SENSOIL: DEVELOPMENT OF AN IOT-BASED SOIL MACRONUTRIENT ANALYSIS SYSTEM UTILIZING ELECTROCHEMICAL SENSORS AND MACHINE LEARNING ALGORITHMS

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Bachelor of Science in Electronics Engineering

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The Authors

Abstract

Rational agriculture that minimizes economic losses can be accomplished through the enhanced administration of principal soil nutrients. The evolution of sensors suitable for quantifying soil properties will enhance the efficiency of on-site observing techniques and soil management. In this paper, Ion Sensitive Field Effect Transistor (ISFET) pH, soil moisture, and RGB color sensors were integrated into the Arduino Mega and machine learning algorithms were utilized to predict the soil macronutrient level. The system's structure is comprised of four sections only namely, soil collection, analog read-out circuit designing, prediction system and results. The Random Forest Classifier provides the highest accuracy among the other three predictive models with an accuracy of 95.83% for Nitrogen, 98.10% for Phosphorus, and 93.75% for Potassium using the 80/20 split ratio. Results can be seen in the offline and online databases for future references. The proponents systematize the testing between the partner facility and the SenSoil by testing a same soil at the same time. Overall, this study analyzes the macronutrient level of the soil namely, Nitrogen, Phosphorus and Potassium with an accuracy of 95.89 %.

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CHAPTER 1

The Problem and Its Background

1.1 Introduction

To maximize crop generation, it is imperative to institute functional soil and fertilizer management practice, sustaining each plant in its optimal state assists in yielding abundant crops in top quality. According to an article from *the Food and Fertilizer Technology Center*, crops which draw needed nutrient at expected valuations are tougher and more resistant to parasites, bugs and plant diseases. In any crop, the development of the plant is exclusive to the nutrients accessible in infinitesimal amounts, even if all other nutrients are present in sufficient supply ("the Law of the Minimum Nutrient"). One of the most prevalent difficulties in the Asian and Pacific region is the overuse of compost. In the early use of soil testing in the area, the method was mainly used to distinguish nutrient insufficiencies, which persists as an important core function of soil analysis. However, most growers in Asian countries have been applying excessive fertilizers for past generations, resulting in soil toxicity. The soil fortifies crop growth - it is the source of necessary nutrients for the plant, thus, diagnosis and prognosis of soil nutrients ought to be rendered for a better harvest.

Soil nutrients are inherent to the soil; It is branched into two groups in accordance with the amount of intake necessary for the plant. Micronutrients are statutory in small portions, while macronutrients are those expected in substantial volumes. Macronutrients are the focus of this research that comprises Nitrogen, Phosphorus and Potassium. Nitrogen is a crucial factor in the undertaking of chlorophyll, plant protein, hormones, vitamins, and cell division. It is obtained from the ions the soil, amino acids, and proteins. Phosphorus initiates metabolic performances particularly photosynthesis, energy storage and transfer, respiration, and cell enlargement which aggregates plant maturity. Potassium is relevant in the performance of enzymes and gas exchange. It also improves aridity resistance by appropriating water distribution within the plant. On a side note, soil pH influences the availability of these nutrients and is weighed the most important soil property as it measures the acidity or alkalinity of the soil. The ideal pH range is 6.0 to 6.5. In this range, nutrients are immediately consumable by plants.

Soil Test is a method in whereby each soil nutrient are extracted from the soil through laboratory analysis and soil test kits. Currently, various methods exist for soil analysis that is used throughout countries. One of the cheapest and accessible methods is the Soil Test Kit (STK) produced by the Bureau of Soils and Water Management (BSWM) – an agency of the Philippine administration supervised by the Department of Agriculture accountable for encouraging and administering compensation on concerns pertinent to the regulation of soils and water as essential agricultural resources. The STK is a method of evaluating the fertility status of the soil. It involves chemical analyses that measure the number of nutrients available for the plant. Results are interpreted qualitatively through a color chart. There are three levels for Nitrogen and Phosphorus – Low, Medium, and High; Potassium can either be Sufficient or Deficient.

Soil nutrient detection ordinarily applies visual analysis. Prevalently, visible/ultraviolet spectrometry employs for detecting nitrogen and phosphorus and flare spectrometry or atomic reception spectrometry for potassium. These techniques are reliable but time-consuming, convoluting and expensive. This results in the limitation of samples that can be tested to identify the variation of soil properties in the field. Thus, a simpler, and more robust system needed to be established.

The edges of potentiometric electrochemical sensors are invigorating the notice of their implementations in soil nutrient detection. It has capabilities for automatic multi-target accelerated apprehension of soil nutrient contents. However, its reliability must be considered. To address this, the proponents began their research on methods that can utilize electrochemical sensors in their study. This directs to an integration of a device composed of electrochemical sensors (ISFET pH sensor node, a soil moisture sensor, and RGB sensor) and implementation of Machine Learning (ML) algorithm.

1.2 Background of the Study

In reference to the study *SOILMATE: Soil Macronutrients and pH Level Assessment for Rice Plant Through Digital Image Processing using Artificial Neural Network* and *Arduino-Based Automated Soil Macronutrients and pH Level Testing and Assessment through Digital Image Processing using Artificial Neural Network*, uses a colorimetric method by mimicking human-eye brain perception. Image processing supported by Artificial Neural Network was digitally done in fulfilling these studies, automation to the conventional process of soil nutrient analysis.

According to the study "*Sensor Technologies for Precision Soil Nutrient Management and Monitoring*" by Bah, A., S.K. Balasundram and M.H.A. Husni (2012), raising matters about the need to enhance harvest generation without prompting disruption to the ecosystem have driven to the implementation of in-situ techniques in soil nutrient administration. Effective monitoring of soil macro- and micronutrient availability is considered advisable.

The intention to attain sustainable farming that diminishes environmental repercussions and economic losses is the enhanced administration of principal soil nutrients (Goulding et al., 2008). Efficient administration in harvest plots can be accomplished by using Precision Agriculture with a foundation in geospatial technologies like remote sensing, geographical information system, global positioning system, geostatistical, and variable rate application (Gebbers and Adamchuk, 2010; Robert, 2002).

The evolution of sensors suitable in determining soil attributes promotes the efficacy of in-situ soil supervision and monitoring methods. Soil sensors are applied to produce concurrent soil data such as pH, nutrient concentration, and moisture.

As stated in the study "*Ion-Specific Nutrient Management in Closed Systems: The Necessity for Ion-Selective Sensors in Terrestrial and Space-Based Agriculture and Water Management Systems*", using electromechanical sensors specifically Ion-Selective Field Effect Transistor (ISFET) is highly prescribed for the future of controlled agriculture crop production.

ISFETs operate on the potentiometric manner which possesses abundant advantageous attributes: high pace, high responsiveness, developed SNR, economical, miniaturization and CMOS adaptability. It can be used to measure ion concentrations in solution.

Therefore, low-cost, robust and real-time soil nutrient detection method using ISFET is needed.

1.3 Statement of the Problem

An exemplary system is an ISFET that is capable of concurrent, multi-targets sensing of macronutrients. Multi-target is one of the advanced and most challenging applications of sensor management. Developing such a system would necessitate intricate programming which requires additional research. Thus, producing a predictive model correlating the parameters that influence the availability of macronutrients such as pH, soil moisture level and the color of the soil is introduced. ISFETs that are proficient of recognizing and measuring ions of the macronutrients are not commercially accessible, nevertheless, the difficulty for this method is the proper calibration of the sensors particularly the ISFET, and accumulating samples of soil for examination. An ISFET is constructed to determine the ion concentration of an aqueous solution, applying it undeviatingly to the soil would harm the sensor, hence, a lysimeter is required. Procuring a fitting lysimeter or any other water acquisition device and maximizing its capability is another assignment for the proponents.

1.4 Objectives

The study seeks to develop an in-situ automated soil nutrient detection system that will analyze macronutrients present in the soil without the use of chemical reagents utilizing electrochemical sensors and machine learning algorithms. In particular, it aims to:

1. To develop a device that utilizes Ion-Selective Field-Effect Transistor and soil moisture sensor using Arduino MEGA as a sensor node.
2. To develop a predictive model correlating the pH, moisture level, and

macronutrients of soil through machine learning algorithms.

3. To create a database system that stores data for later retrieval and analysis through IoT.
4. To test and validate the acquired result by comparing it to the results using the conventional method which is the Soil Test Kit.

1.5 Significance of the Study

The study aids in distinguishing the potency of the soil based on its macronutrient content and provides fertilizer recommendation for its progress. By optimizing the application of fertilizer outlay, soil degradation is restricted, and the value of productivity is smaller hence providing a profitable solution to farmers.

This likewise is useful to agricultural technologists in the country. The developed system provides a database of collected soil samples for its eventual retrieval and examination. By these analyses, crop generation will improve as it focuses on the soil-plant relationship.

The future research in expanding opportunities and advancements about electrochemical sensors may accept this study as a footnote in future research endeavors. This study is also an aid in learning algorithms and smart agriculture.

1.6 Scope and Delimitation

This project principally concentrated on the determination of soil macronutrients that consists of Nitrogen, Phosphorus and Potassium. The crop fertilizer recommendation in the device is limited to sugarcane, corn, and rice. Only Bulacan, Rizal, Quezon, Nueva

Ecija, and Cavite compose the areas comprised in the device interface.

The respondents on this study were exclusive to Filipino farmers who cultivate Philippine's principal agricultural products which are rice, corn, coconut, sugarcane, bananas, pineapple, coffee, mangoes, tobacco, and abaca.

CHAPTER 2

REVIEW OF RELATED LITERATURE

This chapter presents the related literature and studies used in the development of this research. The proponents included discussions of facts and principles to which the present study is related. They also included studies already conducted to which the present proposed study relate, has some bearing or similarity.

2.1 Conceptual Literature

2.1.1 Soil

The soil is a primary reservoir of nutrients for plant germination. From grains up to full-grown trees, plants and trees draw Therefore, soil content affects greatly the yield of the crops growing on it, quantitatively and qualitatively.

2.1.1.1 Nutrients in Soil

Fertility of plants relies mostly on the nutrient content of the soil where these plants are rooted. Hence, obtaining soil as its major reservoir for growth and development. Nutrients are divided into two groups according to their demanded quantity: micro- and macronutrients. Macronutrients, which are demanded highly by the plants, is then divided into two – primary and secondary. The firsthand macronutrients comprise of nitrogen (N), phosphorus (P) and potassium (K), while secondary macronutrients include magnesium (Mg), calcium (Ca) and sulfur (S). Micronutrients, which are demanded in low amounts, include copper (Cu), manganese (Mn), zinc (Zn), molybdenum (Mo), nickel (Ni), iron (Fe), and boron (B).

Plants consume nutrients and water through their roots but in their leaves transpire photosynthesis. Several conditions are sufficed to transfer nutrients. The capacity of absorbing nutrients vary depending on the characteristics of the soil. Circumstances influencing nutrient intake are light, temperature, air humidity, pH, moisture, and even microorganisms (Soil Nutrients).

2.1.1.2 Soil Nutrient Deficiency and Toxicity

The demands of plants require sufficient delivery. Identifying and preventing plant and soil nutrient deficiency and toxicity is an essential part of farming and planting. Deficiency is usually evident on the plant's senescence leaves. Symptoms include chlorosis - yellowish color, necrosis - the death of its tissue, stunted growth, fall of leaves and inhibition of cell division. Toxicity, on the other hand, is difficult to identify as this commonly happens to micronutrients which block the consumption of other elements. These two conditions are not that visible if plants are not severely affected, thus discerning it only through yield decline (Agriculture for Engineers).

2.1.2 pH Level of Soil

Soil pH quantifies the degree of acidity or alkalinity. A pH of 7 is neutral. The lower the pH (below 9) the more acidic the soil is. On the other hand, the higher the pH (above 7) the soil becomes more alkaline.

It is beneficial to identify the pH of a soil because the availability of most nutrient elements for plant growth and occurrence of toxicities of elements is related to soil pH. Most plant nutrients are in readily available form at soil ph ranging from 5.5 to 7.0, hence, most plants prefer to grow within this range. However, nutritional disorders usually appear when pH values become higher or lower. The figure below shows the effects of pH level on soil nutrient availability.

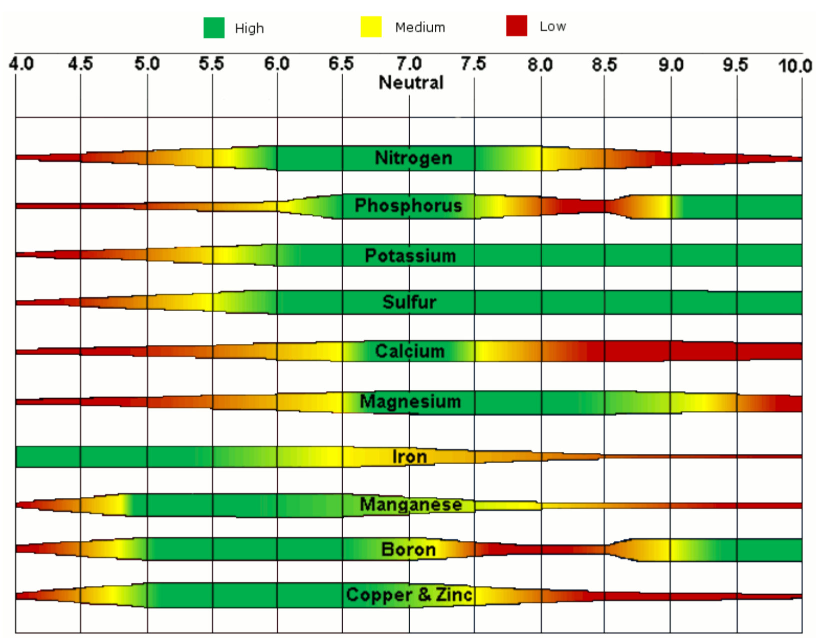


Figure 2.1 Plant Nutrient Uptake in Relation to Soil pH

(Source: https://nutrienttechnologies.com/2017/04/17/manganese-iron-availability/)

2.1.3 Soil Moisture

Soil moisture affects plant nutrition through its influence on nutrient transport to, and absorption by, plant roots, the concentration of available plant nutrients in the soil solution, and soil microbial activity. Although water and nutrient absorption by plants are independent processes (except where some forms of elements may be transported into the root by mass flow), their intimate relationship makes it complicated to separate the importance of soil water into its role in plant nutrition and its role in other plant physiological processes. The results of soil water on germination, water, and nutrient digestion, translocation of minerals and food, transpiration, photosynthesis, and respiration directly or indirectly influence growth. Plenty of research has documented the impacts of water deficits on plant growth. Unnecessary soil water has also been shown to alter physiological processes and hence growth, mainly through its influence on the functioning of plant roots as absorbing elements.

2.1.4 Soil Macronutrients

Soil macronutrients are nutrients which the soil needs in substantial amount. Nutrients that constitutes this bracket are: Nitrogen (N), Phosphorus (P), and Potassium (K).

2.1.4.1 Nitrogen in Soil

Despite its volatile behavior, nitrogen is a vital element in the formation of amino acids, DNA, enzymes, proteins and metabolic systems implicated in the organization and transfer of energy. It is also a constituent of chlorophyll, a green orpiment of the plant, subject the photosynthesis. Nitrogen stimulates plant with accelerated germination, improving grain and fruit-bearing and promoting the variety of leaf and forage yields. It frequently emerges from compost treatment and atmosphere (Plant Nutrients).

2.1.4.2 Phosphorus in Soil

Phosphorus is likewise essential for photosynthesis and energy transfer. It heightens root maturation, accelerates growth, and stimulates flowering. It is also necessary in the development of oils, glucose, and carbohydrates. Phosphorus also strengthens immunity to disease. Phosphorus also develops microbial liveliness in the soil. Bone meals and fertilizers are the principal sources of Phosphorus (Soil Macronutrient Testing).

2.1.4.3 Potassium in Soil

Potassium performs a vital role in the physiological and biochemical capacities of plants. It is ingested in substantial volumes by plants. It is used to create proteins; improves aridity resistance; increases cuticle (waxy layer) to inhibit water loss; helps counter wilting, and improves fruit measurement, zest, feel, and growth (Soil Macronutrient Testing).

2.1.5 Soil Nutrient Variations in the Philippines

Large disparities amongst the general soil properties, including soil macronutrient consistency, are common in the Philippines. The sampling localities of the 197 maize-soil sample pairs accumulated from the Philippines are thoroughly scattered all over the important farming regions in the country. The cumulative nitrogen and phosphorus availability of Philippine soils are prevalent amidst global standards. The N and P contents of maize are imperceptibly inferior. The extensive difference is also normal for the potassium contents in the country as well in the K content of maize but, in general, the K status is comparatively low. A healthy response to potassium is possible in numerous areas in the archipelago (Micronutrients and the Nutrient Status of Soils: A Global Study).

2.1.6 Lysimeter

Soil solution access tubes, also known as Suction Lysimeters, are used to extract the liquid phase of the soil. Determining macronutrient levels is more accessible by Suction Lysimeters. Aside from measuring the nutrient levels, Soil Solution Access Tubes can also be utilized to take the measures of electrical conductivity, nitrate level, and salinity level of the plant.

Figure 2.2 Soil Water Sampling – Suction Lysimeter

(Source: http://www.irrometer.com/ssat.html)

2.1.7 Arduino MEGA 2560

The Arduino MEGA 2560 is a microcontroller developed for electronic designs that include the use of added random access memory (RAM) and input and output ports. The Arduino MEGA 2560 is composed of 54 digital pins which can be programmed as an input or output, 16 analog pins, a USB connection and can interact with a computer.

Figure 2.3 Arduino MEGA 2560

(Source: https://potentiallabs.com/cart/arduino-mega-2560)

2.1.8 Electrochemical Sensors

Requisite data necessary for rational agriculture can be from electrochemical sensors. These sensors function by recognizing the structure of ions in the soil. The precedents of electrochemical sensors are Ion-Selective Field-Effect Transistor and glass electrodes.

2.1.8.1 Ion-Selective Field Effect Transistor (ISFET)

The pH measurement is done conventionally with colorimetry. The colorimetry is an approach to measure the soil solution by comparing the color to a color table using a strip of paper that changes its colors when it reacts with chemicals.

The ISFET pH sensor is a semiconductor device meant for measuring the pH of any solution. It is sensitive specifically to hydrogen ions. The ISFET pH sensor can produce quick response time, has a low consumption in terms of power, and is smaller in size. It is prominent in various industries for different applications, be it in aquaculture, biochemistry, pH monitoring, and many more.

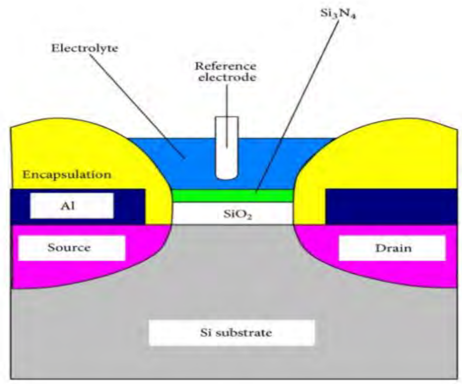


Figure 2.4 ISFET Structure

(Source: https://www.researchgate.net/figure/Structure-of-an-ISFET_fig6_258395169)

Figure 2.5 ISFET Sensor Kit

2.1.8.1.1 Read-out Circuit

Analog readout circuit (ARC) plays an important role in acquiring and processing the signal produced by ISFET sensor and passing it to a data converter for further signal processing (Sulaiman et. al, 2009).

2.1.8.1.2 Design

Many pieces of study in ISFET ARC design have been published in public discourse. Some strategies employed as part of the sensing tools are linked type technique, complementary ISFET-MOSFET pair technique, and Constant- Voltage-Constant-Current (CVCC) technique (a cheap, mono-chip readout circuit for pH defining).

According to *“A novel current-mode readout circuit for ISFET sensor”* by Wang Chunhua (2008), an innovative differential current-based readout circuitry for the ISFET is displayed. The circuit employs two-second generation current conveyors (CCIIs), that are applied to sustain precise constant drain-source voltage and a constant voltage of the reference electrode to source (CVCC) condition. It quantifies the drain current variation of ISFET because of the hydrogen ion in the buffer solution with the pH value varying from 2 to 12. The differential arrangement gives an output current that is linearly correlated to the differential current between the ISFET and the Reference Field Effect Transistor (REFET) that diminishes the thermic features and another result of the parameter inconstancies and environmental provisions on the performance of ISFET.

2.1.8.2 Soil Moisture Sensor

The soil moisture sensor is used to determine the percentage of moisture available in the soil to be informed whether it is dry or wet. Having a shortage or surplus of water in the soil is not a good practice, therefore, measuring the moisture level of the soil is a must.

Figure 2.6 Soil Moisture Sensor

(Source: https://www.smart-prototyping.com/Soil-Hygrometer-Detection-Module-Soil-Moisture-Sensor-For-Arduino.html)

2.1.8.3 RGB Color Sensor

The RGB color sensor is used to determine the red, blue, and green color elements of a specific object. Aside from the RGB, the device can also produce an accurate measurement of other primary and secondary colors because it has a filter blocking the undesirable infrared penetrating the object being examined.

Figure 2.7 RGB Sensor

(Source: https://www.cytron.io/p-rgb-color-sensor-with-ir-filter)

2.1.9 Machine Learning Algorithm

Machine learning is a procedure of data interpretation that automates logical representation construction. Machine Learning utilizes algorithms that repetitively learn from data enabling machines to discover deep insight without being explicitly programmed. As mentioned in the journal "*Artificial intelligence, machine learning and deep learning*" by Pariwat Ongsulee (2017), two most prevalent machine learning processes are supervised learning and unsupervised learning. Most machine learning models – about 70 percent – is supervised learning. Unsupervised learning deems for the 10 to 20 percent. Semi-supervised and reinforcement learning are methods that are unusually practiced.

Supervised learning algorithms use defined examples for training whereas the output has a definition. Unsupervised learning applies to data that has no definition. The algorithm to form conclusions from datasets consisting of input data without labeled outputs. The purpose is to investigate the data and attain remarkable composition within. This works strongly on transactional data. Then, semi-supervised learning is used for identical applications as supervised learning, nevertheless, it can use labeled and unlabeled data concurrently for learning. Ultimately, in reinforcement learning, the algorithm learns by trial and error procedures generate the greatest recompenses. It is frequently used in robotics, gaming, and navigation (Ongsulee, 2017).

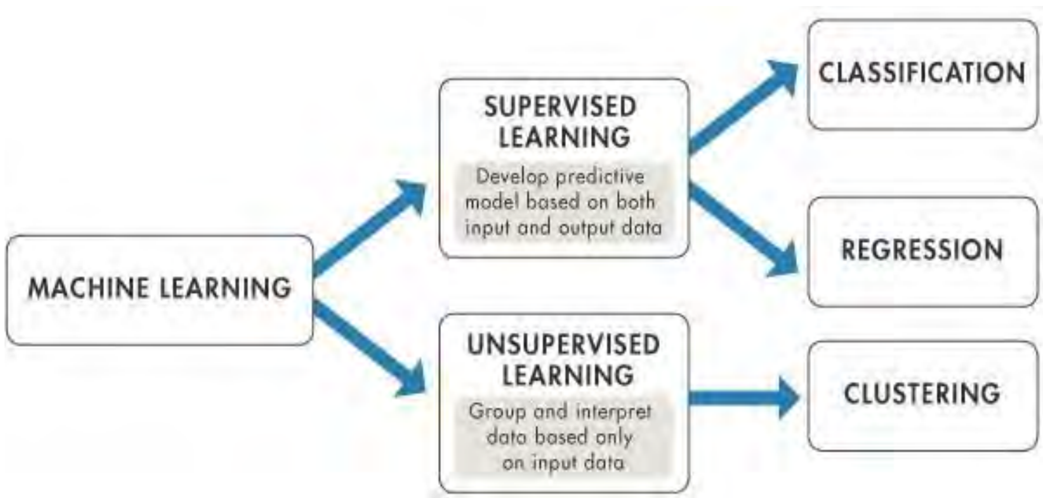


Figure 2.8 Types of Machine Learning

(Source: https://ecmapping.com/2018/02/21/the-10-machine-learning-algorithms-to-master-for-beginners/)

2.1.10 Supervised Learning Algorithm

Supervised learning is a class of machine learning algorithm that employs a training dataset to perform predictions. The training dataset of a supervised learning comprises input data and response values. With this, the supervised learning algorithm attempts to construct a pattern that can generate predictions of the responses from a newly introduced dataset. The test set verifies the model efficacy. Working with bigger training datasets produce predictive models with higher accuracy that can theorize thoroughly for alien datasets.

Supervised learning is branched into two categories of algorithms: Classification and Regression. Classification is for categorical response values, where the data can be separated into specific “classes” while Regression is for continuous- response values.

Common classification algorithms include:

- Support vector machines (SVM)
- Neural networks
- Naïve Bayes classifier
- Decision trees
- Discriminant analysis
- Nearest neighbors (*k*NN)

Common regression algorithms include:

- Linear Regression
- Nonlinear regression
- Generalized linear models
- Decision trees
- Neural networks

2.1.10.1 Support Vector Machine

Support Vector Machine (SVM) falls under the supervised machine learning algorithm category. It is a differential classifier specified by a bisecting hyperplane. Simply put, given identified training data, the algorithm displays an ideal hyperplane that describes distinct patterns. In two- dimensional view, this hyperplane is a lane splitting a plane into two parts wherein each class rested in both surfaces.

2.1.10.2 Random Forest Classifier

Random forest formulates repetitious decision trees and fuses them collectively to acquire a more precise and solid prediction. One prominent advantage of random forest allows it to be used in both classification and regression problems, which constitute the majority of modern machine learning systems. Random Forest sums additional randomness to the model while producing the trees. Rather exploring for the most critical feature while breaking a junction, it combs for the best feature amidst an arbitrary subset of features. This ends in a wide diversity that regularly results in a reliable model (Donges, 2018).

2.1.10.3 Bayesian Classifier

Naive Bayes Classifier is a classifier that applies the Bayes Theorem. It predicts the possibility that a provided account or data point fits an appropriate class. The class with the highest probability is perceived as the most suitable class. Naive Bayes classifier estimates that all feature is independent. Presence or absence of a feature does not influence any other feature.

2.1.10.4 K Nearest Neighbor

The KNN algorithm is a strong and versatile classifier that is frequently used as a foundation for more compact classifiers such as Artificial Neural Networks (ANN) and Support Vector Machines (SVM).

2.1.11 Internet of Things (IoT)

The Internet is one of the most remarkable inventions in history. By the Internet, people can remotely access information from networks of networks globally. With that, the Internet provides a promising future to a smart life – the Internet of Things. IoT depicts a system consisting of each thing in the physical environment with sensors linked or embedded to it that is connected to the Internet in any mode. These IoT-enabled devices distribute data concerning the state of objects and the surrounding scene with the people and interconnected devices. With the Internet of Things, anything will be equipped to interact by the Internet at any time from all location to accommodate co-operation by any given system (Mohammed and Ahmed, 2017).

2.1.12 Python Programming Language

Python is an understood, advanced, flexible programming language used in recent times. Its code readability and syntax enable programmers to formulate ideas in fewer lines of code. Python provides ease to its users thus enabling programs written on both small and large scale, further resulting to a large variety of application. One thing Python can take pride in is how enormous user community it has. As a matter of fact, it is the third largest community in programming language. Chances are documentations, tutorials, guides, and examples are already there to help you along your building process. Another thing that fueled the rapid growth of Python is its use for data science. In combination, this tells a story of data analysis and machine learning commonly on companies (Srinath, 2017).

