SLICE: Multifunction IoT-based Soil Contaminants and Macronutrients Analyzer

A Project Study Presented to the Faculty of

Electronics Engineering Department

College of Engineering

Technological University of the Philippines

In Partial Fulfilment of the Course Requirements for the Degree of

Bachelor of Science in Electronics Engineering

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August 2020

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ACKNOWLEDGEMENT

This study was made possible with the help, support and encouragement of many individuals. The proponents offer their sincere appreciation to these people.

First and foremost, the proponents want to offer this endeavor to Almighty God for the wisdom, knowledge and understanding he accords upon them, the strength and skills, the peace of mind and very good health to finish the study. To Engr. Maria Victoria C. Padilla, the project adviser, in guiding the proponents towards the completion of the study. The Department of Energy and Natural Resources (DENR); Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD); University of the Philippines - Los Baños (UPLB), Department of Engineering, for providing knowledge and advices regarding the study. To Captain Allen Ampaya and the Local Government Unit of Barangay Poblacion, Muntinlupa City; Mr. Gregorio Lagman from Pampanga City for allowing the proponents conduct their study in their locale.

Last but not the least, the proponents offer their utmost gratitude towards their families, friends, colleagues and the people that willingly provides support and motivation throughout the process on finishing this study.

ABSTRACT

Soil nutrients (Nitrogen, Phosphorus, and Potassium) of a certain agricultural area have their selectivity or specificity for the highest potential crop yield. On the other hand, common heavy metals (Arsenic, Cadmium, Lead, and Mercury) found on soil sediments especially beneath polluted bodies of water also became part of our local farmers' struggles. These correspond to laboratory methods used to solve or lessen the amount of the heavy metals content and produce the desired amount of nutrients by applying appropriate fertilizers. The said problems can be managed through efficient soil analysis. The main objective of this study is to develop a multifunction IoT-based device for soil contaminants and macronutrient analysis through Raspberry Pi using NIR spectroscopy to lessen unnecessary efforts by farmers on going to regional soil test laboratories and to provide economical soil analysis. The device used TCD1304AP driven by Arduino MEGA 2560. With Internet of Things (IoT), configured to Raspberry Pi through Django and pgAdmin, anyone connected to the provided WiFi may access the webpage for the results including the soil contents, pH level, crop recommendations, and potential solutions and treatments for the soil. The processed data showed 95% accuracy in measuring soil macronutrient concentration and 44.44% accuracy in measuring soil contaminants concentration. The low percentage for contaminants was due to very low numerical values and the limited number of samples so to further describe the performance of the device, percent error and difference were calculated. The device measured the contaminant concentrations with a 25.56% error and 28.57% difference.

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INTRODUCTION

Agriculture plays an important role in the country's economy. Monitoring the condition of the soil in a land area provides data on what crop will be planted for the best yield to occur in a given time. A soil status that is not well suited for a specific plant would lower the land capability, thus not reaching its potential crop yield [1]. On the other hand, polluted rivers or any bodies of water cause a great deal to the environment making it one of the problems that are given with most attention today. Traditional, automated, and chemical control methods are commonly used in water cleaning but each has shortcomings. These shortcomings such as clean-up efficiency, large labor force, and effectiveness have been a problem since then [2]. Once polluted water is neutralized or cleansed, water begins to be sullied again over some time due to the water pollutants submerging or settling then contaminating the soil underneath. The polluted soil affects the body of water entirely and must be considered in water cleaning in rivers or lakes. The said two problems regarding soil status in either nutrient content in agricultural land or soil contaminants beneath a body of water both affect the environment. Although the problems seem to be different from each other, these share a common solution, an efficient soil analysis.

Different pollutants can be found in soil, most of which are heavy metals namely Antimony (Sb), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Selenium (Se), Silver (Ag), Thallium (Tl) and Zinc (Zn) [3]. As, Cd, Pb, and Hg are necessary to keep at really low levels to prevent soil contamination. These parameters further describe the contents of soil samples and give significant data to

sustain a polluted body of water. A heavy metal analysis is costly and time-consuming since chemical control methods are used in laboratories. Inorganic Arsenic is highly toxic commonly present in polluted water which, when consumed, can cause cancer, skin lesions, cardiovascular disease, and diabetes. Cadmium is usually found in hazardous waste sites contaminating the soil around the area which, with higher-level exposure, damages the kidney and lungs. Lead is a cumulative toxicant that damages different body systems and commonly present in pigments, paints, solder, stained glass, and solid wastes containing glass or plastics. Lead exposure weakens the brain and central nervous system causing coma and convulsions. Mercury is a toxic chemical that causes health problems even with a small amount of exposure making it one of the WHO's top ten chemicals of public health concern. Mercury affects the nervous, digestive, and immune systems naturally found in air, water, and soil [4].

Macronutrients, on the other hand, include Nitrogen (N), Phosphorus (P), and Potassium (K), and pH level are responsible for a plant's growth. Nitrogen is composed of amino acids which are the building blocks of protein necessary for development. Phosphorus converts sunlight into compounds for plant's photosynthesis. Potassium is for the physical development of the plant and a necessity for growth [5].

1.1 Background of the Study

According to ITPS (Intergovernmental Technical Panel on Soils), Soil Contamination is different from the term soil pollution. Soil Contamination is when the presence of a chemical or a substance at a greater concentration is not causing any dangerous effect on the environment. On the contrary, Soil pollution produces harmful effects on any non-

targeted organism [7]. This contamination causes a great problem to the environment, especially in agriculture.

Near Infrared Sensor (NIRS) can be helpful for the accurate and precise application of farming principles. NIRS can be combined with Geographic Information System (GIS) as a rapid technique. Nitrogen (N) and Organic Matter (OM) of a loamy mixed soil can be assessed using different techniques. Near infrared spectroscopy is a good potential for the assessment of the two nutrients of the soil [34]. This precise measurement results in more efficient nutrient analysis.

SoilMac.pH is a device that measures soil macronutrients and pH levels and provides recommendations on the amount of fertilizer for the crops. This study aims to lessen the time of analyzing the soil nutrients. The soil sample is placed in a cuvette and fed into the device. The device uses Visible Near-Infrared (VISNIR) Spectroscopy and Beer-Lambert's Law Absorbance-Concentration Relationship to identify and measure macronutrients [44].

On the other hand, SenSoil develops a device that can measure and analyze the macronutrient content of the soil. Using a lysimeter, a soil sample was collected and fed into the device. The device contains an Ion Selective Field Effect Transistor (ISFET) and Soil Moisture sensor that is connected to the Arduino via Analog Read-out Circuit which measures the number of soil macronutrients. A Machine Algorithm was used for the predictive model correlating the macronutrients, pH, and moisture level. The data acquired will be displayed on a Tablet PC. The device is equipped with Internet of Things or IoT in which the data was sent into a host. The host contains a database that displays all the data acquired by the device. A website is created to access the database [8].

Field Environmental research and soil sample collection of the Shuangqiao River Basin indicates that the soil content of heavy - metal products of Hg, Pb, Cd, Cr, As, Cu, Zn has been analyzed and the geo-accumulation index has assessed soil pollution. In the area under examination, Hg is the most important soil pollutant. The average level of pollution of Hg is higher than degree 2, which is moderate. Second is the Pb, Cd. Cu and Zn are of grade 1 on average and also have no moderate levels of pollution [41].

1.2 Statement of the Problem

The proponents sought to solve the following problems of water and soil cleaning in any bodies of water, as well as crop and soil monitoring in an agricultural land using the Multifunction IoT-based soil contaminants and macronutrients analyzer via Arduino and Raspberry Pi multi microcontroller using spectroscopy:

1. What do the As, Cd, Pb, and Hg level parameters imply in connection with the soil under different polluted bodies of water?
2. What do the N, P, K, and pH level parameters imply in crop's increasing yield?
3. What can the multimode device do to improve the conventional and traditional soil analysis?
4. What can spectroscopy be of help in providing significant data in soil contaminants and macronutrient analysis?
5. What can IoT common platform be of use in processing data and providing faster results?
6. What can Arduino and Raspberry Pi do to provide a user-friendly interface showing the data and results?

1.3 Objectives

1.3.1 General Objectives

The study aims to develop multifunction IoT-based soil contaminants and macronutrient analyzer through Arduino and Raspberry Pi microcontroller using spectroscopy.

1.3.2 Specific Objectives

The study purposely seeks to reach the following objectives in developing an automated soil analysis in agricultural land and beneath a polluted body of water.

1. To design a multifunction device analyzing soil samples from agricultural lands and polluted bodies of water through spectroscopy
2. To build a library containing contaminant and nutrients parameters and their corresponding treatments and recommendations, respectively
3. To develop an IoT common platform in processing the data inputs and providing efficient and faster results
4. To display efficient and qualitative information of the soil, and the recommended treatments and crops of each soil sample
5. To assess and validate the device's gathered data for accuracy and efficiency by comparing soil test kits and laboratory results

1.4 Significance of the Study

This study will help the community in understanding the soil condition in particular agricultural land and beneath a polluted body of water. The soil condition will be of great

use in analyzing the treatments and crop recommendations necessary for higher clean-up efficiency of the polluted water and optimum crop yield. This will use NIR spectroscopy for low-cost heavy metal analysis connected to an IoT-based common platform for faster data process and results. The multifunction device will provide two modes analyzing contaminant or nutrient contents of the soil sample saving to a database for future reference. Effective crop recommendation, and soil and water treatments will result in increased yield and a cleaner environment preventing diseases acquired by contaminants exposure, respectively.

1.5 Scope and Limitations

The study focuses on the following variables:

1. The device calibrates four soil contaminants namely Arsenic, Cadmium, Lead, and Mercury, and four parameters namely Nitrogen, Phosphorus, Potassium, and pH level.
2. The study uses NIR spectroscopy for soil contaminants and macronutrient analysis accommodating limited contaminants at a time that will be fed to the colorimeter for data processes and element calibration.
3. Internet of Things and Raspberry Pi microcontroller serve as the platform and channel of used sensors in the entire system that will provide the output display of the results.
4. The soil samples are gathered manually in both agricultural land and under polluted water.

1.6 Definition of Terms

1. **Platform** – An interface where you can view all the stored data.
2. **Data** – Inputs that were recorded from sensors then were stored and transmitted in the form of electrical signals.
3. **Macronutrients** – Chemical elements (Nitrogen, Phosphorus, Potassium) that are required for plant growth and development.
4. **Channel** – A separate path where signals flow and data exchange or a Communication medium.
5. **Library** – Collection of gathered information or data containing different parameter ranges and corresponding descriptions.
6. **Algorithm –** Organized steps to be followed satisfying specific mathematical calculations or computer operations.
7. **Calibration –** The measurement of a parameter following a given standard scale for consistency.
8. **Colorimeter –** A light-sensitive device that measures the intensity, absorbance, and transmittance of certain wavelengths of light passing through a liquid sample.
9. **Contaminants / Pollutants –** Elements or substances that are undesired or harmful to the environment.
10. **Heavy metals –** Chemical elements that are high densities and can be toxic in high exposure or in certain forms.

Chapter 2

REVIEW OF RELATED LITERATURE

2.1 Conceptual Literature

2.1.1 Soil Pollution

Soil is a mixture of organisms, liquids, gases, organic matter, and minerals that collaboratively support life. Soil can both support and destroy the environment. Soil Pollution occurs when a chemical is present in the soil or when a substance is at a higher concentration than the normal. Soil Contaminants can occur naturally as mineral components and can be toxic if present at a higher concentration.

According to a study (FAO and ITPS, 2015), Soil Pollution is identified as the third most important threat in Europe and Eurasia, fourth in North Africa, fifth in Asia, seventh in the Northwest Pacific, eighth in North America, and ninth in sub-Saharan Africa and Latin America. In 1990, data suggests that an estimated 22 million hectares have been affected by soil pollution [6]. Due to the increasing awareness of Soil Pollution around the world, an increase of research conducted is shown in Figure 1.

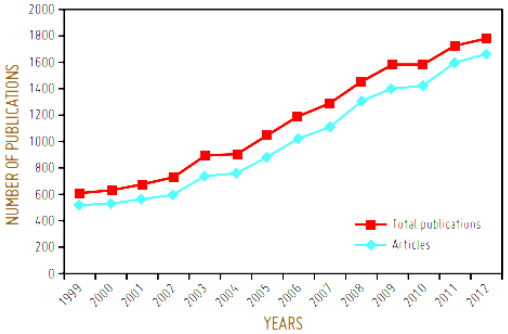


Figure 1. Number of scientific publications on soil pollution in the period of 1999-2012 [7]

2.1.2 Soil Contamination

According to ITPS (Intergovernmental Technical Panel on Soils), Soil Contamination is different from the term soil pollution. Soil Contamination is when the presence of a chemical or a substance at a greater concentration is not causing any dangerous effect on the environment. On the contrary, Soil pollution produces harmful effects on any non-targeted organism [7].

2.1.3 Soil Pollutants

2.1.3.1 Arsenic

Arsenic is one of the most dangerous substances that can be seen on the soil. An arsenic-contaminated soil can produce As-contaminated groundwater and As-containing food crops can cause poisoning to not only humans but any other life forms [8]. Arsenic can be removed by acids like aqua regia inadequate amount or by using neutral salt [9].

2.1.3.2 Zinc

Although Zinc is one of the substances that support life because it is an essential component of protein and other compounds, it is also a toxin to our body depending on the dosage of the exposure. Excessive intake of this results to diseases like leukemia [10].

2.1.3.3 Cadmium

Cadmium is a toxic non-essential substance that may be present in the soil. It is a by-product of zinc. Having this kind of substance contaminates both the soil and the water. According to the Department of Public Health, Catholic University of Louvain, Belgium, once absorbed by humans, it retains and can accumulate in a lifetime. The kidney is the primary target of Cadmium. It can also cause bone demineralization which leads to renal dysfunction [11].

2.1.3.4 Lead

Lead is the 36th in the element in order of its abundance. Leads that are seen in the soil can come from different sources like house paint and even Gas combustion. Although lead is a non-essential element in our body, exposure to it causes mental retardation [12]. Lead that is present in a human body can be measured in blood, and lead concentration above 0.25 mg/L is dangerous to humans and can cause effects on the central nervous system [13].

2.1.3.5 Selenium

Selenium may be beneficial to human health due to it being an antioxidant and reagent for the production of active thyroid hormone [14]. Selenium Pollution is another thing. This contamination can take place anywhere. This poses a risk to aquatic habitats and aquatic resources

because once the contamination spreads, curing this is almost impossible [15].

2.1.3.6 Nickel

Nickel is found in the Earth's Crust that is mainly composed of sulfide, oxide, and some silicate [16]. Although there is a minimum effect of nickel that came from the soil to the human body, there are some various effects of nickels that came from other sources to our body like allergic contact dermatitis [17].

2.1.3.7 Chromium

Chromium found in soil can be of any state. These substances stick to the soil and probably stay as sediments in the water. Chromium can either be essential or destructive to the human body. Long-term exposure can cause damage to the liver, kidney, nerve tissues, and skin [18].

2.1.3.8 Mercury

Mercury can be found as a heavy metal that occurs naturally in the environment. It was also often released via industrial activities such as coal combustion which one of the major causes of mercury contaminations. This heavy metal is most toxic in its alkylated form which is soluble in water and volatile in the air [19]. It is also proven that this heavy metal is a toxic agent to the human body. At a relatively low exposure level of inorganic mercury,

the effects observed were primarily renal and neurological [20]. The inorganic forms of mercury can cause damages to the kidney and lungs, and when transformed into methylmercury it can act as a neurotoxin that can damage brain functions [21].

2.1.4 Macronutrients

2.1.4.1 Nitrogen

Nitrogen (N) is involved in the photosynthesis of the plant. It is necessary to every process of plants such as protein production, enzyme, and metabolic process. It helps in refining the quality of the plant, fruit production, and plant growth [5]. The presence of Nitrogen in the roots is a factor for plant growth. Tons of N fertilizers were used for the increase of crop production globally. However, the plant-soil system lost nitrogen which can result in some environmental problems such as air and water pollution [22].

2.1.4.2 Phosphorus

Phosphorus (P) is one of the soil's primary macronutrients which are essential to plant growth. Phosphorus is the plants' catalyst in converting the solar energy absorbed from the sun into chemical energy providing the plant proper maturation and rapid growth [5]. Several processes such as the development of healthy root systems, uniform crop maturation, cell

division, etc. can be achieved with the presence of phosphorus in the soil. Phosphorus deficiency will produce smaller plants and the growth will be more slowly than those with adequate P levels [23].

2.1.4.3 Potassium

Potassium (K) is one of the nutrients absorbed by the plants in a large amount. It is responsible for the enzyme activation of the plants which affects the production of protein and starch and helps in energy metabolism [5]. Potassium regulates the plants' water usage, photosynthesis, stem strength, and protein synthesis. Plants that lack potassium develop slowly compared to soils or plants with enough amount of potassium content [23].

2.1.5 pH level in the soil

The pH level that is found in the soil can be measured by the concentration of hydrogen ions. This concentration of hydrogen ions is scaled from 0 to 14 with pH 7 as the neutral point to determine the acidity and alkalinity of the soil. Soil pH affects greatly the nutrients and growth of the plants. The nutrients found in the soil must first be dissolved for the plant to be able to absorb them. Some nutrients cannot be readily dissolved because of the acidity or the alkalinity of the soil. A high pH level soil or strong acid soil may be toxic to the plants because the concentrations of iron, aluminum, and manganese may be high. Although, some plants like blueberries can need strong acid soil to grow healthy. Having the soil at a neutral

point of pH range of approximately 6 to 7 makes all the nutrients available to be absorbed by the plant [24].

2.1.6 Spectroscopy

Spectroscopy is a fast, reliable, affordable, and non - destructive measurement technique that can be used to gauge the different soil properties without the use of chemicals in the process. Materials can be distinguished depending on the wavelength and frequencies that were measured using Spectroscopy. Spectroscopy has turned out to be important because of its capability to quantify the absorption of light beyond our eyes. Near-infrared spectrum in a range of 780 – 3200nm wavelength is renowned for analyzing minerals, plant materials, as well as the characteristics of the soil. Through spectroscopy, the soil is acknowledged based on its signature wavelength. The absorbance of incident light is maximum that will remarkably decide the composition of the soil [25].

2.1.7 Near – Infrared Spectroscopy

Near-Infrared Spectroscopy (NIR) is renowned for the benefits of fast analysis, high productivity, low price, and environment friendly. NIR has been broadly utilized in business about agriculture, crops quality analyzer, bio-medicine, etc. The operation of NIR is measuring the specific subject which utilized a light source to illuminate and analyze the reflected or transmitted light that conveys the data gathered on the subject [26].

2.1.8 Colorimeter

The colorimeter is a device used to measure and detect color in any test substance. It assesses the unknown color using the defined colors. The intensity of the color reacted from a chemical test is proportional to the concentration of the substance. This Colorimeter contains four colored light beams and four optical filters. One colored light beam passes through one optical filter in which only one color will be transmitted to the photodetector to measure the concentration [27].

2.1.9 Monochromator

The monochromator is a device that acts as a narrow band wavelength filter equipped with a mechanically adjustable transmission wavelength. A typical monochromator is displayed in figure 1 with two spherical mirrors, grating, and input and output slit. The light from the input slit will be reflected and collected in a spherical mirror. After being reflected into the spherical mirror, a flat wavefront will be directed into the grating. From the grating, a diffracted light will be collected by the second spherical mirror and then reflected into the output slit [28].

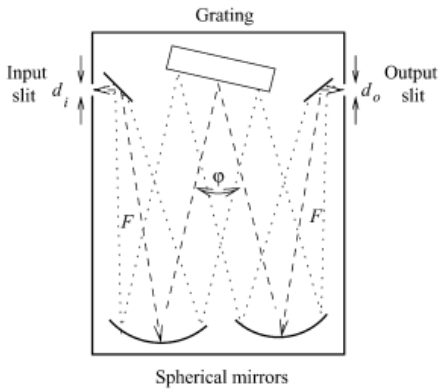


Figure 2. Monochromator Optical Scheme [28]

2.1.10 Microcontroller

2.1.10.1 Raspberry Pi

Raspberry pi is a microcontroller based on Linux OS. It has various versions depending on its functionality and added features. It consists of a Broadcom system with ARM compatible central processing unit (CPU) and on-chip graphics processing unit (GPU). The platform is composed of Wi-Fi, Bluetooth, and USB boot features. The main feature of raspberry pi is that it has 40 general-purpose input/output (GPIO) pins which allows the platform to connect with custom electronics, usually, sensors. It also uses an SD card for OS loading and data storing [29].

2.1.10.2 Arduino

Arduino is an open-source microcontroller that analyzes and processes analog and digital input signals. It is compatible with any other developed platforms making multi microcontrollers possible. It uses a maximum input supply of 5.5 V, low electrical power, and C and C++ as its operating language in its integrated development environment (IDE). Since Arduino is an open-source platform, programs or codes are easily uploaded to the board via USB [30].

2.1.11 Internet of Things

IoT or Internet of things is an interconnection of devices that has access to the internet. Objects equipped with many sensors that were in line with modern

technology can be automated and it is a network of devices with different sensors that were connected in a single device through the use of the internet [31]. It became popular because of its potential for future advancements in technology. Since mobile phones are extremely common nowadays and with the improvement of different high-end phones, the multiple uses of many sensors can be controlled by a single device required for Internet of Things. The idea of Internet of Things was theorized more than a decade ago, since then, it is becoming more of a reality because of quick advancements and innovations on wireless sensor networks. The addition of the Internet and the rising innovations such as built-in sensors in technologies could enable us to change objects that can be seen in our everyday lives into so-called 'smart objects' that can respond to certain conditions [32].

2.1.12 Python

Python is open-source software that is capable of high-level programming language. This programming language was created and first used by Guido van Rossum in the late 1980s and is still currently used by various large companies and organizations as well as Google, Yahoo, NASA, etc. Similar to other programming languages, Python is used to create different programs, web applications, graphical user interface (GUI), and even games. This powerful language is commonly used because of its simple syntax and codes making it one of the easy languages to learn. This language works on different platforms like Windows, Linux, Mac OS, and even in microcontrollers [33].

2.1.13 Beer-Lambert Law

Beer-Lambert Law explains the direct relationship between absorbance and concentration. This relationship makes it possible to be used as a model for spectra. This law states that the length of the light path (**l**) through the sample is directly proportional to the concentration (**c**) of the solution in the sample. The light intensity is denoted by (**I**) and the initial light intensity by (**Io**) The absorbance (**A**) of the light is can be solved by using Equation 1 [34].

$$A = \in \cdot l \cdot c = \log_{10}\left(\frac{I_o}{I}\right)$$

Equation 1. Beer-Lambert Law Absorbance-Concentration Relationship [34]

Whereas ∈ or the extinction coefficient is the proportionality constant and called the absorptivity [34].

2.1.14 PostgreSQL

PostgreSQL is open-source software that offers a free database system. It uses Relational Database Management System (RDBMS). This database is used for data processing like storing, retrieving, and updating a large amount of data. It allows the user to mix and match libraries from different programming languages [35]. It is widely known for its architecture, reliability, data integrity, and is a free or open-source project. It can be used to create databases for applications, to protect and access data easily no matter the size of the dataset. It is also known for its extensibility in defining the data types, building custom functions, and incorporating code from a different programming language. PostgreSQL can also

run on different platforms including Windows, Linux, Unix, Solaris, and even MacOS [36].

2.1.14.1 PgAdmin

PgAdmin is an open-source management tool used for PostgreSQL. It is used as an administration and development platform not just by the PostgreSQL versions but also other derivative relational databases such as the Enterprise DB's EDB Advanced Server. This management tool can be run in either web or desktop application. This offers a huge array of features such as multiplatform capability, extensive documentation, multiple deployment models, and other tools that can be used in databases [37].

