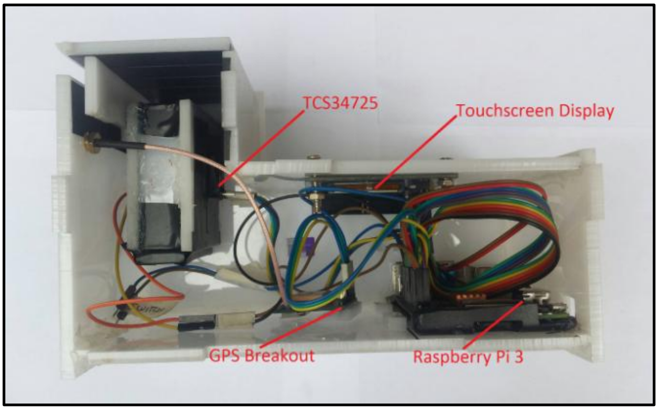


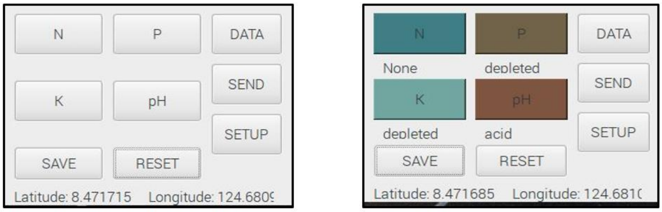
Figure 6. Actual set-up of the hardware

3.2 Actual Software Output

Figure 7 presents the actual software output of the study. Figure 5 shows the display main screen which had NPK, pH, Save, Send, Data, Reset, and Setup buttons. The GPS module was also part of the software, generating coordinates. Calibration of the sensor can be accessed by tapping the SETUP button. Likewise, determination of NPK qualitatively and the pH level was done by tapping the N, P, K, and pH buttons, respectively. By tapping the buttons, possible outcomes were:

1. NPK = surplus, sufficient, adequate, deficient, and depleted
2. pH = alkaline, neutral, slight acid, and very acid

The NONE result appeared if the colors detected were beyond the calibrated color range. Data transmission to the MISSA portal was done by tapping the save and send buttons.



Latitude: 8.471715 Longitude: 124.680

None depleted

depleted acid

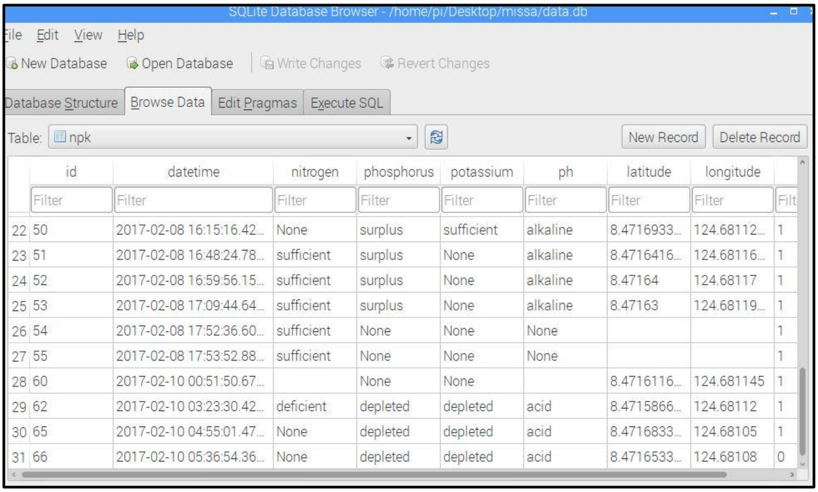
Latitude: 8.471685 Longitude: 124.681

Main Display

Result of tapping the NPK and pH button

Figure 7. Actual software output of the prototype

Figure 8 shows the local database in the computer. New samples were analyzed by initially tapping the resetting button.