2.1.12.1 Flask

There are numerous frameworks for Python: Flask, Django, Pyramid, and Tornado. These frameworks are essential in developing a web application as these provide code libraries making it easier for developers to write common operations. All four frameworks have their own strength and should be chosen depending on what the application is for. Flask framework is the best fit for databases presentation. Packages for operations concerning data manipulations, such as machine learning models are readily available under Flask (Hunt and Walker, 2018).

2.2 Local and International Related Studies

2.2.1 Soil Testing Techniques

Various innovation of conventional method for soil test analysis was developed using current technology. A review of these foreign studies was present hereunder.

According to *"Detection of NPK nutrients of soil using Fiber Optic Sensor"* by Ramane et al. (2015) common soil testing methods are generally implemented in three steps: soil sampling, sample pretreatment, and chemical analysis. At present, soil sampling is manually carried out in a field to obtain representative soil samples at a proper depth (20cm below ground level). Chemical interpretation i.e. exact determination of NPK is conducted out by three methods which are conductivity measurement, an optical method, and electrochemical methods.

The pioneering study that uses advanced techniques in soil nutrient analysis was a study by Quiao et al. (2010). The apprehension method of the soil nutrients was examined based on the near-infrared spectroscopy technology for decision-making in precision fertilization. The predictive model for soil organic matter, usable nitrogen (N), available phosphorus (P), potassium (K) are put with the eight main elements of primary spectra attained by principal component analysis (PCA).

Kulkarni et al. (2014) examined soil characteristics for precisely charting numerous fundamental nutrients. A multi-parametric analytical method for measuring fundamental nutrients content in tilled soil is developed for on-field analysis utilizing the techniques as UV Spectroscopy

Ramane et al. (2015) produced a machine that also determines N, P, and K amounts in the soil sample but by employing fiber optic-based color sensor. Here, colorimetric analysis of an aqueous solution of soil was carried out. The color sensor examines the system through the reflection of color on the solution. The sensor probe along with fitting signal conditioning circuitry is constructed to recognize the inadequate element of the soil. It is valuable in allocating only the needed measure of composts in the soil.

In the *"Automatic Soil Nutrient Detection and Fertilizer Dispensary System",* Amrutha A, Lekha R, A Sreedevi (2016) developed a sensor system for estimation of nutrients present in the soil and an intelligent system for estimation and control of the flow of required amount of fertilizers. The principle used for the identification of the NPK nutrients in the soil is colorimetry. In order to estimate the number of nutrients present from the colored solution a color sensor is used. This color sensor is used to identify different colors and shades. It consists of an LED (emitter), a photodiode (receiver), and microcontroller.

A model was developed by Sudha et. al (2017) that is based on digital image processing technique where digital photographs of the soil samples were used for soil pH determination.

Lastly, one of the recent development in smart precision agriculture is done by Marlet M. et al. (2017). A silicon chip dedicated to the in-situ monitoring of the soil nitrogen cycle in the wheat crop was designed. The study shows that the ion-sensitive field effect transistor (ISFET) microsensors are suitable for quick on-site or long-term analysis of nutrients measured directly in the soil as opposed to soil extracts analysis.

Table 2.1 Summary of Previous Foreign Studies on Soil Nutrient Analysis

Author	Year	Location	Hardware	Software / Algorithm
Qiao et al.	2010	China	computer, spectrometer, halogen light, etc (near-infrared spectroscopy technology)	Linear Square Support Algorithm
Kulkarni et al.	2014	India	optical method UV spectroscopy module	None
Ramane et al.	2015	India	fiber optic based color sensor	None
Amrutha A, Lekha R, A	2016	India	Color sensor consists of an LED (emitter), a photodiode	Arduino Communication
Sreedevi			(receiver), and microcontroller	Software
Sudha et.al	2017	India	Camera	Image Processing
Marlet M. et.al	2017	France	All-solid-state multimodal probe based on ISFET electrochemical microsensors	None

Also, there are already pioneering studies here locally, a review of local studies related to soil nutrient analysis is presented hereunder.

The study of Arago N.M et al. entitled "SoilMATe: Soil Macronutrients and pH Level Assessment for Rice Plant through Digital Image Processing Using Artificial Neural Network" (2017), used the soil test kit manually for each soil nutrient analysis before using digital image processing. The Artificial Neural

Network produced an accuracy of 98.33%.

The "SoilMattic: Arduino-Based Automated Soil Nutrient and pH Level Analyzer using Digital Image Processing and Artificial Neural Network" by Alasco R. et al. (2018) automated the process by using pumps and motors that were programmed to follow the procedures in preparing the sample for soil test analysis. The accuracy of 96.67% was acquired using the process of Image processing through Artificial Neural Network.

In SoilMac.pH of Padila V. et al. (2019) used spectroscopy and Beer-Lambert Law effect in acquiring the soil nutrient. The study removed the use of chemical reagents and decreased the time of acquiring results significantly.

Table 2.2 Summary of Previous Local Studies on Soil Nutrient Analysis

Author	Year	Location	Hardware	Software / Algorithm
Arago et al.	2017	Manila, Philippines	Camera	Digital Image processing Artificial Neural Network
Alasco et al.	2018	Manila, Philippines	Motors and pumps camera	Digital Image processing Artificial Neural Network
Padilla et al.	2019	Manila, Philippines	CCD linear sensor color sensor	Spectroscopy Beer-Lambert law

2.2.2 Soil Sensor Technologies

According to Sensor Technologies for Precision Soil Nutrient Management and Monitoring, the use of immediate sensors for in situ soil analysis could potentially be arraying for accurate nutrient management and monitoring. There are a lot of sensor design concepts, Optical or Electromechanical Sensing is most commonly used in immediately ready soil sensors. Reflectance spectroscopy is the basis of optical sensing, which detects the level of energy absorbed or reflected by soil particles. Electromechanical sensing, on the other hand, uses ion-selective electrodes to generate a voltage or current output in response to the ion of the selected nutrient (Kim et al., 2009)

Table 2.3 Different Electrochemical Sensors Studies in Agriculture

Sensor concept	Status of development	Current results	Key references
Ion-selective field effect transistors (ISFETs) with flow injection analysis	Laboratory tests	Correlation with nitrate concentration in soil extracts	Birrell and Hummel (2001)
Rapid extraction of soil cores	Laboratory tests	Potential for reducing lag time between sample collection and sensor output	Price et al. (2003)
Electro-pneumatic sampling method	Laboratory tests	The method has potential to be used with PVC membrane electrodes	Yildirim et al. (2003)
Direct measurement of ion activity using ion-selective electrodes	Field tests and a commercial implement	Correlation with soluble potassium, residual nitrate content and pH, on-the-go mapping of soil pH is available commercially	Adamchuk et al. (2003)
Utilization of active canopy sensors	Field tests	Reading the presence of nitrogen	Barker, 2011

CHAPTER 3

METHODOLOGY

The chapter present the methods and procedures used in the development and implementation of the project. The proponents also included the design flow process in making the whole system.

3.1 Research Design

The study focuses in the development of a soil nutrient prediction system. The following conceptual framework summarizes the input parameters, the processes done in the study, and the output of the system.

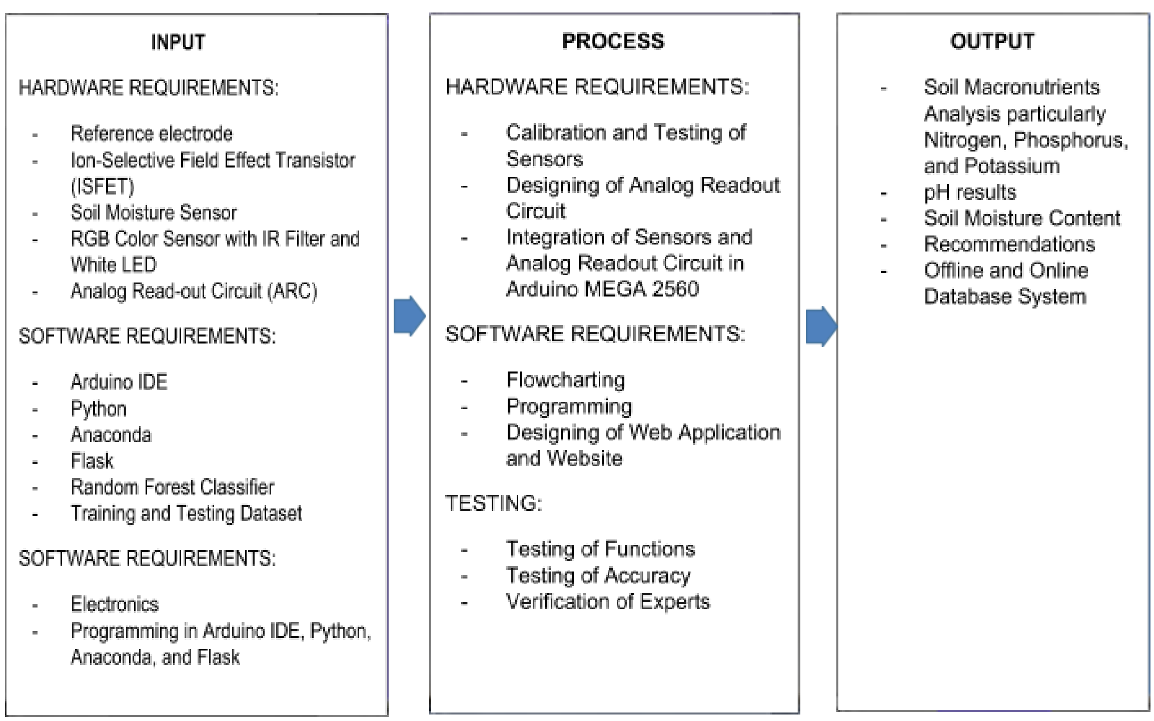


Figure 3.1 Conceptual Framework of the Study

The soil and its liquid phase which is the soil solution are the inputs of the device that were tested by the reference electrode together with the ISFET pH, soil moisture sensor, and RGB color sensor with IR filter and white LED (TCS34725) which are integrated to the Arduino MEGA 2560. The ISFET pH sensor is an electronic device used for measuring the pH of the soil solution having a pH measurement range from 1 to 14. The soil moisture sensor and TCS34725 are intended to determine the moisture content and RGB colors of the soil respectively. In application, the range for the soil moisture sensor is 0 to 1023. The RGB color sensor lessens the amount of infrared infiltrating light to allow precise measurements of the red, blue, and green colors. The Arduino IDE contains the calibration setups for the ISFET, soil moisture sensor, and TCS34725. These data and the results acquired through the conventional method using the Soil Test Kit (STK) were the dataset used for the prediction system. The output of the prediction system was displayed through the web application using Flask. The web application has both an offline and online database that serves as the historical record for future references.

3.2 Research Process Flow

The following figure is the research process flowchart of the whole study:

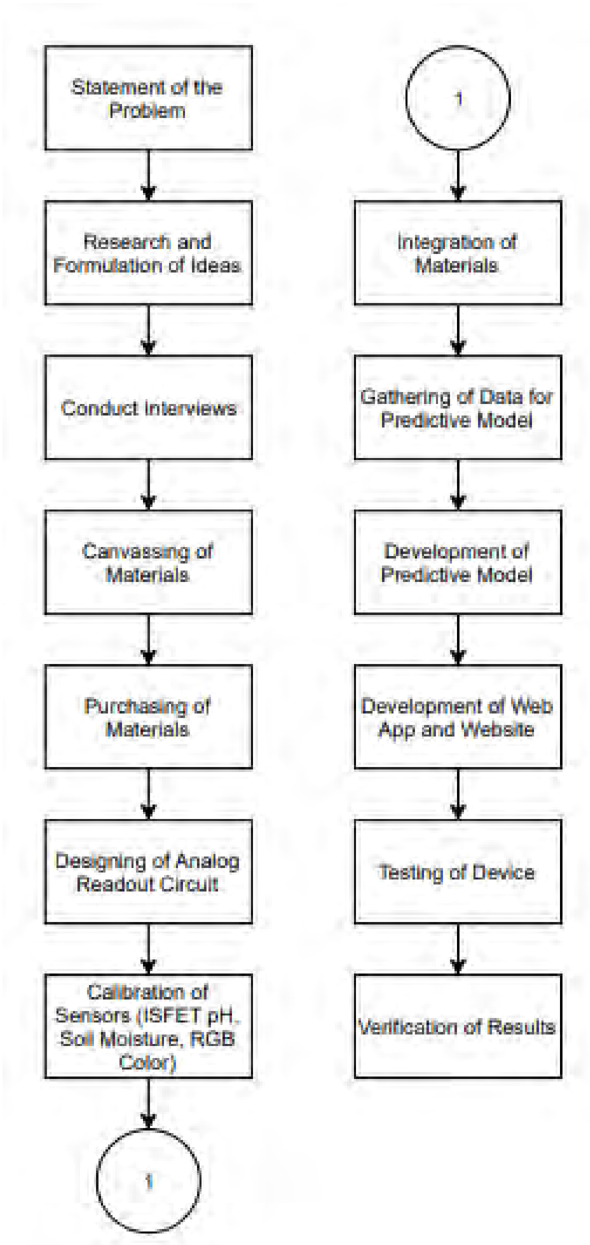


Figure 3.2 Research Process Flowchart of the Study

Figure 3.2 summarizes the overall processes and procedures done in the study. Each process is discussed in detail at the later sections of this paper.

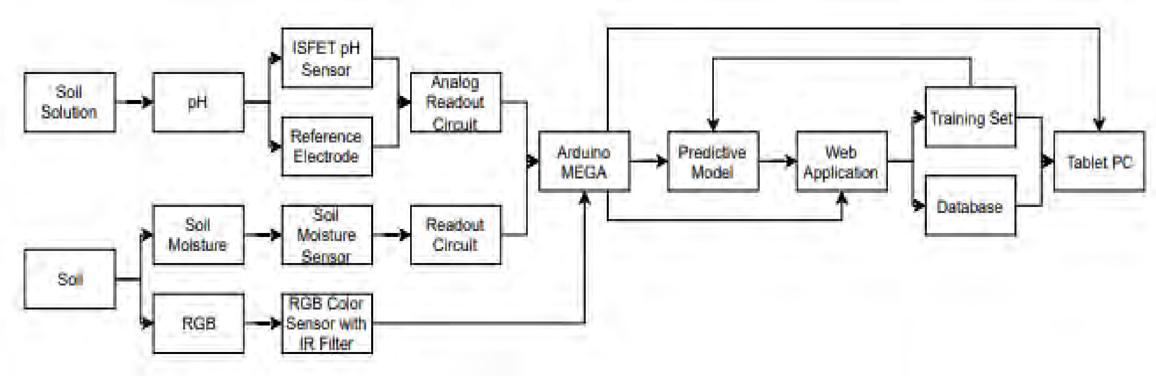


Figure 3.3 General Framework

3.3 Hardware Development

One of the objectives of this study was to develop a device that analyzes the soil macronutrient composition. This was done through the use of different sensors such as ISFET pH sensor for measuring the acidity or alkalinity of the soil solution, a soil moisture sensor for determining the moisture level of the soil, and a TCS34725 for the RGB colors of the soil. These sensors were connected in Arduino MEGA 2560. Alongside the ISFET pH sensor, an analog readout circuit was designed. The outputs of the system will be reflected in a tablet PC. Together, these materials were integrated into an acrylic box.

3.3.1 Calibration of ISFET pH Sensor

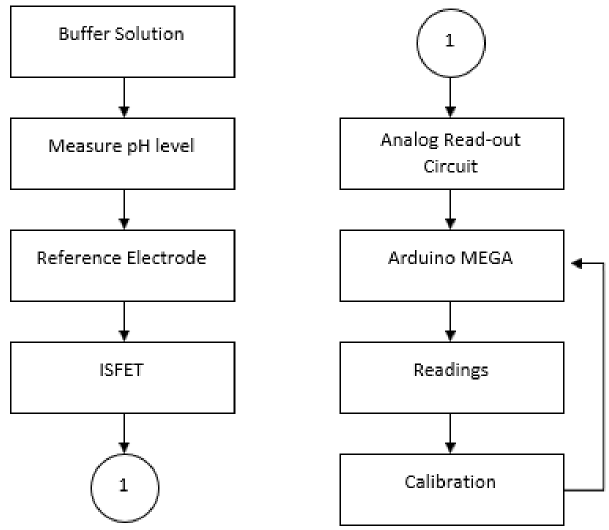


Figure 3.4 ISFET Calibration Flowchart

In practice, it is required to calibrate the ISFET pH sensor before use. The readings of an ISFET pH sensor change over time thus it is recommended to recalibrate the device for its accuracy. Three buffer solutions mainly pH 4, pH 7, and pH 10 were used in this study. The voltages that were generated upon measuring the buffer solutions were shown in the Arduino IDE. The resulting voltages were needed to establish a linear line equation showing the relationship between voltage output and the pH level of the ISFET pH sensor. Figure 3.5 shows an example of a linear trend line.

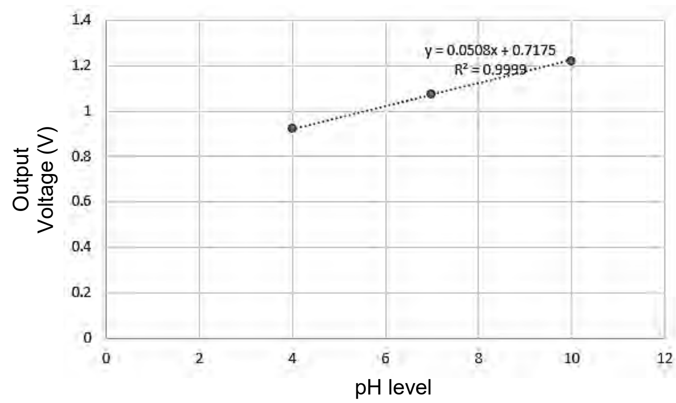


Figure 3.5 Relationship Between the pH Level and the Output Voltage of the ISFET pH Sensor

3.3.2 Calibration of Soil Moisture Sensor

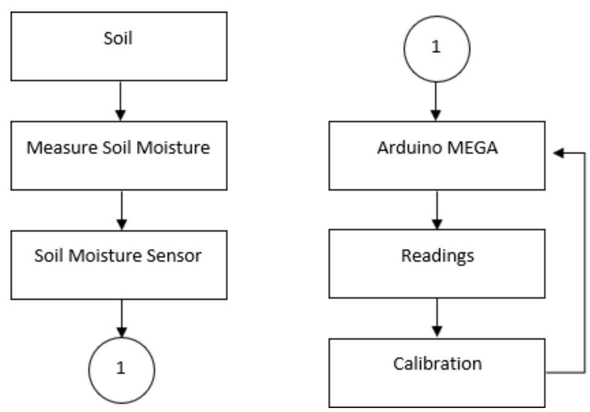


Figure 3.6 Soil Moisture Sensor Calibration Flowchart

Soil moisture sensors were used to determine the amount of moisture present in the soil. Calibrating the soil moisture sensor to produce beneficial data is advisable. The minimum and maximum moisture values of the soil were needed to properly calibrate the sensor. The calibration process was done using the map() method in the Arduino IDE.

3.3.3 Calibration of TCS34725

The calibration of the device was done by sensing the primary and secondary colors of various objects to ensure its accuracy.

3.3.4 Designing of Analog Readout Circuit

The readout circuit of WINSENSE in Figure 3.7 used a constant voltage constant current readout circuit. Wherein the pH is linearly correlated to its Vth output. Conventional ISFET array readout circuitries are the ISFET/MOSFET differential pair (IMDP), and the Constant Voltage Constant Current (CVCC). An alternative ISFET readout circuit topology was designed. Such circuit topology is suitable to be integrated with ISFET array sensors and being economical while still producing the same quality as the previous circuit.

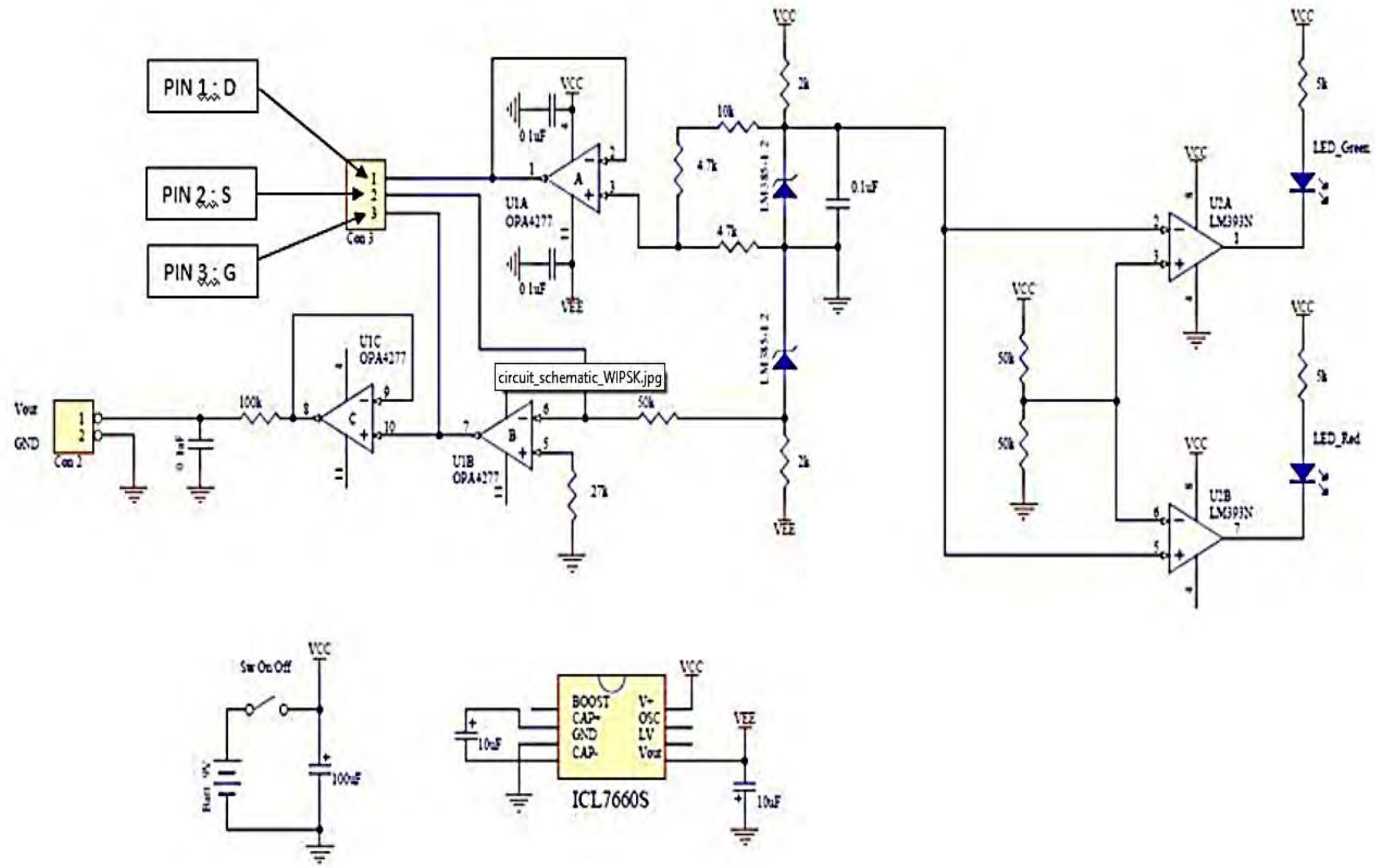


Figure 3.7 WINSENSE Analog Read-out Circuit

(Source: http://www.winsense.co.th/item/item_image/winsense_isfet_ph_sensor_wips_datasheet.pdf)

An alternative readout circuit interface was implemented in this work for the Ion Sensitive Field-Effect Transistor (ISFET). The factors considered in choosing the components used were its characteristics, availability, and its price. Characteristics like dc offset voltage, offset drift and biasing current factors on the precision of the device, and its accuracy.

A total of 35 different precision operational amplifier available locally were selected to be tested through simulations. The most economical operational amplifier that performs splendid through the simulations was tested through hardware implementation.

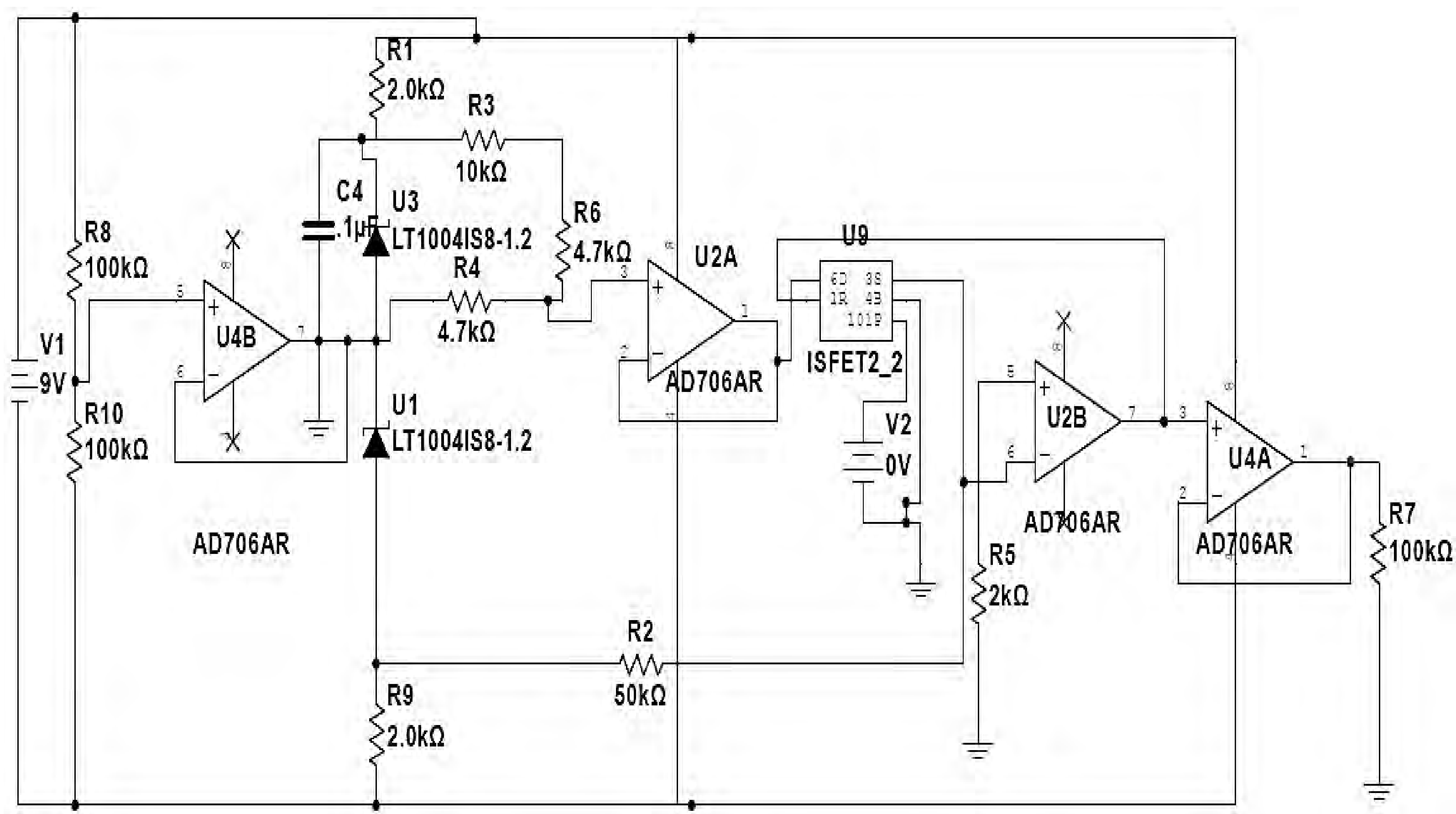


Figure 3.8 Designed Layout of Read-out Circuit

3.3.4.1 Choosing of Operational Amplifiers

Different stores locally were checked if they sell operational amplifiers. Not all stores that sells operational amplifiers IC's also sells precision and instrumentations operational amplifiers. The readout circuit needs to have a very low offset voltage, low offset drift and low voltage noise so that it could provide high precision readings. This is the list of the selected Instrumentation Amplifiers (INA) that qualified the specifications. ADD22050N, AD22057, AD620, AD623, AD623, AD648, AD706, AD707, AD708, AD712, AD712CQ, AD795, AD820, INA144AP, LT1013, LT1014, MAX427, MAX428, MAX 429, MAX430, MAX 431, MAX432, MAX433, MAX434, MAX435, MAX436, OP07C, OP213F, OP27, OP27GZ, OP293, OP77-1, OP97F, OPA177GZ and TLE2142AI.