2.2 Related Literature

2.2.1 Automated Soil Nutrient Monitoring for Improved Agriculture

The proposed model detects the soil macronutrient using different sensors and produces an output together with the soil recommendations that are sent over to their mobile phones. Factors like climate, minerals, soil nutrients, etc. determine agricultural yields. From these factors, soil nutrients are the only factor that can alter the agricultural yield. The key factor to determining the soil condition is the pH level. Nitrogen is the principal nutrient that can increase soil pH Nitrogen is one of the principal nutrients for soil monitoring which should be tested often. Phosphorus can help in agricultural yield and the overall development of the plant is caused by the potassium present in the soil. The model proposed measures the

nutrient content, and then sends the measured data to the nearest Crop Research Institute, then the CRI sends the recommendation that fills the gap in the soil [38].

2.2.2 Crop Recommendation System for Precision Agriculture

Indian Farmers face a productivity setback because they don't select the right crop according to their soil needs. To lessen the wrong decisions most farmers make, precision agriculture is used. Accurate agriculture is a modern agriculture technique, using research data on soil types, soil characteristics, collection of data, and providing farmers with the right crops according to their locations. Plant recommendation depends on different parameters. Precision agriculture is concerned with location-specific identification of such parameters to solve problems with the selection of crops. However, it is important in agriculture that these recommendations are accurate and precise, as failure can lead to a heavy loss of capital and material [39].

2.2.3 A New Approach to Detect Soil Nutrient Content Based on NIR Spectroscopy Technique

Near Infrared Sensor (NIRS) can be helpful for the accurate and precise application of farming principles. NIRS can be combined with Geographic Information System (GIS) as a rapid technique. Nitrogen (N) and Organic Matter (OM) of a loamy mixed soil can be assessed using different techniques. Near infrared spectroscopy is a good potential for the assessment of the two nutrients of the soil [40].

2.2.4 Automatic Soil Nutrient Detection and Fertilizer Dispensary System

A prototype was developed that restores the soil nutrient mainly the Nitrogen, Phosphorus, and Potassium levels. The nutrients present in the soil is measured using chemical process and sensors such as color sensors, solenoid valve, relay and motor which was also used in developing the robot's automated system. The study introduced by the system results in a shorter period of time in obtaining the nutrients and reduced manual labor in restoring the soil nutrients compared to the manual soil testing. Microcontroller is used to analyze the data after using the sensors for the obtained results from the soil test. The estimation of the nutrients to be added for the soil to remain fertile is calculated by the prototype in few seconds. The prototype has small containers holding a little amount of fertilizers for the soil. This will result in a smaller farm or area to be tested and fertilized. The robot must have a container that is appropriate to the area that will be using it [41].

2.2.5 Crop Prediction Using Predictive Analytics

The study constructed a model to test the fertility of the soil. The model is composed of different sensors wherein the values obtained are used to suggest the crop to be planted in a particular soil and the fertilizer to be added to the soil for the crop productivity to increase. A graphical regional wise information about the crops are also provided by the system in this study. It has an application where the farmers or the users will have to register, and they can share and get ideas from the experts. This helps the farmers to easily understand the fertility of their yard and choose the better crop to achieve the increase in crop yield and profit. Nearby fertilizer shops

are also provided by this application along with the information about the fertilizer to be added to the soil [42].

2.2.6 Spectroscopic Detection of Health Hazardous Contaminants in Lipstick using Laser Induced Breakdown Spectroscopy

LIBS or Laser Induced Breakdown Spectroscopy System was used to determine the concentrations of various toxic contaminants, such as lead, chromium, cadmium, and zinc, in different lipstick brands in Saudi Arabia. These elements' concentrations are beyond the safe limits which could result in serious health problems due to the increase in metal levels that one's body cannot contain. The sensitive lines of the toxic contaminants were identified with the use of the National Institute of Standards and Technology (NIST) which provided the standard data for each contaminant. The study used an inductively coupled plasma spectrometer (ICP) as the standard method for the evaluation of the measured concentrations of toxic contaminants [43].

2.2.7 Design and Implementation Soil Analyzer Using IoT

A portable remote data acquisition system combined with new-generation digital sensors could gather results from wider locations. IoT is used for uploading the data acquired from soil testing of the portable handheld device implemented in this study. The system will serve as a microcontroller where different sensors are connected. Bluetooth serial communication is used to transmit the data obtained by the sensors used in the device and the mobile application uploads the data to the

server for analysis and comparison. This study will result in large data collected for the farmers or users who can send the statistics directly to the server [44].

2.2.8 Investigating Soil Pollution with the Aid of EMI and GPR Measurements

The detection and delineation of soil pollution without invasion remains largely experimental. The provision of sufficiently comprehensive information is often lacking for single solar sensor methods. The researchers therefore used a combination of the electromagnetic induction (EMl) multi - receiver system for measuring apparent electrical conductivity (ECa) and the GPR, which is operated over a frequency range of 50 to 1500 MHz with 13 antenna pairs of 1-meter wide antenna array. They concluded that a combination of EML and GPR signals could supplement invasive soil pollution field studies. EMI and GPR's combined use to detect oil contamination in soils is promising. However, further research is needed in order to identify soil pollution in higher concentrations by oil constituents with the combination of EMI and GPR sensors [45].

2.2.9 Sampling and Coding of Soil Environmental Quality Data for Pollution Control

Because of the urbanization life and industrialization in the past centuries, health hazards to humans and other forms are needed to be solved regarding soil pollution. The paper focuses on the coded soil environment quality data (SEQD) and its properties. To analyze the samples, a coding process was developed that

combines soil zoning code with the code for a soil profile. Eventually, there was an experimental survey to show the feasibility of the solution proposed. The SEQD in the database contains soil profile data that are taken from soil samples, environmental background data, polluted samples data in key areas, and assessed data in different methods. The researcher proposed to combine soil zoning code and soil profile code with soil profile code through an analysis of the soil types and properties [46].

2.2.10 Assessment of the Geo-accumulation Index on the Soil Pollution by Heavy Metals in the Shuangqiao River Basin

Field Environmental research and soil sample collection of the Shuangqiao River Basin indicates that the soil content of heavy - metal products of Hg, Pb, Cd, Cr, As, Cu, Zn has been analyzed and the geo-accumulation index has assessed soil pollution. In the area under examination, Hg is the most important soil pollutant. The average level of pollution of Hg is higher than degree 2, which is moderate. Second is the Pb, Cd. Cu and Zn are of grade 1 on average and also have no moderate levels of pollution. The main sources of pollution on the banks of a river are a small quantity of mercury, small roasting cyanide pools, little floats, and helter-skelter stacked resins. Soil pollution through heavy metals will certainly impact the quality of plants and must be strengthened in the treatment of “Three-wastes” and in the remediation of the polluted earth and ensuring soil safety and protecting the human condition is extremely important [47].

2.2.11 The Pollution Degree of Heavy Metals to City Soil Environment

Human activities have a growing impact on the city's environmental quality as the economy develops rapidly and the population increases. Environmental and human life issues are in great connection, as human health is at risk if the environment is contaminated.

The pollution from heavy metals is very harmful to the environment. The analysis applies the Nemerow procedure for the study of the five areas in which the pollution of 8 kinds of heavy metals by heavy metal measured by the GPS is carried out based on the city surface soil data. Environmental pollution by harming heavy metals mainly refers to the toxicity of heavy metals such as Zn, Cu, Co, and other pollutants, including those with obvious biological toxicity of Hg, Cd, Pb, and Cr. Heavy metal sources exogenous sources include industry, agriculture, transport and energy, mining, metallurgy, and different manufacturing activities.

Table 1. The heavy metal pollution effect of different area and pollution level evaluation [48]

Function division	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	*Pz*	Pollution Level
Living area	0.42	1.61	0.68	1.21	0.08	0.46	1.13	1.66	1.47	Light Pollution
Industrial zone	0.52	1.03	0.63	1.12	0.41	0.44	1.08	1.07	2.608	Medium Pollution
Mountain area	0.27	0.81	0.43	0.50	0.04	0.37	0.90	0.73	0.69	Clean Pollution
Traffic area	0.40	1.92	0.60	0.03	0.37	0.43	1.11	1.77	2.669	Medium Pollution
Park area	0.42	0.90	0.57	0.01	0.13	0.33	1.04	1.23	1.18	Light Pollution

In urban regions the entire content is Cd > Hg > Zn > Pb > Cu > Cr > Ni > As. The pollution source analysis of the type of heavy - metal pollution in urban

soil reveals that in the distribution of pollution in the urban soil, there are eight types of heavy metal (i.e., Cd, Hg, Pb, Cr, As, Cu, Zn, and Ni): the space distribution covers the roadsides, the city center and the main plaza of human activities with traditional industrial areas [48].

2.2.12 SenSoil: Development of an IoT-Based Soil Macronutrient Analysis System Utilizing Electrochemical Sensors and Machine Learning Algorithms

SenSoil develops a device that can measure and analyze the macronutrient content of the soil. Using a lysimeter, a soil sample was collected and fed into the device. The device contains an Ion Selective Field Effect Transistor (ISFET) and Soil Moisture sensor that is connected to the Arduino via Analog Read-out Circuit which measures the amount of soil macronutrients. A Machine Algorithm was used for the predictive model correlating the macronutrients, pH, and moisture level. The data acquired will be displayed on a Tablet PC. The device is equipped with the Internet of Things or IoT in which the data was sent into a host. The host contains a database that displays all the data acquired by the device. A website is created to access the database [49].

2.2.13 SoilMac.pH:Arduino-based Automated Soil Macronutrients and pH level Analyzer using Visible-Near Infrared Spectrometer and MatLab Simulink

SoilMac.pH is a device that measures soil macronutrients and pH levels and provides recommendations on the amount of fertilizer for the crops. This study aims to lessen the time of analyzing the soil nutrients. The soil sample is placed in a cuvette and fed into the device. The device uses Visible Near-Infrared (VIS NIR) Spectroscopy and Beer-Lambert's Law Absorbance-Concentration Relationship to identify and measure macronutrients. It will test the concentration of the soil by the light absorbance of the soil sample. The data gathered will be displayed in a touchscreen LCD with a built-in GUI. The user will enter the type of soil used to provide the fertilizer recommendation. The results can also be printed using the thermal printer [50].

2.2.14 Human Health Effects of Heavy Metals

This research aims to determine the level of the toxicity of heavy metals. The eight common heavy metals namely Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, and Silver were studied to determine the effect of these metals on human health when ingested or inhaled. Arsenic, a naturally occurring heavy metal that can be found in dyes, drugs, soaps, etc. This heavy metal can cause cancer of the skin, lungs, liver, and bladder. Also, a decrease in red and white blood cells may happen. Ingestion of the said heavy metal can result in death. Barium, a heavy metal that can be found in paint, ceramics, rubber, etc. It can cause diarrhea,

increase in blood pressure and hear paralysis. Cadmium is a very toxic metal that can be found on batteries, metal coatings, and plastic. Damages to the lungs, kidneys, and bones are the possible health effects of this heavy metal. Ingestion in a very high content may lead to vomiting and diarrhea. Lead is a heavy metal that can be found in batteries, ammunition, solder, gasoline, etc. Exposure to this heavy metal can damage the brain and kidney. It may also cause miscarriage. Chromium is a heavy metal found in rocks, soil, and plants. This heavy metal may cause asthma, nose ulcer, skin ulcer, and damages to the kidney and liver. Mercury, a heavy metal that can be found in thermometers, light bulbs, and batteries. It can cause damages to the brain and kidney. Lung damage, nausea, diarrhea, and an increase in blood pressure may also be observed when exposed to this heavy metal. Selenium a heavy metal found in rocks and soil. Exposure to this heavy metal may result in diarrhea, selenosis, and bronchitis. Silver a well-known heavy metal that is used in pieces of jewelry, silverware, and electronic equipment. This heavy metal causes argyria, breathing problem, and allergic reactions when exposed to a high level [51].

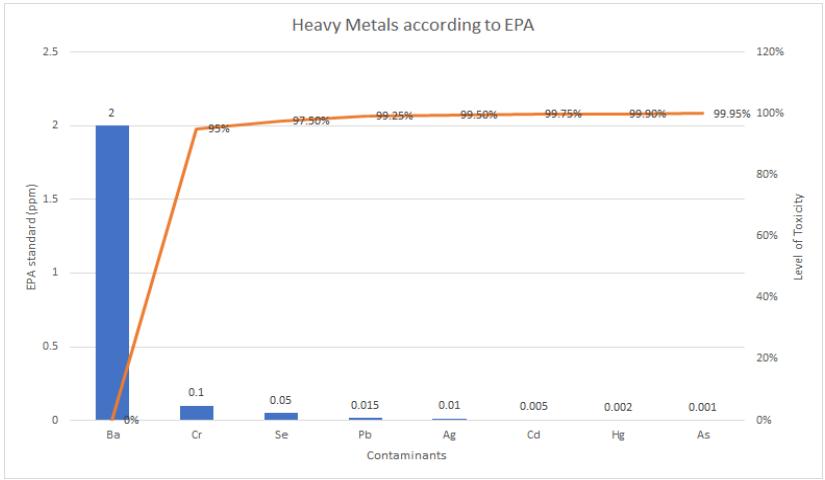


Figure 3. EPA standards and Level of Toxicity of the heavy metals

2.2.15 A Sensor Device for Measuring Soil Macronutrient Proportion using FPGA

Continuous soil cultivation must be accompanied by a constant fertility valuation check for sustainable agriculture development. The proportion of the nutrients is assessed in these laboratories simply by observing the color of the soil solution in response to the reagent. But the results were inaccurate. For proper plant growth and effective fertilization, measuring of soil nutrients is very important. The paper suggests an independent device that follows the same method as that carried out in these laboratories for the measurement of soil macronutrients, however the colors are detected precisely by photodiodes [52].

2.2.16 Review on Determination of Macronutrients from Compost

Ineffective nutrient input management has greatly reduced environmental and human health Also, the unregulated use of fertilizers in Nitrogen and Phosphorus has led to pollution of soil water. Farmers must therefore take a close look at the management of nutrients and add to their farming techniques the concept of equitable plant nutrition. Primary soil nutrient levels are needed to determine how much additional soil content should be added to increase crop fertility. In the decision - making process, information on the inconsistence of various primary nutrients in compost is important. This paper focuses on the examination of existing nutrient status methods and techniques and attempts to compost gas sensors to measure nutrients in compost [53].

2.2.17 Test Implementation of a Sensor Device for Measuring Soil Macronutrients

The sustainability of agriculture can be jeopardized by continuous cultivation without adequate soil nutrient measurement. For proper plant growth and effective fertilization, soil nutrient measurement is very important. However, soil tests are timely and costly in laboratories. In this study, investigators developed a high - precocity, broad-spectrum photodiode (PD) sensing system for measuring macronutrients in soil, low - spectral width Light Emission Diode (LED) microcontroller, and an analog-digital converter (ADC). The experimental samples are taken from different agricultural areas and the results of the tests after laboratory analysis are compared with those obtained in a color chart. The results from the system provided are consistent with the laboratory results [54].

2.2.18 Automatic Soil Nutrient Detection and Fertilizer Dispensary System

Soil fertility is an essential measuring factor in soil quality, indicating how much it can sustain plant lives. Macro and micronutrient amounts, water, pH, and others determine the soil fertility. Fertilizers are added to soil to preserve nutrient levels in the soil in case of deficiency. Most farmers choose to estimate and manually add the amount of fertilizers. The research is designed to restore nitrogen, phosphorus and potassium concentrations in the soil by measuring the nutrient level in the soil. The presence and quantification of nutrients are based on using sensors and chemical processes [55].

2.2.19 SoilMATe: Soil Macronutrients and pH Level Assessment for Rice Plant through Digital Image Processing Using Artificial Neural Network

Soil Macronutrients and pH level are very essential for the plants' growth especially those of rice plants. The four parameters of the soil namely: Nitrogen (N), Phosphorus (P), Potassium (K), and pH, were identified with the use of a digital image processing technique and implemented in the Philippines' farmland. Artificial neural network (ANN) is used to complete image processing with high speed and accuracy on its performance. The system is composed of four phases, the acquisition of images, the image processing, the training system, and the printing of results. The study generates a printed report of the system analysis wherein the results obtained were listed as well as the amount of the fertilizer to be applied and when it is best to be applied. Through the use of MatLab, the system was successfully implemented and proven of its 98.33% accuracy for the inbred rice plant [56].

Chapter 3

METHODOLOGY

3.1 Theoretical Framework

In the study entitled *Assessment of the Geo-accumulation Index on the Soil Pollution by Heavy Metals in the Shuangqiao River Basin*, soil contaminants in a river were determined. Results show that the Hg, Pb, Cd, Cr, As, Cu, Zn are the main heavy metals in the soil. Arsenic, Cadmium, Lead, and Mercury is known to be hazardous chemicals and must be observed to be at a low level. The study *SoilMac.pH: Arduino-based Automated Soil Macronutrients and pH level Analyzer using Visible Near-Infrared Spectroscopy and MatLab Simulink*, the soil was illuminated, and the light absorbance was measured. The acquired data were converted into concentration using the Beer-Lambert's Law. From the study *SenSoil: Development of an IoT-Based Soil Macronutrient Analysis System Utilizing Electrochemical Sensors and Machine Learning Algorithms*, the soil data gathered by the sensors was sent to a host that contains a database using IoT. The data can be displayed and accessed on a website. In the study *SoilMATe: Soil Macronutrients and pH Level Assessment for Rice Plant through Digital Image Processing Using Artificial Neural Network*, the soil macronutrients, and pH level were determined with the use of digital image processing and an artificial neural network. The captured image undergoes four processes; image acquisition, image processing, training system, and result. An artificial Neural network was applied to obtain results accurately and immediately. Using MATLAB, the results obtained from the 448 captured images were proven to be 98.33% accurate.

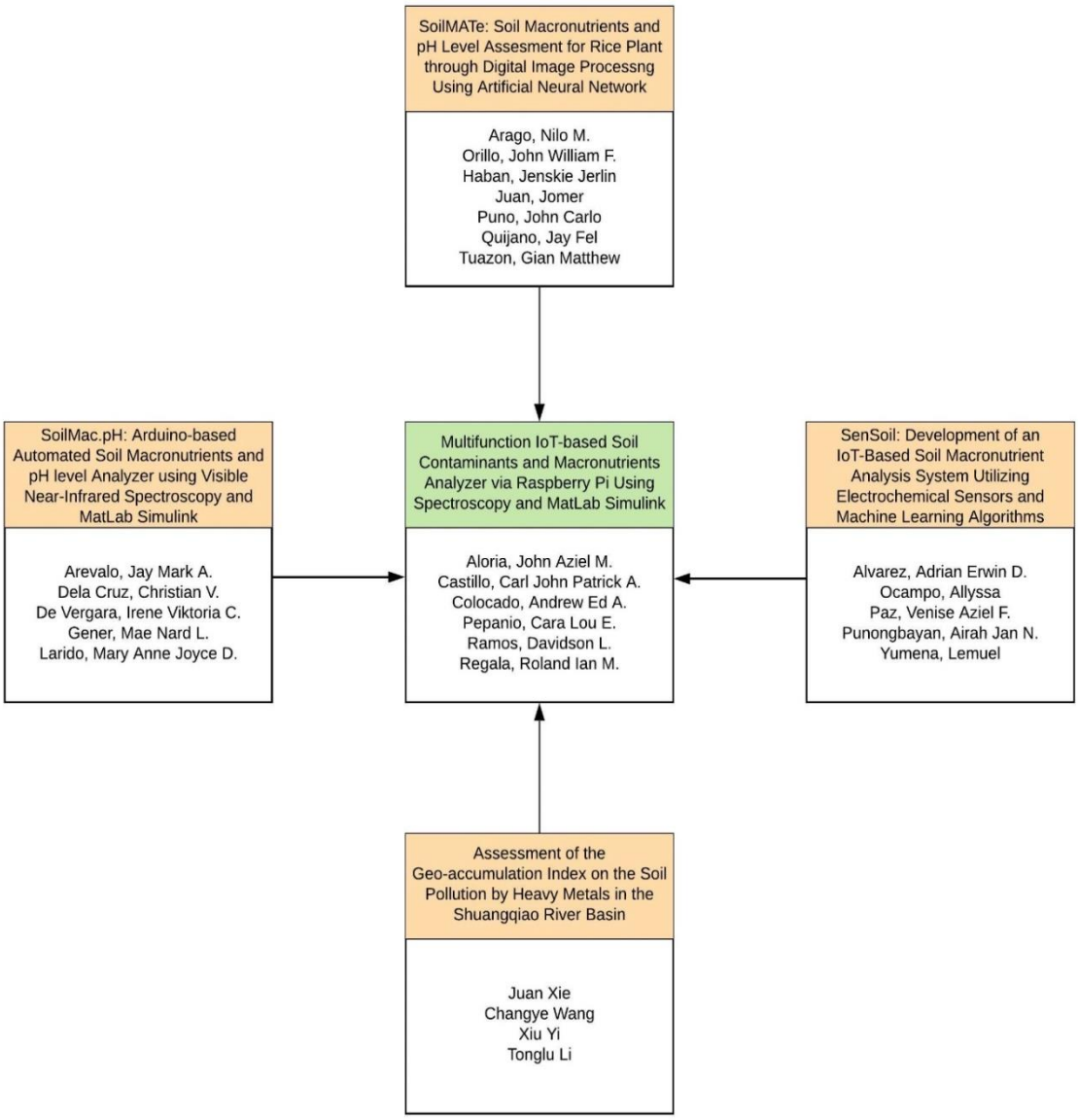


Figure 4. Theoretical Framework of the Study

3.2 Conceptual Framework

Figure 5 shows the system of the study including the inputs, processes involved, and the expected outputs and results. Soil samples from agricultural land undergo chemical processes and measure the amounts of macronutrients and pH levels present in the soil. On

the other hand, underwater soil samples undergo chemical processes including Arsenic, Cadmium, Lead, and Mercury extractions. The results were stored at PostgreSQL Database for future references and the expected outputs are the precise amounts of either soil macronutrients and their crop recommendation or soil contaminants and their corresponding soil treatments depending on the mode set.