	id	datetime	nitrogen	phosphorus	potassium	ph	latitude	longitude	
	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filt
22	50	2017-02-08 16:15:16.42...	None	surplus	sufficient	alkaline	8.4716933...	124.68112...	1
23	51	2017-02-08 16:48:24.78...	sufficient	surplus	None	alkaline	8.4716416...	124.68116...	1
24	52	2017-02-08 16:59:56.15...	sufficient	surplus	None	alkaline	8.47164	124.68117	1
25	53	2017-02-08 17:09:44.64...	sufficient	surplus	None	alkaline	8.47163	124.68119...	1
26	54	2017-02-08 17:52:36.60...	sufficient	None	None	None			1
27	55	2017-02-08 17:53:52.88...	sufficient	None	None	None			1
28	60	2017-02-10 00:51:50.67...		None	None		8.4716116...	124.681145	1
29	62	2017-02-10 03:23:30.42...	deficient	depleted	depleted	acid	8.4715866...	124.68112	1
30	65	2017-02-10 04:55:01.47...	None	depleted	depleted	acid	8.4716833...	124.68105	1
31	66	2017-02-10 05:36:54.36...	None	depleted	depleted	acid	8.4716533...	124.68108	0

Figure 8. Local database in the prototype

3.3 Develop an Integrated Sensor Prototype

3.3.1 Preliminary Testing of the Sample

The TCS34725 color sensor was used, owing to specification compatibility with the study. Figure 9 presents the preliminary testing for NPK and pH level using the soil sensing device. The liquid mixture samples were exposed adjacently to the TCS34725 sensor. The light of the sensor was allowed to pass through the transparent glass container to qualitatively determine the color of the sample. The color detected corresponds to the quality of the soil.

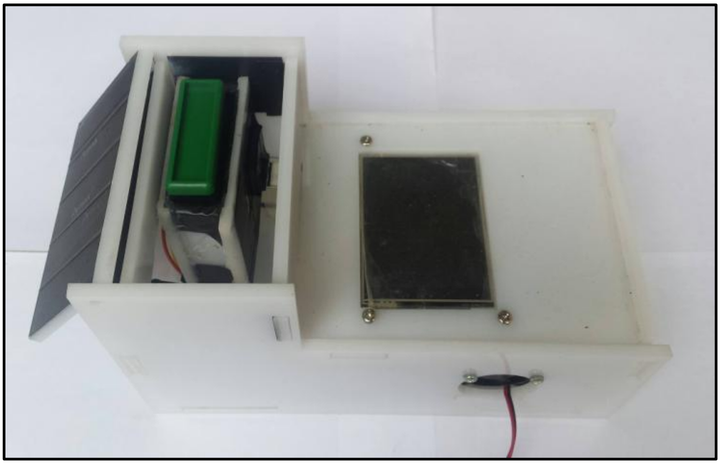


Figure 9. Preliminary testing for the prototype

3.4 Data Gathering

3.4.1 Actual Results

Obtained results were preliminary and qualitative. Each testing that was saved was assigned to an ID number. Table 2 shows the database of the actual results of testing in each farm. ID number 43, 46, and 47 were the results from the mango farm with three trials. The ID number 48, 49, and 50 were for the banana farm. The ID number 51, 52, and 53 were from the tobacco farm.

Table 2. Database of the Actual Results of the Samples

ID no.	Nitrogen	Phosphorous	Potassium	pH	Latitude	Longitude	Sent[*]
43	adequate	Surplus	None	Alkaline	8.4716416	124.68117	1
46	adequate	None	None	None	8.4717533	124.68107	1
47	None	Surplus	None	Alkaline	8.47165	124.68115	1
48	None	None	Sufficient	Alkaline	8.471665	124.68116	1
49	None	Surplus	Sufficient	alkaline	8.471665	124.68116	1
50	None	Surplus	Sufficient	alkaline	8.4716933	124.68112	1
51	Sufficient	Surplus	None	Alkaline	8.4716416	124.68116	1
52	Sufficient	Surplus	None	Alkaline	8.47164	124.68117	1
53	Sufficient	Surplus	None	Alkaline	8.47163	124.67119	1

