IoT-based Assessment and Monitoring of NPK Content and Fertility Condition of Soil

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***Abstract*— Since infertile soil is abundant on Philippine land, farmers need to first know the condition of the soil before planting crops on it. The key to good crop production is providing plants with the proper amount of nutrients at the appropriate time. Farmers who are not exposed to contemporary technologies continue to use traditional methods to enhance yield production, which is no longer a highly productive sort of farming. This study aims to create a system that will help farmers and home gardeners assess and monitor the condition of their crops by checking the variables of the soil such as NPK (Nitrogen, Phosphorus, Potassium) content, moisture level, acidity level, and humidity with the help of Internet-of-Things (IoT), which allows farmers to get fast insights on issues before they happen and make informed decisions on how to avoid them. The system also tells you which crop is best for your soil based on how much NPK it has. This information comes from the result retrieved from sensor that this study will use. The researchers used Evolutionary Prototyping in developing the Sensoil Device for the purpose of making the SAMS (Soil Assessment and Monitoring System) system as user-friendly as possible by implementing what the experts and user respondents wanted. The results show that with the implementation of the device, crop growth becomes healthier and faster, and it increases the potential to have a higher yield production that will boost the income generated from the farmlands while reducing unnecessary fertilizer and water use.**

***Keywords*— IoT, NPK, SAMS sensors, soil-fertility, soil-nutrient.**

I. Introduction

One of the significant factors that has a direct impact on crop production and quality is soil fertility and its nutrient management. Providing plants with the appropriate quantity of nutrients at the right time is the key to a successful crop production [1]. Plants require a variety of life building nutrients to grow properly and optimally. Plants that lack essential nutrients are unable to reach their full potential, produce lesser yields, and evade diseases. There are three vital nutrients which are Nitrogen (N), Phosphorus (P), and Potassium (K) that plants need. These nutrients are very important to plants to survive [2].

In research conducted in North Ethiopia, it is revealed that soil degradation was experienced by 70% of farmers on their farmland. Physical soil deterioration features such as gullies, rills, and landslides were more evident to farmers. More than 75% of farmers said that a decrease in crop output is due to a decrease in soil fertility. [3].

According to GLASOD, over 70% of the Philippines' land area has been degraded, with soil erosion being the most common form of land degradation [4].

According to Briones [5], soil degradation is split into two parts: first is the degree of deterioration, and the second is the extent of deterioration. It is moderate if there is a greatly reduced agricultural suitability; strong if biotic functions are largely destroyed; and extreme if biotic functions are destroyed and land is nonrecoverable.

The extent classes (per mapping unit) are as follows: 0 – 5 percent; 5 – 10 percent, 10 – 25 percent, 25 – 50 percent; and 50 – 100 percent. Degradation of more than 50%; moderate degradation of 10 – 50 percent, strong degradation of 5 – 25 percent, and extreme degradation for 5 – 10 percent.

Based on the interview of the proponents with Senior Agriculturist I, Roderick Hernandez, a senior agriculturist in the office of Agriculture in the City of Cabuyao, farmers in Cabuyao are dealing with issues in high production expenses. Due to the high cost of fertilizer, they are unable to maintain the soil's fertility.

Agriculture in the modern day regularly makes use of advanced technologies such as robotics, temperature and moisture sensors, aerial images, Global Positioning System (GPS), and IoT based technologies. With this, these sophisticated gadgets, precision agriculture, and robotic systems would enable businesses to operate more profitably, efficiently, safely, and sustainably if proper strategies, procedures, and measures are applied [6].

Agricultural probe and sensors are implemented to monitor the humidity, pH, moisture, and fertility of the soil properly. In modern agriculture, IoT monitors and analyzes the soil properties for accurately mapping various primary nutrients in the soil [7].

II. Methods & Materials/Approach/Procedures

The researchers have employed an experimental research method and the experimentation includes differentiating three types of soil is conducted. The

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proponents decided to use different sensors and develop a mobile app that is beneficial in assessing and monitoring the soil's condition. The final output is dependent on the decision of the system that the proponents had made, whether the soil is fertile, mildly fertile, or infertile.