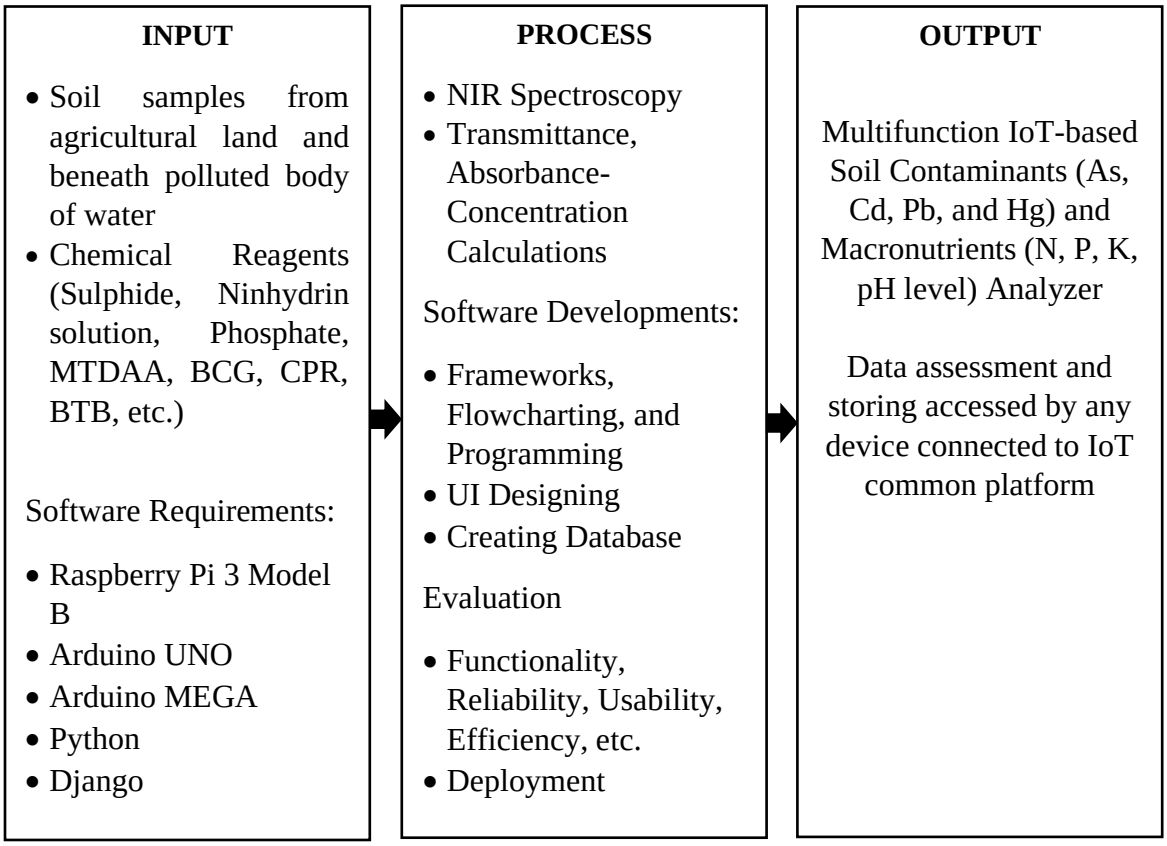


Figure 5. Input-Process-Output (IPO) Model

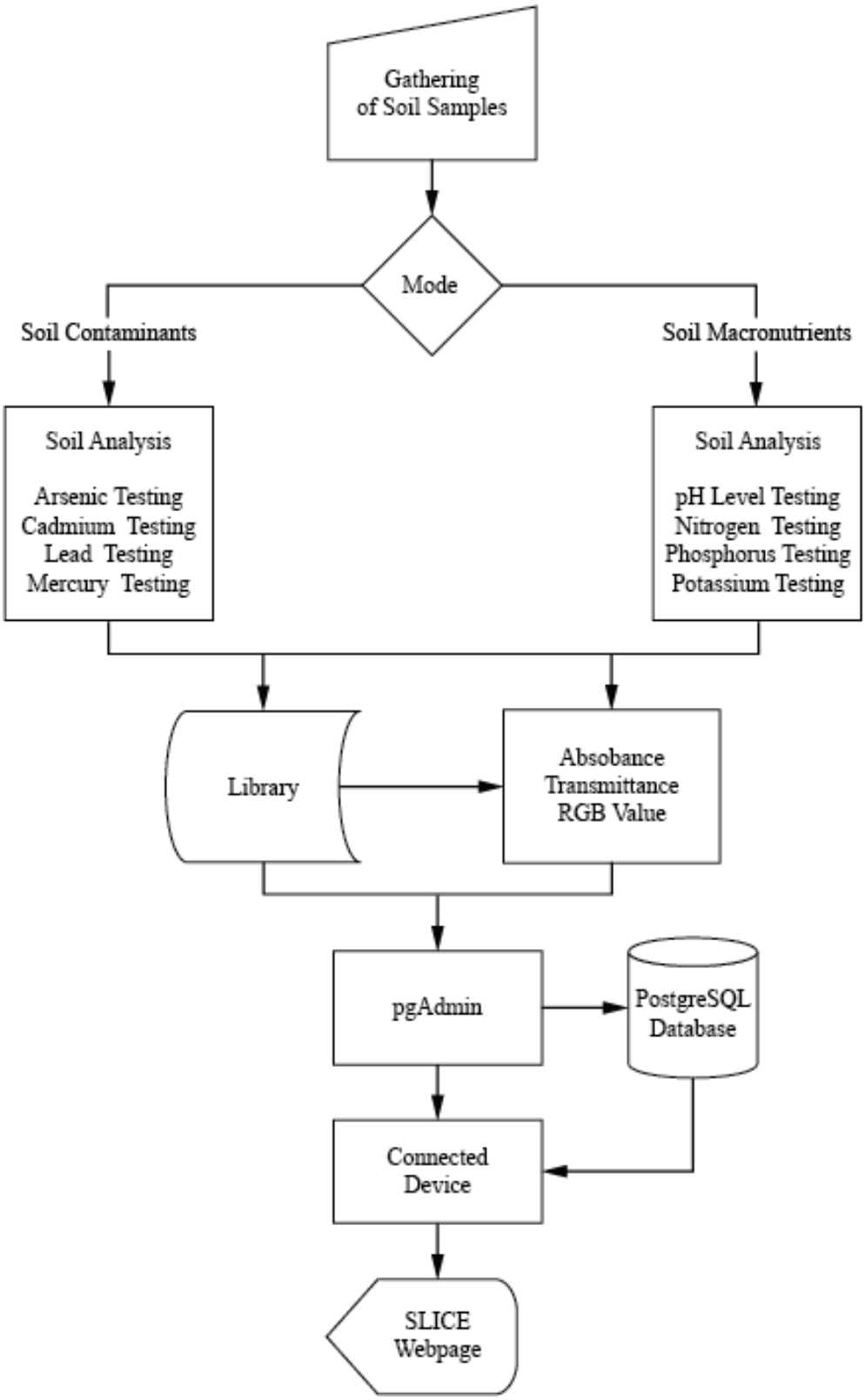


Figure 6. Block Diagram

Soil contaminant and macronutrient analysis undergo an organized system following the SoilMac.pH using spectroscopy. The system has 2 modes, Macronutrient Analyzer and Contaminant Analyzer, and is composed of different process sections: data acquisition, spectrometry, Beer-Lambert's law application, storage, access, and outputs.

Data acquisition retrieves wavelengths or colors from a light source passing through the soil samples. The data will then be received by the sensor and processed by Raspberry Pi. Spectrometry is responsible for light intensity absorption and RGB conversions that serve as inputs. The data will be interpreted and analyzed according to the given color standards.

Beer-Lambert's law will be applied to the gathered data for absorbance and transmittance values. These data will be fed to the Raspberry Pi through Python. The results will be provided as a scale spectrum that will provide the macronutrients' or contaminants' concentrations following Beer-Lambert's law.

Access was provided by the IoT common platform which enables data to flow through different networks and to simulate at the same time. Results will be fed to all connected devices. Outputs will then be displayed on the webpage and provide soil recommendations and treatments.

Surveys and interviews will be conducted by the proponents to identify specific problems and significant factors affecting the community. The prototype device will be constructed, and the results will be interpreted by PgAdmin, displayed through the webpage, and verified with the conventional methods through a 3rd party testing laboratory, Nanotech Analytical Services and Training (NASAT) Labs – Water and Environmental Testing Laboratory.

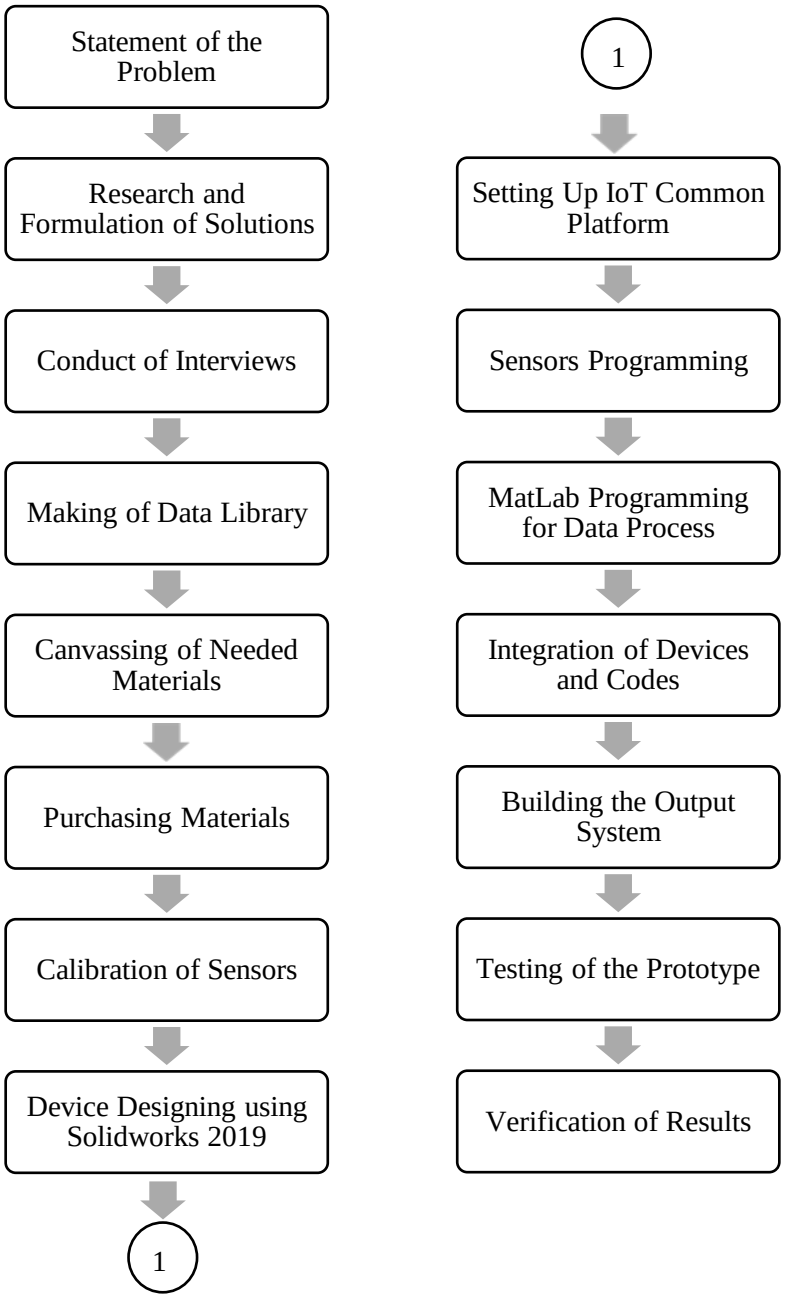


Figure 7. Research Process Flow

3.3 Research Locale

The polluted river in an urbanized place in Metro Manila and a farm in a provincial area were the two locations for the testing and analysis of the device. Magdaong River is a

stream in Muntinlupa City, NCR, located at an elevation of 5 meters above sea level. This body of water drains the water from Muntinlupa and dumps the water into Laguna de Bay. The local government unit (LGU) came up with a Clean Up Drive project to resolve the contamination of the river. However, the said river remains polluted and found no improvement even after several attempts of the solution clean-up drive. One successful invention called the Vigorimin product improves wastewater by absorbing pollutants and bioremediation. It manages the pH level of the water but the solution on the polluted stream in Manila has failed to remove the stench [57]. Thus, a high probability that the soil at the bottom of the said body of water is the reason for the pungent smell. The study aims to help the community determine the number of heavy metals that contaminate the soil underneath a body of water also known as sediment and provide a recommendation for treatment. On the other hand, Mango Farm in San Luis, San Carlos, Pampanga is used for the device's macronutrient analysis. The study is to help the farmers determine the nutrients of the soil in a more efficient way and low-cost than traditional and laboratory analysis and recommend crops appropriate for the nutrient content of the soil. The experiments will be implemented in the said two locales and will be evaluated by particular farmers for future improvements and developments of the study especially the accuracy of the device.

3.4 Research Design

3.4.1 Software Design

The system software will be programmed using Raspberry Pi 3 Module B through Python for absorbance, transmittance, and RGB calculations. The multimode device outputs will be displayed through monitors and to any device

accessing the IoT common platform. This will enable all the users to monitor the results in real-time provided with a user-interface. The soil analysis will be controlled and implement by the device automatically. Django and PgAdmin will be used to generate numerical information of the soil samples using the data gathered from the linear CCD sensors.

USB powered light source will be used as the light source in the device for a more precise light reception. The light will be separated to its corresponding wavelengths through a lens and mirror which is inclined to a specific angle for the wavelength selection called the monochromator. The transmittance data will be measured by the image sensor through Raspberry Pi and will be converted to absorbance using Python functions. This will then be converted to RGB as a data stream and analyzed as integers. The processed data would fall through the predetermined ranges indicated on the library producing desired results. As Raspberry Pi being the common platform, IoT was then developed via WiFi.

Figure 8 shows the detailed processes undergoing in each section. Four soil samples will be placed in a thin rectangular glass prism with four compartments which will be mounted to the built-in soil mount in the device. Chromogenic reagents will be applied to each soil sample extracting Arsenic, Cadmium, Lead, Mercury contaminants, Soil macronutrients (NPK), and pH level, respectively.

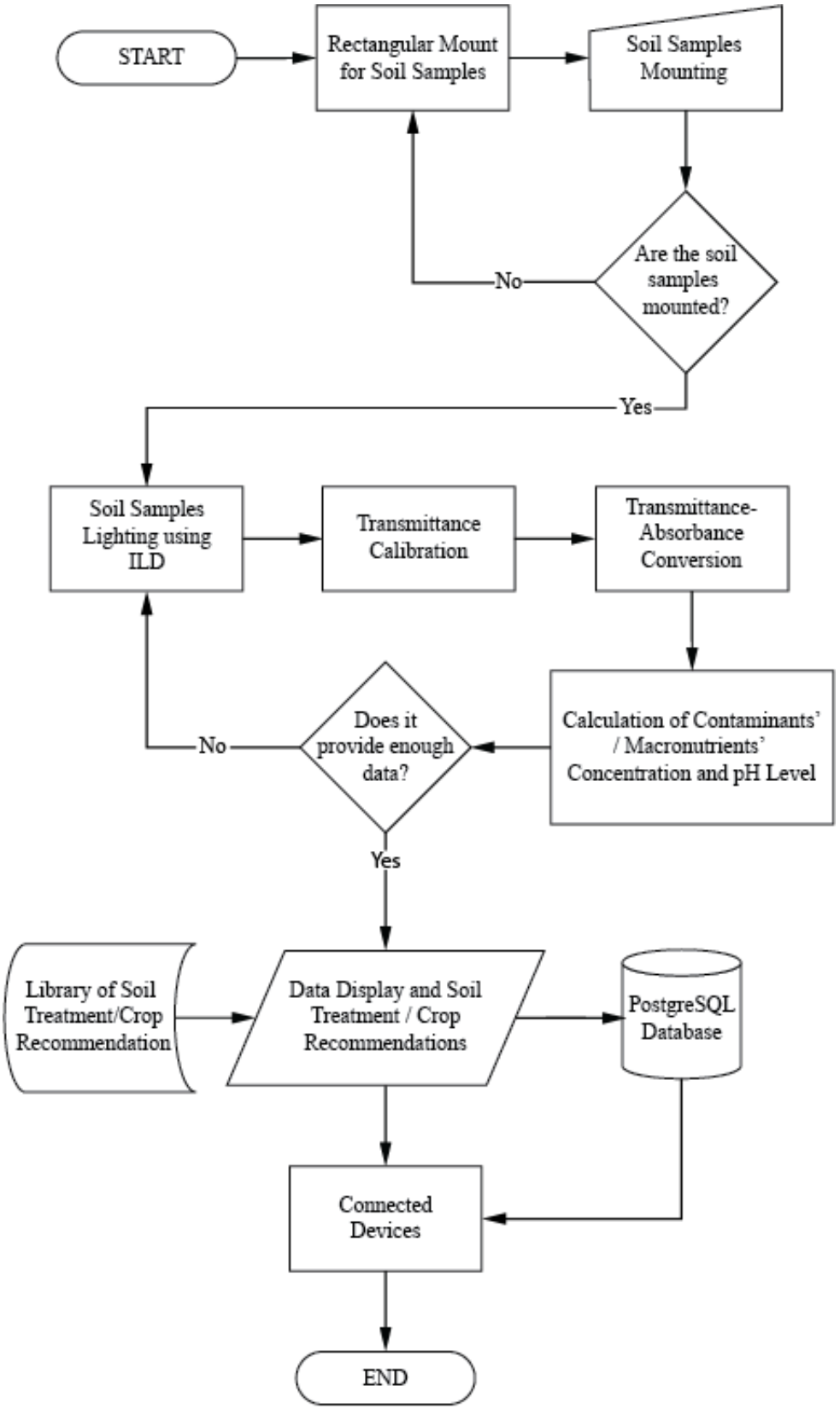
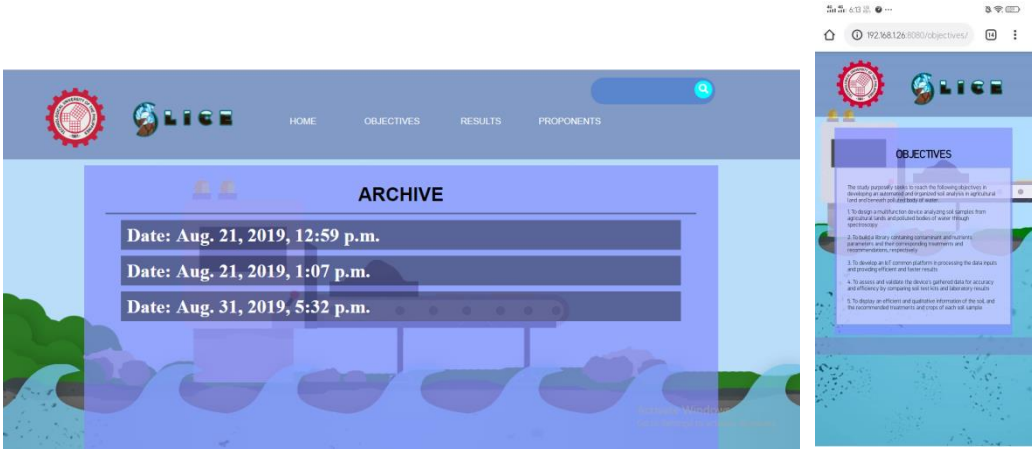


Figure 8. Process Flowchart

3.4.1.1 Web Design

A mobile app and a website will be used to display the results giving all the necessary data of the soil sample processed such as date, location, etc. This will make all the process convenient and economical for the users. With the admin's permission, connected devices will be allowed to run the device wirelessly. WiFi will be provided to ensure the connections of the device and mobile phones. Figure 9 shows the interface of the webpage on desktop and mobile mode.



(a) (b)

Figure 9. (a) Webpage Interface; (b) Mobile Interface

3.4.2 Hardware Design

3.4.2.1 Schematic Diagrams

The spectrometer will be designed using Solidworks 2019 for precise construction and visualization. The device will be composed of ILD for the light source, monochromator as the selector, soil samples compartment prism, CCD sensor as the detector, and amplifier to be utilized

and processed by Raspberry Pi 3 B microcontroller. This will provide initial outputs to the system UI to the provided laptop and will be fed through all the connected devices. All switches and outputs will be monitored by Raspberry Pi feeding through the common platform.

Figures 10 and 11 show the hardware designs of the soil samples mount and the actual device frameworks, respectively, to further visualize the device.

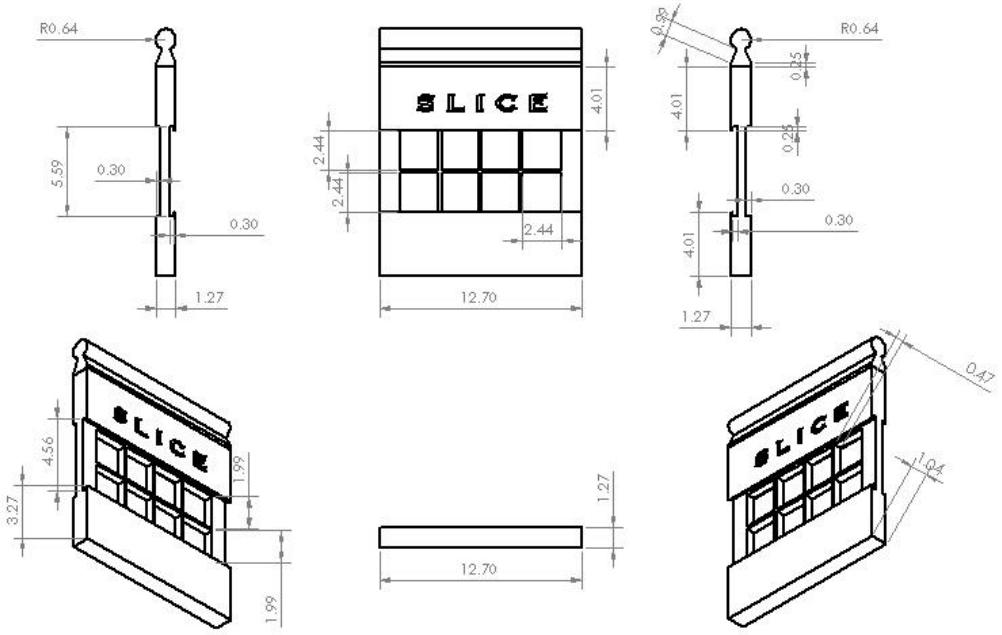
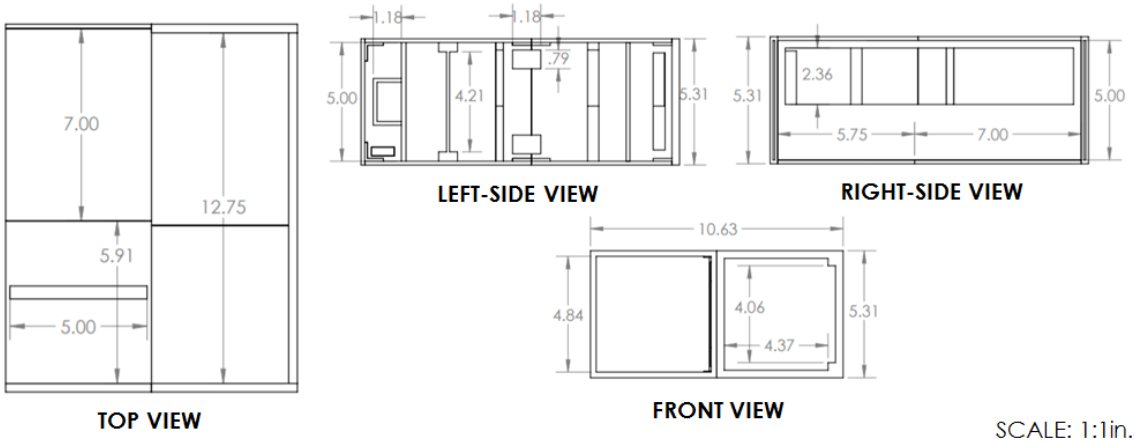
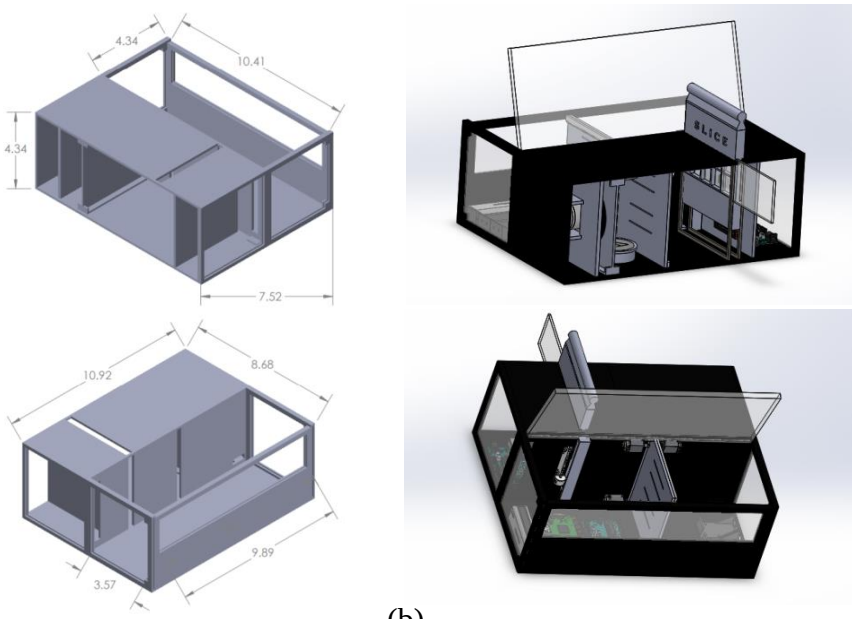


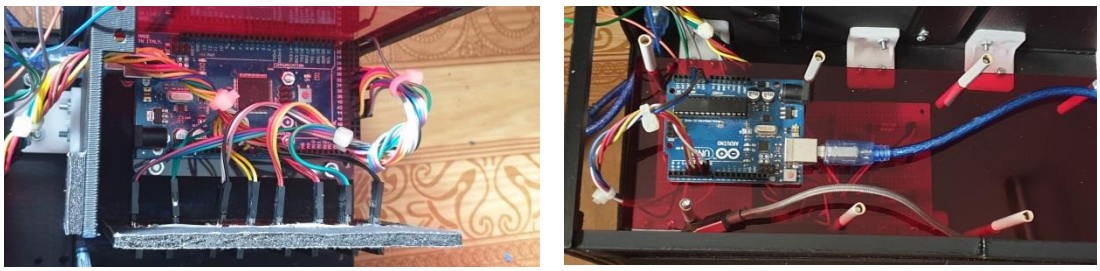
Figure 10. Soil Sample Mount Detailed Design



(a)



(b)



(c) (d)

(e)

Figure 11. (a) Schematic Designs; (b) Isometric Designs; (c) Actual Sensor Driver with Wiring; (d) Actual Motor Driver; (e) Actual Device

3.4.2.2 Calibration of Sensor

The Linear CCD Sensor, TCD1305 must be calibrated to acquire the desired values. These values depend on how much the light source could give off light waves corresponding to the wavelength needed. Figure 12 shows the calibration of maximum light waves in different wavelengths. The calibrated values will be used to create a precise data range in calculating transmittance and absorbance using Beer-Lambert's Equation as shown.