Two stages of comparison were done in this study. The first was the simulation of the readout circuits and the second was the hardware implementations. The circuit`s readings were compared to the commercially available readout circuit in each stage.

3.3.4.2 Software Simulation

The simulation was implemented using NI Multisim 14.0. The SPICE macro model for ISFET was used for all the simulations to imitate the actual response the ISFET would have. The macromodel presented here were based on the models described in "Simulation of ISFET Characteristics Using constant Voltage Constant Current Readout Circuit" and "Principles of Chemical Sensors”. To set the pH that would be tested through the macromodel a voltage source was connected to the 101 pin. Pin 6 is the drain, pin 1 is the for the reference electrode (RE), pin 3 is the source, and pin 4 is the bulk. The macromodel was programmed to read the voltage source as pH level for each voltage level from 0 to 14. The CVCC technique was implemented due to its robustness and suitability for agricultural application.

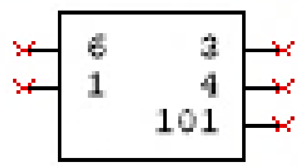


Figure 3.9 ISFET capture symbol in Multisim.

The operational amplifiers that costs more were removed from the simulations. And for the next stage, the operational amplifier that exhibits resemblance to the readings of the commercially available was subjected to hardware implementation.

3.3.4.3 Hardware Implementation.

For the hardware implementation stage the readout circuit was made on a universal PVC board. Most operational amplifiers used for instrumentation uses +V and -V for its sources. The need for a negative voltage could be fixed by connecting batteries in series, using a charged-pump voltage inverter or creating a virtual ground using the op amp in the circuit and use voltage divider on the positive input and the output would be the virtual ground. The latter solution was used because there was one unused operational amplifier left by using the CVCC topology which only uses three operational amplifiers. Being the most economical among the other operational amplifiers that exhibits similar DC transfer characteristics to OPA4277, AD706 dual picoampere input current bipolar op amp was used to test and compare to the commercially available readout circuit.

Both circuits were tested in measuring buffer solutions pH 4, pH 7 and pH 10. The circuit was tested 5 times in each buffer solutions.

3.4 Software Development of Soil Macronutrient Prediction System

3.4.1 Collection of datasets for the predictive model

Soil samples for soil diagnosis are acquired from the soil tank of Bureau of Soil and Water Management. The soil tank consists of 10 sections with dimensions of 10m x 20m x 0.50m depicting seven soil types collected from a various location in Luzon. These soil samples were tested using the Soil Test Kit administered by the Bureau of Soils and Water Management. In the site, soil moisture level and RGB color were tested by the sensors and the pH of its corresponding soil solutions was likewise measured. These samples were acquired by installing tube wells or employing suction lysimeter. Figure 3.10 presents the top view of the location were tube wells were installed. Both instruments were placed 20 cm below the topsoil.

1 - Lahar	10 - San Ildefonso (Vegetable Area 2)
2 - Sampaloc, Tanay, Rizal	11- San Ildefonso (Vegetable Area 3)
3 - Caingin, San Rafael, Bulacan	12 - Pinaod, San Ildefonso, Bulacan
4 - Carolina, Pili, Naga, Camarines Sur	13 - San Ildefonso (Lysimeter Area 1)
5 - San Ildefonso (Hilly Area 1)	14 - San Ildefonso (Lysimeter Area 2)
6 - Mayapyap Riverside, Cabanatuan, N.E	15 - Tagaytay, Cavite
7 - Pinandung, Atimonan, Quezon	16 - San Ildefonso, Bulacan
8 - San Ildefonso (Hilly Area 2)	17 - San Ildefonso, Bulacan
9 - San Ildefonso (Vegetable Area 1)	18 - San Ildefonso, Bulacan

Figure 3.10 Installed Tube Wells location at BSWM

3.4.2 Construction and Evaluation of the Predictive Models

Using a Python Programming, Pearson correlation tests were administered among the variables in the dataset. This is vital in defining the accuracy of the model. Parameters with negligible correlation will generate unreliable predictions. Another pivotal detail considered was the variable importance. Variables with high importance have a notable influence on the output.

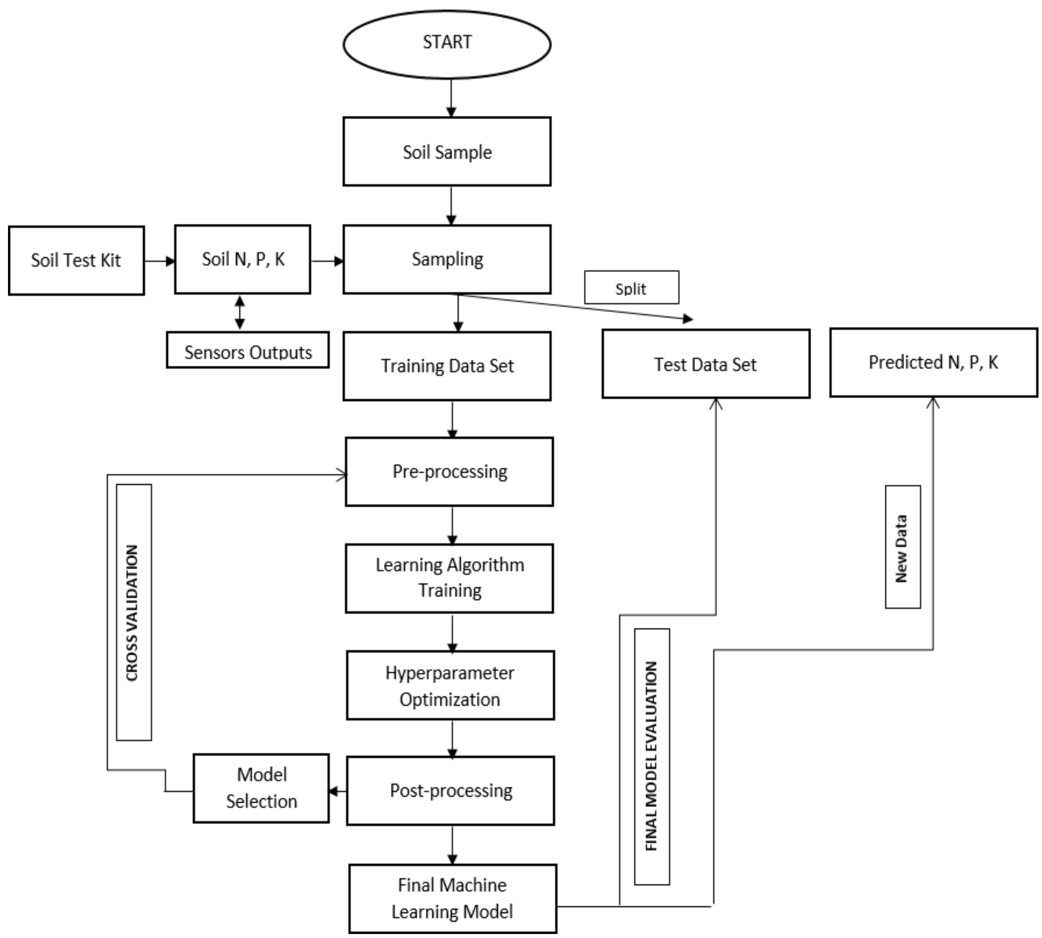


Figure 3.11 Predictive Modelling Flowchart

Subsequently, the development of predictive models was begun. The preceding flowchart presents the actions the system must undergo to precisely determine soil macronutrient levels. Random Forest, Naive Bayes, KNN and Support Vector Machine classifier algorithms were all inscribed in Python language. The data accumulated was applied as the data set divided into two – test set and training set. Three (3) split ratio was tested in three generations– 80/20, 60/40, and 70/30. The trained model was run against test data to see how adequately the model will function. While in hyperparameter optimization, the hyperparameters were attuned to maximize the precision. In model selection, four algorithms are subjected to cross-validation concerning the evaluation of model performance. Substantive validation was also conducted. Alien data – remote data set were operated to test the aptitude of the model in predicting excluding the training set. The best performing model was the final machine learning model.

3.4.3 Creating of Web Application

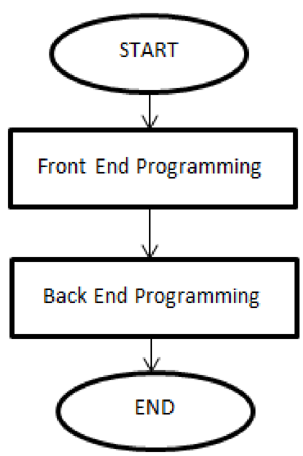


Figure 3.12 Creating of Web Application Flowchart

Figure 3.12 presents the process of designing a web application. Front end programming comes first, followed by the back-end programming. Front end programming is regarded with everything the users perceive in the application: its layout and functionality, while Back end programming denotes concern with everything behind the visuals: its server connection.

Front end programming uses HTML, CSS, and Javascript. HTML was responsible in the organization of contents on a web page; CSS was subject for composing a web page pleasing to its users, and Javascript was effective for assembling an interactive web page. The uniformity or complexity of the design must be suitable for its end users. As the system is developed to benefit the farmers on the field, the design displays big buttons, simplistic framework, and constitutes words which are easy to follow.

Back end programming uses Python programming. A web framework written supporting Python, called Flask, made the deployment of machine learning feasible in the web application. Codes that are written under this define each function created and used.

3.4.4 Creating of Website

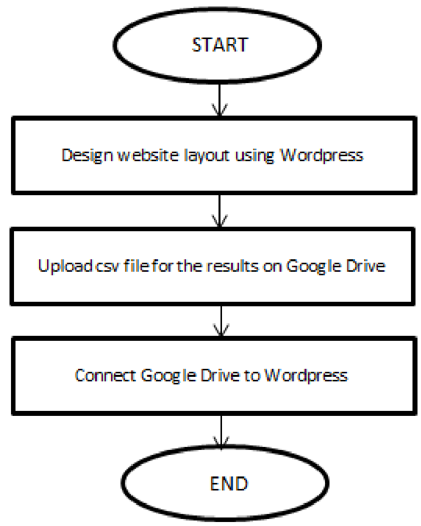


Figure 3.13 Creating a Website Flowchart

Figure 3.13 demonstrates the process of creating a website. A free website builder, Wordpress, was used in designing the website. After the website was ready, it was later connected to a database. Considering that the data to be exhibited is small, there is no need for an online host. Alternatively, Google Drive was used. The CSV file comprising all the results from the system was uploaded to Google Spreadsheet (along with Google Drive) through Python; and from Google Drive, these data are displayed on the Wordpress website after the pair connection.

3.4.5 Database System

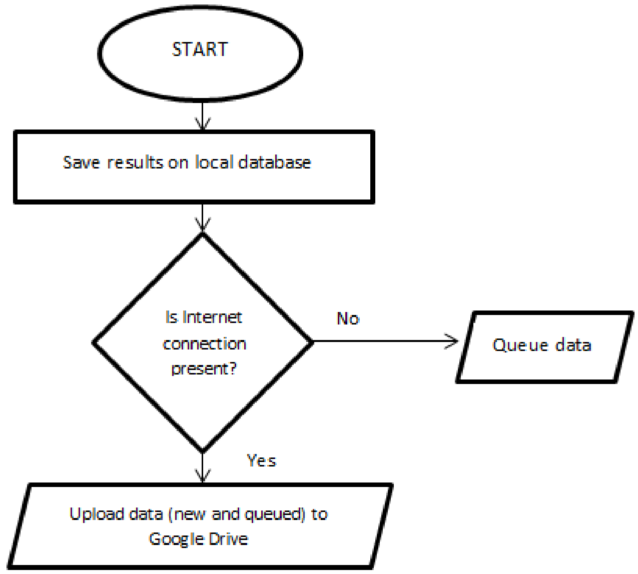


Figure 3.14 Database System Flowchart

Figure 3.14 shows the process of storing data online and offline. Regardless of the Internet connection, the results from the project will be saved on the local database once the user saves it. If a connection to the Internet is secured, offline and online databases will be in sync. All queued data with the new data will be uploaded to Google Drive, which then is exhibited on the Wordpress website afterward. Otherwise, the new data will be on queue.

3.4.6 Programming

3.4.6.1 Machine Learning Algorithms

Spyder, a scientific environment written in Python, was installed to start the construction of predictive models. Importing of required packages was done first such as pandas, scipy, numpy, sci-kit learn and matplotlib. The coding process begun in importing the dataset that was split into training and testing set. To know the best splitting ratio for the dataset, three (3) ratios were used such as 80/20, 70/30 and 60/40.

For fitting, sklearn packages were used. RandomForestClassifier for Random Forest Classifier, svm for Support Vector Machine, KNeighborsClassifier for KNN and GaussianNB for Naïve Bayes.

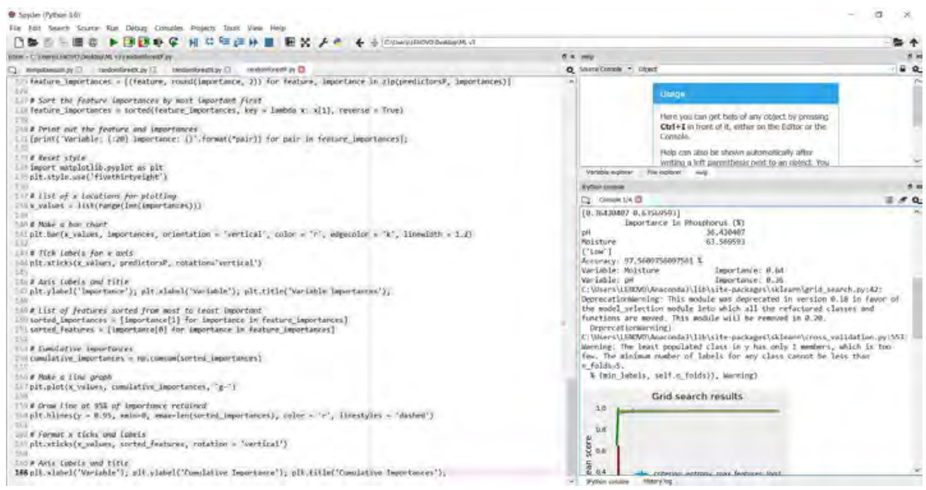


Figure 3.15 Spyder (Python 3.6) Environment for the Prediction System Coding

3.4.6.2 User Interface Software (Web Application)

In creating the web application, two software were used: Bootstrap Studio, for the initial front-end programming; and Microsoft Visual Studio 2013, for the back-end programming (written in Python language) and interfacing of the two. Every page renders different functions for the application which consists of giving a brief insight on the study, manual and automatic input of information needed for testing, displaying results, and presenting a manual on how to use the device.

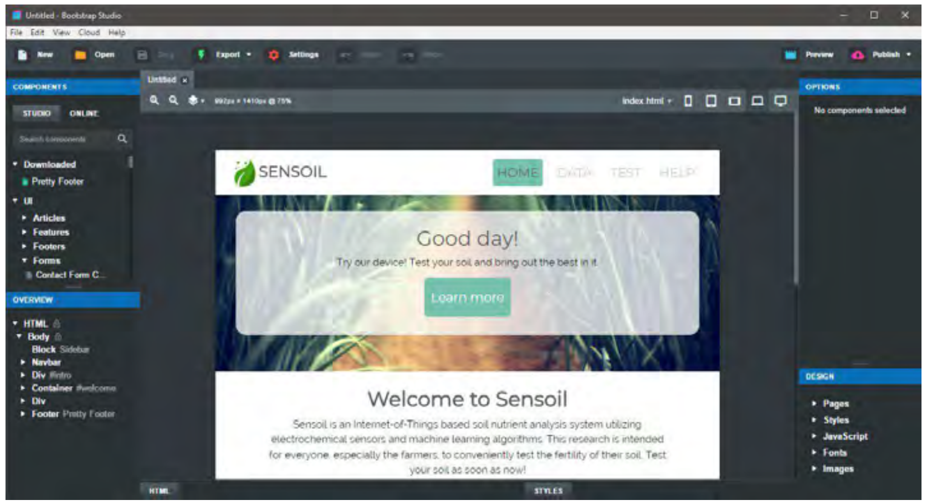


Figure 3.16 Bootstrap Studio Environment

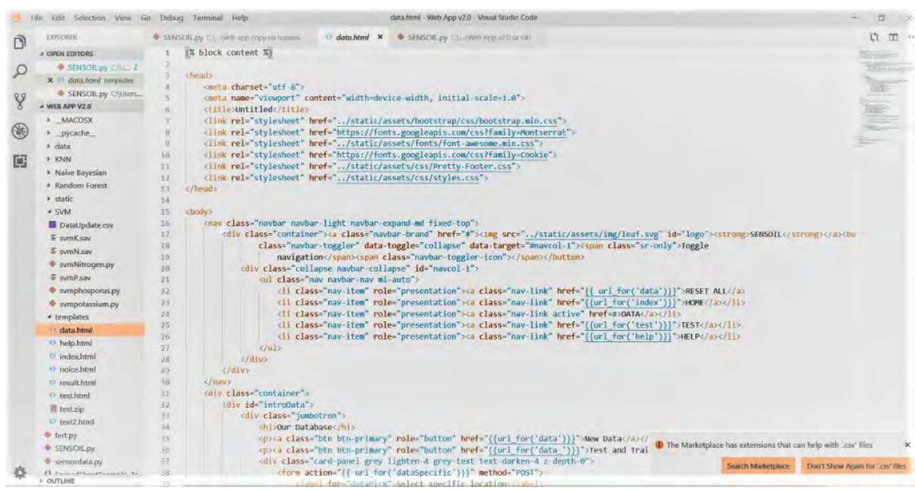


Figure 3.17 Microsoft Visual Studio 2013 (HTML coding)

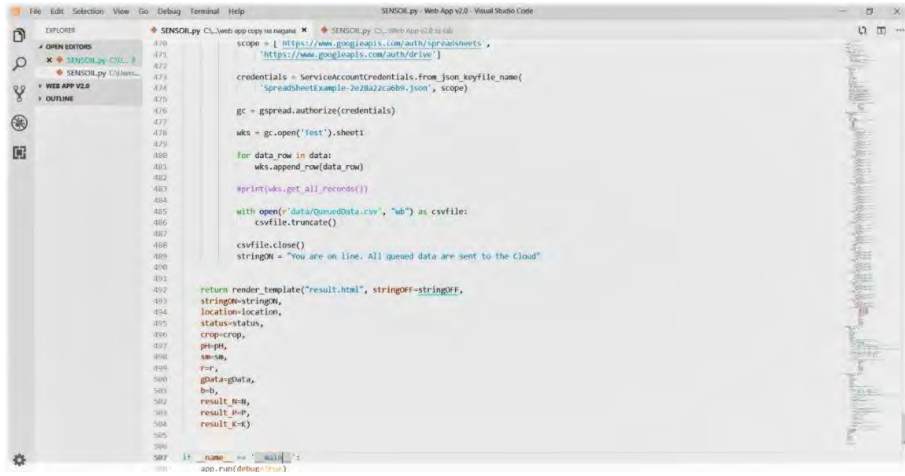


Figure 3.18 Microsoft Visual Studio 2013 (Python coding)

Figure 3.16, 3.17, and 3.18 shows the Integrated Development Environment (IDE) of the software used in which the front- and back end coding took place. Figure 3.11 shows Bootstrap IDE where one can edit the content's position, size, and color. Figure 3.17 and 3.18 shows MS Visual Studio 2013 IDE where one can edit codes written either in HTML or in Python.

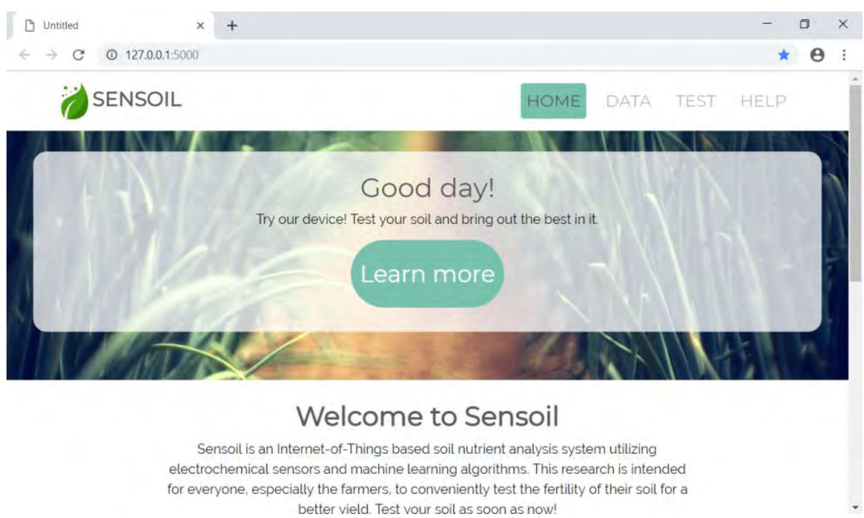


Figure 3.19 Home Page

Figure 3.19 shows the Home Page which contains brief description about the system, likewise its features. A *learn more* button is intentionally placed in the beginning of the page which navigates the user to the Help Page for further understanding of the system.

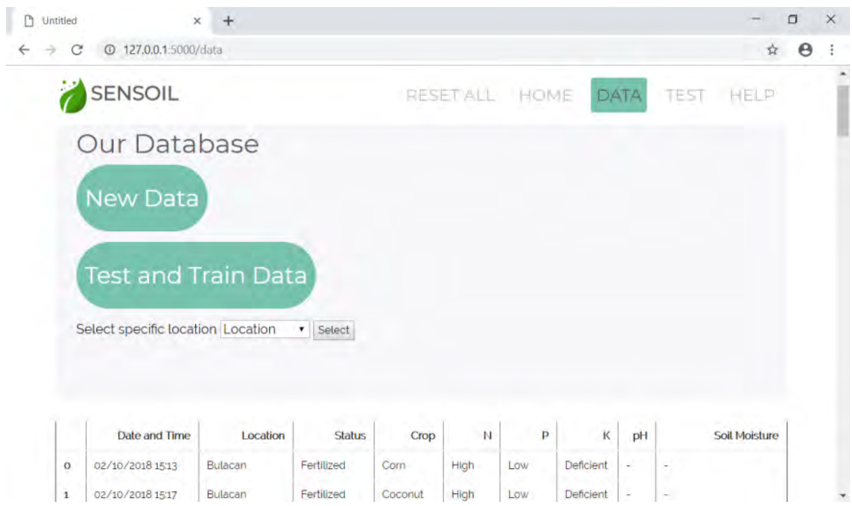


Figure 3.20 Data Page

Figure 3.20 shows the Data Page which displays all test results saved in the local database. *New Data* button redirects the user to the table containing test results; *Test and Train Data* button redirects the user to the table containing all training data without its corresponding results. A dropdown button (location selector) is also created for the user to easily filter the data he wants to see.

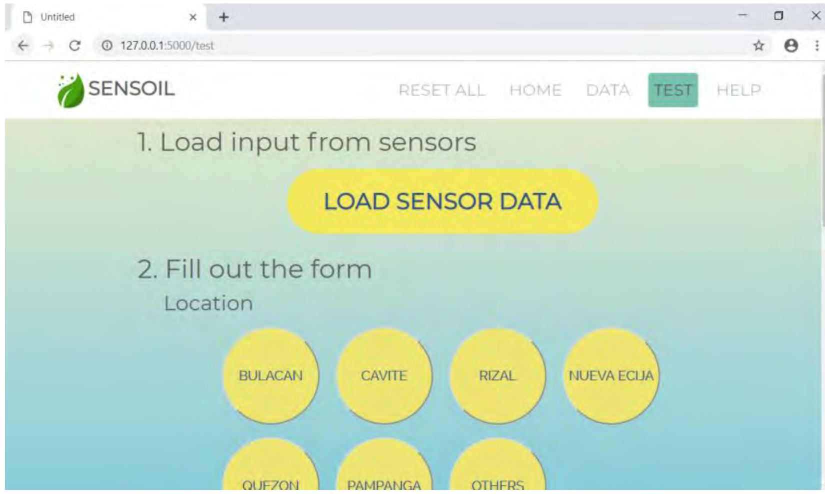


Figure 3.21 Test Page

Figure 3.21 shows the Test Page which contains buttons constituting a fill-out form before a sample undergo testing. The size and color of the buttons were selected in such a way the farmer could easily use. Of all the pages, this page has the utmost importance for the system.

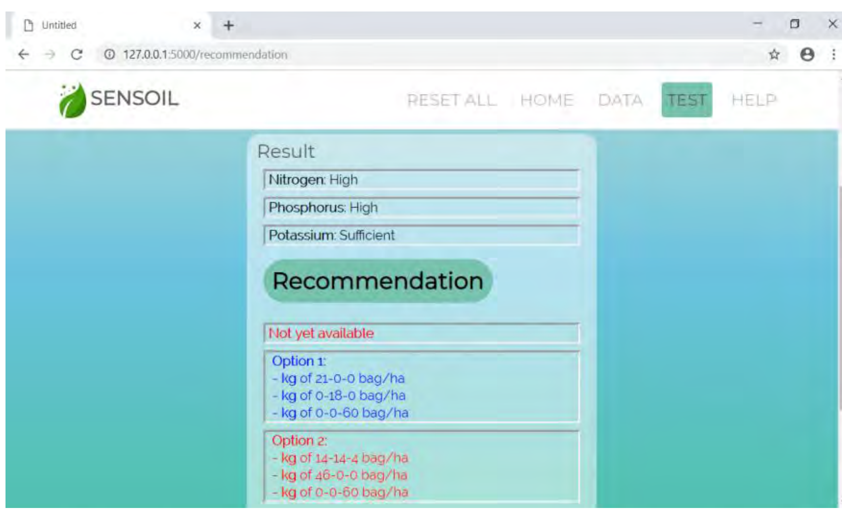


Figure 3.22 Result Page

Figure 3.22 shows the Result Page. This page is divided into two parts, one for the NPK result and one for the fertilizer recommendation. Result block, from the name itself, presents the qualitative result of a sample after it was processed in the system. Fertilizer recommendation block on the other hand was designed for the sole purpose to stand out. Target consumers do not care much about the result as it is ambiguous to interpretation. They use the device to test their soil, and in return, a diagnosis of it is what they look for, hence highlighting the block on the page was done.