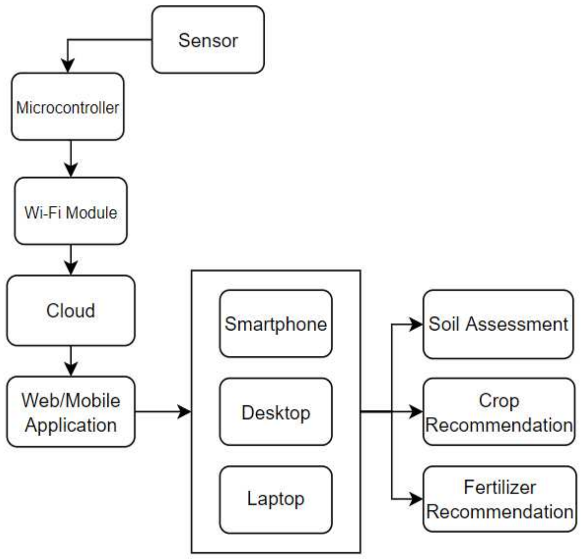

Figure 1. Block diagram of IoT-based Assessment and Monitoring of NPK Content and Fertility Condition of Soil

Figure 1 shows the block diagram of IoT-based Assessment and Monitoring of NPK Content and Fertility Condition of Soil. After setting up and calibrating the sensors, it automatically sends the essential data that would be sent to the database and stores it. The data would then be sent to the mobile application and web server for processing. Based on the soil type, the system would display if the soil is fertile, mildly fertile, or infertile, as well as the moisture level and when irrigation is needed. For improved monitoring, the device would also provide graphs that illustrate the data gathered from the soil. Lastly, the system would suggest the amount of fertilizer that should be applied to rice and corn to ensure good harvest.

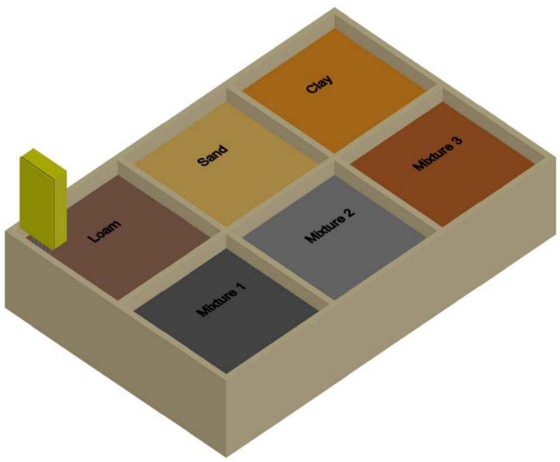

Figure 2. Isometric View of the Container and Device

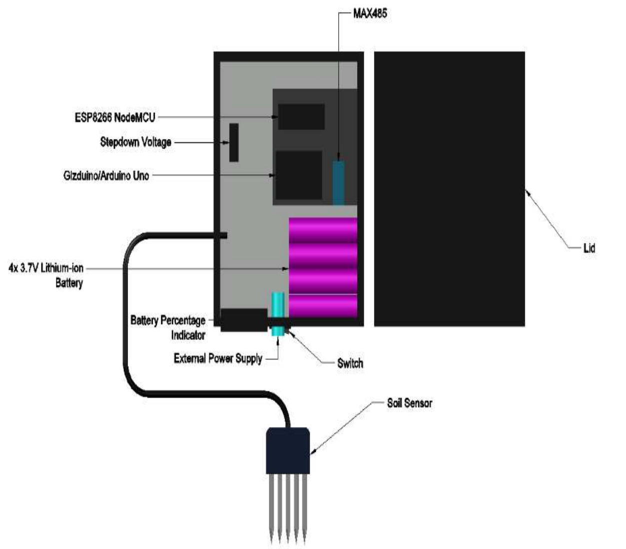

Figure 3. Sensoil Device Components

Figure 2 and 3 presents the project design of the study. Figure 3 shows the components that are deemed necessary to create a prototype for assessment and monitoring of the condition of the soil. The proponents modified the sensor by making it portable using a battery and switch. This would make it easy to move or carry the device from one place to another.