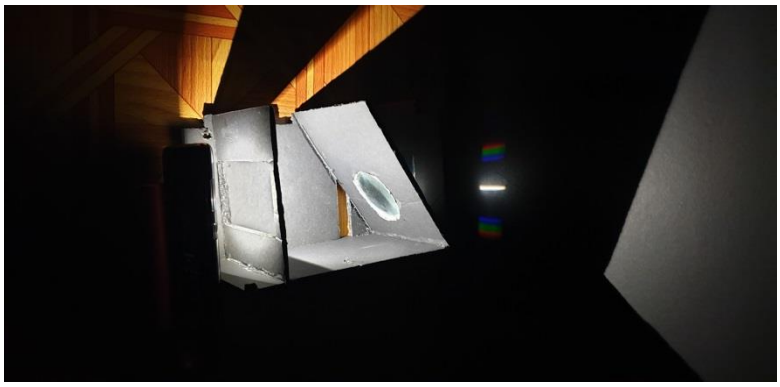


Figure 12. Wavelengths Calibration

$$A = \log_{10}\left(\frac{I_o}{I}\right)$$

Equation 1. Beer-Lambert Law Transmittance-Absorption Relationship

Figure 13 shows the on board driving and calibration of four TCD1304AP CCD sensors. The set up was based on the datasheet provided by the manufacturer of the said sensor but was modified to make the circuit compatible for Arduino in higher bitrate inputs and outputs.

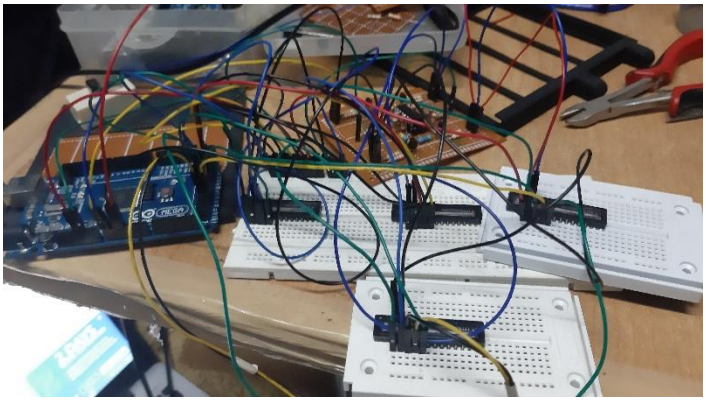


Figure 13. On-Board Calibration

Four soil samples will be illuminated using USB powered LED creating predetermined wavelengths by the chromogenic reagents. The color reflected by each soil sample will be fed to the TCD1304 driven by Arduino ATMEGA producing data streams.

The data streams are received by Raspberry Pi interpreted as numerical data. These data will be further converted as absorbance using the Beer-Lambert law. The absorbance-transmittance relationship will determine the concentration of specific parameters in the soil sample as milligram per Liter (mg/L). The processed data would fall through the predetermined ranges programmed in the library using Django creating desired results.

3.5 Statistical Treatment of Data

The soil samples will be analyzed using both Soil Contaminants and Macronutrients Analyzer and Conventional method, laboratory chemical control method. A total of 30

samples will be tested during the deployment period. The data will then be recorded and compared for the efficiency and accuracy of the results by Chi-Square Test for Independence and Two Sample t-Test. Tolerance will be computed for the reliability and usability of the device. The maintainability will be tested during deployment measuring its stability and testability. Through the process, all data that are sent to all connected devices will then be observed and will be measured following the device's portability.

All test samples and their corresponding data can be accessed from the PostgreSQL database for analytics and future reference.

3.6 Technical Evaluation

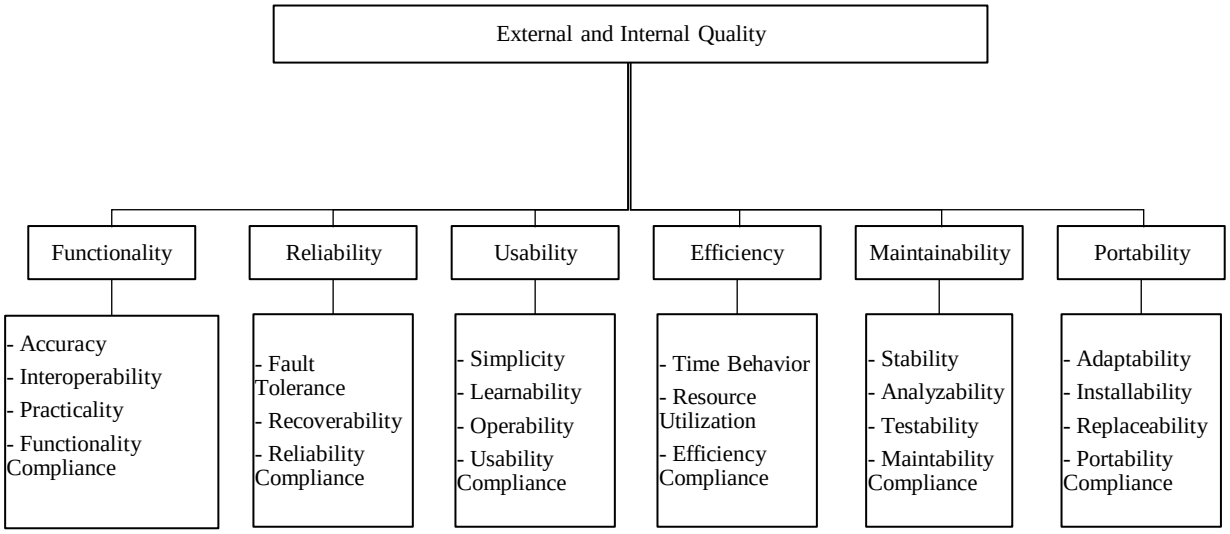


Figure 14. Quality Chart

The evaluation of the system device will be based on the external and internal qualities shown in Figure 14. The soil samples will then be tested using the conventional laboratory chemical control method.

The prototype will also be evaluated by the technician of the Electronic Product Development Center of the Department of Science and Technology (EPDC-DOST). The proponents together with the technicians will be coordinating the two soil contaminants or macronutrient methods, the chemical control, and the organized system. The results will be compared through the Likert scale shown in Table 2.

Table 2. Likert Scale

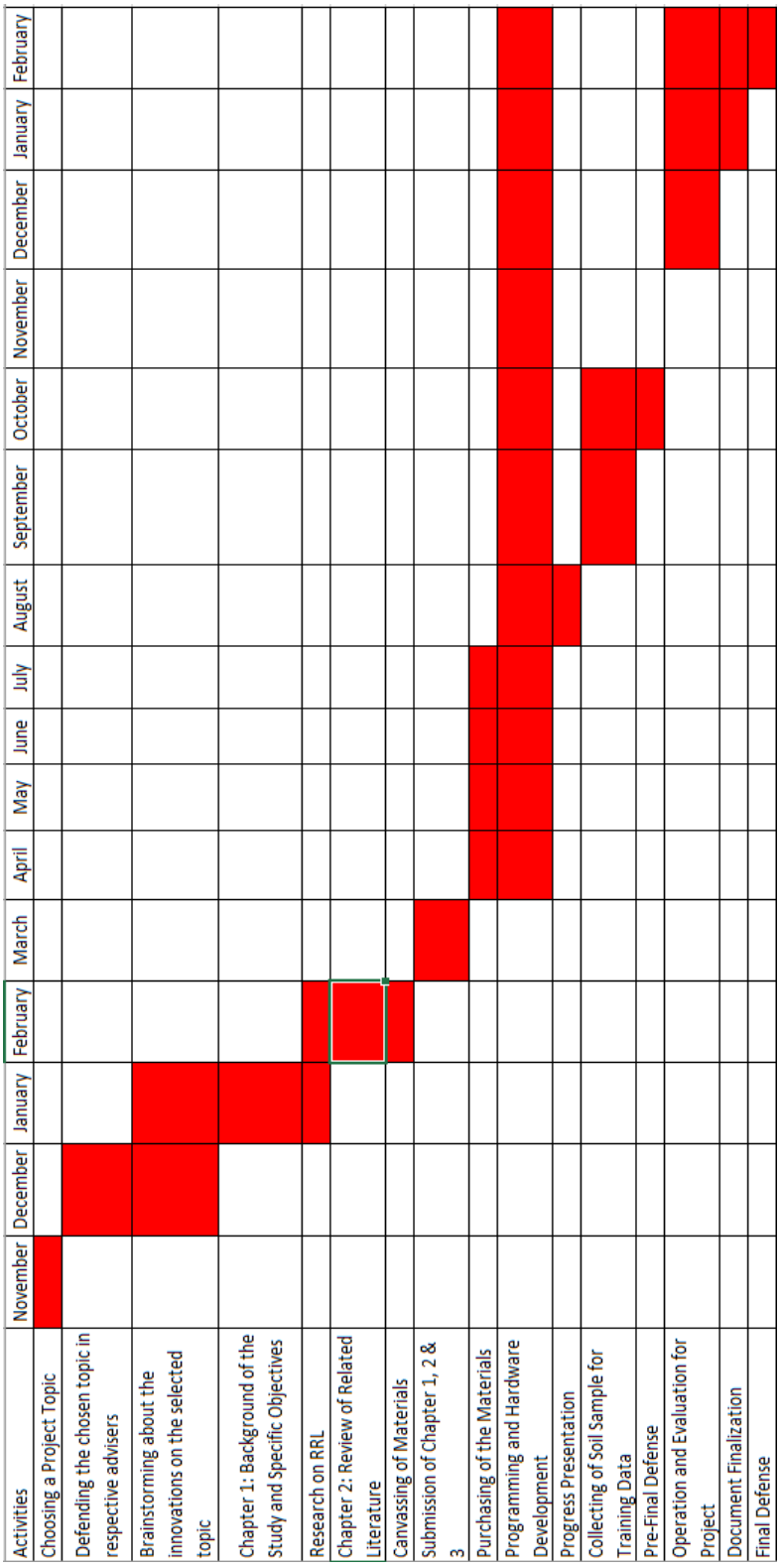
System Evaluation						
Introduction The evaluation of Soil Contaminants and Macronutrients Analyzer based on different statistical testing.						
Instructions: Circle the correct numeric response to each statement **Survey Scale:** 1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree						
I. Functionality						
No.	Statement					
1	The measurements were accurate.	1	2	3	4	5
2	The computer made use of the information gathered.	1	2	3	4	5
3	The study is feasible.	1	2	3	4	5
4	The study can adhere to the standards, conventions or regulations relating to functionality.	1	2	3	4	5
II. Reliability						
1	The prototype continued to operate in the event of a failure of some of its parts or components.	1	2	3	4	5
2	The prototype can regain its normal control in a scenario where it fails.	1	2	3	4	5
3	The study can adhere to the standards, conventions or regulations relating to reliability.	1	2	3	4	5

III. Usability						
1	The operation of the prototype is easy to understand.	1	2	3	4	5
2	The operation of the prototype can easily be learned by the user.	1	2	3	4	5
3	The operation of the prototype is reliable and safe.	1	2	3	4	5
4	The study can adhere to standards, conventions, style guides or regulations relating to usability.	1	2	3	4	5
IV. Efficiency						
1	The prototype can provide appropriate response and processing time when performing its function under given conditions.	1	2	3	4	5
2	The study is cheap and easy to manufacture.	1	2	3	4	5
3	The study can adhere to the standards, conventions or regulations relating to efficiency.	1	2	3	4	5
V. Maintainability						
1	The prototype can endure the external force while it was operating.	1	2	3	4	5
2	The study will examine the soil carefully to identify the contaminants and its concentrations	1	2	3	4	5
3	The results of the measurements were precise.	1	2	3	4	5
4	The study can adhere to standards, conventions, style guides or regulations relating to maintainability.	1	2	3	4	5

VI. Portability						
1	The prototype can adjust to any changes that will be made in the process.	1	2	3	4	5
2	The prototype can be installed in specified environment	1	2	3	4	5
3	The parts can be easily replaced that was used in the prototype	1	2	3	4	5
4	The study can adhere to standards, conventions, style guides or regulations relating to portability.	1	2	3	4	5

3.7 Gantt Chart

Table 3. Gantt Chart



3.8 Bills of Materials

Table 4. Bill of Materials

Material	Quantity	Unit	Price (Php)	Cost (Php)
Raspberry Pi	1	pc	2,500.00	2,500.00
Arduino UNO	2	pc	350.00	700.00
ATMega 2560	1	pc	600.00	600.00
Foam Board	3	pc	250.00	750.00
Acrylic Board	4	pc	250.00	1,000.00
3D printed Chassis	1	pc	8200.00	8200.00
Linear CCD Sensor	4	pc	640.00	2560.00
Mount	1	pc	5,000.00	5,000.00
Ethernet Cable (RJ45)	2	pc	250.00	500.00
USB connector	1	pc	50.00	50.00
Screws	200	pc	0.50	100.00
10,000 mAh Powerbank	1	pc	900.00	900.00
ICs	2	pc	48.00	96.00
Resistors	10	pc	1.50	15.00
PCB	2	pc	20.00	40.00
Mighty Bond	25	pc	10.00	250.00
Angle Bar	4	pc	120.00	480.00
Spray Paint	2	pc	115.00	230.00
Connecting Wires	50	pc	10.00	500.00
LED strips	2	pc	60.00	120.00
Lens 25mm	4	pc	25.00	100.00
Diffraction Grating	8	pc	250.00	2000.00
Collimating Lens	1	pc	130.00	130.00
Connecting Wires	5	pack	47.00	235.00
AC Cord	1	pc	58.00	58.00
Soldering Leads	3	pc	16.77	50.00
Tiny RTC	1	pc	356.00	356.00
Soil Test Kit	1	pc	1500.00	1500.00
Total	**-**	**-**	**-**	**29,020.00**

Chapter 4

ANALYSIS, PRESENTATION AND INTERPRETATION OF DATA

4.1 Project Structural Organization

The data gathered were interpreted, tabulated, and plotted. The device was elaborated by its produced soil contents' results and efficiency of IoT on gathering and displaying desired data. All parameters are shown and expressed by appropriate values.

4.1.1 SLICE

The mainframe of the website accessible for the users is shown in Figure 15. Details about the study such as description and objectives are what can be found here with the results.

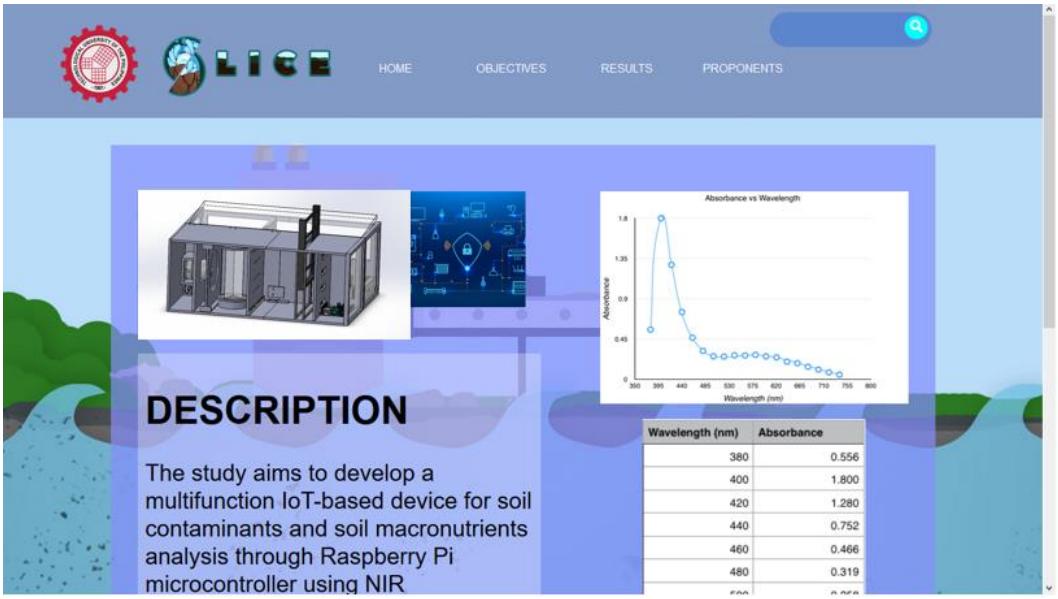


Figure 15. SLICE Mainframe

Figure 16 shows the Command Prompt (CMD) where Python is being managed for the server control of the web page.

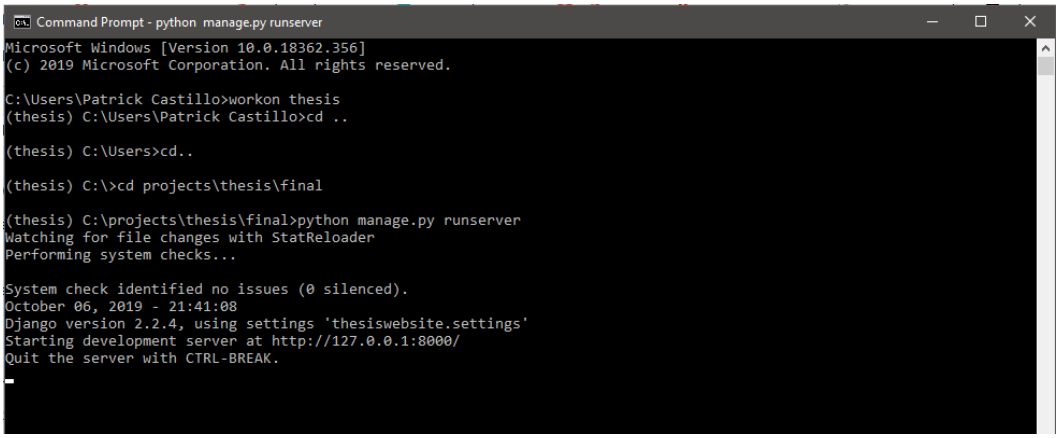


Figure 16. Command Prompt for Server Control

PostGreSQL Database interface is shown in Figure 17 that will store all the data collected by the raspberry pi given by the sensors used for the soil testing. The library of crop recommendations and treatments is also saved in this database.

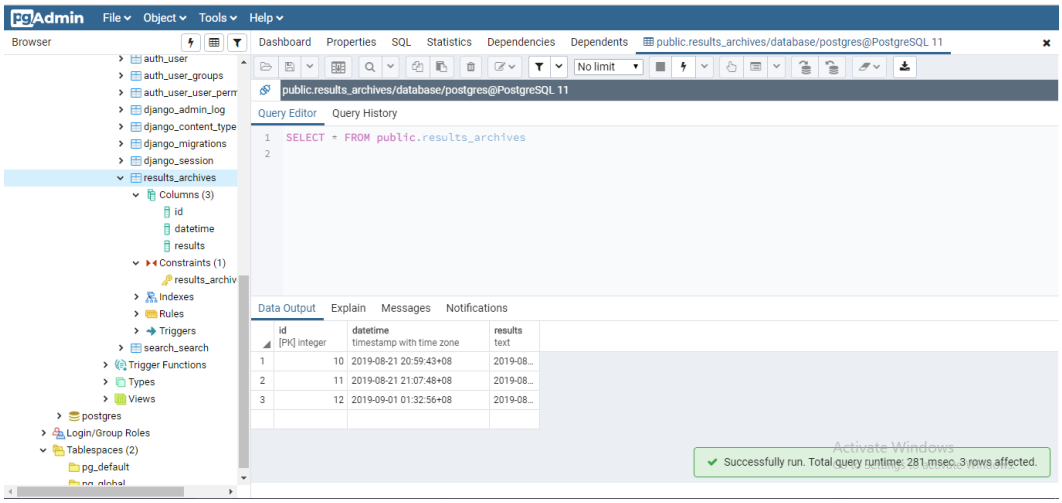


Figure 17. PostgreSQL Database Interface

Figure 18 shows the database of Django framework which is associated to PostgreSQL Database for the dynamic website. This can be controlled by the admin to further improve the efficiency of the data flow and display.

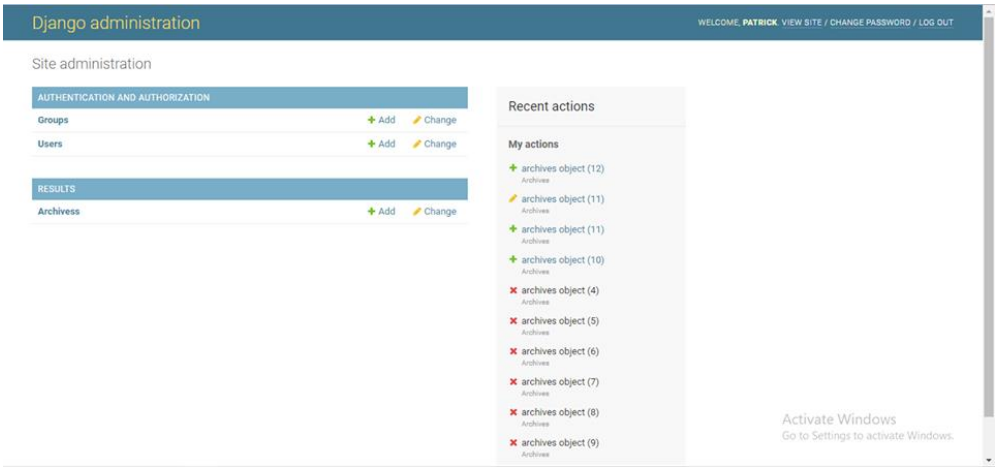


Figure 18. Django Framework Database

Manual input of data in Django Framework is shown in Figure 19. The feature also enables the user to function the device wirelessly. All data are checked and changed depending on their validity.