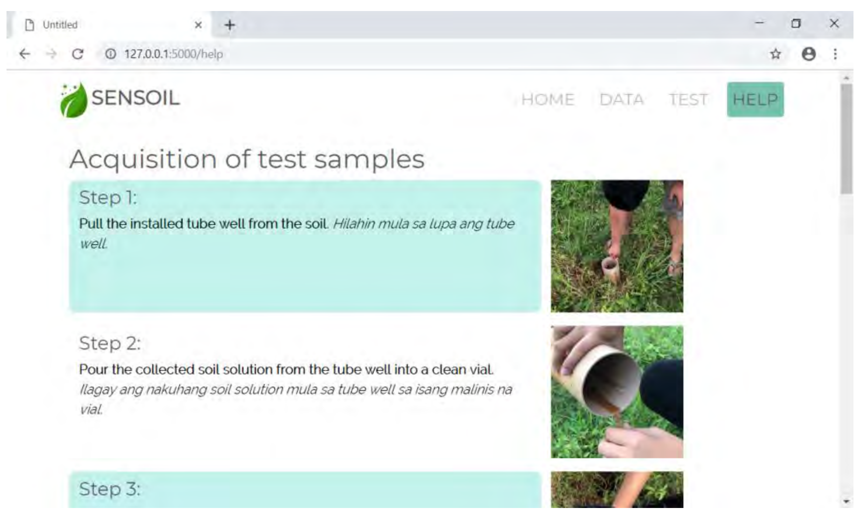


Figure 3.23 Help Page

Figure 3.23 shows the Help Page. This page is intended to serve as a guide in using the device. The step-by-step process, written in English and Filipino, is properly stated for the user's understanding. Pictures correspond to the steps were also added to ensure the user of the process it should follow.

3.5 Integration of Devices

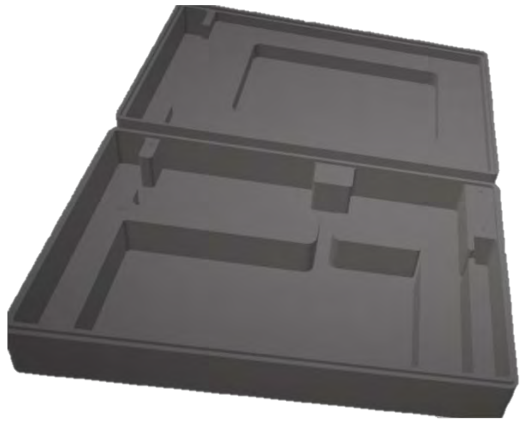


Figure 3.24 Hard Case Design

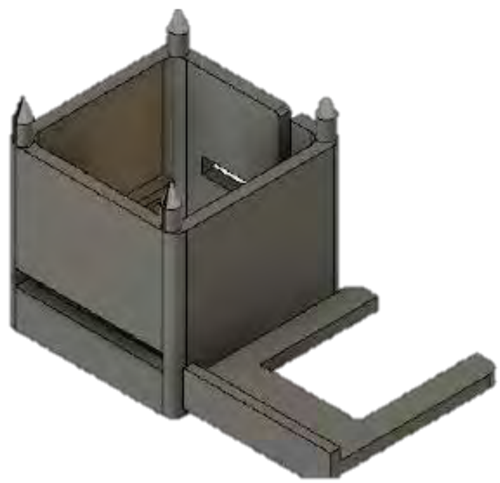


Figure 3.25 Soil Probe Design

Figure 3.24 shows the proposed hard case design of the project. It is idealized to be compact that fits the tablet PC. Thus, the components are positioned with minimal spacing. The probe of the sensors showed in Figure 3.25 are placed on assigned compartment of the chassis, this is to prevent wire and probe damages.

3.6 Testing of Device

3.6.1 Database System Testing

The sensor data and the results were all saved in the system's local database. These data include soil's pH, moisture content, color, Nitrogen-, Phosphorus-, and Potassium content.

At the Test Page, load the sensor data; fill out the form with the required information; then click Test button. This will redirect the page into the Results Page. At the Results Page, click the save button to save the data to the local database, and click the upload button to send data to the cloud.

Remarks: The local database was able to save the data without errors and further delay. Additionally, the online database was able to be in sync with the offline database smoothly.

3.6.2 System Installation

The system was installed in the Bureau of Soils and Water Management Center – Bulacan. The testing was done by implementing multiple soil macronutrient analysis, first through the device, and second through manual testing (soil test kit). The results were compared and helped improve the accuracy of the developed system.

3.6.3 Accuracy Testing

The device was first used to gather the required amount of data a machine learning model need to be able to predict accurately. After the models were shaped, the device was further used for the evaluation of the models. Ten soil samples were tested repeatedly using the four models. After comparing the accuracy percentage of each model, the best one was chosen. Once the desired accuracy rate was met, the proponents conducted soil test using the device and the conventional way.

Remarks: The results from the two were compared and validated by the soil expert.

3.6.4 Reliability Testing

To test the reliability of the device, it was then again used to test four types of soil from different areas including Lysimeter Area, and Greenhouse Area of BSWM-Bulacan, Cabanatuan, Tagaytay. At a certain area, the device tested the same sample repeatedly for 30 times to know whether the device gives off results in a stable or fluctuating manner.

3.7 Gantt Chart

The table below shows the Gantt chart which served as the project time frame.

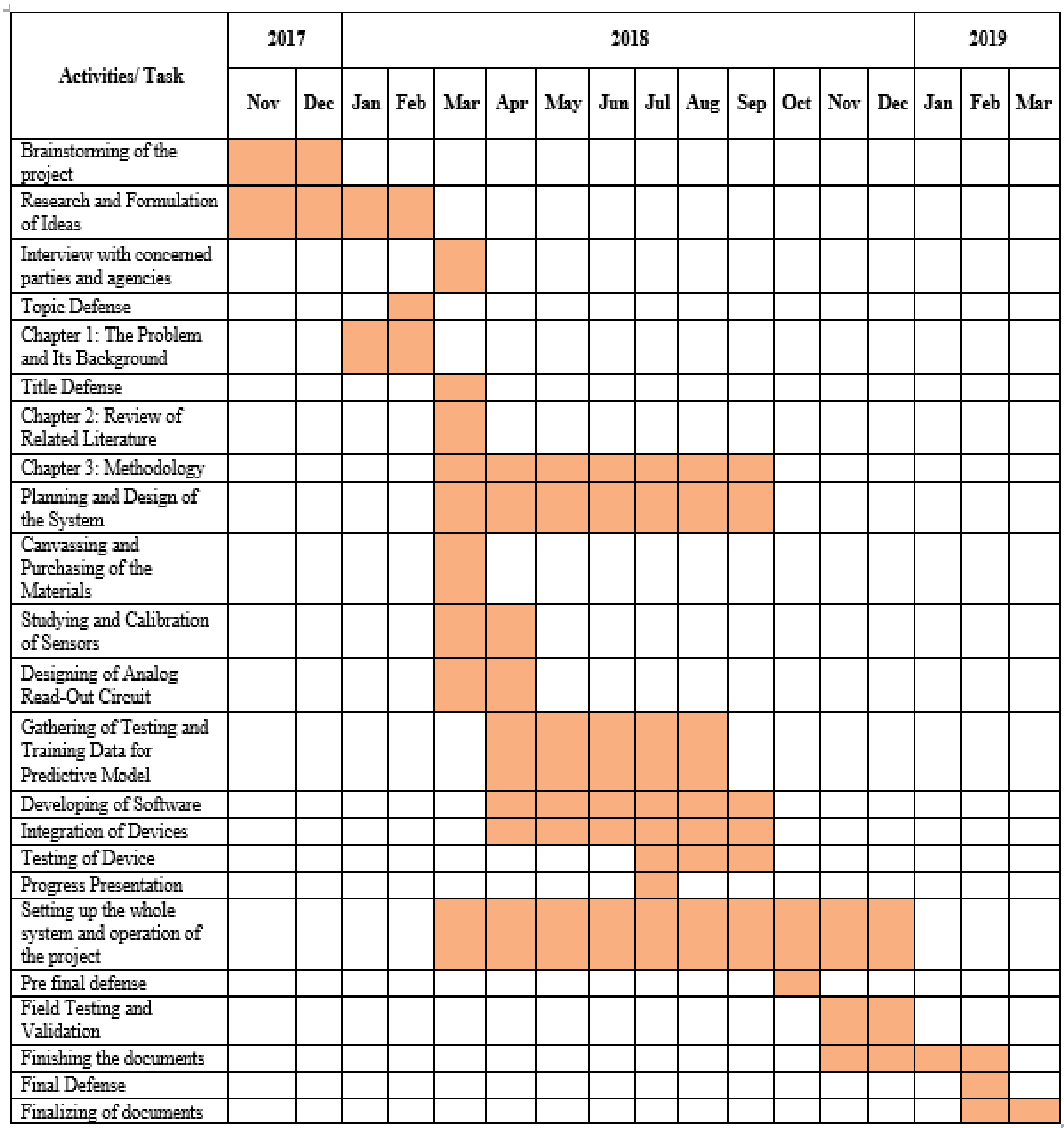


Figure 3.26 Gantt Chart

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the interpretation of data and analysis of findings relative to the tests conducted.

4.1 Project Technical Description

SenSoil is a product of prerequisite in constructing an efficient, robust and simplistic soil nutrient analysis system that utilizes capabilities of electrochemical sensors and machine learning algorithms. This attains to deliver reliable fertilizer recommendations in accordance to the soil macronutrient levels predicted by the device. This will render farmers into an effective soil and fertilizer management application that produces greater crop generation.

SenSoil is a soil analysis system that classifies soil macronutrient levels present in the soil. Macronutrients is comprised by the nutrients: Nitrogen (N), Phosphorus (P) and Potassium (K). The device consists of a Windows based tablet PC connected to three sensors – RGB color sensor, a soil moisture sensor and the ISFET via Arduino MEGA microcontroller board. The sensors act as a soil probe that generates data accumulated by the machine learning algorithm embedded in the tablet PC.

Prevalently, conventional soil diagnostic methods are conducted in a laboratory or away from the fields. In-situ testing is one pivotal feature of SenSoil, giving it a distinction among other methods.

In the operation of SenSoil, it is imperative to have a lysimeter at hand or install tube wells in the site. These are used in the extraction of soil solutions for the pH parameter. Once the preparations are set, the user puts the sensor probe (a conjunction of soil moisture and RGB sensor) 20cm deep from the top soil. The acquired soil solution from the ground is tested using the ISFET. The generated output from these sensors is fed into the Random Forest Classifier algorithm in the Web Application installed in the tablet PC. The graphical user interface of the application displays the selection for the location, soil history and crop for recommendation. Simply clicking the "TEST" button will load the sensor values and produce the predicted levels for N, P and K. In the output interface selecting the button for recommendation will display two options for fertilizer distribution.

SenSoil is an IoT based analysis system that enables farmers to store the tested soil data to an online database, however technological transfer in not yet fully implemented in rural communities, thus an offline database for queuing stored data is also featured.

4.2 Project Structural Organization

Figure 4.1 SenSoil Device Parts

Figure 4.1 shows the components of the SenSoil device. The sensors for pH (ISFET), soil moisture and the RGB color are integrated in the Arduino Mega that was covered in the hard case. Inside the covered compartment with the Arduino Mega is the designed analog read-out circuit provided with a switch. These were covered to protect the circuit boards from liquids like soil solution. The tablet PC contains the software system of the device and the application that the user will use for testing. Buffer solutions, pH 4, 7 and 10, were also provided inside the hard case for the calibration of the pH meter.

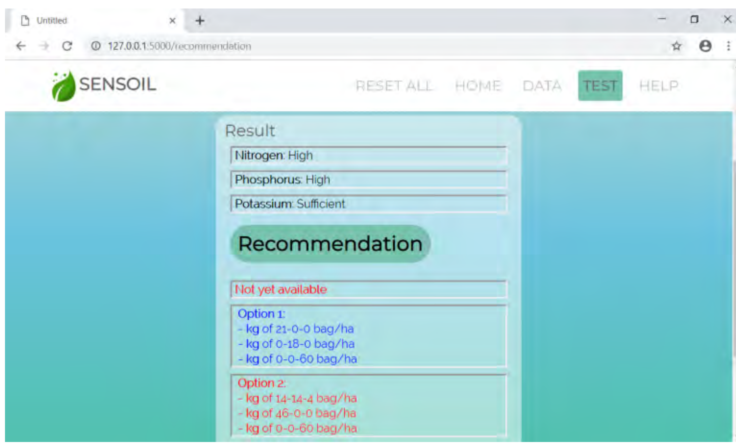


Figure 4.2 Predicted Nitrogen, Phosphorus, Potassium Level and Fertilizer Recommendation

Shown in Figure 4.2 is the results interface where the predicted nutrient levels are exhibited. Clicking the recommendation button directs immediate display the fertilizer recommendation based on the soil macronutrient levels and selected crop. The system provides two options as compost bags vary from each grower, depending on the farmer's discretion.

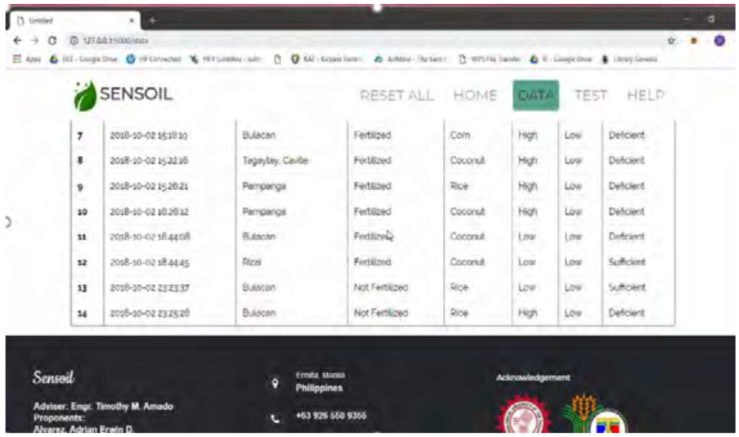


Figure 4.3 Offline Database

Shown in Figure 4.3 is the data page where all test data stored to the local database is presented. The columns in this table represents: the time and date of testing, location of test sample, status of the soil, preferred crop, and corresponding NPK result of a certain test sample, separated by rows.

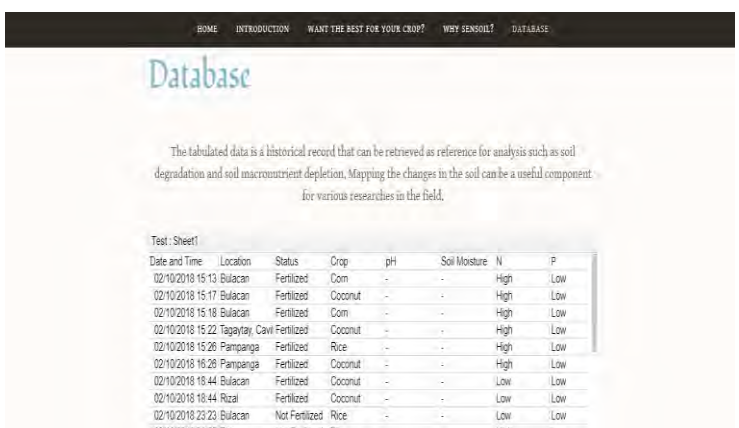


Figure 4.4 Online Database

Shown in Figure 4.4 is the database page of the website where all test data identical local database is presented. The online database instantly updates when a connection between the Internet and the device is established – uploading new data, along with queued data, to the cloud.

4.3 Project Limitation and Capabilities

The program SenSoil is limited to the assessment of macronutrients, Nitrogen, Phosphorus and Potassium, pH level, soil moisture, and color of soil.

4.4 Project Evaluation

4.4.1 Data and Results

Table 4.1 Comparison of OPA4277 and AD706

Voltage Output per pH Level

pH level	Vout (V)		%DIFF
	OPA4277	AD706	
0	0.837881	0.837896	0.001763
1	0.894407	0.894422	0.001627
2	0.950505	0.950519	0.001508
3	1.006009	1.006354	0.034293
4	1.061138	1.060662	0.044884
5	1.113939	1.113953	0.001229
6	1.164921	1.164935	0.001158
7	1.21141	1.211423	0.001098
8	1.247987	1.248	0.001054
9	1.266063	1.26605	0.001034
10	1.26984	1.269827	0.001029
11	1.270279	1.270266	0.001029
12	1.270324	1.270311	0.001029
13	1.270334	1.27032	0.001029
14	1.270347	1.270369	0.001754

Table 4.1 shows that the percentage errors between the Vout of OPA4277 and AD706 operational amplifier from pH 0 to 14 are approximately zero percent. This proves that AD706 can be an alternative operational amplifier for OPA4277.

Table 4.2 Comparison of Voltage and pH Values of the Designed and Default Analog Read-out Circuit for pH 4

	Voltage (V)		**pH Values**	
	Designed	**WINSENSE**	**Designed**	**WINSENSE**
pH 4	0.89	0.9	4	4
	0.9	0.91	4	4
	0.9	0.91	4	4
	0.89	0.9	4	4.1
	0.9	0.9	4	4
Mean:	**0.896**	**0.904**	**4**	**4.02**
% Error:	**0.885**		**0.449**	

Table 4.3 Comparison of Voltage and pH Values of the Designed and Default Analog Read-out Circuit for pH 7

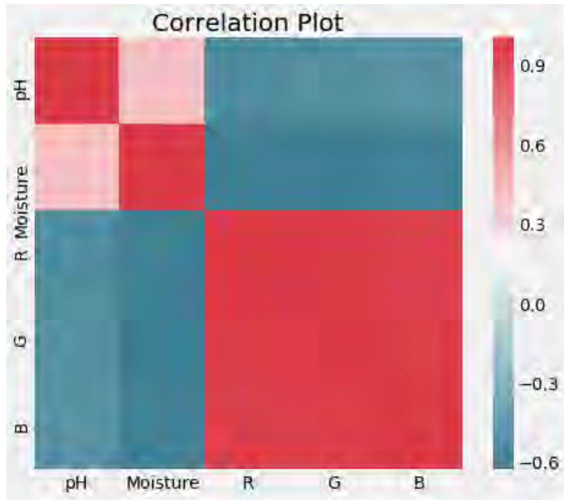
	Voltage (V)		**pH Values**	
	Designed	**WINSENSE**	**Designed**	**WINSENSE**
	1.05	1.06	7.03	7.03
pH 7	1.05	1.06	7.03	7.13
	1.04	1.06	7.03	7.03
	1.05	1.05	7.03	7.03
	1.05	1.06	7.03	7.03
Mean:	**1.048**	**1.058**	**7.03**	**7.05**
% Error:	**0.945**		**0.284**	

Table 4.4 Comparison of Voltage and pH Values of the Designed and Default Analog Read-out Circuit for pH 10

	Voltage (V)		pH Values	
	Designed	**WINSENSE**	**Designed**	**WINSENSE**
pH 10	1.2	1.2	10.05	10.17
	1.2	1.2	10.05	10.17
	1.2	1.2	10.05	10.17
	1.2	1.2	9.96	10.17
	1.2	1.2	9.96	10.17
Mean:	**1.2**	**1.2**	**10.014**	**10.17**
% Error:	**0.945**		**1.534**	

Buffer solutions pH 4, 7 and 10 were used to calibrate ISFET using both WINSENSE analog readout circuit and the designed analog readout circuit. Table 4.2, Table 4.3 and Table 4.4 show that the voltage outputs collected using the designed and default analog readout circuit has minimal disparities with percentage errors of 0.885%, 0.945%, and 0.000% for pH 4, 7, and 10 respectively. The charts further attest that the pH values gathered with the designed and default analog readout circuit have a percentage error of 0.498%, 0.284%, and 1.534% for pH 4, 7, and 10 sequentially.

\



Guide for the absolute value of correlation coefficient:

- .00 - .19 “very weak”
- .20 - .39 “weak”
- .40 - .59 “moderate”
- .60 - .79 “strong”
- .80 – 1.00 “very strong”

Figure 4.5 Correlation Plot of the Variables Used in the Dataset

Figure 4.5 shows that complete correlation coefficients are greater than 0.5. It indicates that all variables are correlated to each other. Soil moisture and pH are inversely correlated with the RGB values that mean as pH or moisture increases, RGB values decline. On the other hand, pH and moisture are directly correlated with each other which implies that as pH increases, soil moisture also increases.

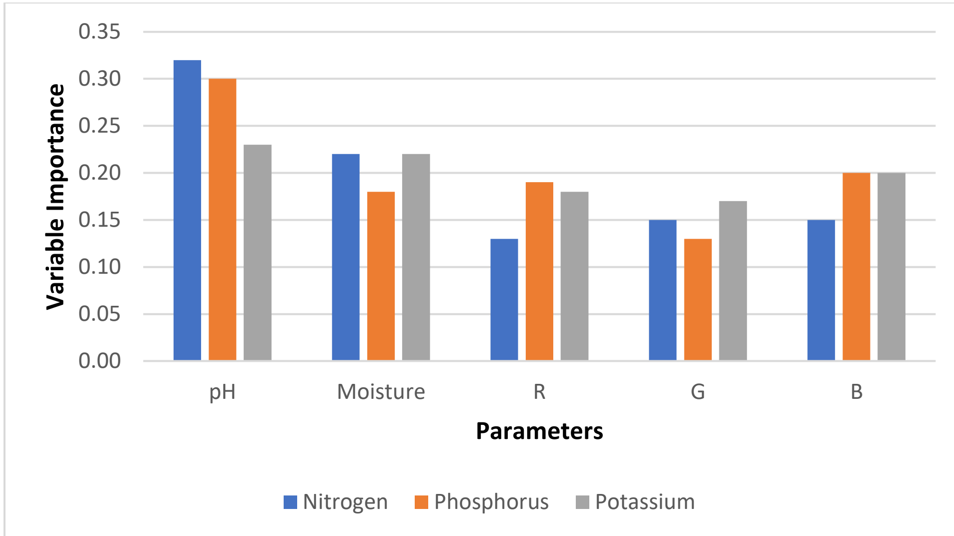


Figure 4.6 Comparison of Variable Importance for Each Nutrient

Figure 4.6 proves that pH has the highest importance for all the three (3) soil nutrient levels NPK. All variables were not omitted from the models for faster fitting and predicting. Variables with high importance are drivers of the outcome and their values have a significant impact on the outcome values.

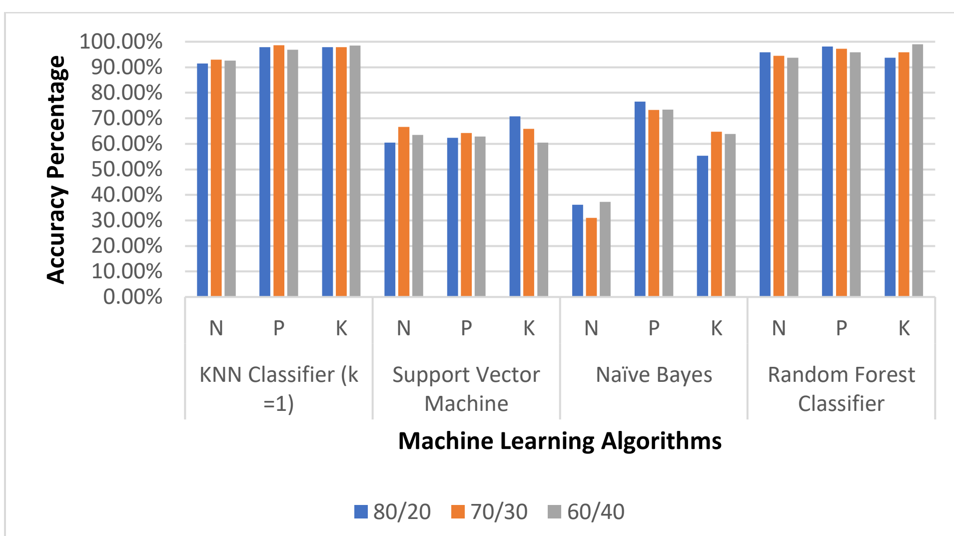


Figure 4.7 Comparison between Machine Learning Algorithms Using 3 Split Ratio

Three (3) split ratio of training and test datasets were compared. The trained model was run against test data to visualize the efficacy of the model. Figure 4.7 presents the differences in accuracy with different ratios between the four (4) machine learning algorithms. Among the four, Random forest classifier and KNN classifier show to have the highest accuracy in 80/20 ratio. This ratio was then used for the dataset.

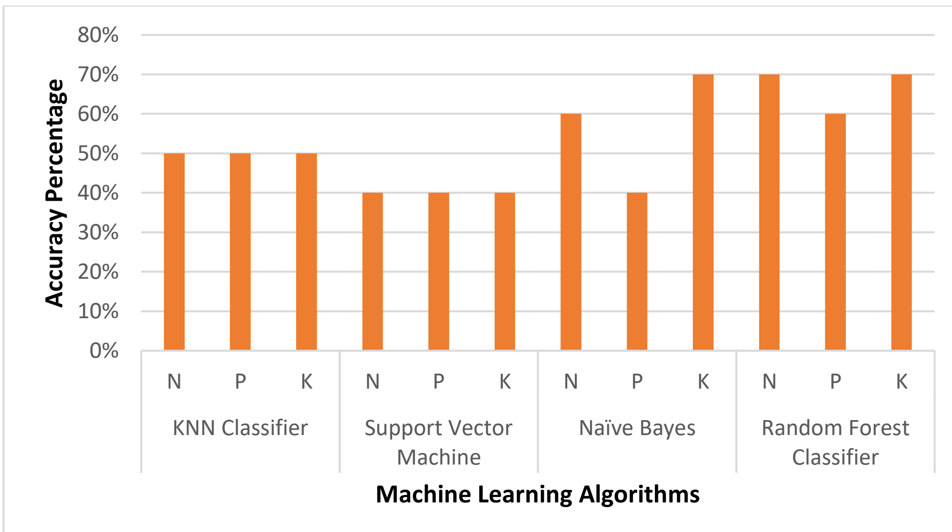


Figure 4.8 Comparison of Machine Learning Algorithms

Using the 80/20 ratio, ten (10) tests were done using the four (4) machine learning algorithms. Figure 4.8 shows that Random Forest Classifier has the highest accuracy per level among other three (3) algorithms. Random Forest Classifier was used to predict the output value (NPK) of the device.