[*] Legend: 1=Sent ; 0=Not Sent

3.4.2 Comparison to DA STK

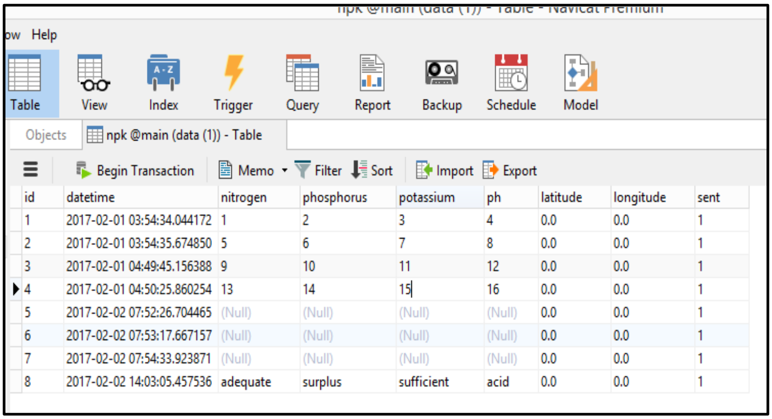
Table 3 shows the results of testing the soil sample, using the DA STK and Rapitest STK. The results in DA STK had a comparable interpretation in Rapitest STK result. In N and P results, the low result in the DA's STK was equivalent to depleted and deficient result in the Rapitest STK. The medium was equivalent to adequate while high represents the sufficient and surplus output. In K analysis, the deficient result in DA STK was comparable to adequate in Rapitest STK while sufficient was equivalent to sufficient and surplus. The 7.6 in the DA's STK was equivalent to alkaline in the output of the sensor, 7.0 was neutral, 6.5 was slight acid, 5.5-6.0 was acid while 4.5-5.0 was very acid (Horneck *et al.* 2011). The result of the NPK and pH of sample 1 in DA STK was low, high, deficient and 7.6 respectively, which was comparable with the result from the Rapistest STK which is deficient, surplus, adequate, and alkaline. Overall, results from other samples were comparable.

Table 3. Comparison between DA STK and Rapitest STK

Sample	Trial	Parameters			
		N	P	K	pH
Rapitest Soil Test Kit					
1	1	Deficient	Surplus	Adequate	Alkaline
	2	Deficient	Surplus	Adequate	Neutral
	3	Adequate	Surplus	Adequate	Alkaline
2	1	Adequate	Surplus	Sufficient	Alkaline
	2	Sufficient	Adequate	Surplus	Neutral
	3	Sufficient	Adequate	Surplus	Alkaline
3	1	Deficient	Adequate	Surplus	Neutral
	2	Adequate	Deficient	Sufficient	Alkaline
	3	Adequate	Sufficient	Sufficient	Alkaline
DA Soil Test Kit					
1	1	Low	High	Deficient	7.6
	2	Medium	High	Sufficient	7.6
	3	Low	High	Deficient	7.6
2	1	Medium	Medium	Deficient	7.6
	2	Medium	Medium	Deficient	7.6
	3	Low	Medium	Deficient	7.6
3	1	Low	Low	Sufficient	7.6
	2	Low	Low	Sufficient	7.6
	3	Low	Low	Sufficient	7.6

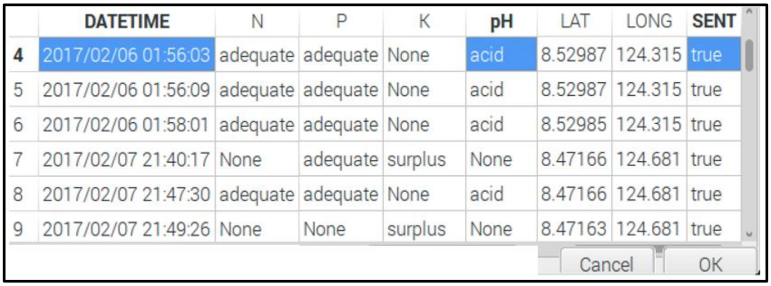
3.5 Design a Local Database

The DA STK analysis data sheet served as the reference standard for designing the MISSA-soil sensing database. The GPS, NPK, and pH were extracted from the DA STK analysis data sheet and processed in the MISSA soil sensing database. The Figure 9 shows that the researchers designed the local database to have the date of testing and the coordinates where the testing took place, the ID number, the value of the NPK and pH specifying if the data has been sent. For every data that was saved to the local database is assigned a unique ID number. The local database can be accessed through the prototype's touchscreen display and a computer connected via a wired or wireless link to the prototype. The user can only delete the data stored in the database through a computer. Figure 10 and 11 shows the database that can be seen in the prototype's screen. The prototype's touchscreen display can only save and send the data but cannot delete the stored data.