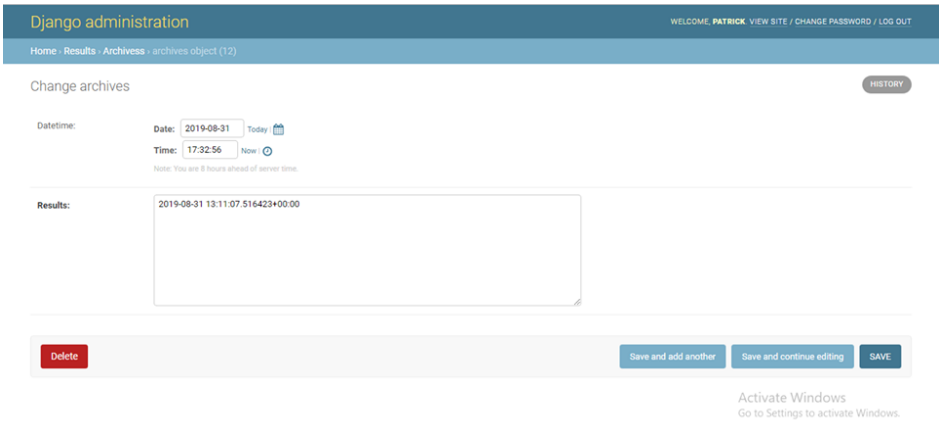
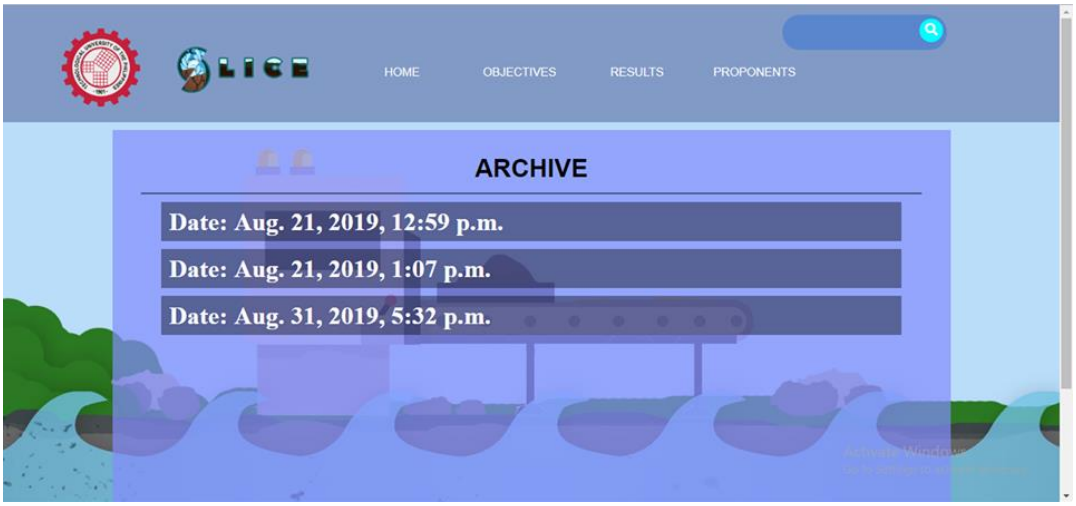


Figure 19. Data input in Django Framework

Soil content and its corresponding recommendation are shown in Figure 20. The date and time of the soil testing are also recorded to access the data easily and for future references.



(a)

(b)

Figure 20. (a) Summary of Soil Analysis Results (b) Measured Soil Macronutrients or Contaminants with Recommendation

4.2 Laboratory and Field-Testing Results

This test provides detailed information on 30 samples validated through conventional/laboratory methods. This contains macronutrients (Nitrogen, Potassium, and Phosphorus), pH, contaminants (Arsenic, Cadmium, Lead, and Mercury) results.

4.2.1 Macronutrients Test Results

Tables 5-8 show the accumulated data of soil nutrient contents using SLICE presenting its source or raw data from the TCD1304 sensor as compared to Soil Test Kit (STK) and laboratory results. Percentage Error and Difference are calculated for further data analysis. Remarks are also included which represented as 1 being less than 3% error and/or 3% difference and 0 if not. This tolerance is set to prepare the data for 3 and more significant values the laboratory results can have.

Due to unforeseen and unfortunate events during the testing period, the proponents were not able to gather all data for validation of results. Nonetheless, STK results are used instead of laboratory data. Percentage error and difference are not able to be calculated due to the difference in values and lack of numerical data from the laboratory.

SLICE results are converted by creating a numerical range corresponding to STK data. These data are then be remarked as 1 for the same results, otherwise, remarked 0. (NA – Not Applicable, CD – Cannot Determine)

Table 5. Nitrogen (N) Test Data

Sample	Result Using STK	Raw Data	Interpreted Value Using SLICE		Calibrated Value by Conventional/ Laboratory Methods	% Error	% Difference	Remarks
			ppm	L/M/H				
1	HIGH	175	78	HIGH	NA	CD	CD	**1**
2	HIGH	175	78	HIGH	NA	CD	CD	**1**
3	HIGH	166	72	HIGH	NA	CD	CD	**1**
4	HIGH	164	72	HIGH	NA	CD	CD	**1**
5	HIGH	160	70	HIGH	NA	CD	CD	**1**
6	HIGH	192	86	HIGH	NA	CD	CD	**1**
7	HIGH	192	86	HIGH	NA	CD	CD	**1**
8	HIGH	192	86	HIGH	NA	CD	CD	**1**
9	HIGH	192	86	HIGH	NA	CD	CD	**1**
10	HIGH	190	84	HIGH	NA	CD	CD	**1**
11	HIGH	188	84	HIGH	NA	CD	CD	**1**
12	HIGH	188	84	HIGH	NA	CD	CD	**1**
13	HIGH	187	84	HIGH	NA	CD	CD	**1**
14	HIGH	187	84	HIGH	NA	CD	CD	**1**
15	HIGH	185	82	HIGH	NA	CD	CD	**1**
16	HIGH	190	84	HIGH	NA	CD	CD	**1**
17	HIGH	192	86	HIGH	NA	CD	CD	**1**
18	HIGH	192	86	HIGH	NA	CD	CD	**1**
19	HIGH	187	84	HIGH	NA	CD	CD	**1**
20	HIGH	190	84	HIGH	NA	CD	CD	**1**
21	HIGH	190	84	HIGH	NA	CD	CD	**1**
22	HIGH	190	84	HIGH	NA	CD	CD	**1**
23	HIGH	192	86	HIGH	NA	CD	CD	**1**
24	HIGH	192	86	HIGH	NA	CD	CD	**1**
25	HIGH	187	84	HIGH	NA	CD	CD	**1**
26	HIGH	187	84	HIGH	NA	CD	CD	**1**
27	HIGH	187	84	HIGH	NA	CD	CD	**1**
28	HIGH	187	84	HIGH	NA	CD	CD	**1**
29	HIGH	190	84	HIGH	NA	CD	CD	**1**
30	HIGH	190	84	HIGH	NA	CD	CD	**1**
AVE	**-**	**185.87**	**82.80**	**-**	**-**	**-**	**-**	**1.00**

Table 6. Phosphorus (P) Test Data

Sample	Result Using STK	Raw Data	Interpreted Value Using SLICE		Calibrated Value by Conventional/ Laboratory Methods	% Error	% Difference	Remarks
			ppm	L/M/H				
1	LOW	77	5	LOW	NA	CD	CD	**1**
2	LOW	77	5	LOW	NA	CD	CD	**1**
3	LOW	79	5	LOW	NA	CD	CD	**1**
4	LOW	75	5	LOW	NA	CD	CD	**1**
5	LOW	75	5	LOW	NA	CD	CD	**1**
6	LOW	75	5	LOW	NA	CD	CD	**1**
7	LOW	79	5	LOW	NA	CD	CD	**1**
8	MED	86	6	LOW	NA	CD	CD	**1**
9	LOW	79	5	LOW	NA	CD	CD	**1**
10	MED	88	6	MED	NA	CD	CD	**1**
11	MED	88	6	MED	NA	CD	CD	**1**
12	LOW	77	5	LOW	NA	CD	CD	**1**
13	LOW	65	4	LOW	NA	CD	CD	**1**
14	LOW	66	4	LOW	NA	CD	CD	**1**
15	LOW	66	4	LOW	NA	CD	CD	**1**
16	LOW	65	4	LOW	NA	CD	CD	**1**
17	LOW	65	4	LOW	NA	CD	CD	**1**
18	LOW	69	5	LOW	NA	CD	CD	**1**
19	LOW	69	5	LOW	NA	CD	CD	**1**
20	LOW	70	5	LOW	NA	CD	CD	**1**
21	MED	88	6	MED	NA	CD	CD	**1**
22	MED	88	6	MED	NA	CD	CD	**1**
23	HIGH	89	6	MED	NA	CD	CD	**0**
24	LOW	68	4	LOW	NA	CD	CD	**1**
25	LOW	68	4	LOW	NA	CD	CD	**1**
26	LOW	69	5	LOW	NA	CD	CD	**1**
27	LOW	69	5	LOW	NA	CD	CD	**1**
28	LOW	68	4	LOW	NA	CD	CD	**1**
29	LOW	70	5	LOW	NA	CD	CD	**1**
30	LOW	70	5	LOW	NA	CD	CD	**1**
AVE	**-**	**74.57**	**4.93**	**-**	**-**	**-**	**-**	**0.97**

Table 7. Potassium (K) Test Data

Sample	Result Using STK	Raw Data	Interpreted Value Using SLICE		Calibrated Value by Conventional/ Laboratory Methods	% Error	% Difference	Remarks
			ppm	S/D				
1	SUFFICIENT	145	90	S	NA	CD	CD	**1**
2	SUFFICIENT	145	90	S	NA	CD	CD	**1**
3	SUFFICIENT	148	90	S	NA	CD	CD	**1**
4	SUFFICIENT	150	90	S	NA	CD	CD	**1**
5	SUFFICIENT	150	90	S	NA	CD	CD	**1**
6	SUFFICIENT	150	90	S	NA	CD	CD	**1**
7	SUFFICIENT	152	95	S	NA	CD	CD	**1**
8	SUFFICIENT	152	95	S	NA	CD	CD	**1**
9	SUFFICIENT	160	95	S	NA	CD	CD	**1**
10	SUFFICIENT	160	95	S	NA	CD	CD	**1**
11	SUFFICIENT	145	90	S	NA	CD	CD	**1**
12	SUFFICIENT	148	90	S	NA	CD	CD	**1**
13	SUFFICIENT	148	90	S	NA	CD	CD	**1**
14	SUFFICIENT	156	95	S	NA	CD	CD	**1**
15	SUFFICIENT	161	100	S	NA	CD	CD	**1**
16	SUFFICIENT	161	100	S	NA	CD	CD	**1**
17	SUFFICIENT	161	100	S	NA	CD	CD	**1**
18	SUFFICIENT	161	100	S	NA	CD	CD	**1**
19	SUFFICIENT	170	100	S	NA	CD	CD	**1**
20	SUFFICIENT	168	100	S	NA	CD	CD	**1**
21	SUFFICIENT	167	100	S	NA	CD	CD	**1**
22	SUFFICIENT	167	100	S	NA	CD	CD	**1**
23	SUFFICIENT	170	100	S	NA	CD	CD	**1**
24	SUFFICIENT	170	100	S	NA	CD	CD	**1**
25	SUFFICIENT	175	110	S	NA	CD	CD	**1**
26	SUFFICIENT	174	110	S	NA	CD	CD	**1**
27	SUFFICIENT	169	100	S	NA	CD	CD	**1**
28	SUFFICIENT	169	100	S	NA	CD	CD	**1**
29	SUFFICIENT	168	100	S	NA	CD	CD	**1**
30	SUFFICIENT	168	100	S	NA	CD	CD	**1**
AVE	-	**159.60**	**96.83**	-	-	-	-	**1.00**

Table 8. pH Test Data

Sample	Result Using STK	Raw Data	Interpreted Value Using SLICE	Calibrated Value by Conventional/ Laboratory Methods	% Error	% Difference	Remarks
1	6.0	122	6.2	NA	CD	3.28	**0**
2	6.0	105	6.0	NA	CD	0	**1**
3	6.0	105	6.0	NA	CD	0	**1**
4	6.0	110	6.0	NA	CD	0	**1**
5	6.0	112	6.1	NA	CD	1.65	**1**
6	6.0	112	6.1	NA	CD	1.65	**1**
7	6.0	108	6.0	NA	CD	0	**1**
8	6.0	108	6.0	NA	CD	0	**1**
9	6.0	109	6.0	NA	CD	0	**1**
10	6.0	110	6.0	NA	CD	0	**0**
11	6.0	130	6.2	NA	CD	3.28	**0**
12	6.0	124	6.2	NA	CD	3.28	**0**
13	6.0	116	6.1	NA	CD	1.65	**1**
14	6.0	108	6.0	NA	CD	0	**1**
15	6.0	108	6.0	NA	CD	0	**1**
16	6.0	108	6.0	NA	CD	0	**1**
17	6.0	108	6.0	NA	CD	0	**1**
18	6.0	108	6.0	NA	CD	0	**1**
19	6.0	110	6.0	NA	CD	0	**1**
20	6.0	106	6.0	NA	CD	0	**1**
21	6.0	106	6.0	NA	CD	0	**1**
22	6.0	110	6.0	NA	CD	0	**1**
23	5.8	98	5.8	NA	CD	0	**1**
24	5.8	98	5.8	NA	CD	0	**1**
25	6.0	104	6.0	NA	CD	0	**1**
26	6.0	104	6.0	NA	CD	0	**1**
27	6.0	108	6.0	NA	CD	0	**1**
28	5.8	108	6.0	NA	CD	3.39	**0**
29	6.0	108	6.0	NA	CD	0	**1**
30	6.0	108	6.0	NA	CD	0	**1**
AVE	**6.0**	**110.40**	**6.03**	**-**	**-**	**0.50**	**0.83**

The Nitrogen (N), Phosphorus (P), Potassium (K), and pH level results show the development and improvement of the data compared to STK methods. Despite not having laboratory results to validate exact numeric values, the processed data comprehend the objectives of the study. The Chi-Square test is used to further interpret and analyze the data and produce precise calculations for accuracy.

4.2.2 Contaminants Test Results

Tables 9-11 show the accumulated data of soil contaminants contents using SLICE presenting its source or raw data from the CCD sensor as compared to laboratory results. Percentage Error and Difference are calculated for further data analysis. Remarks are also included which represented as 1 being less than 10% error and/or 10% difference and 0 if not. This tolerance is set to ensure an equal distribution for data analysis since all data are numerical with four (4) significant figures.

Due to the unforeseen events during the testing period, the proponents were not able to gather Mercury (Hg) laboratory results. This affects the final data necessary for calculating accuracy and efficiency. Nevertheless, the Arsenic, Cadmium, and Lead test data are used to create sufficient values in determining necessary parameters and results.

Table 9. Arsenic (As) Test Data

Sample	Raw Data	Interpreted Value Using SLICE	Calibrated Value by Conventional Method (mg/L)	Percentage Error	Percentage Difference	Remarks
1	115	0.029	0.032	9.375	9.836	**1**
2	116	0.030	0.032	6.250	6.452	**1**
3	115	0.029	0.032	9.375	9.836	**1**
4	115	0.029	0.032	9.375	9.836	**1**
5	114	0.029	0.032	9.375	9.836	**1**
6	115	0.029	0.032	9.375	9.836	**1**
7	112	0.028	0.027	3.704	3.636	**1**
8	112	0.028	0.027	3.704	3.636	**1**
9	112	0.028	0.027	3.704	3.636	**1**
10	112	0.028	0.027	3.704	3.636	**1**
11	112	0.028	0.027	3.704	3.636	**1**
12	112	0.028	0.027	3.704	3.636	**1**
13	55	0.014	0.008	75.000	54.545	**0**
14	56	0.015	0.008	87.500	60.870	**0**
15	56	0.015	0.008	87.500	60.870	**0**
16	58	0.015	0.008	87.500	60.870	**0**
17	58	0.015	0.008	87.500	60.870	**0**
18	55	0.014	0.008	75.000	54.545	**0**
19	55	0.014	0.008	75.000	54.545	**0**
20	53	0.014	0.008	75.000	54.545	**0**
21	54	0.014	0.008	75.000	54.545	**0**
22	54	0.014	0.008	75.000	54.545	**0**
23	58	0.015	0.008	87.500	60.870	**0**
24	57	0.015	0.008	87.500	60.870	**0**
25	77	0.020	0.015	33.333	28.571	**0**
26	76	0.019	0.015	26.667	23.529	**0**
27	76	0.019	0.015	26.667	23.529	**0**
28	77	0.020	0.015	33.333	28.571	**0**
29	78	0.020	0.015	33.333	28.571	**0**
30	78	0.020	0.015	33.333	28.571	**0**
AVE	**83.100**	**0.021**	**0.018**	**17.593**	**16.170**	**0.40**

Figure 21 shows the graphical comparison of two soil analysis methods to visualize a value error in each soil sample for Arsenic concentration. The graph also shows a significant difference in the middle period of sampling and over measured data to certain soil samples.

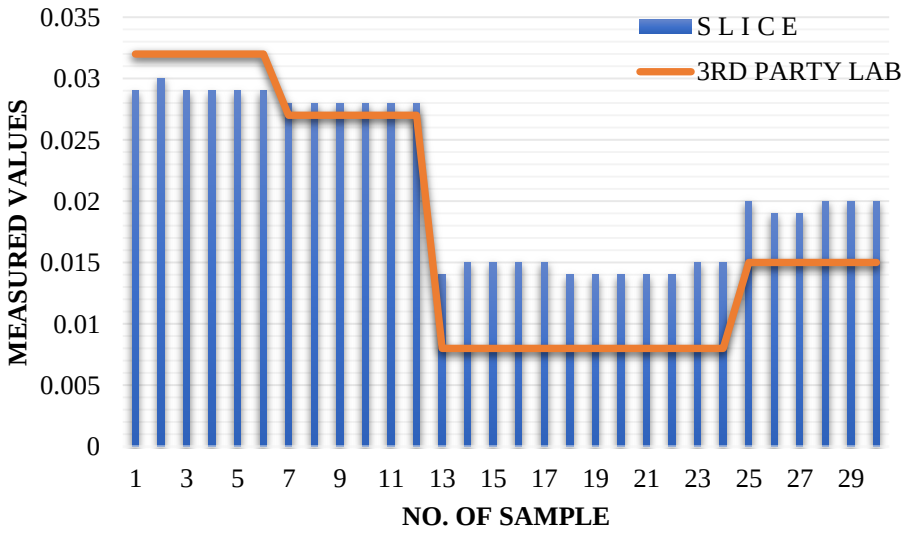


Figure 21. SLICE vs 3rd Party Testing Laboratory for Arsenic (As) Concentrations

Table 10. Cadmium (Cd) Test Data

Sample	Raw Data	Interpreted Value Using SLICE	Calibrated Value by Conventional Method (mg/L)	Percentage Error	Percentage Difference	Remarks
1	12	0.002	0.004	50.000	66.667	**0**
2	15	0.003	0.004	25.000	28.571	**0**
3	14	0.002	0.004	50.000	66.667	**0**
4	15	0.003	0.004	25.000	28.571	**0**
5	18	0.003	0.004	25.000	28.571	**0**
6	18	0.003	0.004	25.000	28.571	**0**
7	26	0.005	0.008	37.500	46.154	**0**
8	28	0.005	0.008	37.500	46.154	**0**
9	32	0.005	0.008	37.500	46.154	**0**
10	30	0.005	0.008	37.500	46.154	**0**
11	28	0.005	0.008	37.500	46.154	**0**
12	26	0.004	0.008	50.000	66.667	**0**
13	26	0.004	0.004	0.000	0.000	**1**
14	21	0.003	0.004	25.000	28.571	**0**
15	23	0.004	0.004	0.000	0.000	**1**
16	23	0.004	0.004	0.000	0.000	**1**
17	20	0.003	0.004	25.000	28.571	**0**
18	18	0.003	0.004	25.000	28.571	**0**
19	15	0.003	0.004	25.000	28.571	**0**
20	14	0.002	0.004	50.000	66.667	**0**
21	15	0.003	0.004	25.000	28.571	**0**
22	22	0.004	0.004	0.000	0.000	**1**
23	13	0.002	0.004	50.000	66.667	**0**
24	13	0.002	0.004	50.000	66.667	**0**
25	15	0.003	0.004	25.000	28.571	**0**
26	7	0.001	0.004	75.000	120.000	**0**
27	12	0.002	0.004	50.000	66.667	**0**
28	12	0.002	0.004	50.000	66.667	**0**
29	15	0.003	0.004	25.000	28.571	**0**
30	15	0.003	0.004	25.000	28.571	**0**
AVE	**18.700**	**0.003**	**0.0048**	**33.333**	**40.000**	**0.1333**

Figure 22 shows the graphical comparison of two soil analysis methods to visualize a value error in each soil sample for Cadmium concentration. The graph also shows a significant difference in certain soil samples. This represents inconsistency on SLICE generated values that are affected by several factors such as limited sample population, low concentration values, human error, testing error, device inaccuracy, etc.