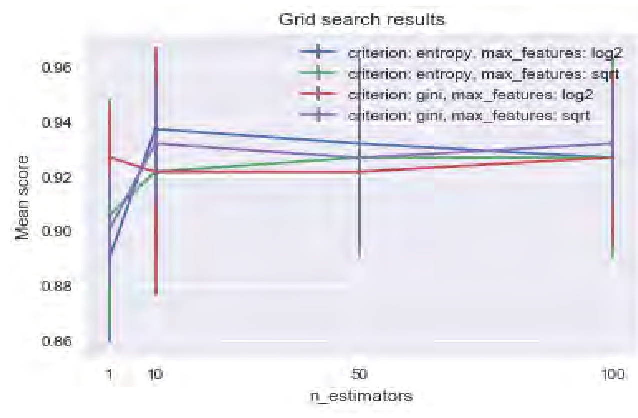


Figure 4.9 Hyperparameter Optimization for Nitrogen

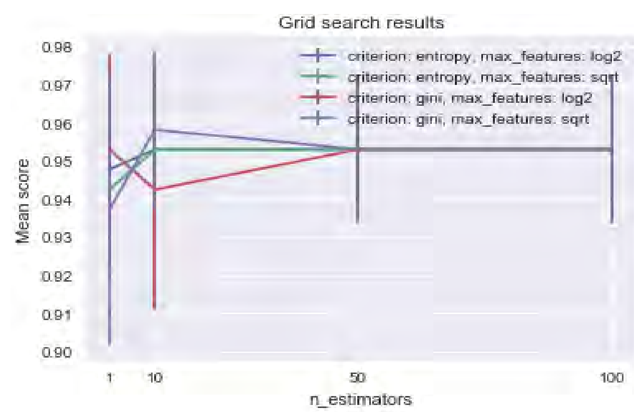


Figure 4.10 Hyperparameter Optimization for Phosphorus

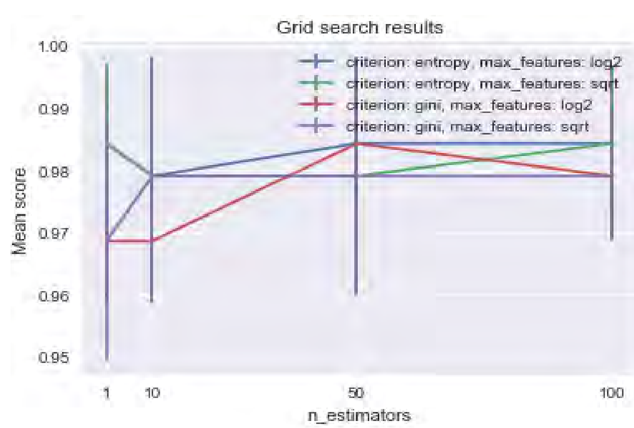


Figure 4.11 Hyperparameter Optimization for Potassium

To improve model's accuracy, additional data gathering to extend the dataset and hyperparameter tuning was conducted. Figure 4.9, Figure 4.10 and Figure 4.11 shows the hyperparameter optimization results using Grid search so that the model can optimally solve the machine learning problem. The best n_estimators, criterion and max_features for Nitrogen is 10, gini and log 2 respectively. While for the Phosphorus, the best n_estimators, criterion and max_features are 10, gini and sqrt respectively. Pottasium has the same best n_estimators, criterion and max_features with Phosphorus.

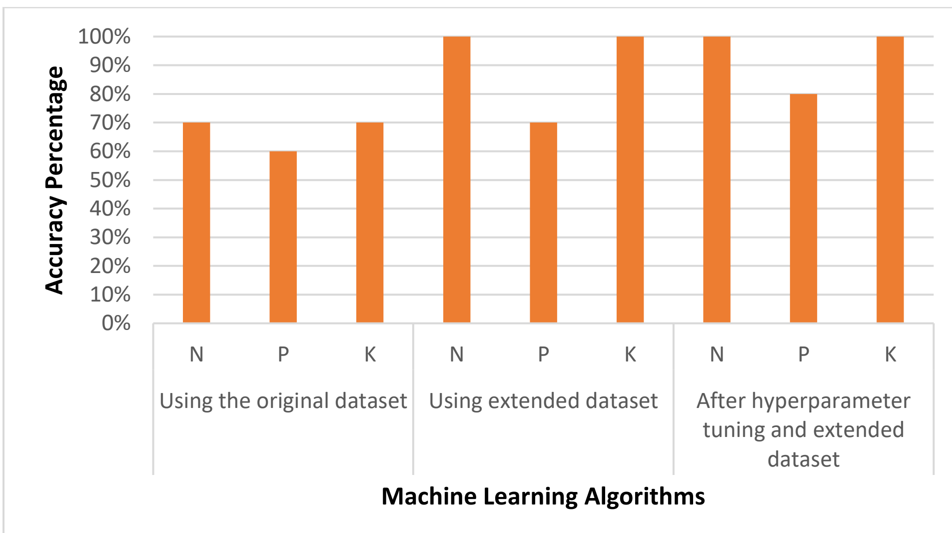


Figure 4.12 Comparison of Accuracy Using Random Forest Classifier After Extending Dataset and Hyperparameter Tuning

Based on Figure 4.12, after extending the dataset, the accuracy improved for the NPK. For N level, there was a 30% increase, 10% for P and 30% for K. Also, after the hyperparameter tuning, there was 10% increase for P level.

This proves that adding data and hyperparameter optimization is effective in improving the model's accuracy.

4.4.1.1 Summary

Table 4.5 Summary of Results

	Accuracy	Reliability
Nitrogen	95.83%	92.22%
Phosphorus	98.10%	85.55%
Potassium	93.75%	100%
Total:	**95.89%**	**92.59%**

Table 4.5 shows the summary of results of each nutrient and the total results of accuracy (95.89%) and reliability (92.59%).

4.4.2 Evaluation

Table 4.6 Evaluation Ratings of Soil Experts

Criteria	Ratings
Functionality	4.4
Reliability	4.4
Usability	4.75
Efficiency	4.8

Table 4.6 shows that out of five soil experts the criteria that has the highest ratings is the efficiency. Usability is next to the highest which is 4.75 and lastly, the functionality and reliability which is 4.4. Refer to Appendix C for the detailed evaluation of each soil expert.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter shows the summary of findings, conclusions produced according to the generated results, and the recommendations for the advancement of the project.

5.1 Summary of Findings

The aim of this project is to integrate electrochemical sensors and utilize machine learning algorithms to develop a device that will accurately determine the soil macronutrient content levels of various soil types.

The proponents used two electrochemical sensors – ISFET pH sensor, and soil moisture sensor. An additional RGB color sensor was added for a wider range of dataset. Python programming was used in building the four machine learning models namely, K-Nearest Neighbor, Naïve Bayes, Support Vector Machine, and Random Forest Classifiers. Python is a free programming software with abundant resources and packages to import. The proponents tested 240 soil samples and soil solutions for the gathering of data that will be used as dataset in the predictive model.

The project was conducted and implemented in Bureau of Soils and Water Management, a Philippine government agency under the Department of Agriculture in San Ildefonso, Bulacan. The said agency provided the proponents a soil tank that consists of 10 sections depicting seven soil types collected from a various location in Luzon namely Rizal, Camarines Sur, Bulacan, Nueva Ecija, Quezon, Cavite and Laguna. The proponents

systematize the testing between the partner facility and the SenSoil by examining a same soil at the same time. These samples were tested using the Soil Test Kit by the agriculturist

and after the conventional method, the soil with its solution was examined using SenSoil for consistency. The results of the system were compared to the results done by the agriculturist. This technique shows the accuracy and reliability of the project.

5.2 Conclusions

According to the findings of the research project, the following conclusions have been made by the proponents:

1. An alternative analog readout circuit was successfully made which is cheaper and easier to reproduce compared to the commercially available readout circuit while still being able to maintain its quality.
2. The Random Forest Classifier provides the highest accuracy among the predictive models with an accuracy of 95.83% for Nitrogen, 98.10% for Phosphorus, and 93.75% for Potassium using the 80/20 split ratio.
3. The development of the system that predicts the macronutrient composition of the soil for crops specifically rice, corn, and sugarcane through machine learning algorithms was successfully implemented using Python.
4. The target accuracy of 75% was successfully met by having an accuracy of 95.89% for macronutrient level assessment.
5. Offline and Online databases were completely provided for future analysis and reference.

6. The web application provides fertilizer recommendations for the effective use of farmers, regardless of the bag partitions they are using, as computed values for commonly used are presented and offline and online databases for future information sources.

5.3 Recommendations

The project was enforced and done successfully; however, the proponents would like to make the following recommendations for the further improvement the project:

1. Collect more samples of different soil types for the data sets to yield much accurate results.
2. Add more types of crops to be tested using the program.
3. Consider other fertilizer bags for the computation of fertilizer recommendations.
4. Add features for the predictive model by adding a parameter that correlates to the soil macronutrient level (e.g. electrical conductivity meter).
5. Develop a good power supply system for the read-out circuit.

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APPENDIX A

Letters and Documents

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Ayala Blvd., Ermita, Manila
COLLEGE OF ENGINEERING

ELECTRONICS ENGINEERING DEPARTMENT

January 25, 2018

George Y. Culaste
Director
Bureau of Plant Industry

BUREAU OF PLANT INDUSTRY
Office of the Director
RECEIVED
By: Thoreth Date: 1/25/18
#525-79-09

Dear Sir:

Greetings!

We are writing to request an interview with the soil scientists or experts in soil of your department to obtain some relevant information regarding our research study

We are 4th year Electronics Engineering students of Technological University of the Philippines who are taking ELE 11 - Methods of Research. It would be our honor if your department can share some information to assist us in our research. The information which will be provided to us shall be used in the strictest confidence.

We are looking forward for your favorable response regarding this matter. God bless you today and always.

Very respectfully yours,

Alvarez, Adrian Erwin D.

Ocampo, Allyssa

Paz, Venise Aziel F.

Punongbayan, Alrah Jan N.

Yumena, Lemuel M.
Students

Noted by:

Engr. August C. Thio-Ac
Professor, ECE Department

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
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COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT

SERVICE AGREEMENT

Title of Activity: **(Deployment)** "Development of an IoT-Based Soil Macronutrient Analysis System Utilizing Electrochemical Sensors and Machine Learning Algorithms"

Description of Activity:

The "SenSoil: Development of an IoT-Based Soil Macronutrient Analysis System Utilizing Electrochemical Sensors and Machine Learning Algorithms" is a study that aims to develop an automated, and in-situ soil macronutrient level detection system without using chemical reagents through an efficient application of electrochemical sensors and machine learning algorithms.

Responsibilities of the Client:

1. Regularly maintain and ensure its functionality.
2. Regarding for any potential development to the project study the client may suggest it to the researchers from TUP.
3. The parties hereto understand that during the technology adoption, the Transferor (TUP) shall give Transferee (Client) a gratis usage for four months. After four months, a rent-to-transfer scheme shall be employed. Payments shall be made payable by the Transferee to the Transferor under this agreement under the following scheme:
   a. Gratis usage for the first four (4) months.
   b. Rental fee of Php 500.00 of technology adoption stage.
4. Provide the necessary information in which the project is beneficial to its client.
5. Accommodate researchers from TUP if there are further studies that will be conducted related to the transferred technology/machine/prototype/project/study.

Responsibilities of TUP:

1. Provide the device, instruction manual and necessary training to operate the machine to ensure a satisfactory turn-over to the Client.
2. Give necessary information about the limitation of the device.
3. Provide technical support in case of device malfunction.

The parties hereto agree to keep any information identified as confidential by the disclosing party confidential using methods at least as stringent as each party uses to protect its own confidential information. "Confidential Information" shall include the Proprietor's development plan, the Option Technology and all information concerning it and any other information marked confidential or accompanied by correspondence indicating such information is confidential exchanged between the parties hereto prior to or during the Option Period.

This agreement has been signed by authorized representatives of the Parties and shall enter effect upon signature by the parties.

Conforme:

Project Proponents/Researchers from TUP:

ENGR. TIMOTHY M. AMADO
Adviser

ALVAREZ, ADRIAN ERWIN D.
ECE 5TH Year Student

OCAMPO, ALLYSSA
ECE 5TH Year Student

PAZ, VENISE AZIEL F.
ECE 5TH Year Student

PUNONGBAYAN, AIRAH JAN N.
ECE 5TH Year Student

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ECE 5TH Year Student

Client:

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NSWRRDC LUPEZ
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Witness:

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Faculty-in-charge, Project Study 2, Lab

ENGR. LEAN KARLO S. TOLENTINO
Head, Electronics Engineering Department

ENGR. BENEDICTO N. FORTALEZA
Dean, College of Engineering

Date Signed: ____________________

DEXTER A. AGUSTIN
Agriculturist II, NSWRRDC LUPEZ

ALVIN BRYLLE C. CONCEPCION
Agricultural Technician II, NSWRRDC LUPEZ

VICENTE T. CANAWAY
Laborer II, NSWRRDC LUPEZ

Date Signed: ________________

Republic of the Philippines
DEPARTMENT OF AGRICULTURE
Bureau of Soils and Water Management
Soils Research and Development Center Building
Elliptical Rd. cor. Visayas Ave., Diliman Quezon City

SOIL ANALYSIS RESULT (STK)

GENERAL INFORMATION

Date Submitted:	January 09, 2018
Date Finished:	January 11, 2018
Name:	ADRIAN ERWIN D. ALVAREZ
Location of sample:	NSWRRDC LUPEZ, San Ildefonso Bulacan
No. of Samples:	5
Crops Grown:	-
Landform:	Flat
Yield Record of the past crop:	Unknown
Fertilizer Material Used:	Unknown

RESULT

SOIL SAMPLE (S)	pH	N	P	K
Atimonan	6.8	Low	Low	Sufficient
Cabanatuan	6.0	Low	Low	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Lysimeter	5.8	Low	Low	Sufficient
Greenhouse	6.0	Low	Low	Deficient
**********NOTHING FOLLOW**************				

Analyzed By:

DEXTER A. AGUSTIN
Agriculturist II

Approved By:

MERCEDES S. FERNANDO
Agricultural Center Chief IV

Republic of the Philippines
DEPARTMENT OF AGRICULTURE
Bureau of Soils and Water Management
Soils Research and Development Center Building
Elliptical Rd. cor. Visayas Ave., Diliman Quezon City

SOIL ANALYSIS RESULT (STK)

GENERAL INFORMATION

Date Submitted:	January 07. 2018
Date Finished:	January 08, 2018
Name:	ADRIAN ERWIN D. ALVAREZ
Location of sample:	NSWRRDC LUPEZ, San Ildefonso Bulacan
No. of Samples:	5
Crops Grown:	-
Landform:	Flat
Yield Record of the past crop:	Unknown
Fertilizer Material Used:	Unknown

RESULT

SOIL SAMPLE (S)	pH	N	P	K
Atimonan	7.0	Low	Low	Sufficient
Cabanatuan	6.0	Low	Medium	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Lysimeter	6.0	Low	Low	Sufficient
Greenhouse	5.8	Low	Low	Deficient
**********NOTHING FOLLOW**************				

Analyzed By:

DEXTER A. AGUSTIN
Agriculturist II

Approved By:

MERCEDES S. FERNANDO
Agricultural Center Chief IV

Republic of the Philippines
DEPARTMENT OF AGRICULTURE
Bureau of Soils and Water Management
Soils Research and Development Center Building
Elliptical Rd. cor. Visayas Ave., Diliman Quezon City

SOIL ANALYSIS RESULT (STK)

GENERAL INFORMATION

Date Submitted:	January 09. 2018
Date Finished:	January 11, 2018
Name:	ADRIAN ERWIN D. ALVAREZ
Location of sample:	NSWRRDC LUPEZ, San Ildefonso Bulacan
No. of Samples:	5
Crops Grown:	-
Landform:	Flat
Yield Record of the past crop:	Unknown
Fertilizer Material Used:	Unknown

RESULT

SOIL SAMPLE (S)	pH	N	P	K
Atimonan	6.8	Low	Low	Sufficient
Atimonan	6.8	Low	Low	Sufficient
Atimonan	6.8	Low	Low	Sufficient
Atimonan	6.8	Low	Low	Sufficient
Atimonan	6.8	Low	Low	Sufficient
Cabanatuan	6.0	Low	Low	Sufficient
Cabanatuan	6.0	Low	Low	Sufficient
Cabanatuan	6.0	Low	Low	Sufficient
Cabanatuan	6.0	Low	Low	Sufficient
Cabanatuan	6.0	Low	Low	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Tagaytay	6.0	Medium	Medium	Sufficient
Lysimeter	5.8	Low	Low	Sufficient
Lysimeter	5.8	Low	Low	Sufficient
Lysimeter	5.8	Low	Low	Sufficient
Lysimeter	5.8	Low	Low	Sufficient
Lysimeter	5.8	Low	Low	Sufficient
Greenhouse	6.0	Low	Low	Deficient
Greenhouse	6.0	Low	Low	Deficient
Greenhouse	6.0	Low	Low	Deficient
Greenhouse	6.0	Low	Low	Deficient
Greenhouse	6.0	Low	Low	Deficient
**********NOTHING FOLLOW**************				

Republic of the Philippines
DEPARTMENT OF AGRICULTURE
Bureau of Soils and Water Management
Soils Research and Development Center Building
Elliptical Rd. cor. Visayas Ave., Diliman Quezon City

Analyzed By:

DEXTER A. AGUSTIN
Agriculturist II

Approved By:

MERCEDES S. FERNANDO
Agricultural Center Chief IV

APPENDIX B

Evaluation Forms

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT
Ayala Boulevard, Ermita, Manila
Telefax No. 522-3524 | Website: http://www.tup.edu.ph

PROJECT ASSESSMENT

PROFILE

Name: Alwin Bruce C. Concepcion **Position/Work:** Agtech II **Date:** 02 / 01 / 2019
Address/Location: Poblacion, San Ildefonso, Bulacan
Phone number (mobile, if available) 0922 793 8443 **Age:** 28 **Gender:** Male

Instruction: Kindly rate your response to the statements below using the following scale value interpretation. 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent
Put tick mark.

FUNCTIONALITY:	1	2	3	4	5
The device performed the assigned tasks.					✓
The device produced a result accurately.				✓	
RELIABILITY:					
The device gives consistent or dependable results					✓
The device can handle errors.					✓
USABILITY:					
The device can be learned easily.					
The device can be operated with minimal effort.					✓
The user interface of the device can be understood easily.				✓	
The interface of the software is appealing.					✓
EFFICIENCY:					✓
The device produces results in less than 10 seconds.					✓

Overall Rating:

Poor Fair Average <u>Good</u> Excellent

Feedbacks/Reviews/Suggestions:

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT
Ayala Boulevard, Ermita, Manila
Telefax No. 522-3524 | Website: http://www.tup.edu.ph

PROJECT ASSESSMENT

PROFILE

Name: VICENTE T. CANAWAY **Position/Work:** LABORER - I **Date:** 02/01/19
Address/Location: NSWRRDC LUPEZ, Poblacion, San Ildefonso Bulacan
Phone number (mobile, if available) ______ **Age:** 33 **Gender:** MALE

Instruction: Kindly rate your response to the statements below using the following scale value interpretation. 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent
Put tick mark.

FUNCTIONALITY:	1	2	3	4	5
The device performed the assigned tasks.				✓	
The device produced a result accurately.				✓	
RELIABILITY:					
The device gives consistent or dependable results					✓
The device can handle errors.				✓	
USABILITY:					
The device can be learned easily.					✓
The device can be operated with minimal effort.					✓
The user interface of the device can be understood easily.				✓	
The interface of the software is appealing.				✓	
EFFICIENCY:					
The device produces results in less than 10 seconds.				✓	

Overall Rating:

Poor Fair Average <u>Good</u> Excellent

Feedbacks/Reviews/Suggestions:

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT
Ayala Boulevard, Ermita, Manila
Telefax No. 522-3524 | Website: http://www.tup.edu.ph

PROJECT ASSESSMENT

PROFILE

Name: JAYAR V. RIVERA Position/Work: SASS II Date: 02/01/19
Address/Location: MGWRRUC LUPEZ, SAN ILDEFONSO, BULACAN
Phone number (mobile, if available) 09975775926 Age: 27 Gender: MALE

Instruction: Kindly rate your response to the statements below using the following scale value interpretation. 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent
Put tick mark.

FUNCTIONALITY:	1	2	3	4	5
The device performed the assigned tasks.				✓	
The device produced a result accurately.				✓	
RELIABILITY:					
The device gives consistent or dependable results				✓	
The device can handle errors.	✓				
USABILITY:					
The device can be learned easily.					✓
The device can be operated with minimal effort.					✓
The user interface of the device can be understood easily.				✓	
The interface of the software is appealing.				✓	
EFFICIENCY:					
The device produces results in less than 10 seconds.					✓

Overall Rating:

Poor Fair Average Good Excellent

Feedbacks/Reviews/Suggestions:

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COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT
Ayala Boulevard, Ermita, Manila
Telefax No. 522-3524 | Website: http://www.tup.edu.ph

PROJECT ASSESSMENT

PROFILE

Name: Nerizza S. Allon **Position/Work:** Agriculturist I **Date:** 02 / 01 / 2019
Address/Location: Poblacion, San Ildefonso, Bul.
Phone number (mobile, if available) 09211482162 **Age:** 26 **Gender:** F

Instruction: Kindly rate your response to the statements below using the following scale value interpretation. 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent
Put tick mark.

FUNCTIONALITY:	1	2	3	4	5
The device performed the assigned tasks.					✓
The device produced a result accurately.					✓
RELIABILITY:					
The device gives consistent or dependable results					✓
The device can handle errors.					✓
USABILITY:					
The device can be learned easily.					✓
The device can be operated with minimal effort.					✓
The user interface of the device can be understood easily.					✓
The interface of the software is appealing.					✓
EFFICIENCY:					
The device produces results in less than 10 seconds.					✓

Overall Rating:

Poor Fair Average Good Excellent

Feedbacks/Reviews/Suggestions:

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT
Ayala Boulevard, Ermita, Manila
Telefax No. 522-3524 | Website: http://www.tup.edu.ph

PROJECT ASSESSMENT

PROFILE

Name: RAUL R. VILLALORTE **Position/Work:** SRS II **Date:** 02/01/2019
Address/Location: POBLACION SAN ILDEFONSO, BULACAN
Phone number (mobile, if available) ______ **Age:** 60 **Gender:** MALE

Instruction: Kindly rate your response to the statements below using the following scale value interpretation. 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent
Put tick mark.

FUNCTIONALITY:	1	2	3	4	5
The device performed the assigned tasks.					✓
The device produced a result accurately.				✓	
RELIABILITY:					
The device gives consistent or dependable results					✓
The device can handle errors.					✓
USABILITY:					
The device can be learned easily.					✓
The device can be operated with minimal effort.				✓	
The user interface of the device can be understood easily.					✓
The interface of the software is appealing.					✓
EFFICIENCY:					
The device produces results in less than 10 seconds.					✓

Overall Rating:

Poor **Fair** **Average** <u>**Good**</u> **Excellent**

Feedbacks/Reviews/Suggestions:
Please ~~x~~ include other crops to your fertilizer recommendation

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
COLLEGE OF ENGINEERING
ELECTRONICS ENGINEERING DEPARTMENT
Ayala Boulevard, Ermita, Manila
Telefax No. 522-3524 | Website: http://www.tup.edu.ph

PROJECT ASSESSMENT

PROFILE

Name: VICENTE T. CANAWAY **Position/Work:** LABORER - I **Date:** 02/01/19
Address/Location: NSWRRDC LUPEZ, Poblacion, San Ildefonso Bulacan
Phone number (mobile, if available) ______ **Age:** 33 **Gender:** MALE

Instruction: Kindly rate your response to the statements below using the following scale value interpretation. 1 = Poor, 2 = Fair, 3 = Average, 4 = Good, 5 = Excellent
Put tick mark.

FUNCTIONALITY:	1	2	3	4	5
The device performed the assigned tasks.				/	
The device produced a result accurately.				/	
RELIABILITY:					
The device gives consistent or dependable results					/
The device can handle errors.				/	
USABILITY:					
The device can be learned easily.					/
The device can be operated with minimal effort.					/
The user interface of the device can be understood easily.				/	
The interface of the software is appealing.				/	
EFFICIENCY:					
The device produces results in less than 10 seconds.				/	

Overall Rating:

Poor **Fair** **Average** **<u>Good</u>** **Excellent**

Feedbacks/Reviews/Suggestions:

APPENDIX C

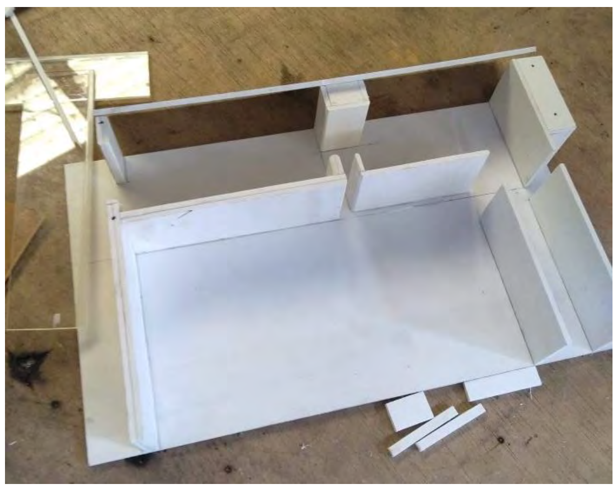
Project Documentation

Defenses

Interview at Bureau of Soils and Water Management – Quezon City

March 2, 2018

Calibration of Sensors



Construction of Chassis

Designed Analog Read-out Circuit Components

BSWM – Bulacan Visit

Soil Tank at BSWM – Bulacan

Preparation and installation of tube wells

Collection of soil samples

Collection of soil solutions

Testing of soil using Soil Test kit (conventional)

Testing of the device

A farmer using the device

A computer engineer testing the device.