Table 1
Parameters to be measured

Parameter	High	Normal	Low	Very Low
Nitrogen (ppm)	>20	10 - 20	<10	
Phosphorus (ppm)	50 - 26	10 - 20	<10	
Potassium (ppm)	>250	250 – 150	<150	
Acidity (pH)	>7.5	7.5 - 6.5	6.4 - 5.5	<5.5
Moisture (Clay Soil Type) (%)		31	15 - 20	
Moisture (Loamy Soil Type) (%)		20 - 28	14	
Moisture (Sandy Soil Type) (%)		7 - 10	5	
Moisture (Clay – Loamy Soil Type) (%)		27 - 36	22	
Moisture (Sandy Clay – Loamy Soil Type) (%)		24 - 27	17	

Table 1 shows how soils are classified based on their NPK content, pH level, and moisture level. The following parameters will be measured using sensors.

Table 2
Recommended NPK Content in soil

	Recommended (ppm)	Level
Nitrogen in soil	20 and above	High
Phosphorus in soil	1 - 10	Low
Potassium in soil	150 – 250	Normal

The details in table 2 are the recommended level of NPK in soils for it to be considered as fertile. The proponents have used them as a reference in assessing the condition of the soil.

Table 3
Group reading

Condition	Nitrogen	Phosphorus	Potassium
Fertile	H	N	N
	H	H	N
	H	L	H
	H	L	N
	H	L	L
Mildy Fertile	H	H	L
	H	N	L
	N	H	H
	N	N	N
	N	H	N
	N	N	H
	N	L	H
	N	L	N
	L	H	H
	L	N	N
	L	H	N
	L	N	H
	L	L	H
	L	L	N
	N	L	L
Infertile	N	H	L
	N	N	L
	L	L	L
	L	H	L
	L	N	L
	H	N	L
	N	H	H
	N	N	N
	N	H	N
	N	N	H
	N	L	H
	N	L	N
	L	H	H
	L	N	N
	L	H	N
	L	N	H
	L	L	H
	L	L	N
	N	L	L

Legend: H – High, N – Normal, L – Low

Table 3 shows the group reading of data where the sensor will base its readings.

Statistical Treatment of Data

The proponents have employed the following mathematical concepts, formulas, models, and techniques in statistical analysis in order to prove the hypothesis.

T-Test

T-Test was used by the proponents to determine whether the experiment results are significant. T-test is usually used in comparing the means of two groups and if there is a significant difference among them [8].

$$t = \frac{m - u}{\frac{s}{\sqrt{n}}} \qquad \text{Equation 1}$$

Where:

t = test value
m = mean
μ = theoretical value
s = standard deviation
n = variable set size

III. RESULTS

The design project IoT-based Assessment and Monitoring of NPK Content and Fertility Condition of Soil is a concept of measuring the capability of the soil to handle the growth of a plant and crop based on its NPK content.

In order to utilize the IoT, the researchers created a software and a web application where the data from the sensor and the graph of it is being stored.

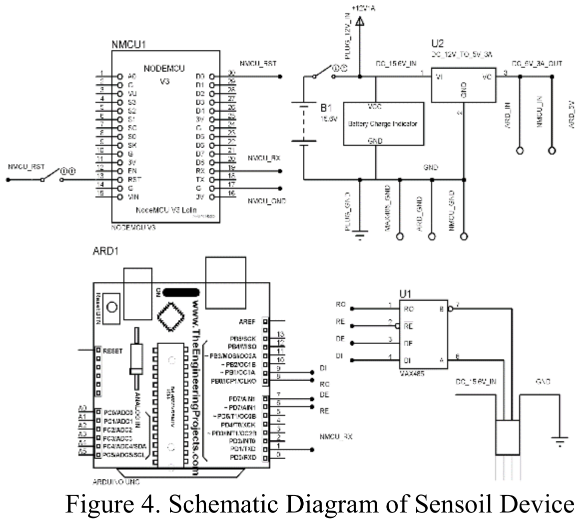

Figure 4. Schematic Diagram of Sensoil Device

Figure 4 shows the final output and schematic diagram of the connections of the design project.