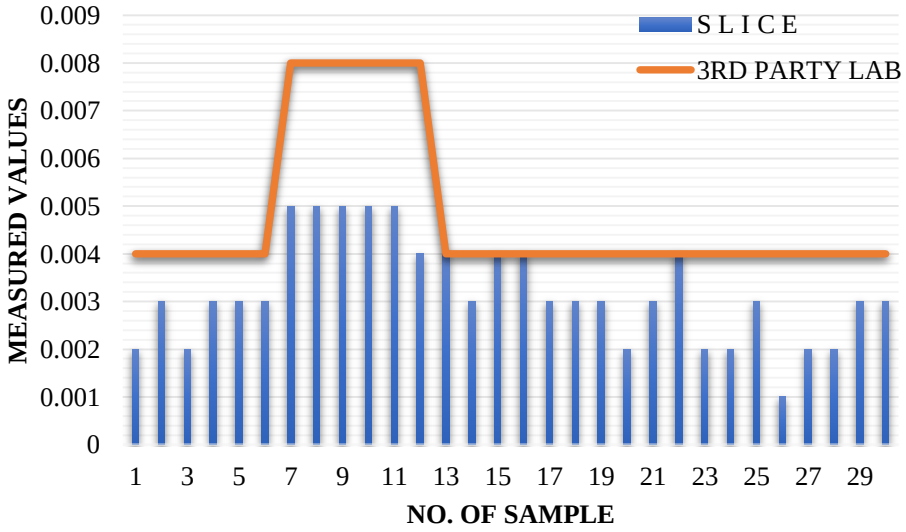


Figure 22. SLICE vs 3rd Party Testing Laboratory for Cadmium (Cd) Concentrations

Table 11. Lead (Pb) Test Data

Sample	Raw Data	Interpreted Value Using SLICE	Calibrated Value by Conventional Method (mg/L)	Percentage Error	Percentage Difference	Remarks
1	249	0.163	0.151	7.947	7.643	**1**
2	249	0.163	0.151	7.947	7.643	**1**
3	253	0.164	0.151	8.609	8.254	**1**
4	260	0.166	0.151	9.934	9.464	**1**
5	260	0.166	0.151	9.934	9.464	**1**
6	254	0.164	0.151	8.609	8.254	**1**
7	678	0.270	0.259	4.247	4.159	**1**
8	678	0.270	0.259	4.247	4.159	**1**
9	680	0.271	0.259	4.633	4.528	**1**
10	684	0.271	0.259	4.633	4.528	**1**
11	683	0.271	0.259	4.633	4.528	**1**
12	683	0.271	0.259	4.633	4.528	**1**
13	1552	0.488	1.220	60.000	85.714	**0**
14	1554	0.489	1.220	59.918	85.547	**0**
15	1553	0.489	1.220	59.918	85.547	**0**
16	1553	0.489	1.220	59.918	85.547	**0**
17	1551	0.488	1.220	60.000	85.714	**0**
18	1551	0.488	1.220	60.000	85.714	**0**
19	1968	0.592	0.578	2.422	2.393	**1**
20	1968	0.592	0.578	2.422	2.393	**1**
21	1971	0.593	0.578	2.595	2.562	**1**
22	1970	0.593	0.578	2.595	2.562	**1**
23	1970	0.593	0.578	2.595	2.562	**1**
24	1970	0.593	0.578	2.595	2.562	**1**
25	1966	0.592	0.631	6.181	6.378	**1**
26	1966	0.592	0.631	6.181	6.378	**1**
27	1967	0.592	0.631	6.181	6.378	**1**
28	1967	0.592	0.631	6.181	6.378	**1**
29	1967	0.592	0.631	6.181	6.378	**1**
30	1968	0.592	0.631	6.181	6.378	**1**
AVE	**1284.767**	**0.422**	**0.568**	**25.743**	**29.546**	**0.800**

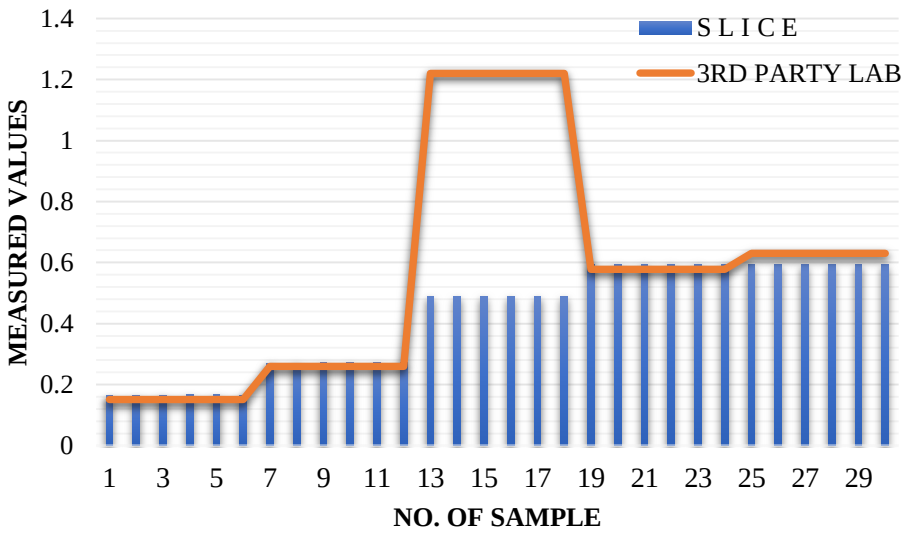


Figure 23. SLICE vs 3rd Party Testing Laboratory for Lead (Pb) Concentrations

Figure 23 shows the graphical comparison of two soil analysis methods to visualize a value error in each soil sample for Lead concentration. The graph also shows a significant difference in the middle period of sampling.

The numerical data provided by the laboratory results show the concentrations of Arsenic, Cadmium, and Lead in the given five (5) soil samples gathered from five (5) different spots of the locale.

The same samples are also tested using SLICE to produce 30 individual values to precisely compute for accuracy and efficiency. However, the lack of Mercury test data affects the desired results and conclusion. Two Sample t-Test is used to further interpret and analyze the data and produce precise calculations for significant differences.

Tables 12-16 show the five laboratory results and the test methods used processed by the 3rd party testing laboratory. The unit used is mg/L which is equivalent to Parts Per Million (ppm). The full details of the laboratory test results are shown in Appendix E. Having 3 significant digits in the results and extremely low numerical values affect the data analysis especially for contaminants.

Table 12. Soil Sample No.1 Laboratory Results

Test Description	Results	Unit	Test Methods
Cadmium	0.008	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.631	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	0.027	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Table 13. Soil Sample No.2 Laboratory Results

Test Description	Results	Unit	Test Methods
Cadmium	<0.004*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	1.220	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	<0.008*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Table 14. Soil Sample No.3 Laboratory Results

Test Description	Results	Unit	Test Methods
Cadmium	<0.004*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.578	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	<0.008*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Table 15. Soil Sample No.4 Laboratory Results

Test Description	Results	Unit	Test Methods
Cadmium	0.004	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.259	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	0.015	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Table 16. Soil Sample No.5 Laboratory Results

Test Description	Results	Unit	Test Methods
Cadmium	<0.004*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.151	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	0.032	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

4.3 Project Statistical Evaluation

Chi-Square Test of Independence and Two Sample (Independent) t-Test were used to determine the differences and relationships of the two categorical variables, conventional method values, and SLICE values. Since all data are supposed to be numerical and used 3% tolerance for macronutrient results and 10% tolerance for contaminants results, the proponents added a variable using the given tolerance and the percent difference to further distinguish expected values in each parameter.

4.3.1 Statistical Evaluation using Chi-Square Test for Macronutrients Data

The data has a 3.841 critical value computed using the Chi-Square Distribution with a significance level of 5%. Tables 17-20 show the data analysis for each parameter.

Table 17. Chi-Square for Nitrogen (N)

	Expected Values	**Observed**	$\frac{(\text{Obs} - \text{Exp})^2}{\text{Exp}}$
STK = SLICE	27	30	0.333
STK ≠ SLICE	3	0	3.000
		X^2	**3.333**

Table 18. Chi-Square for Phosphorus (P)

	Expected Values	**Observed**	$\frac{(\text{Obs} - \text{Exp})^2}{\text{Exp}}$
STK = SLICE	27	29	0.148
STK ≠ SLICE	3	1	1.333
		X^2	**1.481**

Table 19. Chi-Square for Potassium (K)

	Expected Values	**Observed**	$\frac{(\text{Obs} - \text{Exp})^2}{\text{Exp}}$
STK = SLICE	27	30	0.333
STK ≠ SLICE	3	0	3.000
		X^2	**3.333**

Table 20. Chi-Square for pH Level

	Expected Values	**Observed**	$\frac{(\text{Obs} - \text{Exp})^2}{\text{Exp}}$
STK = SLICE	27	25	0.148
STK ≠ SLICE	3	5	1.333
		X^2	**1.481**

The analyzed data has Chi-Square values of less than the critical value, 3.481, which means the results of the experimented data (SLICE results) have no significant difference from the expected data (STK results).

4.3.2 Statistical Evaluation using Two Sample t-Test for Contaminants Data

This test is used for a profound analysis of the exact values calibrated by SLICE compared to the laboratory results provided by the 3rd party laboratory with a significance level of 5%. The statistical significance is usually determined by the probability of error or the p-value through the t ratio. Tables 21-23 show the detailed contaminants data analysis in which Mercury result is excluded. The table includes statistical parameters in determining data difference such as Mean, Variance, Degrees of Freedom, t Stat, and the most significant data, the p-value, and t critical value for the two-tailed test.

Table 21. Two Sample t-Test for Arsenic (As)

	SLICE	*Lab Test*
Mean	0.02117	0.01800
Variance	0.00004	0.00010
Observations	30.00000	30.00000
Pooled Variance	0.00007	
Hypothesized Mean Difference	0.00000	
df	58.00000	
t Stat	1.45302	
P(T<=t) one-tail	0.07580	
t Critical one-tail	1.67155	
P(T<=t) two-tail	0.15161	
t Critical two-tail	2.00172	

The two highlighted rows on Table 21 show that there is no significant difference, higher or lower the value (two tail), between the data from SLICE and Lab test since p-value is greater than the alpha value 0.05. This is further evaluated through its t-distribution hypothesis test graph shown in Figure 24.

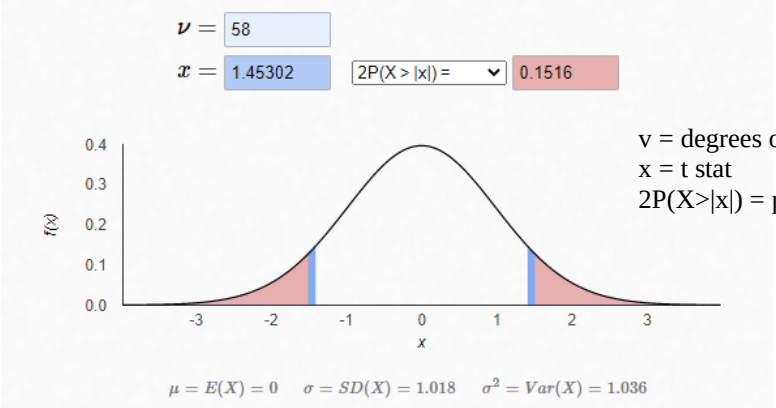


Figure 24. t-Distribution Test Graph of Arsenic (As) Concentration Values

The two highlighted rows on Table 22 show that there is a significant difference, higher or lower the value (two tail), between the data from SLICE and Lab test since the p-value is less than the alpha value, 0.05. This significant difference is due to the low values generated by SLICE and values provided by the 3rd party laboratory. The data will improve in a higher number of population and more significant values in the results. This is further evaluated through its t-distribution hypothesis test graph shown in Figure 25. The highlighted parts are not observable in the graph.

Table 22. Two Sample t-Test for Cadmium (Cd)

	SLICE	*Lab Test*
Mean	0.00320	0.00480
Variance	0.00000	0.00000
Observations	30.00000	30.00000
Pooled Variance	0.00000	
Hypothesized Mean Difference	0.00000	
df	58.00000	
t Stat	-4.46732	
P(T<=t) one-tail	0.00002	
t Critical one-tail	1.67155	
P(T<=t) two-tail	0.00004	
t Critical two-tail	2.00172	

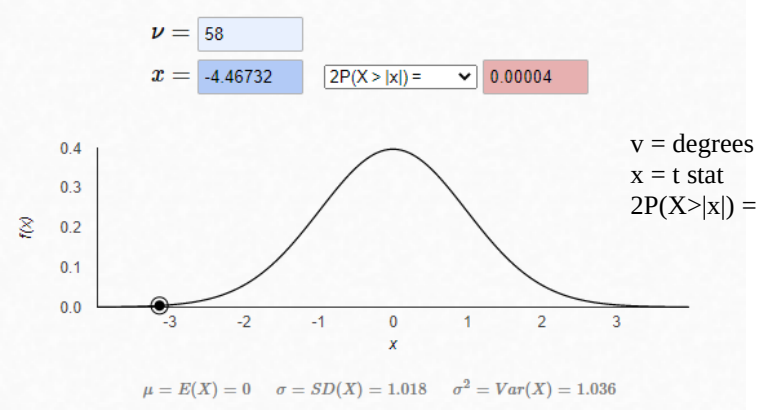


Figure 25. t-Distribution Test Graph of Cadmium (Cd) Concentration Values

Table 23. Two Sample t-Test for Lead (Pb)

	SLICE	*Lab Test*
Mean	0.42163	0.56780
Variance	0.03140	0.14453
Observations	30.00000	30.00000
Pooled Variance	0.08796	
Hypothesized Mean Difference	0.00000	
df	58.00000	
t Stat	-1.90875	
P(T<=t) one-tail	0.03062	
t Critical one-tail	1.67155	
P(T<=t) two-tail	0.06125	
t Critical two-tail	2.00172	

The two highlighted rows on Table 23 show that there is no significant difference, higher or lower the value (two tail), between the data from SLICE and Lab test since the p-value is greater than the alpha value, 0.05. This is further evaluated through its t-distribution hypothesis test graph shown in Figure 26.

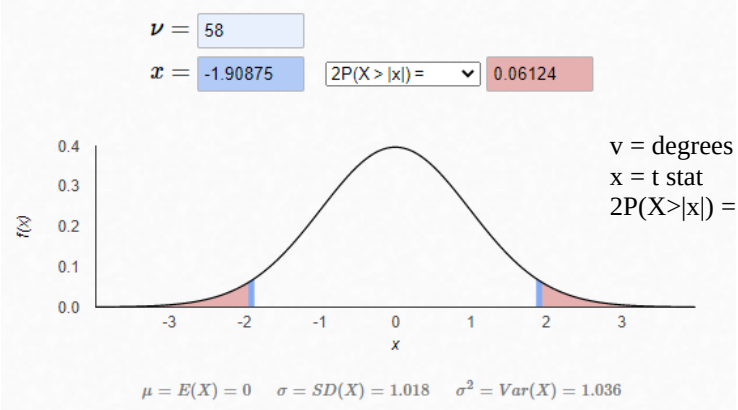


Figure 26. t-Distribution Test Graph of Lead (Pb) Concentration Values

4.4 Validation of Results Accuracy

The accuracy of the device is dependent on the computed values in each parameter. 3% and 10% tolerance for macronutrients and contaminants, respectively, managed the data since the results are expressed numerically. Table 24 shows the accuracies of testing in each soil component.

Table 24. Computed Accuracies

Macronutrients	***Within Tolerance Range***	***Out of Tolerance Range***	***Accuracy (%)***
Nitrogen (N)	30	0	100.00
Phosphorus (P)	29	1	96.67
Potassium (K)	30	0	100.00
pH Level	25	5	83.33
		Average	**95.00**
Contaminants			
Arsenic (As)	12	18	40.00
Cadmium (Cd)	4	26	13.33
Lead (Pb)	24	6	80.00
Mercury (Hg)	CD	CD	CD
		Average	**44.44**

The data showed 95% accuracy for macronutrient testing given the 30 samples and numeric data. Since all the values are compared to STK data which has limited and fixed values, the accuracy of the device is higher given that it has an exact numeric value that STK doesn't have. For contaminants accuracy, the lack of Mercury results can either lower or improve the produced accuracy. The table showed 44.44% accuracy due to extremely low values and a limited number of samples. These factors greatly affect the device's recorded performance so to further describe its efficiency and accuracy, the percent error and difference are computed shown in Table 25.

Table 25. Percent Error and Difference of Contaminants Results

Contaminants	***Error (%)***	***Difference (%)***
Arsenic (As)	17.59	16.17
Cadmium (Cd)	33.33	40.00
Lead (Pb)	25.74	29.55
Mercury (Hg)	CD	CD
Average	**25.56**	**28.57**

Despite having 44.44% accuracy, the device can produce contaminant concentration results with a 25.56% error and a 28.57% difference. These high percentages reflect low-value computations and comparisons that become significant even with a 0.001 difference to the laboratory value.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of the results and drawn conclusions through the tabulated, plotted, and computed data. This also includes recommendations for further improvement and development of the study.

5.1 Summary of Findings

The SLICE project study was developed to profoundly understand soil analysis via spectroscopy conceptually, theoretically, and as a solution to agricultural and pollution problems. Through Raspberry Pi, Arduino, Django, Python, and PgAdmin, multifunction IoT-based soil contaminants and macronutrient analyzer was created successfully which can calibrate four parameters in each sample simultaneously. This study statistically compared SLICE results to laboratory data calibrated by the 3rd party testing laboratory. The device featured an IoT-Based system in displaying results and storing data through created website and database which is accessible for future references.

5.2 Conclusions

The following conclusions were drawn through the interpreted results and evaluation of the device:

1. Soil samples from agricultural lands and polluted bodies of water were successfully measured and analyzed by the developed device using spectroscopy.

2. The library was created by different sources including the studies from the Bureau of Soils and Water Management as references.
3. Through the Raspberry Pi being the common platform, IoT was developed via WiFi which accepts data inputs from Arduino Mega driving four TCD1304 simultaneously.
4. The study provided a webpage displaying the results of each testing including date, time, mode of sampling, treatments or recommendations, raw data, and location of the gathered sample.
5. The processed data showed 95% accuracy in measuring soil macronutrient concentration and 44.44% accuracy in measuring soil contaminants concentration. The low percentage for contaminants was due to extremely low numerical values and the limited number of samples so to further describe the performance of the device, percent error and difference were calculated. The device measured the contaminant concentrations with a 25.56% error and 28.57% difference.

5.3 Recommendations

Due to unforeseen events, the proponents were unable to perform all necessary procedures which created some shortcomings to the results, thus would want to recommend the following to further improve and develop the study:

1. Increase the sample population to produce more precise results and avoid significant difference towards an extremely low-value computation.

2. Use the digital image processing method in calibrating four parameters simultaneously. This will reduce the complexity of the device and the system.
3. Apply the concept of the study in a broader range of contaminants and nutrients.

APPENDICES

APPENDIX A

(Project Documentation)

APPENDIX B

(Source Codes)

APPENDIX C

(How to Use SLICE)

APPENDIX D

(Data Sheets)

APPENDIX E

(Macronutrients and Contaminants Reagents)

APPENDIX F

(Macronutrients Raw Data to ppm Conversion and Concentration Range)

APPENDIX G

(Laboratory Results for Contaminants)

APPENDIX H

(Circuits)

APPENDIX I

(References)

APPENDIX J

(Proponent's Profile Layout)

APPENDIX K

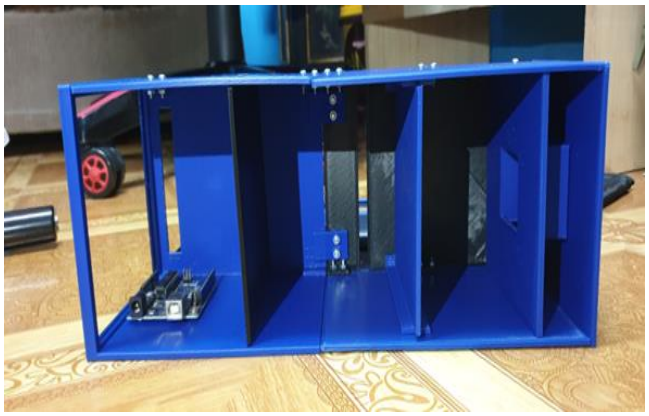
(Proofread Certification)

Appendix A

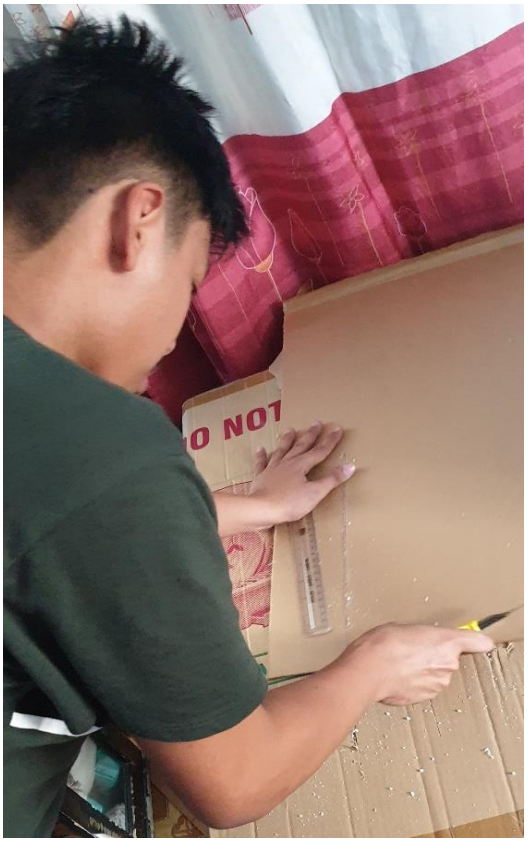
Project Documentation

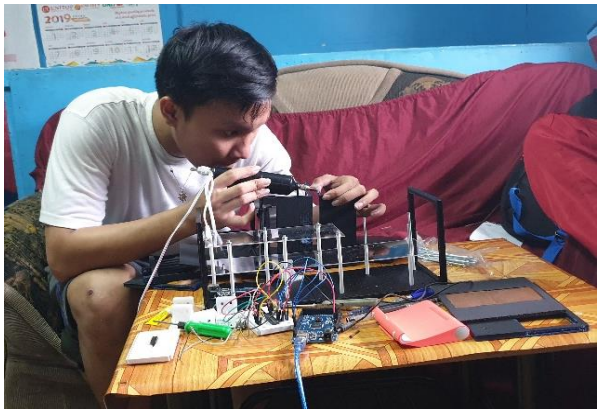
DENR Consultation

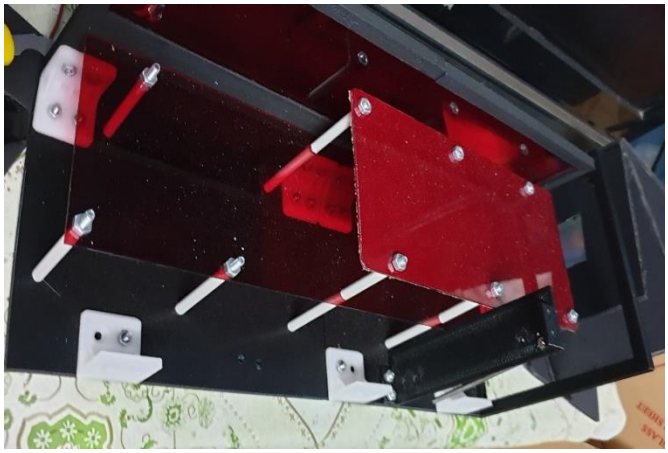
3D Printed

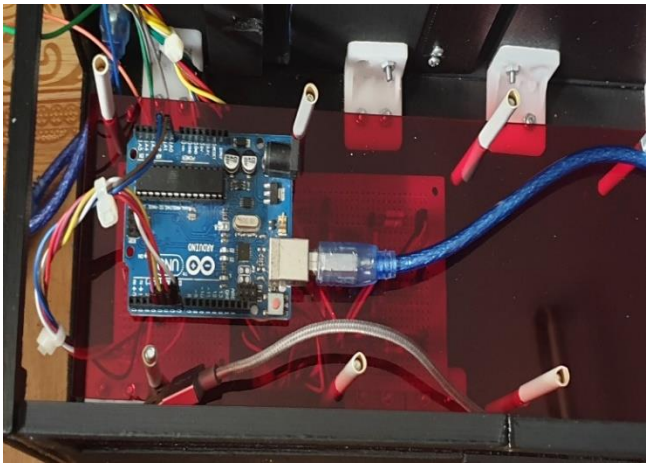


Building of Prototype









Soil Gathering for Macronutrients Testing

Soil Testing using STK

Sediment Gathering for Heavy Metal Testing

NASAT Labs for Laboratory Testing

Appendix B

Source Codes

TCD1304AP DRIVER CODE (ARDUINO)

```
#include <util/delay_basic.h>
#ifdef ARDUINO_AVR_MEGA2560
#define LAMP 0x20
#define SH 0x40
#define ICG 0x80
#define MCLK 0x10
#else
#define LAMP 0x01
#define SH 0x02
#define ICG 0x04
#define MCLK 0x08
#endif
#define CLOCK PORTB
uint8_t buffer[800];
uint8_t avg = 0;
char cmdBuffer[16];
int cmdIndex;
int exposureTime = 20;

void setup()
{
  uint8_t val;

  // Initialize the clocks.
  DDRB |= (LAMP | SH | ICG | MCLK);  // Set the clock lines
to outputs
  CLOCK |= ICG;       // Set the integration clear gate
high.

  // Enable the serial port.
  Serial.begin(115200);

  // Setup timer2 to generate a 470kHz frequency on D11
  TCCR2A =  + (0 << COM2A1) | (1 << COM2A0) | (1 << WGM21)
| (0 << WGM20);
  TCCR2B = (0 << WGM22) | (1 << CS20);
  OCR2A = 20;
  TCNT2 = 1;

  // Set the ADC clock to sysclk/32
  ADCSRA &= ~((1 << ADPS2) | (1 << ADPS1) | (1 << ADPS0));
  ADCSRA |= (1 << ADPS2) | (1 << ADPS0);
}

void readCCD(void)
```

```
{
  int x;
  uint8_t result;

  CLOCK &= ~ICG;
  _delay_loop_1(12);
  CLOCK |= SH;
  delayMicroseconds(5);
  CLOCK &= ~SH;
  delayMicroseconds(15);
  CLOCK |= ICG;
  delayMicroseconds(1);

  for (x = 0; x < 800; x++)
  {
    CLOCK |= SH;
    if (x == 0)
    {
      avg = (uint8_t)(analogRead(A0) >> 2);
      result = (uint8_t)(analogRead(A0) >> 2);
    }
    else
    {
      result = (uint8_t)(analogRead(A0) >> 2);
      if (result < avg)
      {
        result = 0;
      }
      else
      {
        result -= avg;
      }
      buffer[x] = result;
      delayMicroseconds(20);
    }
    CLOCK &= ~SH;
  }
}

uint16_t centroid()
{
  uint16_t x;
  uint32_t sum = 0;
  uint32_t so_far = 0;
  uint32_t half_max;

  for (x = 0; x < sizeof(buffer); ++x)
```

```
  {
    sum += buffer[x];
  }
  half_max = sum / 2;
  for (x = 0; x < sizeof(buffer); ++x)
  {
    so_far += buffer[x];
    if (so_far >= half_max)
    {
      return x;
    }
  }
}

void sendData(void)
{
  int x;

  for (x = 0; x < 800; ++x)
  {
    Serial.println(buffer[x]);
  }
}

void loop()
{
  int x;
  Serial.print("Centroid position: ");
  Serial.println(centroid());
  if (Serial.available())
  {
    cmdBuffer[cmdIndex++] = Serial.read();
  }
  if (cmdBuffer[0] == 'r')
  {
    sendData();
  }
  else if (cmdBuffer[0] == 'l')
  {
    CLOCK &= ~LAMP;
  }
  else if (cmdBuffer[0] == 'L')
  {
    CLOCK |= LAMP;
  }
  else if (cmdBuffer[0] == 'e')
  {
```

```
    if (--exposureTime < 0) exposureTime = 0;
    Serial.print("Exposure time ");
    Serial.println(exposureTime);
  }
  else if (cmdBuffer[0] == 'E')
  {
    if (++exposureTime > 200) exposureTime = 200;
    Serial.print("Exposure time ");
    Serial.println(exposureTime);
  }
  else if (cmdBuffer[0] == 'c')
  {
    Serial.print("Centroid position: ");
    Serial.println(centroid());
  }
  cmdBuffer[0] = '\0';
  cmdIndex = 0;

  readCCD();
  delay(exposureTime);
}
```