APPENDIX D

Data

Data Gathered in Testing the Device

Date and Time	Location	Status	Crop	N	P	K
02/10/2018 15:13	Bulacan	Fertilized	Corn	High	Low	Deficient
02/10/2018 15:17	Bulacan	Fertilized	Coconut	High	Low	Deficient
02/10/2018 15:18	Bulacan	Fertilized	Corn	High	Low	Deficient
02/10/2018 15:22	Tagaytay, Cavite	Fertilized	Coconut	High	Low	Deficient
02/10/2018 15:26	Pampanga	Fertilized	Rice	High	Low	Deficient
02/10/2018 16:26	Pampanga	Fertilized	Coconut	High	Low	Deficient
02/10/2018 18:44	Bulacan	Fertilized	Coconut	Low	Low	Deficient
02/10/2018 18:44	Rizal	Fertilized	Coconut	Low	Low	Sufficient
02/10/2018 23:23	Bulacan	Not Fertilized	Rice	Low	Low	Sufficient
02/10/2018 23:25	Bulacan	Not Fertilized	Rice	High	Low	Deficient
03/10/2018 12:49	Pampanga	Not Fertilized	Rice	Low	Low	Sufficient
03/10/2018 13:11	Pampanga	Fertilized	Sugarcane	Low	Medium	Sufficient
03/10/2018 17:51	Bulacan	Not Fertilized	Others	Medium	Low	Deficient
04/12/2018 16:15	Pampanga	Fertilized	Coconut	Low	High	Sufficient
19/12/2018 10:48	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 10:50	Bulacan	Fertilized	Corn	Low	High	Sufficient
19/12/2018 10:51	Rizal	Fertilized	Coconut	Low	High	Sufficient
19/12/2018 10:52	Tagaytay, Cavite	Fertilized	Coconut	Low	High	Sufficient
19/12/2018 10:53	Pampanga	Not Fertilized	Rice	High	High	Sufficient
19/12/2018 10:53	Bulacan	Not Fertilized	Corn	Low	High	Sufficient
19/12/2018 10:54	Rizal	Not Fertilized	Coconut	Low	High	Sufficient
19/12/2018 10:55	Tagaytay, Cavite	Not Fertilized	Others	High	High	Sufficient
19/12/2018 10:56	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 10:56	Bulacan	Fertilized	Corn	Low	High	Sufficient
19/12/2018 11:14	Pampanga	Fertilized	Rice	Low	Low	Sufficient
19/12/2018 11:15	Bulacan	Fertilized	Corn	Low	Low	Sufficient
19/12/2018 11:16	Rizal	Fertilized	Coconut	Low	Low	Sufficient
19/12/2018 11:20	Tagaytay, Cavite	Fertilized	Rice	Low	Low	Sufficient
19/12/2018 11:20	Pampanga	Not Fertilized	Rice	Medium	High	Sufficient
19/12/2018 11:21	Bulacan	Not Fertilized	Corn	Low	High	Sufficient
19/12/2018 11:21	Rizal	Not Fertilized	Coconut	Low	High	Sufficient
19/12/2018 11:22	Tagaytay, Cavite	Not Fertilized	Others	Low	High	Sufficient
19/12/2018 11:23	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 11:23	Bulacan	Fertilized	Corn	Medium	High	Sufficient
19/12/2018 11:33	Pampanga	Fertilized	Rice	High	High	Sufficient
19/12/2018 11:33	Bulacan	Fertilized	Corn	Low	High	Sufficient
19/12/2018 11:34	Rizal	Fertilized	Coconut	Low	High	Sufficient
19/12/2018 11:34	Tagaytay, Cavite	Fertilized	Others	Low	High	Sufficient
19/12/2018 11:35	Pampanga	Not Fertilized	Rice	Low	High	Sufficient
19/12/2018 11:35	Bulacan	Not Fertilized	Corn	Low	High	Sufficient

19/12/2018 11:35	Rizal	Not Fertilized	Coconut	Low	High	Sufficient
19/12/2018 11:36	Tagaytay, Cavite	Not Fertilized	Others	Low	High	Sufficient
19/12/2018 11:36	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 11:37	Bulacan	Fertilized	Corn	Low	High	Sufficient
19/12/2018 12:18	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 12:19	Bulacan	Fertilized	Corn	High	High	Sufficient
19/12/2018 12:19	Rizal	Fertilized	Coconut	High	High	Sufficient
19/12/2018 12:20	Tagaytay, Cavite	Fertilized	Others	High	High	Sufficient
19/12/2018 12:20	Pampanga	Not Fertilized	Rice	Low	High	Sufficient
19/12/2018 12:20	Bulacan	Not Fertilized	Corn	High	High	Sufficient
19/12/2018 12:21	Rizal	Not Fertilized	Coconut	Low	High	Sufficient
19/12/2018 12:21	Tagaytay, Cavite	Not Fertilized	Others	High	High	Sufficient
19/12/2018 12:21	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 12:22	Bulacan	Fertilized	Corn	High	High	Sufficient
19/12/2018 12:29	Pampanga	Fertilized	Rice	Low	Low	Sufficient
19/12/2018 12:30	Bulacan	Fertilized	Corn	Low	Low	Sufficient
19/12/2018 12:30	Rizal	Fertilized	Coconut	Low	High	Sufficient
19/12/2018 12:31	Tagaytay, Cavite	Fertilized	Rice	Low	High	Sufficient
19/12/2018 12:31	Pampanga	Not Fertilized	Rice	Low	High	Sufficient
19/12/2018 12:31	Bulacan	Not Fertilized	Corn	Low	High	Sufficient
19/12/2018 12:32	Rizal	Not Fertilized	Coconut	Low	High	Sufficient
19/12/2018 12:32	Tagaytay, Cavite	Not Fertilized	Others	Low	High	Sufficient
19/12/2018 12:33	Pampanga	Fertilized	Rice	Low	High	Sufficient
19/12/2018 12:33	Bulacan	Not Fertilized	Corn	Low	High	Sufficient
09/01/2019 12:09	Atimonan	Fertilized	Rice	Low	High	Sufficient
09/01/2019 12:45	Cabanatuan	Not Fertilized	Corn	Low	Medium	Sufficient
09/01/2019 13:09	Tagaytay, Cavite	Not Fertilized	Rice	Medium	Medium	Sufficient
09/01/2019 14:17	Bulacan	Not Fertilized	Rice	Low	Low	Sufficient
04/02/2019 10:35	Bulacan	Fertilized	Rice	High	High	Sufficient
21/02/2019 11:55	Bulacan	Not Fertilized	Rice	High	High	Sufficient
21/02/2019 12:20	Rizal	Fertilized	Rice	High	High	Sufficient
21/02/2019 13:00	Cavite	Fertilized	Corn	Low	High	Sufficient
21/02/2019 13:11	Bulacan	Not Fertilized	Corn	High	High	Sufficient
21/02/2019 13:55	Bulacan	Fertilized	Corn	High	High	Sufficient
21/02/2019 14:36	Bulacan	Not Fertilized	Sugarcane	High	High	Sufficient
21/02/2019 15:10	Rizal	Not Fertilized	Rice	High	High	Sufficient
21/02/2019 15:50	Bulacan	Not Fertilized	Rice	Low	High	Sufficient
22/02/2019 13:05	Bulacan	Not Fertilized	Corn	High	High	Sufficient
22/02/2019 13:17	Rizal	Fertilized	Sugarcane	High	High	Sufficient
22/02/2019 13:23	Pampanga	Not Fertilized	Corn	High	High	Sufficient
22/02/2019 16:33	Cavite	Fertilized	Sugarcane	High	High	Sufficient

Dataset Used in the Prediction System

N	P	K	pH	Moisture	R	G	B
Low	High	Sufficient	6.45	308	532	313	233
Medium	Medium	Sufficient	6.48	296	564	369	315
Medium	Medium	Sufficient	6.48	296	564	369	315
Medium	Medium	Sufficient	6.48	296	564	369	315
Medium	Medium	Sufficient	6.48	296	564	369	315
Medium	Medium	Sufficient	6.48	297	564	369	315
Medium	Medium	Sufficient	6.48	297	564	369	315
Medium	Medium	Sufficient	6.39	297	564	369	315
Medium	Medium	Sufficient	6.39	297	564	369	315
Medium	Medium	Sufficient	6.39	298	564	369	315
Medium	Medium	Sufficient	6.39	298	564	369	315
Medium	Medium	Sufficient	6.39	298	564	369	315
Medium	Medium	Sufficient	6.39	298	564	369	315
Medium	Medium	Sufficient	6.39	299	564	369	315
Medium	Medium	Sufficient	6.29	299	564	369	315
Medium	Medium	Sufficient	6.29	299	564	369	315
Medium	Medium	Sufficient	6.29	299	564	369	315
Medium	Medium	Sufficient	6.29	300	564	369	315
Medium	Medium	Sufficient	6.29	300	564	369	315
Medium	Medium	Sufficient	6.29	300	564	369	315
Medium	Medium	Sufficient	6.29	300	564	369	315
High	High	Sufficient	6.57	472	454	276	213
High	High	Sufficient	6.57	472	454	276	213
High	High	Sufficient	6.57	472	454	276	213
High	High	Sufficient	6.57	472	454	276	213
High	High	Sufficient	6.57	479	454	276	213
High	High	Sufficient	6.57	480	454	276	213
High	High	Sufficient	6.57	479	454	276	213
High	High	Sufficient	6.57	479	454	276	213
High	High	Sufficient	6.57	480	454	276	213
High	High	Sufficient	6.57	480	454	276	213
High	High	Sufficient	6.67	480	454	276	213
High	High	Sufficient	6.67	472	454	276	213
High	High	Sufficient	6.67	472	454	276	213
High	High	Sufficient	6.57	472	454	276	213
High	High	Sufficient	6.57	479	454	276	213
High	High	Sufficient	6.57	480	454	276	213
High	High	Sufficient	6.57	479	454	276	213
High	High	Sufficient	6.57	479	454	276	213
High	High	Sufficient	6.57	480	454	276	213

High	High	Sufficient	6.57	480	454	276	213
High	High	Sufficient	6.57	480	454	276	213
Low	High	Sufficient	8.04	517	352	179	139
Low	High	Sufficient	8.04	518	351	178	138
Low	High	Sufficient	8.04	520	352	179	139
Low	High	Sufficient	8.04	521	355	181	140
Low	High	Sufficient	8.04	523	359	184	143
Low	High	Sufficient	8.04	523	358	183	142
Low	High	Sufficient	8.13	523	358	183	142
Low	High	Sufficient	8.13	523	359	183	142
Low	High	Sufficient	8.13	524	359	183	143
Low	High	Sufficient	8.13	525	359	184	143
Low	High	Sufficient	8.13	525	360	184	143
Low	High	Sufficient	8.13	525	360	184	143
Low	High	Sufficient	8.22	525	361	184	143
Low	High	Sufficient	8.22	526	361	184	143
Low	High	Sufficient	8.22	526	360	184	143
Low	High	Sufficient	8.22	526	360	185	143
Low	High	Sufficient	8.22	526	360	185	143
Low	High	Sufficient	8.22	526	360	185	143
Low	High	Sufficient	8.22	526	360	185	143
Low	Low	Deficient	5.72	285	588	390	321
Low	Low	Deficient	5.72	285	588	390	321
Low	Low	Deficient	5.72	285	588	390	321
Low	Low	Deficient	5.72	284	588	390	321
Low	Low	Deficient	5.72	284	588	390	321
Low	Low	Deficient	5.72	284	588	390	321
Low	Low	Deficient	5.72	281	588	390	321
Low	Low	Deficient	5.72	279	588	390	321
Low	Low	Deficient	5.72	278	588	390	321
Low	Low	Deficient	5.63	276	588	390	321
Low	Low	Deficient	5.63	275	588	390	321
Low	Low	Deficient	5.63	273	588	390	321
Low	Low	Deficient	5.63	272	588	390	321
Low	Low	Deficient	5.63	270	588	390	321
Low	Low	Deficient	5.63	269	588	390	321
Low	Low	Deficient	5.63	267	588	390	321
Low	Low	Deficient	5.63	266	588	390	321
Low	Low	Deficient	5.63	265	588	390	321
Low	Low	Deficient	5.63	264	588	390	321
Low	Low	Deficient	5.63	263	588	390	321
Low	Low	Sufficient	5.91	274	562	361	302
Low	Low	Sufficient	5.91	274	562	361	302

Low	Low	Sufficient	5.91	274	562	361	302
Low	Low	Sufficient	5.91	274	562	361	302
Low	Low	Sufficient	5.91	274	562	361	302
Low	Low	Sufficient	5.91	275	562	361	302
Low	Low	Sufficient	5.82	275	562	361	302
Low	Low	Sufficient	5.82	275	562	361	302
Low	Low	Sufficient	5.82	275	562	361	302
Low	Low	Sufficient	5.82	276	562	361	302
Low	Low	Sufficient	5.82	276	562	361	302
Low	Low	Sufficient	5.82	276	562	361	302
Low	Low	Sufficient	5.82	277	562	361	302
Low	Low	Sufficient	5.91	277	562	361	302
Low	Low	Sufficient	5.91	277	562	361	302
Low	Low	Sufficient	5.91	277	562	361	302
Low	Low	Sufficient	5.91	276	562	361	302
Low	Low	Sufficient	5.91	276	562	361	302
Low	Low	Sufficient	5.91	276	562	361	302
Low	Low	Sufficient	5.91	276	562	361	302
Low	Low	Sufficient	6.76	398	743	495	398
Low	Low	Sufficient	6.06	527	302	137	108
Low	Low	Sufficient	6.06	526	302	137	108
Low	Low	Sufficient	6.15	526	302	137	108
Low	Low	Sufficient	6.06	527	302	137	108
Low	Low	Sufficient	6.15	527	302	137	108
Low	Low	Sufficient	6.15	527	302	137	108
Low	Low	Sufficient	6.15	527	302	137	108
Low	Low	Sufficient	6.15	527	302	137	108
Low	Low	Sufficient	6.15	526	300	135	107
Low	Low	Sufficient	6.15	527	300	135	107
Low	Low	Sufficient	6.15	526	300	135	107
Low	Low	Sufficient	6.06	527	300	135	107
Low	Low	Sufficient	6.06	527	300	135	107
Low	Low	Sufficient	6.06	527	300	135	107
Low	Low	Sufficient	6.06	527	300	135	107
Low	Low	Sufficient	6.06	527	300	135	107
Low	Low	Sufficient	6.06	527	301	136	108
Low	Low	Sufficient	6.06	527	301	136	108
Low	Low	Sufficient	6.06	527	301	136	108
Low	Low	Deficient	7.94	317	335	166	133
Low	Low	Deficient	7.94	318	333	163	131
Low	Low	Deficient	7.85	317	333	164	132
Low	Low	Deficient	7.85	318	335	166	133
Low	Low	Deficient	7.85	318	334	164	132

Low	Low	Deficient	7.85	317	330	161	129
Low	Low	Deficient	7.85	317	330	161	130
Low	Low	Deficient	7.85	321	331	162	130
Low	Low	Deficient	7.94	319	331	162	130
Low	Low	Deficient	7.85	321	330	162	130
Low	Low	Deficient	7.85	322	331	161	130
Low	Low	Deficient	7.85	322	332	162	131
Low	Low	Deficient	7.94	324	332	162	132
Low	Low	Deficient	7.85	323	334	163	133
Low	Low	Deficient	7.85	323	334	163	130
Low	Low	Deficient	7.85	323	334	165	130
Low	Low	Deficient	7.94	323	331	165	130
Low	Low	Deficient	7.85	323	331	165	129
Low	Low	Deficient	7.85	323	331	165	129
High	High	Sufficient	7.27	532	298	131	103
High	High	Sufficient	7.27	531	298	132	103
High	High	Sufficient	7.27	532	296	130	102
High	High	Sufficient	7.18	531	297	130	102
High	High	Sufficient	7.18	531	296	130	102
High	High	Sufficient	7.1	531	297	130	102
High	High	Sufficient	7.18	532	304	131	103
High	High	Sufficient	7.18	532	304	136	107
High	High	Sufficient	7.18	532	309	136	107
High	High	Sufficient	7.18	532	316	141	111
High	High	Sufficient	7.18	532	318	147	116
High	High	Sufficient	7.27	532	319	148	117
High	High	Sufficient	7.1	532	319	149	177
High	High	Sufficient	7.18	532	319	149	117
High	High	Sufficient	7.18	532	319	149	117
High	High	Sufficient	7.27	532	319	149	117
High	High	Sufficient	7.27	532	319	149	118
High	High	Sufficient	7.27	532	319	149	118
High	High	Sufficient	7.27	532	320	149	118
High	High	Sufficient	7.27	532	320	149	119
Low	High	Sufficient	5.8	533	460	235	186
Low	High	Sufficient	5.46	541	461	235	186
Low	High	Sufficient	5.24	543	461	235	186
Low	High	Sufficient	6.03	545	462	236	187
High	High	Sufficient	6.36	545	461	235	186
Low	High	Sufficient	5.69	545	461	235	186
Low	High	Sufficient	6.14	546	461	236	187
High	High	Sufficient	6.25	546	461	236	187
Low	High	Sufficient	6.14	546	461	235	186

Low	High	Sufficient	6.03	545	460	235	186
Medium	High	Sufficient	6.25	384	379	183	152
Low	High	Sufficient	6.59	383	388	190	158
Low	High	Sufficient	6.59	383	386	189	157
Low	High	Sufficient	6.48	382	387	189	158
Low	High	Sufficient	6.59	382	391	193	161
Medium	High	Sufficient	6.25	383	393	194	162
High	High	Sufficient	7.6	715	370	179	151
Low	High	Sufficient	7.72	713	369	179	151
Low	High	Sufficient	7.72	714	371	181	153
Low	High	Sufficient	7.72	710	371	181	153
Low	High	Sufficient	7.83	708	370	180	152
Low	High	Sufficient	7.72	708	371	180	152
Low	High	Sufficient	7.72	706	364	175	147
Low	High	Sufficient	7.72	705	362	173	146
Low	High	Sufficient	7.72	702	363	174	146
Low	High	Sufficient	7.72	702	364	175	147
Low	High	Sufficient	7.38	448	406	204	170
High	High	Sufficient	6.93	449	384	187	154
High	High	Sufficient	7.27	450	384	187	154
High	High	Sufficient	7.15	452	380	184	151
Low	Low	Sufficient	7.38	337	426	217	180
Low	Low	Sufficient	7.04	364	420	212	176
Low	Low	Sufficient	6.93	373	418	211	175
Low	Low	Sufficient	6.93	373	420	212	176
Low	Low	Sufficient	6.82	373	424	215	179
Low	Low	Sufficient	6.82	373	424	215	179
Low	Low	Sufficient	6.82	372	425	216	179
Low	Low	Sufficient	6.82	374	421	212	176
Low	Low	Sufficient	6.89	427	435	228	189
Low	Medium	Sufficient	6.67	349	434	229	190
Medium	Medium	Sufficient	6.78	296	338	160	133
Low	Low	Sufficient	5.7	357	442	236	191
High	Sufficient	7.19	1022	323	151	30	
High	High	Sufficient	7.19	1022	323	151	129
Low	High	Sufficient	8.03	1023	317	144	80
High	High	Sufficient	7.3	1023	317	144	30
High	High	Sufficient	7.3	1023	317	144	121
Low	High	Sufficient	4	1023	342	174	143
High	High	Sufficient	7.28	451	382	197	166
Low	Low	Sufficient	6.34	365	503	280	80
High	High	Sufficient	6.44	735	663	402	335
Low	High	Sufficient	6.55	359	367	180	147

Percentage Accuracy Using Three Different Train/Testing Set Ratio

Train/Testing Set Ratio	**KNN Classifier (k =1)**			**Support Vector Machine**		
	N	*P*	*K*	*N*	*P*	*K*
80/20	91.49%	97.87%	97.85%	60.42%	62.35%	70.83%
70/30	92.96%	98.59%	97.92%	66.67%	64.28%	65.83%
60/40	92.55%	96.81%	98.44%	63.50%	62.89%	60.42%
Train/Testing Set Ratio	**Naïve Bayes**			**Random Forest Classifier**		
	N	*P*	*K*	*N*	*P*	*K*
80/20	36.17%	76.59%	55.32%	95.83%	98.10%	93.75%
70/30	30.99%	73.24%	64.79%	94.44%	97.22%	95.83%
60/40	37.23%	73.40%	63.83%	93.75%	95.83%	98.95%

Soil Testing Using STK and Four Predictive Models

Test No.	**Colorimetric Method (STK)**			**KNN Classifier**			**Support Vector Machine**		
	N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
1	Low	Low	Sufficient	High	Low	Sufficient	High	High	Deficient
2	Low	High	Sufficient	Low	Low	Deficient	Medium	Medium	Deficient
3	High	High	Deficient	High	High	Sufficient	High	High	Sufficient
4	Low	Low	Sufficient	High	Low	Deficient	High	Medium	Deficient
5	Low	High	Deficient	Low	Low	Deficient	Low	High	Sufficient
6	High	High	Sufficient	Low	High	Sufficient	Low	High	Sufficient
7	Low	Low	Sufficient	High	High	Sufficient	Low	High	Deficient
8	Low	Medium	Sufficient	Low	Low	Deficient	Medium	High	Sufficient
9	Medium	Medium	Sufficient	Low	Low	Deficient	Low	Low	Sufficient
10	Low	Low	Sufficient	High	High	Sufficient	Low	Low	Sufficient
ACCURACY				**50%**	**50%**	**50%**	**40%**	**40%**	**40%**
Test No.	**Colorimetric Method (STK)**			**Naïve Bayes**			**Random Forest Classifier**		
	N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
1	Low	Low	Sufficient	Low	Low	Sufficient	High	Low	Sufficient
2	Low	High	Sufficient	Low	Low	Deficient	Low	Low	Sufficient
3	High	High	Deficient	High	Low	Sufficient	High	High	Sufficient
4	Low	Low	Sufficient	Low	Low	Sufficient	Low	Low	Sufficient
5	Low	High	Deficient	Low	Low	Sufficient	Low	High	Sufficient
6	High	High	Sufficient	Low	Low	Sufficient	High	High	Sufficient
7	Low	Low	Sufficient	High	Low	Sufficient	High	High	Sufficient
8	Low	Medium	Sufficient	Medium	Low	Sufficient	Medium	Low	Sufficient
9	Medium	Medium	Sufficient	Low	Low	Sufficient	Low	Low	Deficient
10	Low	Low	Sufficient	Low	Low	Sufficient	Low	High	Sufficient
ACCURACY				**60%**	**40 %**	**70%**	**70%**	**60%**	**70%**

Reliability Test

Lysimeter

Trial No.	pH		% Error	Nitrogen		Phosphorus		Potassium	
	Predicted	Actual		Predicted	Actual	Predicted	Actual	Predicted	Actual
1	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
2	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
3	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
4	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
5	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
6	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
7	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
8	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
9	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
10	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
11	5.85	5.8	0.862069	Low	Low	Low	Low	Sufficient	Sufficient
12	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
13	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
14	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
15	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
16	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
17	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
18	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
19	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
20	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
21	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
22	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
23	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
24	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
25	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
26	6.05	5.8	4.310345	Medium	Low	High	Low	Sufficient	Sufficient
27	6.05	5.8	4.310345	Medium	Low	High	Low	Sufficient	Sufficient
28	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
29	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
30	5.95	5.8	2.586207	Low	Low	Low	Low	Sufficient	Sufficient
				93.33%		**93.33%**		**100%**	

APPENDIX F

SenSoil User Guide

USER'S MANUAL

DEVICE AND SYSTEM SUMMARY

SenSoil is a soil macronutrient detection system without the use of chemical reagents.

Device/System Configuration

SenSoil is a web application in a Windows based tablet PC. It is an IoT-based soil macronutrient detection system which allows the user to store data acquired into a locally hosted database. With the use of three sensors – color sensor, soil moisture sensor and the ISFET. The measurements generated by these sensors will be loaded into the application through the Arduino. The application will then use four machine learning algorithms to provide an output for three macronutrients – Nitrogen, Phosphorus, and Potassium.

User Access Levels

All users are granted to use all components in this project, but each component has specific instructions before use.

Contingencies

In case of power outage data are not saved in the local database. Sudden closing of the application and freezing will cost data loss, however previous data are still stored in the database.

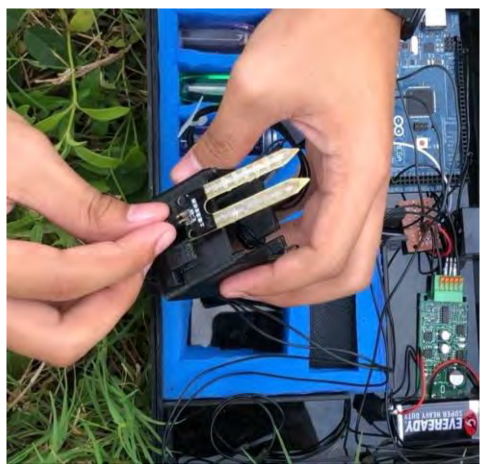
Parts of the Device

The device consists of the following components:

Step 1: Pull the tube well from the soil.

Step 2: Pour the collected soil solution from the tube well into a clean vial.

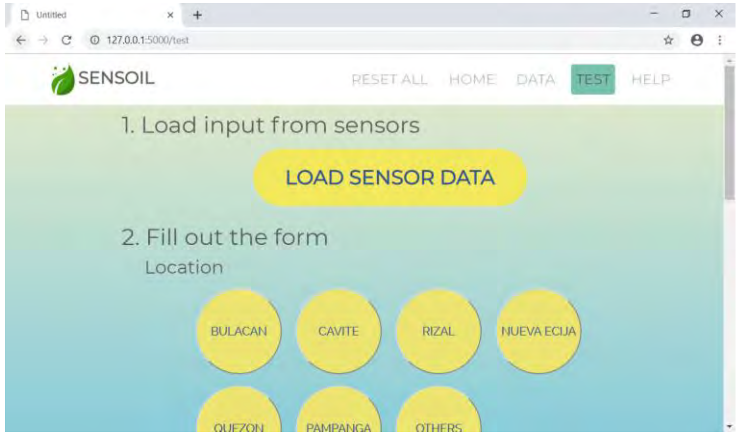
Step 3: Set-up soil moisture sensor to the SOIL PROBE.



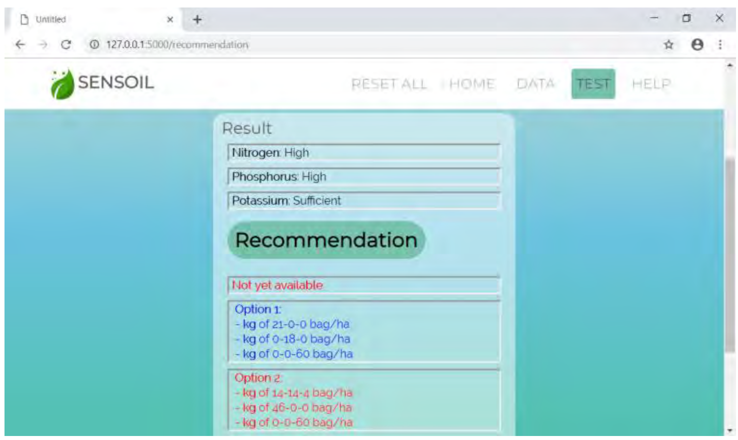
Together, dig the SOIL PROBE **20 cm deep** onto the soil where the tube well was initially placed.

Soak the ISFET and RE PROBE into the vial.

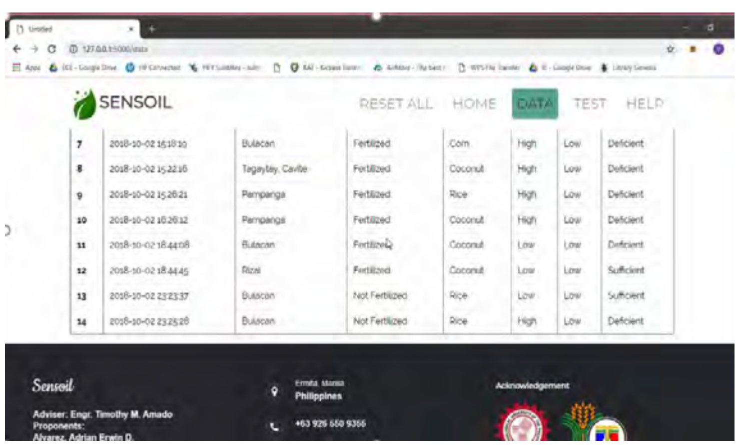
Step 4: On the tablet pc, click on Load Sensor; choose from the buttons for Location, Status, Crop; finally, click Predict.



See results on the screen.



Save the new data to the database (online or offline).



APPPENDIX G

Equipment's Specification Sheet

pH Meter

Product datasheet

Ion Sensitive Field Effect Transistor (ISFET)

Winsense ISFET pH Sensor (WIPS)

Special Features:

- Si_3N_4 (Silicon Nitride) Insulating gate
- Operates as a MOSFET at a constant voltage V_{ds} current I_{ds}
- Quality control by predetermined electrical measurement cycle after packaging
- Single supply, low power, small size

Product Description:

Sensing principle:
The sensitive element is a Field Effect Transistor; whose metal gate is replaced by a Reference Electrode and the solution of interest.

The ISFET devices are realized with microelectronic technology compatible with CMOS processes.

- Si_3N_4 insulating gate ISFET devices measure the pH value in a wide range from basic to acidic solutions

Applications:

- Smart farming
- Water Quality monitoring
- Environment control
- Security, industrial process control

Interface electronics:

- Analog read out circuit with output 1-2 V.