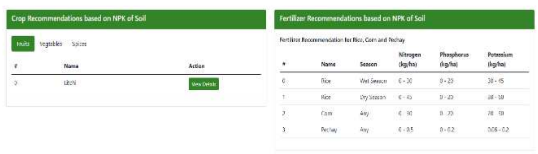

Figure 5. Crop and Fertilizer recommendation

Figure 5 shows the crop and fertilizer recommendations for the system based on the NPK content of the soil. The system will only recommend a fertilizer for rice, corn, and pechay since these are the most commonly planted crops in the Philippines. The availability of vital plant nutrients in a balanced form has a direct impact on the growth and development of any plant and crop, as well as the amount and quality of the yield [9].

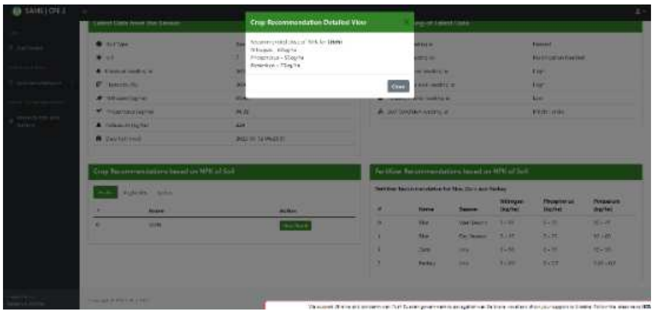

Figure 6. Recommended doses of NPK

Figure 6 shows the recommended dose of NPK for the crop that satisfies the latest reading from the sensor.

Table 4
NPK content of specific soils at wilting point

Soils	Wilting point (ppm)			Remarks
	N	P	K	
Clay	3	5	13	Infertile
Loam	17	24	56	Infertile
Sand	6	7	26	Infertile
Clay-Loam	65	90	209	Fertile
Clay-Loamy Sand	20	27	63	Infertile
Sandy Clay-Loam	21	28	66	Mildly Fertile

Table 5
NPK content of specific soils at field capacity

Soils	Field Capacity (ppm)			Remarks
	N	P	K	
Clay	9	12	30	Infertile
Loam	28	52	93	Mildly Fertile
Sand	10	15	37	Infertile
Clay-Loam	74	100	231	Fertile
Clay-Loamy Sand	30	41	96	Mildly Fertile
Sandy Clay-Loam	85	118	280	Fertile

Table 4 and 5 shows the data gathered from the soil's wilting point and field capacity. The amount of soil moisture or water content held in the soil over an extended period of time is referred to as field capacity. The wilting point is the point at which water becomes unavailable to plants due to a lack of moisture in the soil. The difference in data is evident, and the table shows that when soil is properly irrigated, it holds more nutrients.

Table 6
Soil Evaluation

Soils	Soil Condition	Crop Output	
		Height (cm)	Germination Percentage
Clay	Infertile	10	33.33%
Loam	Mildly Fertile	13	66.67%
Sand	Infertile	14	33.33%
Clay-Loam	Fertile	21	100%
Clay-Loamy Sand	Mildly Fertile	15	66.67%
Sandy Clay-Loam	Fertile	16	66.67%

Table 6 shows the soil condition of each soil type based on the NPK reading of the sensor at field capacity. Clay-Loam and Sandy Clay-Loam are found to be fertile, so they have the highest percentage of seeds that germinated and lead in terms of height. Crop output justifies each level of fertility in terms of height and germination percentage. Seed germination is an important step that determines crop output and quality [10].

Table 7
Increase in height of Pechay in 2 weeks

Soil	Growth in 2 weeks		Height Difference (cm)
	Controlled (cm)	Monitored (cm)	
Clay	0.4	0.4	0
Loam	0.6	3.8	3.2
Sand	0.7	4.1	3.4
Clay-Loam	2.5	5.2	2.7
Clay-Loamy Sand	0.9	3.6	2.7
Sandy Clay-Loam	2.2	4.2	2

Table 7 shows the difference of growth of Pechay in terms of height in 2 weeks between controlled and monitored environment setting. The result shows that the T-statistics is equivalent to 3.058157134 and T table is equivalent to 1.812. The null hypothesis is rejected since T-statistics is higher than the value of T-table. Meaning, there's a significant difference between the two settings.