PYTHON CODE (DJANGO)

```
import psycopg2
from datetime import datetime
import serial
import time

arduino1=serial.Serial("/dev/ttyACM1")
arduino1.baudrate=9600

data=arduino1.readline()
time.sleep(1)

mode=data


now=datetime.now()

conn= psycopg2.connect("dbname=postgres user=postgres
password=1234 host=localhost")

cur = conn.cursor()
```

```
cur.execute("SELECT datetime, mode, nitrogen, phosphorus,
potassium, ph, arsenic, cadmium, lead, mercury from
results_archives")

cur.execute("INSERT INTO results_archives (datetime ,mode,
nitrogen, phosphorus, potassium, ph, arsenic, cadmium,
lead, mercury) VALUES (%s, %s, %s, %s, %s, %s, %s, %s, %s,
%s)", (now, mode, "#", "#1", "#2", "#3", "#4", "#5", "#6",
"#7"))
conn.commit()

cur.execute("SELECT datetime, mode, nitrogen, phosphorus,
potassium, ph, arsenic, cadmium, lead, mercury from
results_archives")
rows = cur.fetchall()
rows

cur.close
conn.close
#!/usr/bin/env python
"""Django's command-line utility for administrative
tasks."""
import os
import sys


def main():
    os.environ.setdefault('DJANGO_SETTINGS_MODULE',
'thesiswebsite.settings')
    try:
        from django.core.management import
execute_from_command_line
    except ImportError as exc:
        raise ImportError(
            "Couldn't import Django. Are you sure it's
installed and "
            "available on your PYTHONPATH environment
variable? Did you "
            "forget to activate a virtual environment?"
        ) from exc
    execute_from_command_line(sys.argv)


if __name__ == '__main__':
    main()

"""
```

```
Django settings for thesiswebsite project.

Generated by 'django-admin startproject' using Django
2.2.4.

For more information on this file, see
https://docs.djangoproject.com/en/2.2/topics/settings/

For the full list of settings and their values, see
https://docs.djangoproject.com/en/2.2/ref/settings/
"""

import os

# Build paths inside the project like this:
os.path.join(BASE_DIR, ...)
BASE_DIR =
os.path.dirname(os.path.dirname(os.path.abspath(__file__)))


# Quick-start development settings - unsuitable for
production
# See
https://docs.djangoproject.com/en/2.2/howto/deployment/chec
klist/

# SECURITY WARNING: keep the secret key used in production
secret!
SECRET_KEY =
'+c8pgkh#yrk!nexc+j4e+xs0o6ncbvahvq$+o#1todl7191uu1'

# SECURITY WARNING: don't run with debug turned on in
production!
DEBUG = True

ALLOWED_HOSTS = ['*']


# Application definition

INSTALLED_APPS = [
    'home',
    'search',
    'results',
    'mobileobjectives',
    'mobilehome',
    'mobileresults',
```

```
    'mobileproponents',
    'django.contrib.admin',
    'django.contrib.auth',
    'django.contrib.contenttypes',
    'django.contrib.sessions',
    'django.contrib.messages',
    'django.contrib.staticfiles',
]

MIDDLEWARE = [
    'django.middleware.security.SecurityMiddleware',
    'django.contrib.sessions.middleware.SessionMiddleware',
    'django.middleware.common.CommonMiddleware',
    'django.middleware.csrf.CsrfViewMiddleware',

'django.contrib.auth.middleware.AuthenticationMiddleware',
    'django.contrib.messages.middleware.MessageMiddleware',

'django.middleware.clickjacking.XFrameOptionsMiddleware',
]

ROOT_URLCONF = 'thesiswebsite.urls'

TEMPLATES = [
    {
        'BACKEND':
'django.template.backends.django.DjangoTemplates',
        'DIRS': [],
        'APP_DIRS': True,
        'OPTIONS': {
            'context_processors': [
                'django.template.context_processors.debug',

'django.template.context_processors.request',

'django.contrib.auth.context_processors.auth',

'django.contrib.messages.context_processors.messages',
            ],
        },
    },
]

WSGI_APPLICATION = 'thesiswebsite.wsgi.application'


# Database
```

```
#
https://docs.djangoproject.com/en/2.2/ref/settings/#databas
es

DATABASES = {
    'default': {
        'ENGINE': 'django.db.backends.postgresql',
        'NAME': 'postgres',
        'USER': 'postgres',
        'PASSWORD': '1234',
        'HOST': 'localhost',
    }
}



# Password validation
# https://docs.djangoproject.com/en/2.2/ref/settings/#auth-
password-validators

AUTH_PASSWORD_VALIDATORS = [
    {
        'NAME':
'django.contrib.auth.password_validation.UserAttributeSimil
arityValidator',
    },
    {
        'NAME':
'django.contrib.auth.password_validation.MinimumLengthValid
ator',
    },
    {
        'NAME':
'django.contrib.auth.password_validation.CommonPasswordVali
dator',
    },
    {
        'NAME':
'django.contrib.auth.password_validation.NumericPasswordVal
idator',
    },
]


# Internationalization
# https://docs.djangoproject.com/en/2.2/topics/i18n/
```

```
LANGUAGE_CODE = 'en-us'

TIME_ZONE = 'Singapore'

USE_I18N = True

USE_L10N = True

USE_TZ = True


# Static files (CSS, JavaScript, Images)
# https://docs.djangoproject.com/en/2.2/howto/static-files/

STATIC_URL = '/static/'
STATICFILES_DIRS = [
    os.path.join(BASE_DIR,'static')
]
STATIC_ROOT = os.path.join(BASE_DIR, 'assets')
"""thesiswebsite URL Configuration

The `urlpatterns` list routes URLs to views. For more
information please see:
    https://docs.djangoproject.com/en/2.2/topics/http/urls/
Examples:
Function views
    1. Add an import:  from my_app import views
    2. Add a URL to urlpatterns:  path('', views.home,
name='home')
Class-based views
    1. Add an import:  from other_app.views import Home
    2. Add a URL to urlpatterns:  path('', Home.as_view(),
name='home')
Including another URLconf
    1. Import the include() function: from django.urls
import include, path
    2. Add a URL to urlpatterns:  path('blog/',
include('blog.urls'))
"""
from django.contrib import admin
from django.urls import path, include

urlpatterns = [
    path('',include('mobilehome.urls')),
    path('home/',include('home.urls')),
    path('admin/', admin.site.urls),
```

```
    path('results/', include('results.urls')),
    path('search/',include('search.urls')),
    path('objectives/',include('objectives.urls')),
    path('proponents/',include('proponents.urls')),
    path('results/mobile/',include('mobileresults.urls')),

path('proponents/mobile/',include('mobileproponents.urls'))
,

path('objectives/mobile/',include('mobileobjectives.urls'))
,
]
```

WEBPAGE CODES

```
{% load static %}
<html>
<link href="{% static 'css.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
 <script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>

<title>SLICE</title>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>

          <div id="link-container">
               <ul>
                    <a href="{% url 'home'
%}"><li>HOME</li></a>
                    <a href="{% url 'objectives'
%}"><li>OBJECTIVES</li></a>
                    <a href="{% url 'results'
%}"><li>RESULTS</li></a>
                    <a href="{% url 'proponents'
%}"><li>PROPONENTS</li></a>
               </ul>
          </div>
          <!-- SEARCH
          <div id="search">
               <input type="text" placeholder="Search"
id="searchtext">
```

```
                <a id="button"
href="http://localhost:8000/search"><i class="fas fa-
search"></i></a>
          </div>
          --->
     </div>
     </header>

<div class="container" style="height: 1000px; margin-top:
35px;">
          <div id="c1">
               <div id="c2"></div>
               <div id="c3">
                    <div id="c4"></div>
                    <div id="c5"></div>
               </div>
               <div id="c6">
                 <h1 style="font-size: 50">DESCRIPTION</h1>
                 <p style="font-size: 30">The study aims to
develop a multifunction IoT-based device for soil
contaminants and soil macronutrients analysis through
Raspberry Pi microcontroller using NIR spectroscopy. This
provides a real-time and easy-to-access data display
website for an efficient results.</p>
               </div>

          </div>
     <div id="container-c78">
          <div id="c7"></div>
          <div id="c8"> </div>
     </div>

</div>
     <footer>
     <DIV id="footer">
                    <ul>
               <li><a>Privacy Policy</a></li>
               <li><a>About Us</a></li>
               <li><a>Contact Us</a></li>
               <li><a>SLICE2019</a></li>
          </ul>

     </DIV>
     </footer>
</body>
</html>
```

```
from django.urls import path
from . import views


urlpatterns = [
    path ('', views.home, name='home')
 ]
```

```
{% load static %}
<html>
<link href="{% static 'css3.css' %}" rel="stylesheet">
<link
href="https://fonts.googleapis.com/css?family=Anton&display
=swap" rel="stylesheet">
<link
href="https://fonts.googleapis.com/css?family=Kulim+Park&di
splay=swap" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jqu
ery.min.js"></script>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>SLICE Homepage</title>
<script src="{% static 'jquery-3.1.1.js' %}"></script>
<script src="{% static 'js/jquery-2.1.3.min.js'
%}"></script>
<script src="{% static 'js/cycle2.js' %}"></script>
<header>
     <div id="header">
          <div id="logo"></div>
     </div>
</header>

<body>
          <div id="gallery"></div>
<div id="con1">
          <div id="logo2"></div> <br>

          <p>SLICE</p>
          <div style="width: 700px; height: 5px;
background: black; margin: 0 auto;"></div>

          <div id="intro">
               <h1 style="font-size: 15px; font-family:
'Kulim Park', sans-serif;">Soil nutrients (Nitrogen,
Phosphorus, and Potassium) of a certain agricultural area
```