Characteristics

Input/Outputs:

- Bias condition: Vds=0.3 mV
  Ids=25-35 uA
- Output: Analog voltage 1-2 V

Base structure

- Sensor base materials: Silicon, Silicon nitride, Silicondioxide
- Technology: 6" planar CMOS process

Selective membrane

- pH-sensitive material: Si_3N_4

Sensor dimensions:

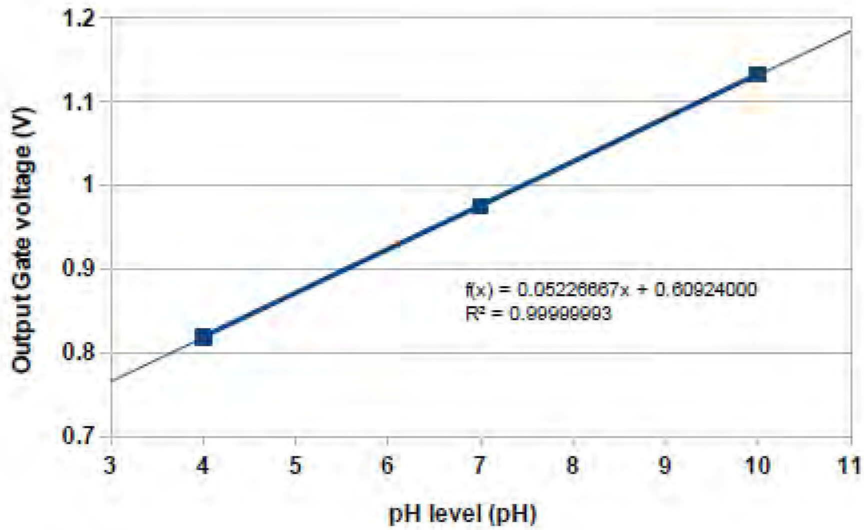
	Width	Length	Thickness	Unit
Sensor chip dimension	1400	3550	650	Um
PCB dimension	2	20	1.6	mm

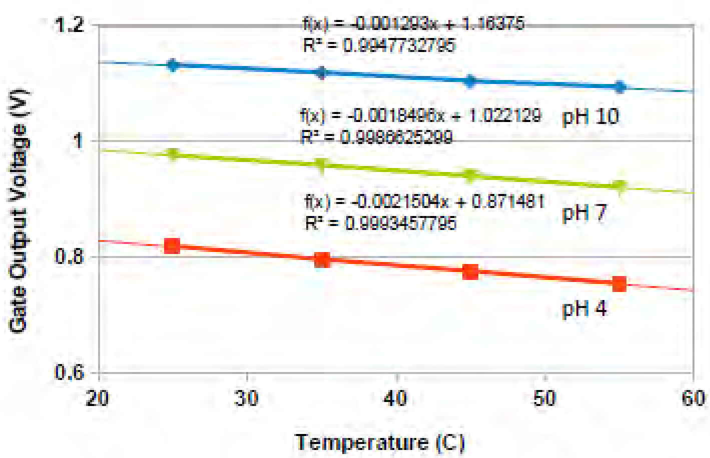
Winsense Co., LTD
131 Room# INC1-316D 3rd Floor, INC1 Bldg., Thailand Science Park,
Moo9, Paholyothin Road, Klong 1, Klong Luang, Pathumthani 12120
Tel: +66 81 144 3644 email:winsense@winsense.co.th

pH Sensor Characteristics

DC Specifications:

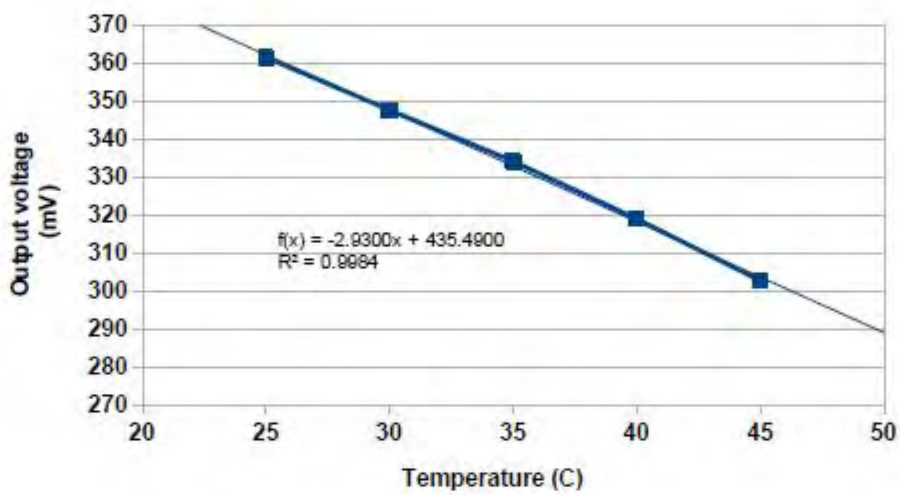
	Min	Typical	Max
Biased Vds		0.3 V	
Biased Ids		30 uA	
Sensitivity ($\Delta V/\Delta pH$)	45 mV/pH	50 mv/pH	58 mV/pH
Temperature coefficient	1.29 mV/°C (pH 10)	1.84 mV/°C (pH 7)	2.15 mV/°C (pH 4)





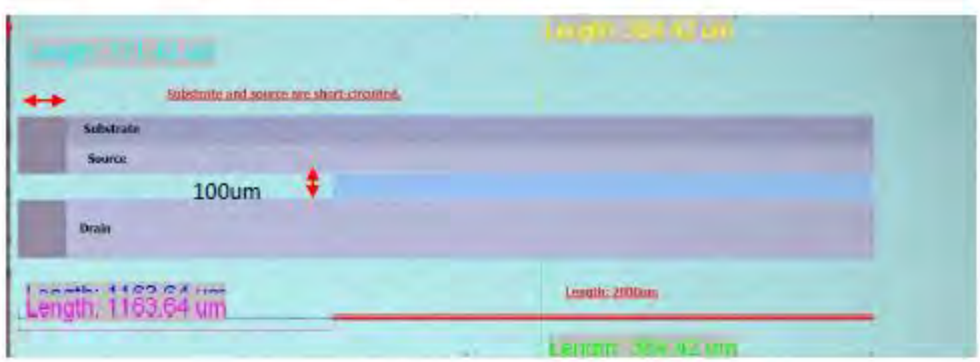
pH Sensor Specifications
Sensitivity: 50 mV/pH
Range: pH 2 - pH 12
Accuracy: 0.01 pH
Operating temperature: 0°C - 100°C
Response time: 10 s

Temperature Sensor Characteristics
Temperature Sensor Diode:



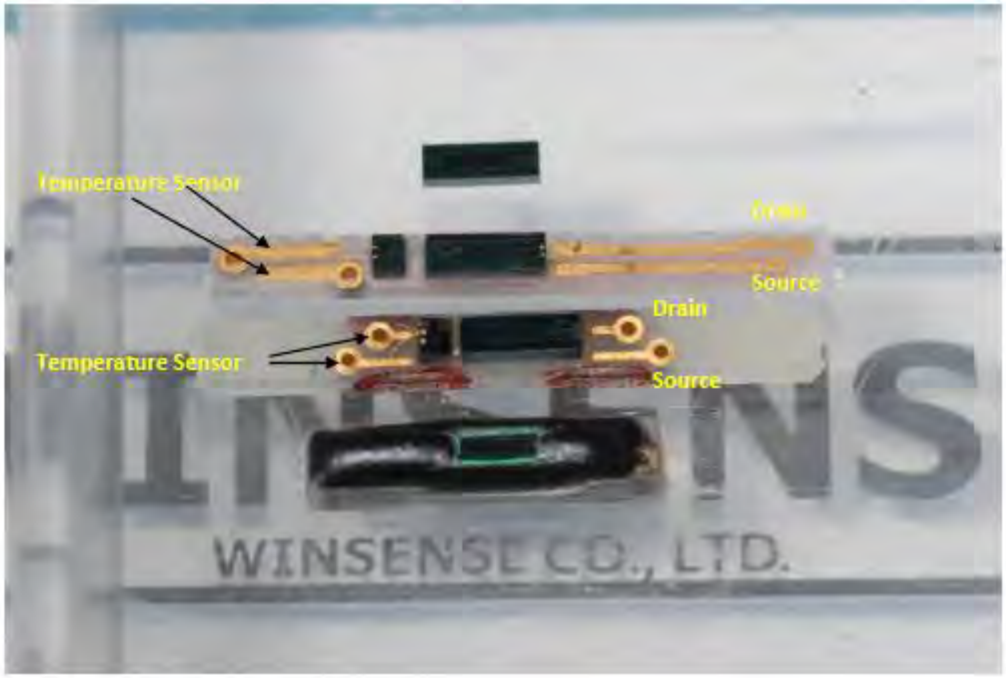
Temperature Sensor Specifications
Sensitivity: -2.93 mV/degC
Range: 0 - 100°C
Response time: 1s

Sensor terminals and connections:



Winsense Co., LTD
131 Room# INC1-316D 3rd Floor, INC1 Bldg., Thailand Science Park,
Moo9, Paholyothin Road, Klong 1, Klong Luang, Pathumthani 12120
Tel: +66 81 144 3644 email:winsense@winsense.co.th

Chip connections and connections of packaged sensor:



From top to bottom:

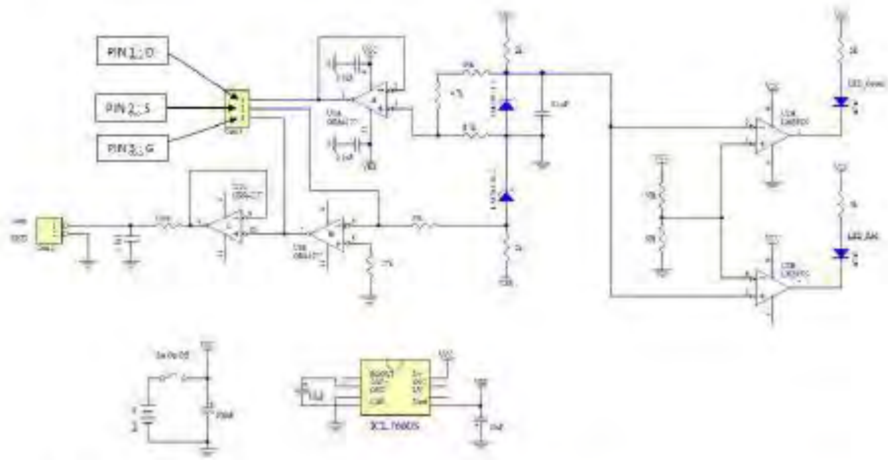
1. ISFET chip
2. Temperature (left) and ISFET (right) chips wire bonded on a PCB
3. Temperature (left) and ISFET (right) chips wire bonded on another PCB with shorter wiring
4. ISFET wire bonded to PCB after encapsulation

Reference-electrode

For stable measurements an Ag/AgCl Reference electrode is required. Submerged together with the packaged ISFET chip, it acts as metal gate electrode and provides a stable reference potential.

WIPS Control Electronic

Measurement circuit:



Operating mode:

Principle: The circuit configuration is used to keep a constant drain current (I_{ds}) and voltaqge (Vfs) for the ISFET operation providing an output voltage (V_g) linearly depending on pH level of the solution under test.

Recommended Handling and Operating Conditions:

- The ISFET is sensitive to light, it is then preferably operated out of direct light as calibration is normally performed in dark.

Important precautions:

- Avoid any electrostatic discharge at the ISFET connections when handling in dry air
- Store the Ref Electrode in KCl solution when not in use.

Operational Amplifier

ANALOG DEVICES

Dual Picoampere Input Current Bipolar Op Amp

AD706

FEATURE

HIGH DC PRECISION
50 μV max Offset Voltage
0.6 μV/°C max Offset Drift
110 pA max Input Bias Current

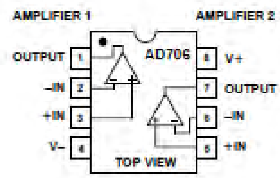
LOW NOISE
0.5 μV p-p Voltage Noise, 0.1 Hz to 10 Hz

LOW POWER
750 μA Supply Current
Available in 8-Lead Plastic Mini-DIP, Hermetic Cerdip and Surface Mount (SOIC) Packages
Available in Tape and Reel in Accordance with EIA-481A Standard
Single Version: AD705, Quad Version: AD704

PRIMARY APPLICATIONS
Low Frequency Active Filters
Precision Instrumentation
Precision Integrators

CONNECTION DIAGRAM

Plastic Mini-DIP (N)
Cerdip (Q) and
Plastic SOIC (R) Packages



The AD706 is offered in three varieties of an 8-lead package: plastic mini-DIP, hermetic cerdip and surface mount (SOIC). "J" grade chips are also available.

PRODUCT DESCRIPTION

The AD706 is a dual, low power, bipolar op amp that has the low input bias current of a BiFET amplifier, but which offers a significantly lower I_B drift over temperature. It utilizes superbeta bipolar input transistors to achieve picoampere input bias current levels (similar to FET input amplifiers at room temperature), while its I_B typically only increases by 5× at 125°C (unlike a BiFET amp, for which I_B doubles every 10°C for a 1000× increase at 125°C). The AD706 also achieves the microvolt offset voltage and low noise characteristics of a precision bipolar input amplifier.

Since it has only 1/20 the input bias current of an OP07, the AD706 does not require the commonly used "balancing" resistor. Furthermore, the current noise is 1/5 that of the OP07, which makes this amplifier usable with much higher source impedances. At 1/6 the supply current (per amplifier) of the OP07, the AD706 is better suited for today's higher density boards.

The AD706 is an excellent choice for use in low frequency active filters in 12- and 14-bit data acquisition systems, in precision instrumentation and as a high quality integrator. The AD706 is internally compensated for unity gain and is available in five performance grades. The AD706J and AD706K are rated over the commercial temperature range of 0°C to +70°C. The AD706A and AD706B are rated over the industrial temperature range of –40°C to +85°C.

PRODUCT HIGHLIGHTS

1. The AD706 is a dual low drift op amp that offers BiFET level input bias currents, yet has the low I_B drift of a bipolar amplifier. It may be used in circuits using dual op amps such as the LT1024.
2. The AD706 provides both low drift and high dc precision.
3. The AD706 can be used in applications where a chopper amplifier would normally be required but without the chopper's inherent noise.

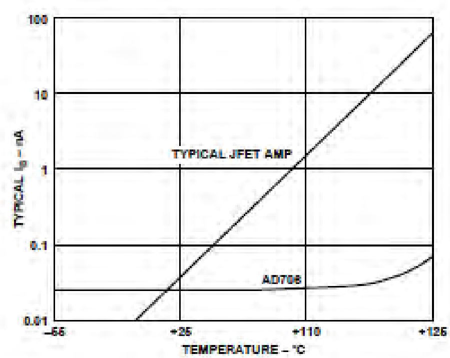


Figure 1. Input Bias Current vs. Temperature

REV. C

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

AD706–SPECIFICATIONS (@ T_A = +25°C, V_{CM} = 0 V and ±15 V dc, unless otherwise noted)

Parameter	Conditions	AD706J/A Min	AD706J/A Typ	AD706J/A Max	AD706K/B Min	AD706K/B Typ	AD706K/B Max	Units
INPUT OFFSET VOLTAGE								
Initial Offset			30	100		10	50	μV
Offset	T_{MIN} to T_{MAX}		40	150		25	100	μV
vs. Temp., Average TC			0.2	1.5		0.2	0.6	μV/°C
vs. Supply (PSRR)	V_S = ±2 V to ±18 V	110	132		112	132		dB
T_{MIN} to T_{MAX}	V_S = ±2.5 V to ±18 V	106	126		108	126		dB
Long Term Stability			0.3			0.3		μV/Month
INPUT BIAS CURRENT[1]								
	V_{CM} = 0 V		50	200		30	110	pA
	V_{CM} = ±13.5 V			250			160	pA
vs. Temp, Average TC			0.3			0.2		pA/°C
T_{MIN} to T_{MAX}	V_{CM} = 0 V			300			200	pA
T_{MIN} to T_{MAX}	V_{CM} = ±13.5 V			400			300	pA
INPUT OFFSET CURRENT	V_{CM} = 0 V		30	150		30	100	pA
	V_{CM} = ±13.5 V			250			200	pA
vs. Temp, Average TC			0.6			0.4		pA/°C
T_{MIN} to T_{MAX}	V_{CM} = 0 V		80	250		80	200	pA
T_{MIN} to T_{MAX}	V_{CM} = ±13.5 V		80	350		80	300	pA
MATCHING CHARACTERISTICS								
Offset Voltage				150			75	μV
	T_{MIN} to T_{MAX}			250			150	μV
Input Bias Current[2]				300			150	pA
	T_{MIN} to T_{MAX}			500			250	pA
Common-Mode Rejection		106			110			dB
	T_{MIN} to T_{MAX}	106			108			dB
Power Supply Rejection		106			110			dB
	T_{MIN} to T_{MAX}	104			106			dB
Crosstalk	@ f = 10 Hz							
(Figure 19a)	R_L = 2 kΩ		150			150		dB
FREQUENCY RESPONSE								
Unity Gain Crossover Frequency			0.8			0.8		MHz
Slew Rate	G = –1		0.15			0.15		V/μs
	T_{MIN} to T_{MAX}		0.15			0.15		V/μs
INPUT IMPEDANCE								
Differential			40‖2			40‖2		MΩ‖pF
Common Mode			300‖2			300‖2		GΩ‖pF
INPUT VOLTAGE RANGE								
Common-Mode Voltage		±13.5	±14		±13.5	±14		V
Common-Mode Rejection Ratio	V_{CM} = ±13.5 V	110	132		114	132		dB
	T_{MIN} to T_{MAX}	108	128		108	128		dB
INPUT CURRENT NOISE	0.1 Hz to 10 Hz		3			3		pA p-p
	f = 10 Hz		50			50		fA/√Hz
INPUT VOLTAGE NOISE	0.1 Hz to 10 Hz		0.5			0.5	1.0	μV p-p
	f = 10 Hz		17			17		nV/√Hz
	f = 1 kHz		15	22		15	22	nV/√Hz
OPEN-LOOP GAIN	V_O = ±12 V							
	R_{LOAD} = 10 kΩ	200	2000		400	2000		V/mV
	T_{MIN} to T_{MAX}	150	1500		300	1500		V/mV
	V_O = ±10 V							
	R_{LOAD} = 2 kΩ	200	1000		300	1000		V/mV
	T_{MIN} to T_{MAX}	150	1000		200	1000		V/mV
OUTPUT CHARACTERISTICS								
Voltage Swing	R_{LOAD} = 10 kΩ	±13	±14		±13	±14		V
	T_{MIN} to T_{MAX}	±13	±14		±13	±14		V
Current	Short Circuit		±15			±15		mA
Capacitive Load Drive Capability	Gain = +1		10,000			10,000		pF

Parameter	Conditions	AD706J/A Min	AD706J/A Typ	AD706J/A Max	AD706K/B Min	AD706K/B Typ	AD706K/B Max	Units
POWER SUPPLY								
Rated Performance			±15			±15		V
Operating Range		±2.0		±18	±2.0		±18	V
Quiescent Current, Total			0.75	1.2		0.75	1.2	mA
	T_{MIN} to T_{MAX}		0.8	1.4		0.8	1.4	mA
TRANSISTOR COUNT	# of Transistors		90			90		

NOTES
[1]Bias current specifications are guaranteed maximum at either input.
[2]Input bias current match is the difference between corresponding inputs (I_B of –IN of Amplifier #1 minus I_B of –IN of Amplifier #2).

CMRR match is the difference between $\frac{\Delta V_{OS}\ \#1}{\Delta V_{CM}}$ for amplifier #1 and $\frac{\Delta V_{OS}\ \#2}{\Delta V_{CM}}$ for amplifier #2 expressed in dB.

PSRR match is the difference between $\frac{\Delta V_{OS}\ \#1}{\Delta V_{SUPPLY}}$ for amplifier #1 and $\frac{\Delta V_{OS}\ \#2}{\Delta V_{SUPPLY}}$ for amplifier #2 expressed in dB.

All min and max specifications are guaranteed.
Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS[1]

Supply Voltage . . . . ±18 V
Internal Power Dissipation
(Total: Both Amplifiers)[2] . . . . 650 mW
Input Voltage . . . . ±V_S
Differential Input Voltage[3] . . . . +0.7 Volts
Output Short Circuit Duration . . . . Indefinite
Storage Temperature Range (Q) . . . . –65°C to +150°C
Storage Temperature Range (N, R) . . . . –65°C to +125°C
Operating Temperature Range
AD706J/K . . . . 0°C to +70°C
AD706A/B . . . . –40°C to +85°C
Lead Temperature (Soldering 10 secs) . . . . +300°C

NOTES
[1]Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
[2]Specification is for device in free air:
8-Lead Plastic Package: θ_{JA} = 100°C/Watt
8-Lead Cerdip Package: θ_{JA} = 110°C/Watt
8-Lead Small Outline Package: θ_{JA} = 155°C/Watt
[3]The input pins of this amplifier are protected by back-to-back diodes. If the differential voltage exceeds ±0.7 volts, external series protection resistors should be added to limit the input current to less than 25 mA.

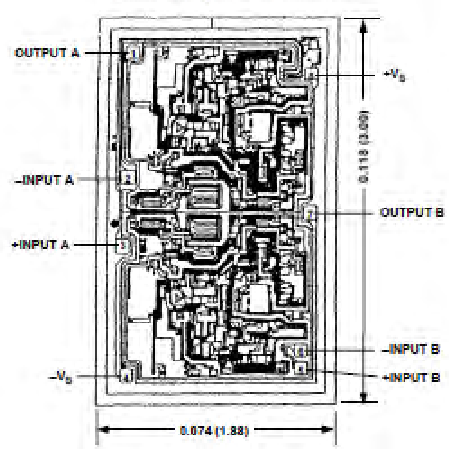
ORDERING GUIDE

Model	Temperature Range	Description	Package Option*
AD706AN	–40°C to +85°C	Plastic DIP	N-8
AD706JN	0°C to +70°C	Plastic DIP	N-8
AD706KN	0°C to +70°C	Plastic DIP	N-8
AD706JR	0°C to +70°C	SOIC	R-8
AD706JR-REEL	0°C to +70°C	Tape and Reel	
AD706AQ	–40°C to +85°C	Cerdip	Q-8
AD706BQ	–40°C to +85°C	Cerdip	Q-8
AD706AR	–40°C to +85°C	SOIC	R-8
AD706AR-REEL	–40°C to +85°C	Tape and Reel	

*N = Plastic DIP; Q = Cerdip, R = Small Outline Package.

METALIZATION PHOTOGRAPH

Dimensions shown in inches and (mm).
Contact factory for latest dimensions.



CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD706 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

RGB SENSOR

TAOS TEXAS ADVANCED OPTOELECTRONIC SOLUTIONS®

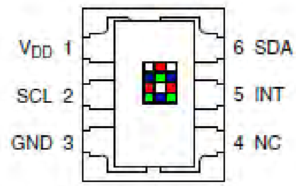
TCS3472 COLOR LIGHT-TO-DIGITAL CONVERTER with IR FILTER

TAOS135 – AUGUST 2012

Features

- Red, Green, Blue (RGB), and Clear Light Sensing with IR Blocking Filter
  - Programmable Analog Gain and Integration Time
  - 3,800,000:1 Dynamic Range
  - Very High Sensitivity — Ideally Suited for Operation Behind Dark Glass
- Maskable Interrupt
  - Programmable Upper and Lower Thresholds with Persistence Filter
- Power Management
  - Low Power — 2.5-μA Sleep State
  - 65-μA Wait State with Programmable Wait State Time from 2.4 ms to > 7 Seconds
- I²C Fast Mode Compatible Interface
  - Data Rates up to 400 kbit/s
  - Input Voltage Levels Compatible with V_{DD} or 1.8 V Bus
- Register Set and Pin Compatible with the TCS3x71 Series
- Small 2 mm × 2.4 mm Dual Flat No-Lead (FN) Package

PACKAGE FN
DUAL FLAT NO-LEAD
(TOP VIEW)



Package Drawing Not to Scale

Applications

- RGB LED Backlight Control
- Light Color Temperature Measurement
- Ambient Light Sensing for Display Backlight Control
- Fluid and Gas Analysis
- Product Color Verification and Sorting

End Products and Market Segments

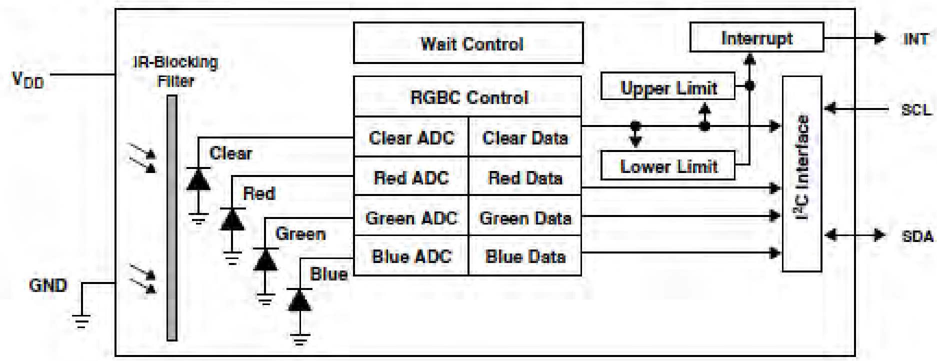
- TVs, Mobile Handsets, Tablets, Computers, and Monitors
- Consumer and Commercial Printing
- Medical and Health Fitness
- Solid State Lighting (SSL) and Digital Signage
- Industrial Automation

Description

The TCS3472 device provides 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, minimizes the IR spectral component of the incoming light and allows color measurements to be made accurately. The high sensitivity, wide dynamic range, and IR blocking filter make the TCS3472 an ideal color sensor solution for use under varying lighting conditions and through attenuating materials.

The TCS3472 color sensor has a wide range of applications including RGB LED backlight control, solid-state lighting, health/fitness products, industrial process controls and medical diagnostic equipment. In addition, the IR blocking filter enables the TCS3472 to perform ambient light sensing (ALS). Ambient light sensing is widely used in display-based products such as cell phones, notebooks, and TVs to sense the lighting environment and enable automatic display brightness for optimal viewing and power savings. The TCS3472, itself, can enter a lower-power wait state between light sensing measurements to further reduce the average power consumption.

Functional Block Diagram



Detailed Description

The TCS3472 light-to-digital converter contains a 3 × 4 photodiode array, four analog-to-digital converters (ADC) that integrate the photodiode current, data registers, a state machine, and an I^2C interface. The 3 × 4 photodiode array is composed of red-filtered, green-filtered, blue-filtered, and clear (unfiltered) photodiodes. In addition, the photodiodes are coated with an IR-blocking filter. The four integrating ADCs simultaneously convert the amplified photodiode currents to a 16-bit digital value. Upon completion of a conversion cycle, the results are transferred to the data registers, which are double-buffered to ensure the integrity of the data. All of the internal timing, as well as the low-power wait state, is controlled by the state machine.

Communication of the TCS3472 data is accomplished over a fast, up to 400 kHz, two-wire I^2C serial bus. The industry standard I^2C bus facilitates easy, direct connection to microcontrollers and embedded processors.

In addition to the I^2C bus, the TCS3472 provides a separate interrupt signal output. When interrupts are enabled, and user-defined thresholds are exceeded, the active-low interrupt is asserted and remains asserted until it is cleared by the controller. This interrupt feature simplifies and improves the efficiency of the system software by eliminating the need to poll the TCS3472. The user can define the upper and lower interrupt thresholds and apply an interrupt persistence filter. The interrupt persistence filter allows the user to define the number of consecutive out-of-threshold events necessary before generating an interrupt. The interrupt output is open-drain, so it can be wire-ORed with other devices.

Terminal Functions

TERMINAL NAME	TERMINAL NO.	TYPE	DESCRIPTION
GND	3		Power supply ground. All voltages are referenced to GND.
INT	5	O	Interrupt — open drain (active low).
NC	4	O	No connect — do not connect.
SCL	2	I	I^2C serial clock input terminal — clock signal for I^2C serial data.
SDA	6	I/O	I^2C serial data I/O terminal — serial data I/O for I^2C .
V_{DD}	1		Supply voltage.

Available Options

DEVICE	ADDRESS	PACKAGE – LEADS	INTERFACE DESCRIPTION	ORDERING NUMBER
TCS34721†	0x39	FN–6	I^2C Vbus = V_{DD} Interface	TCS34721FN
TCS34723†	0x39	FN–6	I^2C Vbus = 1.8 V Interface	TCS34723FN
TCS34725	0x29	FN–6	I^2C Vbus = V_{DD} Interface	TCS34725FN
TCS34727	0x29	FN–6	I^2C Vbus = 1.8 V Interface	TCS34727FN

† Contact TAOS for availability.