id	datetime	nitrogen	phosphorus	potassium	ph	latitude	longitude	sent
1	2017-02-01 03:54:34.044172	1	2	3	4	0.0	0.0	1
2	2017-02-01 03:54:35.674850	5	6	7	8	0.0	0.0	1
3	2017-02-01 04:49:45.156388	9	10	11	12	0.0	0.0	1
4	2017-02-01 04:50:25.860254	13	14	15	16	0.0	0.0	1
5	2017-02-02 07:52:26.704465	(Null)	(Null)	(Null)	(Null)	0.0	0.0	1
6	2017-02-02 07:53:17.667157	(Null)	(Null)	(Null)	(Null)	0.0	0.0	1
7	2017-02-02 07:54:33.923871	(Null)	(Null)	(Null)	(Null)	0.0	0.0	1
8	2017-02-02 14:03:05.457536	adequate	surplus	sufficient	acid	0.0	0.0	1

Figure 10. Database in the computer

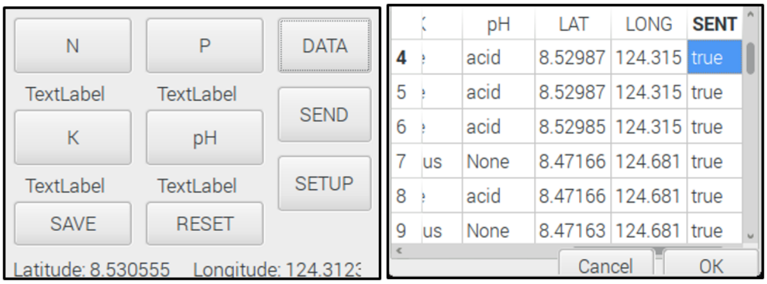


	DATETIME	N	P	K	pH	LAT	LONG	SENT
4	2017/02/06 01:56:03	adequate	adequate	None	acid	8.52987	124.315	true
5	2017/02/06 01:56:09	adequate	adequate	None	acid	8.52987	124.315	true
6	2017/02/06 01:58:01	adequate	adequate	None	acid	8.52985	124.315	true
7	2017/02/07 21:40:17	None	adequate	surplus	None	8.47166	124.681	true
8	2017/02/07 21:47:30	adequate	adequate	None	acid	8.47166	124.681	true
9	2017/02/07 21:49:26	None	None	surplus	None	8.47163	124.681	true

Figure 11. Local Database in the prototype

3.6 Transmit Data and Generate Coordinates

The prototypes were able to send data to the MISSA Portal database through internet access and were able to generate the coordinates by the use of GPS. Data transmission to the MISSA portal was done by tapping the save and send button. The MISSA Portal database consisted of soil-sensing, generated database. The system successfully sent the data to the MISSA Portal indicating the latitude and longitude of the area where testing was conducted (Figure 12). If the systems fail to send data to the MISSA Portal database, it can manually input using the MISSA Farm Profiler Android Application.



Latitude: 8.530555 Longitude: 124.312

		pH	LAT	LONG	SENT
4		acid	8.52987	124.315	true
5		acid	8.52987	124.315	true
6		acid	8.52985	124.315	true
7	us	None	8.47166	124.681	true
8		acid	8.47166	124.681	true
9	us	None	8.47163	124.681	true

Display with latitude and longitude

Local database with sent. latitude and longitude column

Figure 12. The Main display and local database

4. Conclusion

Overall, the sensor prototype was capable of determining the NPK and pH level of the soil. The result from the DA STK was comparable with the result from the Rapitest STK. Moreover, the study was able to design a local database. The data from the prototype was successfully sent to the MISSA Portal through an internet access. The use of GPS generated the coordinates of the testing area. With this prototype, the result of conducting the NPK and pH testing will be more reliable because the human visual perception of determining those data will be eliminated.

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