Table 8
Increase in height of Pechay after 2 weeks

Soil	Growth in week 2		Height Difference (cm)
	Monitored (cm)	Fertilizer (cm)	
Loam	3.8	5.9	2.1
Clay-Loam	5.2	6	0.8
Sandy Clay-Loam	4.2	6.3	2.1

Since the monitored environment is found to be better compare in controlled, Table 8 shows the difference of pechay growth in terms of height between monitored and with fertilizer. The T-statistics for this setting is 5.43928296 and T-table value is 2.132. The null hypothesis is once again rejected since T-statistics is higher than the value of T-table. Therefore, there's a significant difference between the two settings. The height of the plant has a significant impact on yield potential. Plant height and yield are tightly associated, and as plant height is increased, within a given range, yield increases as well [11].

IV. Discussions

Farmers have recently encountered issues that have affected their financial returns and well-being, thus it is important to be cautious in cultivating on infertile soil to prevent replanting your crops [12]. The study aimed to provide a system on how to assess and monitor the condition of the soil using sensors, web, and mobile applications with the help of IoT. Based on the data gathered, clay-loam has the highest nutrient content, followed by sandy clay-loam. Loam and clay-loamy sand fall under the criteria of being mildly fertile, whereas clay and sand are found to be infertile (Table 5). This result was consistent with the interview of a professor from the University of the Philippines (UPLB) where he said that clayey type soil tends to be more fertile compared to sandy types of soil. The soft clay soil was typically unsuitable for crop production. Previous research on soft clay soil issues in agricultural areas discovered that the soft clay soil had a low level of organic matter, making it an infertile type of soil. [13].

The researchers performed product testing to evaluate the fertility of various types of soil, namely clay, loam, sandy, clay-loam, sandy clay-loam, and clay-loamy sand, as well as their ability to support crop growth soil as a solution on how to lessen the problem of plants getting a disease because of infertile soil. The sensor sends the necessary data, such as pH, moisture, humidity, and soil NPK, to the system for monitoring purposes. Precision farming was rigorously tested, reviewed, and reported to increase efficiency, productivity, and profitability while remaining ecologically friendly [14].

The difference in crop output in soils that are monitored using the sensor compared to soils that are in controlled settings is very noticeable in terms of height and leaf count (Table 6), which is helpful in identifying the best type of soil suitable for a crop. Moreover, using a fertilizer according to what the system recommends leads to a healthier output. A study about a system making informed judgments in fertilizer application gave a satisfactory result in terms of giving an enhanced crop output [15]. The proponents therefore gathered data from the UPLB about the acceptable NPK content a specific crop needs that can be used by the Soil Assessment and Monitoring System in suggesting a crop to be planted and fertilizer to be added. The NPK content obtained from the soil via the sensor is helpful in analyzing crops that are suited to a soil. A crop recommendation is also added, so the users will have the chance to adjust the nutrient content of their soil, making it suitable for the crop they wish to plant.

Overall, the study can help make the assessment and monitoring of soil conditions easier by using the Sensoil device with the integration of IoT. Furthermore, the IoT makes it possible to have immediate access to information anywhere, at any time, on any device. But the availability of an internet connection is not all the time, so this study suggests programming the microcontroller to store the data from the sensor if there is no available internet connection and sends the data when the internet is ready. The application of fertilizer at the right time boosts the health of the crop and reduces the disease that it could get during its early growth stage. To better monitor the crop's physical growth without human intervention, the integration of cameras with machine learning can help analyze and draw inferences from data patterns using algorithms and statistical models to allow users to easily evaluate crop growth and predict crop yield. The information that the system provides matches the conducted experiment and is helpful in maintaining the health of the crop that is being monitored. However, nutrient content in different areas of soil is different and a single sensor is not ideal for that, so the integration of wireless sensor networks for large scale assessment of soil can determine the best type of soil more accurately by getting the average obtained from the area where the different sensors are embedded.

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