Absolute Maximum Ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (Note 1) . . . . 3.8 V
Input terminal voltage . . . . −0.5 V to 3.8 V
Output terminal voltage . . . . −0.5 V to 3.8 V
Output terminal current . . . . −1 mA to 20 mA
Storage temperature range, T_{stg} . . . . −40°C to 85°C
ESD tolerance, human body model . . . . 2000 V

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltages are with respect to GND.

Recommended Operating Conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD} (TCS34721 & TCS34725) (I^2C V_{bus} = V_{DD})	2.7	3	3.6	V
Supply voltage, V_{DD} (TCS34723 & TCS34727) (I^2C V_{bus} = 1.8 V)	2.7	3	3.3	V
Operating free-air temperature, T_A	−30		70	°C

Operating Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{DD}	Supply current	Active		235	330	μA
		Wait state		65		
		Sleep state — no I^2C activity		2.5	10	
V_{OL}	INT, SDA output low voltage	3 mA sink current	0		0.4	V
		6 mA sink current	0		0.6	
I_{LEAK}	Leakage current, SDA, SCL, INT pins		–5		5	μA
I_{LEAK}	Leakage current, LDR pin		–5		5	μA
V_{IH}	SCL, SDA input high voltage	TCS34721 & TCS34725	0.7 V_{DD}			V
		TCS34723 & TCS34727	1.25			
V_{IL}	SCL, SDA input low voltage	TCS34721 & TCS34725			0.3 V_{DD}	V
		TCS34723 & TCS34727			0.54	

Optical Characteristics, V_{DD} = 3 V, T_A = 25°C, AGAIN = 16×, ATIME = 0xF6 (unless otherwise noted) (Note 1)

PARAMETER		TEST CONDITIONS	Red Channel			Green Channel			Blue Channel			Clear Channel			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
R_e	Irradiance responsivity	λ_D = 465 nm Note 2	0%		15%	10%		42%	65%		88%	11.0	13.8	16.6	counts/ μW/ cm²
		λ_D = 525 nm Note 3	4%		25%	60%		85%	10%		45%	13.2	16.6	20.0	
		λ_D = 615 nm Note 4	80%		110%	0%		14%	5%		24%	15.6	19.5	23.4	

NOTES:
1. The percentage shown represents the ratio of the respective red, green, or blue channel value to the clear channel value.
2. The 465 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D = 465 nm, spectral halfwidth $\Delta\lambda½$ = 22 nm.
3. The 525 nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics: dominant wavelength λ_D = 525 nm, spectral halfwidth $\Delta\lambda½$ = 35 nm.
4. The 615 nm input irradiance is supplied by a AlInGaP light-emitting diode with the following characteristics: dominant wavelength λ_D = 615 nm, spectral halfwidth $\Delta\lambda½$ = 15 nm.

RGBC Characteristics, VDD = 3 V, TA = 25°C, AGAIN = 16×, AEN = 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Dark ADC count value	E_e = 0, AGAIN = 60×, ATIME = 0xD6 (100 ms)	0	1	5	counts
ADC integration time step size	ATIME = 0xFF	2.27	2.4	2.56	ms
ADC number of integration steps (Note 5)		1		256	steps
ADC counts per step (Note 5)		0		1024	counts
ADC count value (Note 5)	ATIME = 0xC0 (153.6 ms)	0		65535	counts
Gain scaling, relative to 1× gain setting	4×	3.8	4	4.2	×
	16×	15	16	16.8	
	60×	58	60	63	

NOTE 5: Parameter ensured by design and is not tested.

Wait Characteristics, V_{DD} = 3 V, T_A = 25°C, WEN = 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	CHANNEL	MIN	TYP	MAX	UNIT
Wait step size	WTIME = 0xFF		2.27	2.4	2.56	ms
Wait number of integration steps (Note 1)			1		256	steps

NOTE 1: Parameter ensured by design and is not tested.

AC Electrical Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

	PARAMETER†	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{(SCL)}$	Clock frequency (I^2C only)		0		400	kHz
$t_{(BUF)}$	Bus free time between start and stop condition		1.3			µs
$t_{(HDSTA)}$	Hold time after (repeated) start condition. After this period, the first clock is generated.		0.6			µs
$t_{(SUSTA)}$	Repeated start condition setup time		0.6			µs
$t_{(SUSTO)}$	Stop condition setup time		0.6			µs
$t_{(HDDAT)}$	Data hold time		0			µs
$t_{(SUDAT)}$	Data setup time		100			ns
$t_{(LOW)}$	SCL clock low period		1.3			µs
$t_{(HIGH)}$	SCL clock high period		0.6			µs
t_F	Clock/data fall time				300	ns
t_R	Clock/data rise time				300	ns
C_i	Input pin capacitance				10	pF

† Specified by design and characterization; not production tested.

PARAMETER MEASUREMENT INFORMATION

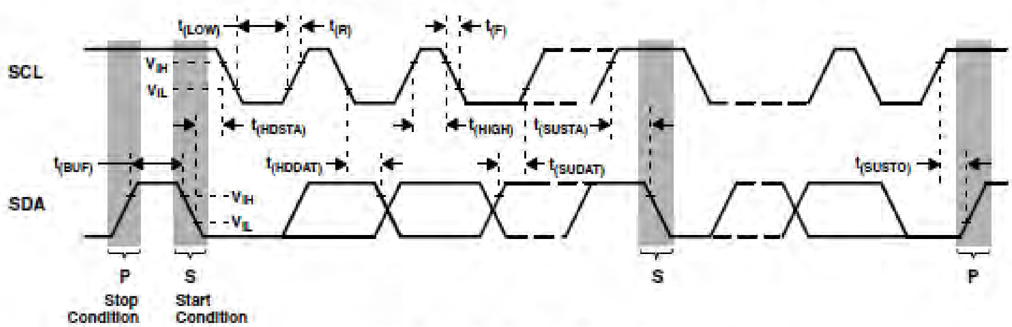


Figure 1. Timing Diagrams

TYPICAL CHARACTERISTICS

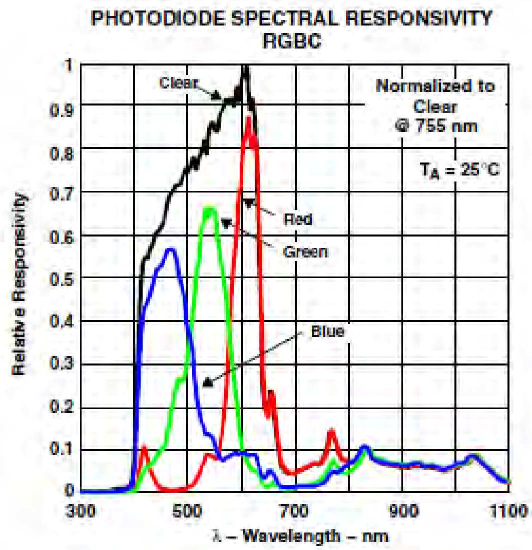


Figure 2

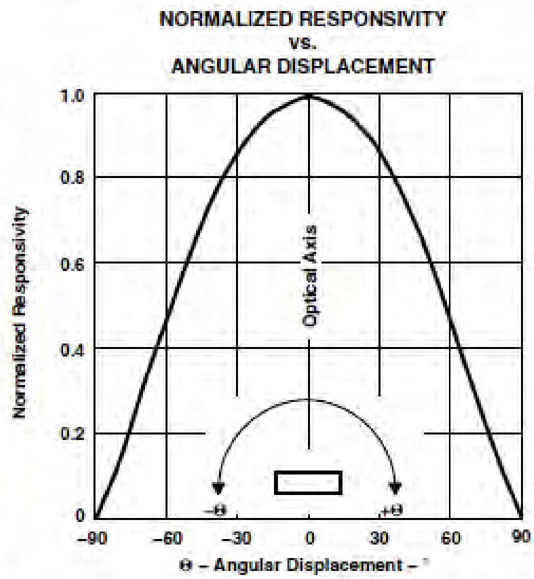


Figure 3

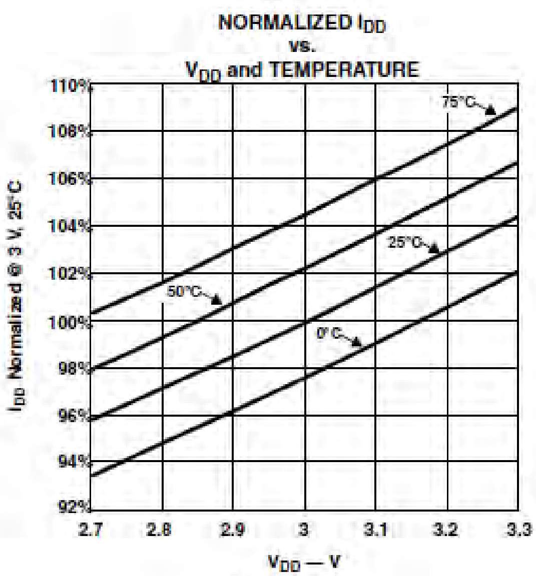


Figure 4

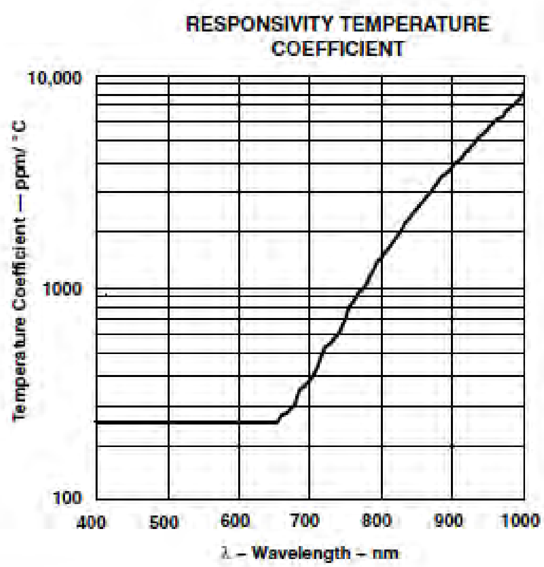


Figure 5

Soil Moisture Sensot

SNOSBJ6F –OCTOBER 1999–REVISED DECEMBER 2014

LMx93-N, LM2903-N Low-Power, Low-Offset Voltage, Dual Comparators

1 Features

- Wide Supply
  - Voltage Range: 2.0 V to 36 V
  - Single or Dual Supplies: ±1.0 V to ±18 V
- Very Low Supply Current Drain (0.4 mA) — Independent of Supply Voltage
- Low Input Biasing Current: 25 nA
- Low Input Offset Current: ±5 nA
- Maximum Offset voltage: ±3 mV
- Input Common-Mode Voltage Range Includes Ground
- Differential Input Voltage Range Equal to the Power Supply Voltage
- Low Output Saturation Voltage: 250 mV at 4 mA
- Output Voltage Compatible with TTL, DTL, ECL, MOS and CMOS logic systems
- Available in the 8-Bump (12 mil) DSBGA Package
- See AN-1112 (SNVA009) for DSBGA Considerations
- Advantages
  - High Precision Comparators
  - Reduced V_{OS} Drift Over Temperature
  - Eliminates Need for Dual Supplies
  - Allows Sensing Near Ground
  - Compatible with All Forms of Logic
  - Power Drain Suitable for Battery Operation

2 Applications

- Battery powered applications
- Industrial applications

3 Description

The LM193-N series consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM193-N series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM19-N series will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators.

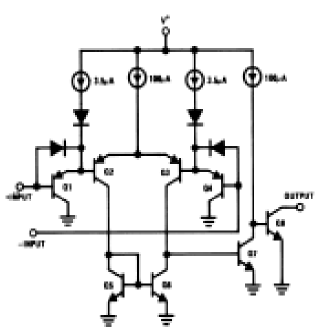
The LM393 and LM2903 parts are available in TI's innovative thin DSBGA package with 8 (12 mil) large bumps.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM193-N	TO-99 (8)	9.08 mm x 9.08 mm
LM293-N		
LM393-N	SOIC (8)	4.90 mm x 3.91 mm
LM2903-N		

(1) For all available packages, see the orderable addendum at the end of the datasheet.

4 Simplified Schematic



APPENDIX H

Bill of Materials

Total Expenses

Material	Seller	Price
Ion Selective Field Effect Transistor (ISFET) pH Sensor Kit	Winsense	US $90 (₱ 4,680)
SSAT 12" Soil Solution Access Tube	Mega Depot	US $30.29 (₱1575.08)
SSAT Vacuum Pump	Mega Depot	US $83.79 (₱ 4357.08)
Soil Moisture Sensor Module	Makerlab Electronics	₱ 124.75
SRGB Color Sensor with IR Filter and White LED	Makerlab Electronics	₱ 500
Arduino Mega ATmega2560-16AU CH340G	Makerlab Electronics	₱ 699.75
Nextbook 8" Intel- Powered Windows Tablet PC	AVision Philippines	₱ 4,499.00
Chassis and 3rd print	Fiber glass fabrication	₱3,456.00
Readout circuit components	Gizduino	₱ 1389
PVC cap for tube well	Hardware store	₱ 794
	Total	**₱16,329**

APPENDIX I

Proponent’s Profile Layout

PUNONGBAYAN, AIRAH JAN N., ECT

License No. 0015207
008 Brgy. Ramirez, Magallanes, Cavite
0916-940-7602
rahjan21@gmail.com

CAREER OBJECTIVE

To be part of a well-established and managed organization where I can utilize and improve my knowledge and skills I have acquired from school and there is an accelerating career with highly inspiring environment and to face creative and challenging assignments with responsibility and sincerity.

PERSONAL INFORMATION

Date of birth	: November 29, 1997
Place of birth	: Rosario, Cavite
Civil status	: Single
Age	: 20-year-old
Sex	: Female
Citizenship	: Filipino
Height	: 5’7’’
Weight	: 58 kg

EDUCATIONAL ATTAINMENT

Primary	**Gazellian College Foundation Inc.**
	2004-2010
	De Guia St., Magallanes, Cavite
Secondary	**Cavite National Science High School**
	2010-2014
	Garita-B, Maragondon, Cavite

Tertiary	**Technological University of the Philippines - Manila**
	2014-Present
	Ayala Blvd. Ermita, Manila
	(Bachelor of Science in Electronics Engineering)

AFFILIATIONS

- Electronics and Communication Technician (2017)
- Civil Service Exam Passer – Professional Level (2017)
- DOST-SEI Scholar (2014-Present)
- Member, Organization of Electronics Engineering Students (2014-Present)
- Junior Certificate and Publication Committee Head, OECES (2016-2017)
- Assistant Secretary, OECES (2017-Present)
- Member, IECEP-MSC (2016-Present)
- ECT Associate Member, IECEP-MSC (2017-Present)
- 3^{rd} placer ICT Quiz Bee, Cavite National Science High School, 2013-2014

SKILLS

- Simulation and Design Software
    - Multisim
    - Express PCB
    - Electric/ Winspice
- Technical Skills
    - Basic Electronics and Communication
    - Troubleshooting and soldering
- Programming Languages
    - Basic knowledge in C++ (Dev ++) and Java Programming (Eclipse)
    - MATLAB / GNU Octave
    - Machine Learning with Python
- Computer Skills
    - Microsoft Office
- Fast learner

TRAININGS OR SEMINARS

May 2017	PHASES: Preparing the Headway for Achievement and Success of ECE Students Technological University of the Philippines
September 2017	Modern Approach to Progressing Future:

	Electronics Product and Development Center ECE Board Exam Awareness Technological University of the Philippines
	Colaborate. Share Ideas. Socialize. Inspire. PalEEEtan 2017 University of the Philippines, Diliman
February 2018	APPRECIATE: Annual Presentation of Project Research in Engineering Technological University of the Philippines
	CAD Workshop: Autodesk FUSION 360 De La Salle Zobel University
	Cryptocurrency and Blockchain Technology 101 Technological University of the Philippines
	Talk from Start-up Founders Innovators Technopreneurs Technological University of the Philippines-Manila
November 2018	Virtual Reality of Things IECEP Manila Student Chapter Seminar National University, Manila
	Internet of Things and Telecom: The New Golden Era IECEP Manila Student Chapter Seminar National University, Manila
	Impact and Benefits of Industry 4.0: A Smart Factory Automation IECEP Manila Student Chapter Seminar National University, Manila
December 2018	Digital TV System Design and Measurement ECE Seminar: Industry Preparedness Colegio de Suan de Letran, Manila

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CHARACTER REFERENCE

Engr. Lean Karlo Tolentino
Department Head, Electronics Engineering Department
Technological University of the Philippines - Manila
Ayala Blvd. Ermita, Manila
+(63) 995-892-5845

Engr. Timothy M. Amado
Faculty, Electronics Engineering Department
Research Adviser
Technological University of the Philippines – Manila

I hereby certify that all the information indicated in this resume is true and correct to the best knowledge and belief.

Airah Jan N. Punongbayan
Applicant's Signature

PAZ, VENISE AZIEL F., ECT

81 Sitio Balut, Tonsuya, Malabon City

Contact No.: +(63) 917 178 0529/364-10-58

Email Address: veniseaziel.paz@tup.edu.ph

CAREER OBJECTIVE

- To utilize my skills and abilities in the field of Electronics Engineering industry that offers professional growth while being resourceful, innovative, and flexible, as well as to practice my leadership skills and decision-making skills.

PERSONAL SKILLS

- Basic knowledge in Python, and C Language
- Web Design with HTML
- Knowledge in Electronic Workbenches: Multisim, ExpressPCB, Electric/Winspice
- Knowledge in Computing Software: MATLAB, and LabVIEW
- Knowledge in Multimedia Application: Adobe Photoshop
- Proficiency in Microsoft Office Applications
- Hard-working, quick learner, team player, people-oriented and flexible

PERSONAL INFORMATION

Date of Birth	: May 29, 1998
Age	: 20 years old
Gender	: Female
Height	: 155 cm
Weight	: 60 kg
Religion	: Roman Catholic
Civil Status	: Single
Citizenship	: Filipin

EDUCATIONAL ATTAINMENT

TERTIARY	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY: 2014-Present
SECONDARY	ARELLANO UNIVERSITY Gov. Pascual Ave, Malabon, Metro Manila SY: 2010-2014
PRIMARY	IMMACULATE CONCEPTION PAROCHIAL SCHOOL 272 Gen. Luna St, Malabon, 1470 Metro Manila SY: 2006 – 2010

ORGANIZATION

June 2014 – Present	Organization of Electronics Engineering Students Member College of Engineering Technological University of the Philippines
June 2015 – Present	Commission on Higher Education Scholar
January 2017 – Present	Institute of Electronics Engineering Students of the Philippines ECT Associate Member

SEMINARS

May 2017	PHASES: Preparing the Headway for Achievement and Success of ECE Students Technological University of the Philippines
Sep 2017	Modern Approach to Progressing Future: Electronics Product and Development Center ECE Board Exam Awareness Technological University of the Philippines

Feb 2018 APPRECIATE: Annual Presentation of Project Research in Engineering
Technological University of the Philippines

CAD Workshop: Autodesk FUSION 360
De La Salle Zobel University

Cryptocurrency and Blockchain Technology 101
Technological University of the Philippines

Nov 2018 Virtual Reality of Things
IECEP Manila Student Chapter Seminar
National University, Manila

Internet of Things and Telecom: The New Golden Era
IECEP Manila Student Chapter Seminar
National University, Manila

Impact and Benefits of Industry 4.0: A Smart Factory Automation
IECEP Manila Student Chapter Seminar
National University, Manila

Dec 2018 Digital TV System Design and Measurement
ECE Seminar: Industry Preparedness
Colegio de Suan de Letran, Manila

<u>WORK EXPERIENCE</u>

April – May 2018 Supervised Industrial Training
MDF Assistant
CaMaNaVa Customer Service Operation Zone
PLDT Sales & Service Center, Malabon, Metro Manila

CHARACTER REFERENCES

Engr. Lean Karlo Tolentino

Department Head, Electronics Engineering Department Technological University of the Philippines - Manila Ayala Blvd. Ermita, Manila

+(63) 995-892-5845

Engr. Timothy M. Amado
Faculty, Electronics Engineering Department
Research Adviser
Technological University of the Philippines – Manila

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

VENISE AZIEL F. PAZ.

Applicant's Signature

ALLYSSA OCAMPO

Contact No.: 0977 781 4924
552 Baltazar St. Tondo, Manila
Email Address: allyssa.ocampo@tup.edu.ph

CAREER OBJECTIVE

- To be part of an environment where I can utilize and hone my abilities and extend the knowledge I have acquired in the university.

PERSONAL SKILLS

- Simulation and Design Software
  - Multisim
  - Express PCB
  - Electric/ Winspice
  - Virtuoso Circuit Designing
  - Autodesk Fusion
  - Microsoft Visio
- Technical Skills
  - Electronic Circuitry and wiring
  - Troubleshooting and soldering
- Programming Languages
  - Basic knowledge in C++ (Dev ++) and Java Programming (Eclipse)
  - MATLAB / GNU Octave
  - Intermediate knowledge in Python Programming
  - Intermediate Microsoft ACCESS Database GUI designing
- Computer Skills
  - Microsoft Office
  - Photoshop and Paint Tool Sai Editing
  - Advanced Graphic Designing
  - Video Editing using PowerPoint, PowerDirector and Adobe Premiere
- Fast learner
- Can work with minimum supervision
- Knowledgeable in 8-Discipline Reporting

PERSONAL INFORMATION

Date of Birth	: September 24, 1998
Age	: 20
Gender	: Female
Height	: 5’2’’
Weight	: 88 lbs
Religion	: Roman Catholic
Civil Status	: Single
Citizenship	: Filipino

EDUCATIONAL ATTAINMENT

TERTIARY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Bachelor of Science in Electronics Engineering
Ayala Blvd. Ermita, Manila
AY : 2014-Present

SECONDARY

DASMARINAS INTEGRATED NATIONAL HIGH SCHOOL
DBB-B, Congressional Rd., Dasmarinas City, Cavite
SY : 2010-2014

PRIMARY

SIBUG ELEMENTARY SCHOOL
General Tinio, Nueva Ecija
SY:2004 – 2010

ORGANIZATION

June 2014-2016

Organization of Electronics Engineering Students
Member
College of Engineering
Technological University of the Philippines

June 2017-Present

Organization of Electronics Engineering Students
Auditor
College of Engineering
Technological University of the Philippines

June 2016-Present

Institute of Electronics Engineers of the Philippines

Member

SEMINARS

February 2018	CAD Workshop: Autodesk FUSION 360 De La Salle Zobel University
	Cryptocurrency and Blockchain Technology 101 Technological University of the Philippines
October 2018	2018 IoT Summit SM Megamall Trade Hall 3

ACHIEVEMENTS

PhilNITS	IP Examination Passer Mean Score: 695 April 2018

CHARACTER REFERENCES

Engr. Lean Karlo S. Tolentino
Department Head, Electronics Engineering Department
Technological University of the Philippines - Manila
Ayala Blvd. Ermita, Manila
+(63) 995-892-5845

James Ann Joyce D. Carillo
Electronics Engineering Student
City Homes, DBB-F , Dasmarinas City, Cavite
09292583163

I hereby certify that the above information is true and correct to the best of my knowledge and ability.

Applicant's Signature

ALVAREZ, ADRIAN ERWIN D.
Blk. 55 Lot 8 Teachers Village Catmon, Malabon City
Contact No.: 09661500128
Email Address: adrianerwin.alvarez@tup.edu.ph

CAREER OBJECTIVE

- To utilize my skills and abilities in the field of Electronics Engineering industry that offers professional growth while being resourceful, innovative, and flexible, as well as to practice my leadership skills and decision-making skills, and to be a part of a team whose development I can contribute to as a member.

PERSONAL SKILLS

- Focused, versatile, and multi-task oriented
- Able to adapt effectively to challenging and emergency situation
- Simulation and Design Software (Express PCB and Multisim)
- Technical Skills (Soldering and Troubleshooting)
- Computer Skills (Microsoft Office)
- Knowledgeable in Arduino IDE and MATLAB/GNU Octave
- Knowledgeable in basic Electronics and Communication
- Knowledgeable in Adobe Photoshop
- Knowledgeable in 8-Discipline Reporting

PERSONAL INFORMATION

Date of Birth	: August 11, 1997
Age	: 21 years old
Gender	: Male
Height	: 5’8’’
Weight	: 127.6 lbs
Religion	: Roman Catholic
Civil Status	: Single
Citizenship	: Filipino

EDUCATIONAL ATTAINMENT

TERTIARY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Bachelor of Science in Electronics Engineering
Ayala Blvd. Ermita, Manila
AY : 2014-Present

SECONDARY	IMMACULATE CONCEPCION PAROCHIAL SCHOOL 272 Gen. Luna Street, Concepcion, Malabon City SY : 2010-2014
PRIMARY	IMMACULATE CONCEPCION PAROCHIAL SCHOOL 272 Gen. Luna Street, Concepcion, Malabon City SY : 2004-2010

ORGANIZATION

June 2014-Present	Organization of Electronics Engineering Students Member College of Engineering Technological University of the Philippines

SEMINARS

May 2017	PHASES: Preparing the Headway for Achievement and Success of ECE Students Technological University of the Philippines
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IECEP Manila Student Chapter Seminar
National University, Manila

December 2018 — Digital TV System Design and Measurement
ECE Seminar: Industry Preparedness
Colegio de San Juan de Letran, Manila

WORK EXPERIENCE

April – May 2018 — Supervised Industrial Training
Assistant
North GMM Fixed Access and Transport Operations
PLDT NGMMFxATOp Office, Diliman, Quezon City

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+(63) 995-892-5845

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Applicant's Signature

YUMENA, LEMUEL M.
440 Raja Soliman st. Marulas B. Caloocan city.
Contact No.: 09354088181
Email Address: lyumena1a@gmail.com

CAREER OBJECTIVE

- To be part of an organization where I can utilize and improve my knowledge and skills I have acquired from school and accept challenging work and contribute forward the success of the organization by hard work and acquired skills.

PERSONAL SKILLS

- Simulation and Design Software
- Multisim
- Express PCB
- Winspice
- Virtuoso
- Technical Skills
- Basic Electronics and Communication
- Troubleshooting and soldering
- Programming Languages
- MATLAB / GNU Octave
- Computer Skills
- Microsoft Office
- Basic knowledge in how to write 8D report
- Knowledge in Failure Analysis
- Knowledge in Cause Analysis

PERSONAL INFORMATION

Date of Birth	: July 25,1997
Age	: 20 years old
Gender	: Male
Height	: 5'7''
Weight	: 176 lbs
Religion	: Born Again Christian

Civil Status : Single
Citizenship : Filipino

EDUCATIONAL ATTAINMENT

TERTIARY	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY : 2014-Present
SECONDARY	CALOOCAN HIGH SCHOOL F.Roxas, Grace Park West, Caloocan, Metro Manila SY : 2010-2014
PRIMARY	BETHEL LUTHERAN SCHOOL 2308 Almeda Street, Tondo Manila, Philippines SY : 2004-2010

ORGANIZATION

June 2014-Present	Organization of Electronics Engineering Students Member College of Engineering Technological University of the Philippines

SEMINARS

September 2017	Modern Approach to Progressing Future: Electronics Product and Development Center ECE Board Exam Awareness Technological University of the Philippines
February 2018	APPRECIATE: Annual Presentation of Project Research in Engineering Technological University of the Philippines
	Cryptocurrency and Blockchain Technology 101 Technological University of the Philippines

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Technological University of the Philippines – Manila

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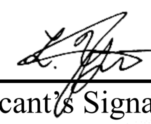

Applicant's Signature