has its selectivity or specificity for highest potential crop yield. On the other hand, common heavy metals (Arsenic, Cadmium, Lead, and Mercury) found on soil sediments especially beneath polluted bodies of water also became part of our local farmers' struggles. These correspond to laboratory methods used to solve or lessen the amount of the heavy metals content and produce the desired amount of nutrients by applying appropriate fertilizers. The said problems can be managed through efficient soil analysis. The main objective of this study is to develop a multifunction IoT-based device for soil contaminants and macronutrients analysis through Raspberry Pi using NIR spectroscopy to lessen unnecessary efforts by farmers on going to regional soil test laboratories and to provide economical soil analysis. The device used TOSHIBA TCD1304AP as CCD linear sensor driven by Arduino MEGA 2560. With the Internet of Things (IoT), configured to Raspberry Pi through Django and pgAdmin, anyone connected to the provided WiFi may access the webpage for the results including the soil contents, pH level, crop recommendations, and potential solutions and treatments for the soil. The gathered data proved 96.0% accuracy and 1.55% error, and 94.5% accuracy and 2.90% error referenced to conventional/laboratory values on macronutrients and contaminants, respectively. The data especially percent error implied discrepancies to both device and human input to be further improved and refined.

```
                </h1>
            </div>
</div>
<div id="con2">
     <div id="proponents">  </div>
     <p> PROPONENTS </p>
          <div style="width: 700px; height: 5px;
background: #813F0B; margin: 0 auto;"></div>
     <div class="propcon">
          <div id="prop1" class="proppp"></div>
          <div id="prop2" class="proppp"></div>
          <div id="prop3" class="proppp"></div>
          <div id="prop4" class="proppp"></div>
          <div id="prop5" class="proppp"></div>
          <div id="prop6" class="proppp"></div>
          <div id="prop7" class="proppp"></div>

     </div>
     <div style="height: 1px; width: 10px;"></div>
</div>
```

```
<div id="con3">
     <div id="results">  </div>
     <p> RESULTS </p>
          <div style="width: 700px; height: 5px;
background: #813F0B; margin: 0 auto;"></div>
<div id="rescon">

{% for ent in entry %}
     <div class="box"> <a href="{% url 'details' pk=ent.pk
%}"><h1>ASDASD</h1></a></div>
{% endfor %}

</div>
     <div style="height: 50px; width: 100px; float:
left;"></div>

</div>
<div id="con4"></div>

<script type="text/javascript">

     $(document).ready(function(){
          $('.result').click(function(e){
               $this = $(this).find("#others");
               $this.toggleClass('active');
          })

     })



     $(document).ready(function(){
          $('#con1').click(function(e){
               $('#intro').toggleClass('active');
               $('#con1').toggleClass('active');
          $('body').toggleClass('active');
          $('html, body').animate({
          scrollTop: $("#con1").offset().top
          }, 500);
          })



     })
     $(document).ready(function(){
          $('#con2').click(function(e){
               $('.propcon').toggleClass('active');
```

```
                $('#con2').toggleClass('active');
                $('html, body').animate({
            scrollTop: $("#con2").offset().top
            }, 500);
            $('body').toggleClass('active');
            $('#propbutton').toggleClass('active');
            })


      })
      $(document).ready(function(){
            $('#con3').click(function(e){
                $('.box').toggleClass('active');
                $('#con3').toggleClass('active');
                $('html, body').animate({
            scrollTop: $("#con3").offset().top
            }, 500);
            $('body').toggleClass('active');
            })

      })
      $(document).ready(function(){
            $('#con4').click(function(e){
                $('#con4').toggleClass('active');
                $('html, body').animate({
            scrollTop: $("#con4").offset().top
            }, 500);
            $('body').toggleClass('active');
            })

      })

</script>
<!--HEIGHT
<script type="text/javascript">

function height() {
      var h = window.innerHeight;
      var a = document.getElementById('container-img');
      a.style.height = h+"px";
      }

window.addEventListener('load',height);
window.addEventListener('resize',height);
</script>
-->
```

```
</body>
</html>

{% load static %}
<html>
<link href="{% static 'css3.css' %}" rel="stylesheet">
<link
href="https://fonts.googleapis.com/css?family=Anton&display
=swap" rel="stylesheet">
<link
href="https://fonts.googleapis.com/css?family=Kulim+Park&di
splay=swap" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jqu
ery.min.js"></script>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>SLICE Homepage</title>
<script src="{% static 'jquery-3.1.1.js' %}"></script>
<script src="{% static 'js/jquery-2.1.3.min.js'
%}"></script>
<script src="{% static 'js/cycle2.js' %}"></script>
<header>
     <!--
     <div id="header">
          <div id="logo"></div>
     </div>
     -->
</header>

<body>
          <h1 style="padding-top: 10px; text-align: center;
color: green; font-size: 50px;">Soil Macronutrients</h1>
               <h1 style="padding-top: 10px; text-align:
center; color: BLUE; font-size: 50px;">CONCENTRATION</h1>
               <p style="text-align: center; color: black;
font-size: 40px; margin-bottom: -50px">Nitrogen:
{{detail.nitrogen}} ppm</p>
               <p style="text-align: center; color: black;
font-size: 40px;
               margin-bottom: -50px">Phosphorus:
{{detail.phosphorus}} ppm</p>
```

```
                <p style="text-align: center; color: black;
font-size: 40px;
                margin-bottom: -50px">Potassium:
{{detail.potassium}} ppm</p>
                <p style="text-align: center; color: black;
font-size: 40px;">pH: {{detail.ph}} ppm</p>

                <form>
                     <input type="button" value="Go Back"
onclick="history.go(-1)">
                </form>

</body>
</html>

{% load static %}
<html>
<link href="{% static 'css2.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>Results</title>
<script src="{% static 'jquery-3.1.1.js' %}"></script>
<script src="{% static 'js/jquery-2.1.3.min.js'
%}"></script>
<script src="{% static 'js/cycle2.js' %}"></script>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>
     </div>
     <div id="link-container">
                <ul>
                     <a href="{% url 'mobilehome'
%}"><li>HOME</li></a>
                     <a href="{% url 'mobileobjectives'
%}"><li>OBJECTIVES</li></a>
                     <a href="{% url 'mobileresults'
%}"><li>RESULTS</li></a>
                     <a href="{% url 'mobileproponents'
%}"><li>PROPONENTS</li></a>
                </ul>
     </div>
```

```
     </header>


<div class="container">

<h1 style=" text-align: center; font-size: 50; padding:
50px 0 0 0; font-family: Helvetica;">OBJECTIVES</h1>
     <div style="width: 700px; height: 620px; background:
rgba(255,255,255,0.44); margin: 0 auto; padding: 50px;">
     <p style="font-size: 25px; font-family:
Helvetica;">The study purposely seeks to reach the
following objectives in developing an automated and
organized soil analysis in agricultural land and beneath
polluted body of water.</p>

     <p style="font-size: 25px; font-family: Helvetica;">
          1.   To design a multifunction device analyzing
soil samples from agricultural lands and polluted bodies of
water through spectroscopy <br><br>
2.   To build a library containing contaminant and
nutrients parameters and their corresponding treatments and
recommendations, respectively <br><br>
3.   To develop an IoT common platform in processing the
data inputs and providing efficient and faster
results<br><br>
4.   To assess and validate the device's gathered data for
accuracy and efficiency by comparing soil test kits and
laboratory results
<br><br>
5.   To display an efficient and qualitative information of
the soil, and the recommended treatments and crops of each
soil sample<br><br>

     </p>
          </div>

</div>

<script type="text/javascript">

     $(document).ready(function(){
          $('.result').click(function(e){
               $this = $(this).find("#others");
               $this.toggleClass('active');
          })

     })
```

```
     $(document).ready(function(){
          $('#header-container').click(function(e){
               $('#link-container').toggleClass('drop');
          })

     })
</script>
<!--HEIGHT
<script type="text/javascript">

function height() {
     var h = window.innerHeight;
     var a = document.getElementById('container-img');
     a.style.height = h+"px";
     }

window.addEventListener('load',height);
window.addEventListener('resize',height);
</script>
-->
     </div>
     </div>
     <footer>
     </footer>
</body>
</html>

{% load static %}
<html>
<link href="{% static 'css2.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>Results</title>
<script src="{% static 'jquery-3.1.1.js' %}"></script>
<script src="{% static 'js/jquery-2.1.3.min.js'
%}"></script>
<script src="{% static 'js/cycle2.js' %}"></script>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>
     </div>
```

```
     <div id="link-container">
               <ul>
                    <a href="{% url 'mobilehome'
%}"><li>HOME</li></a>
                    <a href="{% url 'mobileobjectives'
%}"><li>OBJECTIVES</li></a>
                    <a href="{% url 'mobileresults'
%}"><li>RESULTS</li></a>
                    <a href="{% url 'mobileproponents'
%}"><li>PROPONENTS</li></a>
               </ul>
     </div>
     </header>
<div class="container">
     <div id="proponents-container">
                    <div class="mates"
style="background:url({% static 'images/id/maam.jpg' %});
background-repeat: no-repeat; background-size: contain;"><p
style="font-size: 40px; margin-top: 750px; ">Engr. Maria
Victoria Padilla </br> Adviser</p>
                    </div>
                    <div class="mates"
style="background:url({% static 'images/id/ed.jpg' %});
margin-top: 80px; background-repeat: no-repeat; background-
size: contain;"><p style="font-size: 40px; margin-top:
750px; ">Andrew Ed Colocado</p></div>
                    <div class="mates"
style="background:url({% static 'images/id/ian.jpg' %});
background-repeat: no-repeat; background-size: contain;"><p
style="font-size: 40px; margin-top: 750px; ">Roland Ian
Regala</p></div>
                    <div class="mates"
style="background:url({% static 'images/id/cara.jpg' %});
background-repeat: no-repeat; background-size: contain;"><p
style="font-size: 40px; margin-top: 750px; ">Cara Lou
Pepanio</p> </div>
                    <div class="mates"
style="background:url({% static 'images/id/aziel.jpg' %});
background-repeat: no-repeat; background-size: contain;"><p
style="font-size: 40px; margin-top: 750px; ">John Aziel
Aloria</p> </div>
                    <div
class="mates"style="background:url({% static
'images/id/patrick.jpg' %}); background-repeat: no-repeat;
background-size: contain;"><p style="font-size: 40px;
margin-top: 750px; ">Carl John Patrick Castillo</p> </div>
```

```
                    <div class="mates"
style="background:url({% static 'images/id/davidson.jpg'
%}); background-repeat: no-repeat; background-size:
contain;"><p style="font-size: 40px; margin-top: 750px;
">Davidson Ramos</p> </div>
          </div>
</div>

<script type="text/javascript">

     $(document).ready(function(){
          $('.result').click(function(e){
               $this = $(this).find("#others");
               $this.toggleClass('active');
          })

     })



     $(document).ready(function(){
          $('#header-container').click(function(e){
               $('#link-container').toggleClass('drop');
          })

     })
</script>
<!--HEIGHT
<script type="text/javascript">

function height() {
     var h = window.innerHeight;
     var a = document.getElementById('container-img');
     a.style.height = h+"px";
     }

window.addEventListener('load',height);
window.addEventListener('resize',height);
</script>
-->


     </div>


     </div>
```

```
     <footer>


     </footer>
</body>
</html>

{% load static %}
<html>
<link href="{% static 'css2.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>Results</title>
<script src="{% static 'jquery-3.1.1.js' %}"></script>
<script src="{% static 'js/jquery-2.1.3.min.js'
%}"></script>
<script src="{% static 'js/cycle2.js' %}"></script>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>
     </div>
     <div id="link-container">
               <ul>
                    <a href="{% url 'mobilehome'
%}"><li>HOME</li></a>
                    <a href="{% url 'mobileobjectives'
%}"><li>OBJECTIVES</li></a>
                    <a href="{% url 'mobileresults'
%}"><li>RESULTS</li></a>
                    <a href="{% url 'mobileproponents'
%}"><li>PROPONENTS</li></a>
               </ul>
     </div>



     </header>


<div class="container">

<h1 style="text-align: center; font-family: Helvetica;
font-size: 50px">ARCHIVE</h1>
```

```
     <div style="height: 5px; background-color: rgba(0,0,0,
0.5); width: 95%; margin: 0 auto; margin-top: -
10px;"></div>

     {% for ent in entry %}

     <div class="result" style="overflow-y: hidden;">
          <h1 style=" float: left; color:white; line-
height: 70px; margin: 0 10px 0 10px; font-size:
50px;">{{ent.id}} .) {{ent.datetime}} </h1>
          <h1 style="float:left; color: white; line-height:
50px; margin: 0 0 0 50px;"></h1>
          <div id="others">

               <!-- MODE 1 -->
          {% if ent.mode == 1 %}
               <h1 style="padding-top: 10px; text-align:
center; color: green; font-size: 50px;">Soil
Macronutrients</h1>
               <h1 style="padding-top: 10px; text-align:
center; color: white; font-size: 50px;">CONCENTRATION</h1>
               <p style="text-align: center; color: white;
font-size: 40px; margin-bottom: -50px">Nitrogen:
{{ent.nitrogen}} lb/area</p>
               <p style="text-align: center; color: white;
font-size: 40px;
               margin-bottom: -50px">Phosphorus:
{{ent.phosphorus}} lb/area</p>
               <p style="text-align: center; color: white;
font-size: 40px;
               margin-bottom: -50px">Potassium:
{{ent.potassium}} lb/area</p>
               <p style="text-align: center; color: white;
font-size: 40px;">pH: {{ent.ph}} lb/area</p>

               <h1 style="padding-top: 10px; text-align:
center; color: white; font-size: 50px;">RECOMMENDATION</h1>




               {% if ent.nitrogen >= 100.0 %}
               <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;">Lime </br> Dolomitic Limestone <br> Wheat <br>
Cabbage <br> Rice </p>
               {% else %}
```

```
                {% endif %}

                {% if ent.phosphorus > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;"></p>
                {% else %}
                {% endif %}

                {% if ent.potassium > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;"></p>
                {% else %}
                {% endif %}

                {% if ent.ph > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;"></p>
                {% else %}
                {% endif %}

                <!-- MODE 2 -->
           {% elif ent.mode == 2 %}
                <h1 style="padding-top: 10px; text-align:
center; color: orange; font-size: 50px;">Soil
Contaminants</h1>
                <h1 style="padding-top: 10px; text-align:
center; color: white; font-size: 50px;">CONCENTRATION</h1>
                <p style="text-align: center; color: white;
font-size: 40px; margin-bottom: -50px">Arsenic:
{{ent.arsenic}} lb/area</p>
                <p style="text-align: center; color: white;
font-size: 40px;
                margin-bottom: -50px">Cadmium:
{{ent.cadmium}} lb/area</p>
                <p style="text-align: center; color: white;
font-size: 40px;
                margin-bottom: -50px">Lead: {{ent.lead}}
lb/area</p>
                <p style="text-align: center; color: white;
font-size: 40px;">Mercury: {{ent.mercury}} lb/area</p>

                <h1 style="padding-top: 10px; text-align:
center; color: white; font-size: 50px;">RECOMMENDATION</h1>
```

```
                {% if ent.arsenic > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;">if arsenic is high</p>
                {% else %}
                {% endif %}

                {% if ent.cadmium > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;">if cadmium is high</p>
                {% else %}
                {% endif %}

                {% if ent.lead > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;">if lead is high</p>
                {% else %}
                {% endif %}

                {% if ent.mercury > 1.0 %}
                <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white; font-size:
40px;">if mercury is high</p>
                {% else %}
                {% endif %}
           {% else %}
           {% endif %}

           </div>
     </div>

     {% endfor %}

</div>

<script type="text/javascript">

     $(document).ready(function(){
          $('.result').click(function(e){
               $this = $(this).find("#others");
               $this.toggleClass('active');
          })

     })
```

```
     $(document).ready(function(){
          $('#header-container').click(function(e){
               $('#link-container').toggleClass('drop');
          })

     })
</script>
<!--HEIGHT
<script type="text/javascript">

function height() {
     var h = window.innerHeight;
     var a = document.getElementById('container-img');
     a.style.height = h+"px";
     }

window.addEventListener('load',height);
window.addEventListener('resize',height);
</script>
-->


     </div>


     </div>


     <footer>


     </footer>
</body>
</html>

{% load static %}
<html>
<link href="{% static 'css.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>SLICE- Objectives</title>
```

```
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"></div>

          <div id="link-container">
               <ul>
                    <a href="{% url 'home'
%}"><li>HOME</li></a>
                    <a href="{% url 'objectives'
%}"><li>OBJECTIVES</li></a>
                    <a href="{% url 'results'
%}"><li>RESULTS</li></a>
                    <a href="{% url 'proponents'
%}"><li>PROPONENTS</li></a>
               </ul>
          </div>
          <!-- SEARCH
          <div id="search">
               <input type="text" placeholder="Search"
id="searchtext">
               <a id="button"
href="http://localhost:8000/search"><i class="fas fa-
search"></i></a>
          </div>
          --->
     </div>
     </header>

<div class="container">
          <h1 style=" text-align: center; font-size: 50;
padding: 50px 0 0 0; font-family:
Helvetica;">OBJECTIVES</h1>
     <div style="width: 800px; height: 580px; background:
rgba(255,255,255,0.44); margin: 0 auto; padding: 50px;">
     <p style="font-size: 25px; font-family:
Helvetica;">The study purposely seeks to reach the
following objectives in developing an automated and
organized soil analysis in agricultural land and beneath
polluted body of water.</p>

     <p style="font-size: 25px; font-family: Helvetica;">
          1.   To design a multifunction device analyzing
soil samples from agricultural lands and polluted bodies of
water through spectroscopy <br><br>
```

```
2.   To build a library containing contaminant and
nutrients parameters and their corresponding treatments and
recommendations, respectively <br><br>
3.   To develop an IoT common platform in processing the
data inputs and providing efficient and faster
results<br><br>
4.   To assess and validate the device's gathered data for
accuracy and efficiency by comparing soil test kits and
laboratory results
<br><br>
5.   To display an efficient and qualitative information of
the soil, and the recommended treatments and crops of each
soil sample<br><br>

     </p>
     </div>
</div>


     </div>


     <footer>


     </footer>
</body>
</html>
{% load static %}
<html>
<link href="{% static 'css.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>SLICE- Proponents</title>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>

          <div id="link-container">
               <ul>
                    <a href="{% url 'home'
%}"><li>HOME</li></a>
                    <a href="{% url 'objectives'
%}"><li>OBJECTIVES</li></a>
```

```
                    <a href="{% url 'results'
%}"><li>RESULTS</li></a>
                    <a href="{% url 'proponents'
%}"><li>PROPONENTS</li></a>
                </ul>
          </div>
          <!-- SEARCH
          <div id="search">
               <input type="text" placeholder="Search"
id="searchtext">
               <a id="button"
href="http://localhost:8000/search"><i class="fas fa-
search"></i></a>
          </div>
          --->
     </div>
     </header>

     <div class="container">

          <div id="proponents-container">
                    <div class="mates"
style="background:url({% static 'images/id/ed.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p></p></div>
                    <div class="mates"
style="background:url({% static 'images/id/ed.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p>Engr. Maria Victoria Padilla</p></div>
                    <div class="mates"
style="background:url({% static 'images/id/ed.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p></p></div>
                    <div class="mates"
style="background:url({% static 'images/id/ian.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p>Andrew Ed Colocado</p></div>
                    <div class="mates"
style="background:url({% static 'images/id/ian.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p>Roland Ian Regala</p></div>
                    <div class="mates"
style="background:url({% static 'images/id/ian.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p>Cara Lou Pepanio</p> </div>
                    <div class="mates"
style="background:url({% static 'images/id/ian.jpg' %});
```

```
background-repeat: no-repeat; background-size:
contain;"><p>John Aziel Aloria</p> </div>
                    <div
class="mates"style="background:url({% static
'images/id/ian.jpg' %}); background-repeat: no-repeat;
background-size: contain;"><p>Carl John Patrick
Castillo</p> </div>
                    <div class="mates"
style="background:url({% static 'images/id/ian.jpg' %});
background-repeat: no-repeat; background-size:
contain;"><p>Davidson Ramos</p> </div>
          </div>

     </div>


     </div>


     <footer>


     </footer>
</body>
</html>

{% load static %}
<html>
<link href="{% static 'css.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>Results</title>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>

          <div id="link-container">
               <ul>
                    <a href="{% url 'home'
%}"><li>HOME</li></a>
                    <a href="{% url 'objectives'
%}"><li>OBJECTIVES</li></a>
                    <a href="{% url 'results'
%}"><li>RESULTS</li></a>
```

```
                    <a href="{% url 'proponents'
%}"><li>PROPONENTS</li></a>
          </div>
          <!-- SEARCH
          <div id="search">
               <input type="text" placeholder="Search"
id="searchtext">
               <a id="button"
href="http://localhost:8000/search"><i class="fas fa-
search"></i></a>
          </div>
          --->
     </div>
     </header>

<div class="container">
     <h1 style="text-align: center; font-family:
Helvetica;">ARCHIVE</h1>
     <div style="height: 2px; background-color: rgba(0,0,0,
0.5); width: 95%; margin: 0 auto; margin-top: -
10px;"></div>

     {% for ent in entry %}

     <div class="result" style="overflow-y: hidden;">
          <h1 style=" float: left; color:white; line-
height: 50px; margin: 0 10px 0 10px;"> Date:
{{ent.datetime}} {{ent.id}}</h1>
          <h1 style="float:left; color: white; line-height:
50px; margin: 0 0 0 50px;"></h1>
          <div id="others">
               <h1 style="padding-top: 10px; text-align:
center; color: white;">CONCENTRATION</h1>
               <p style="text-align: center; color:
white;">{{ent.results}}</p>
               <h1 style="padding-top: 10px; text-align:
center; color: white;">RECOMMENDATION</h1>
               <p style="text-align: center; padding-left:
10px; padding-right: 10px; color: white;">{{ent.reco}}</p>

          </div>
     </div>

     {% endfor %}

<script src="https://code.jquery.com/jquery-
3.4.1.js"></script>
```

```
<script type="text/javascript">
     $(document).ready(function(){
          $('.result').click(function(e){
               $this = $(this).find("#others");
               $this.toggleClass('active');
          })
     })
</script>
     </div>
     </div>
     <footer>
     </footer>
</body>
</html>

{% load static %}
<html>
<link href="{% static 'css.css' %}" rel="stylesheet">
<link href="{% static 'images/TUPLOGO.png' %}" rel="icon"/>
<script
src="https://kit.fontawesome.com/cc6bf2707d.js"></script>
<title>Search Results</title>
<body>
     <header>
     <div id="header-container">
          <div id="logo"></div>
          <div id="slice-logo"> </div>

          <div id="link-container">
               <ul>
                    <a
href="http://localhost:8000/"><li>HOME</li></a>
                    <a href="{% static 'objective.html'
%}"><li>OBJECTIVES</li></a>
                    <a
href="http://localhost:8000/results/"><li>RESULTS</li></a>
                    <a href="{% static 'proponent.html'
%}"><li>PROPONENTS</li></a>
               </ul>
          </div>
          <div id="search">
               <input type="text" placeholder="Search"
id="searchtext">
               <a id="button"
href="http://localhost:8000/search"><i class="fas fa-
search"></i></a>
```

```
          </div>
     </div>
     </header>

     <div class="container">
          <h1 style="color: white; margin-left: 30px;
float: left;">Search Results ...</h1>
     </div>


     </div>


     <footer>


     </footer>
</body>
</html>
```

CASCADED STYLESHEET

CSS1

```
body{
     background-image: url(images/bg.jpg);
     padding: 0px;
     margin:0 0 0 0;
     background-size: 100%;
     background-attachment: fixed;
}
header{
     width: 100%;
     height: 150px;
     background: rgba(0, 0, 80, 0.3);
}
#header-container{
     height:100px;
     width: 1200px;
     margin: 0 auto;
     padding: 30px 0;
     text-align:center;

}
#logo{

     height: 100px;
```

```
     width: 100px;
     background: url(images/TUPLOGO.png);
     background-size: contain;
     background-repeat: no-repeat;
     float:left;
     margin-right: 30px;
     display: inline-block;
}
#slice-logo{
     height: 100px;
     width: 200px;
     background:url(images/logo.png);
     background-size: contain;
     background-repeat: no-repeat;
     background-position: center;
     float:left;
     margin-right: 30px;
     display: inline-block;
     text-align: center;
     line-height: 100px
}
::placeholder{
     color: white;
}
.result{
     min-height: 50px;
     width: 90%;
     margin: 10px auto;
     background-color: rgba(0,0,0,0.4);
     overflow: auto;
}

.result:active{
     background-color: rgba(255,255,255,0.4);
}

#others{
 height: 0px;
 width:800px;
 background-color: rgba(0,0,0,0.4);
 position: relative;
 margin:50px auto 10px auto;
 transition: 0.5s;
 overflow: auto;
}
#others.active{
     height: 300px;
```

```
     padding: 0 1px;
}

#others::-webkit-scrollbar {
    width: 15px;
}

#others::-webkit-scrollbar-track {
    -webkit-box-shadow: inset 0 0 6px rgba(0,0,0,0.3);
    border-radius: 10px;
}

#others::-webkit-scrollbar-thumb {
    border-radius: 10px;
    -webkit-box-shadow: inset 0 0 6px rgba(0,0,0,0.5);
}
#search{
     top:35px;
     height:35px;
     width: 200px;
     padding: 5px;
     background-color:rgba(52,115,213,.50);
     border-radius: 35px;
     transform: translate(-50%,-50%);
     position:absolute;
     float:right;
     left: 1100px;
     transition: 0.4s;

}
#button{
     float: right;
     border-radius: 50%;
     padding:5px;
     background-color:aqua;
     height: 20px;
     width: 20px;
     justify-content: center;
     align-items: center;
}
#search:hover > #searchtext{
     width: 150px;
     padding: 0 6px;
}
#search:hover {
     width: 200px;
}
```

```
#search a{
     color: white;
}
#searchtext{
     border: none;
     background: none;
     color: white;
     line-height: 35px;
     transition: 0.4s;
     width: 0px;
     padding: 0;
     float: left;

}

header ul li{
     font-family: Helvetica;
     font-size: 20;
     color: white;
     display: inline;
     margin-right: 0px;
     height: 50px;
     width: 150px;
     float: left;
     text-align:center;
     margin-top: 15px;
     line-height: 50px;
     transition: background-color 0.5s ease-out;

}
header ul li:hover{
     background: rgba(0,0,0,0.3);
}
header ul li a:hover {
     color: black;
}
header ul li:active{
     color: rgba(255,255,255,0.3);
}
#c1{
     position: absolute;
     margin: 50px 0 0 25px;
     height: 700px;
     width: 503px;
     float: left;
}
```

```
#c2{
     height: 191.19px;
     width: 350px;
     background:url(images/1.png);
     background-size: contain;
     float: left;
}
#c3{
     width: 150px;
     height: 150px;
     background:url(images/2.jpg);
     background-size: cover;
     background-position: center;
     background-repeat: no-repeat;
     position: relative;
     float: left;
     margin-left: 3px;

}

#c6{
     width: 503px;
     height: 480px;
     background-color:rgba(255,255,255,0.30);
     margin-top: 210px;
     margin-bottom: 10px;
     font-family: Helvetica;
     padding: 10px;
}
#container-c78{
     float: right;
     width: 400px;
     height: 700px;
     margin: 50px 25px 0 0;

}
#c7{
     float: right;
     height: 275px;
     width: 400px;
     background-color: aliceblue;
     background: url(images/avsw.png);
     background-repeat: no-repeat;
     background-size:cover;

}
```

```
#c8{
     position: relative;
     float: right;
     height: 600px;
     width: 400px;
     background-color: aliceblue;
     margin-top: 20px;
     line-height: 450px;
     text-align: center;
     background: url(images/table.png)no-repeat;
     background-position:center;
     background-size: contain;
}

/* container */

.mates p{
     font-family: Helvetica;
     font-size: 20;
     text-align: center;
     margin-top: 310px;
     color: white;

}

.container{
     width: 1050px;
     min-height: 500px;
     padding-bottom: 50px;
     padding-top: 10px;
     padding-left: 10px;
     padding-right: 10px;
     background: rgba(132,142,255,0.7);
     margin: 10px auto 10px auto;
}

.mates{
     width: 300px;
     height: 350px;
     background-color: rgba(0,0,0,0.3);
     float: left;
     margin: 12.5px;
}

#proponents-container{
     margin: 0 auto;
     width:975px;
```

```
     height: 1100px;
     margin-top: 20px;
}

/* END OF BODY */


footer{
     width: 100%;
     height: 80px;
     background: rgba(118,145,192,0.7);
}

footer ul li{
     float: left;
     display: inline;
     margin-right: 30px;
     font-family: Helvetica;
     line-height: 80px;
}

ul li a{
     text-decoration: none;
     color: white;
}
```

Css2

```
body{
     background-image: url(images/bg.jpg);
     padding: 0px;
     margin:0 0 0 0;
     background-attachment: fixed;
     background-position: -500px -50px;
     width:1000px;
}
header{
     width: 100%;
     min-height: 300px;
     background: rgba(0, 0, 80, 0.3);
}
#header-container{
     height:200px;
     width: 800px;
     margin: auto auto;
     padding: 40px 0;
     text-align:center;
```

```
}
#logo{

     height: 220px;
     width: 220px;
     background: url(images/TUPLOGO.png);
     background-size: contain;
     background-repeat: no-repeat;
     float:left;
     margin-right: 30px;
     display: inline-block;
}
#slice-logo{
     height: 250px;
     width: 500px;
     background:url(images/logo.png);
     background-size: contain;
     background-repeat: no-repeat;
     background-position: center;
     float:right;
     margin-right: 0px;
     display: inline-block;
     text-align: center;
     line-height: 100px
}
::placeholder{
     color: white;
}
.result{
     min-height: 70px;
     width: 90%;
     margin: 10px auto;
     background-color: rgba(0,0,0,0.4);
     overflow: auto;
}

.result:active{
     background-color: rgba(255,255,255,0.4);
}

#others{
 height: 0px;
 width:700px;
 background-color: rgba(0,0,0,0.4);
 position: relative;
 margin:50px auto 10px auto;
 transition: 0.5s;
```

```
 overflow: auto;
}

#others.active{
     height: 300px;
     padding: 0 1px;
}

#others::-webkit-scrollbar {
    width: 15px;
}

#others::-webkit-scrollbar-track {
    -webkit-box-shadow: inset 0 0 6px rgba(0,0,0,0.3);
    border-radius: 10px;
}

#others::-webkit-scrollbar-thumb {
    border-radius: 10px;
    -webkit-box-shadow: inset 0 0 6px rgba(0,0,0,0.5);
}
#search{
     top:35px;
     height:35px;
     width: 200px;
     padding: 5px;
     background-color:rgba(52,115,213,.50);
     border-radius: 35px;
     transform: translate(-50%,-50%);
     position:absolute;
     float:right;
     left: 1100px;
     transition: 0.4s;

}
#button{
     float: right;
     border-radius: 50%;
     padding:5px;
     background-color:aqua;
     height: 20px;
     width: 20px;
     justify-content: center;
     align-items: center;
}
#search:hover > #searchtext{
     width: 150px;
```

```
     padding: 0 6px;
}
#search:hover {
     width: 200px;
}
#search a{
     color: white;
}
#searchtext{
     border: none;
     background: none;
     color: white;
     line-height: 35px;
     transition: 0.4s;
     width: 0px;
     padding: 0;
     float: left;

}
#link-container{
     float: left;
     height: 0px;
     width: 1000px;
     margin-top: 20px;
     position: absolute;
     overflow: auto;
     background-color: #a0b6fa;
      transition: 0.5s;
      z-index: 1000;
}

#link-container.drop{
     height: 100%;
     padding: 0 1px;
}
#link-container a{
     text-decoration: none;
}
#link-container ul li{
     font-family: Helvetica;
     font-size: 80px;
     color: white;
     margin-right: auto;
     margin-left: auto;
     height: 100px;
     width: 800px;
     text-align:center;
```

```
     margin-top: 50px;
     border-bottom: black;
     line-height: 50px;
     transition: background-color 0.5s ease-out;
     display: block;
     text-decoration: none;

}
#link-container ul li:hover{
     color: black;

}

#c1{
     position: absolute;
     margin: 50px 0 0 25px;
     height: 700px;
     width: 503px;
     float: left;
}

#c2{
     height: 191.19px;
     width: 350px;
     background:url(images/1.png);
     background-size: contain;
     float: left;
}
#c3{
     width: 150px;
     height: 150px;
     background:url(images/2.jpg);
     background-size: cover;
     background-position: center;
     background-repeat: no-repeat;
     position: relative;
     float: left;
     margin-left: 3px;

}

#c6{
     width: 503px;
     height: 480px;
     background-color:rgba(255,255,255,0.30);
     margin-top: 210px;
     margin-bottom: 10px;
```

```
     font-family: Helvetica;
     padding: 10px;
}
#container-c78{
     float: right;
     width: 400px;
     height: 700px;
     margin: 50px 25px 0 0;

}
#c7{
     float: right;
     height: 275px;
     width: 400px;
     background-color: aliceblue;
     background: url(images/avsw.png);
     background-repeat: no-repeat;
     background-size:cover;

}

#c8{
     position: relative;
     float: right;
     height: 600px;
     width: 400px;
     background-color: aliceblue;
     margin-top: 20px;
     line-height: 450px;
     text-align: center;
     background: url(images/table.png)no-repeat;
     background-position:center;
     background-size: contain;
}

/* container */

.mates p{
     font-family: Helvetica;
     font-size: 20;
     text-align: center;
     margin-top: 310px;
     color: white;

}

.container{
```

```
     width: 800px;
     min-height: 500px;
     padding-bottom: 50px;
     padding-top: 10px;
     padding-left: 10px;
     padding-right: 10px;
     background: rgba(132,142,255,0.7);
     margin: 50px auto 10px auto;
}

.mates{
     width: 750px;
     height:750px;
     background-color: rgba(0,0,0,0.3);
     float: left;
     margin: 12.5px;
     margin-top: 50px;

}

#proponents-container{
     margin: 0 auto;
     width:750px;
     min-height: 5700px;
     margin-top: 20px;
}

/* END OF BODY */


footer{
     width: 100%;
     height: 80px;
     background: rgba(118,145,192,0.7);
}

footer ul li{
     float: left;
     display: inline;
     margin-right: 30px;
     font-family: Helvetica;
     line-height: 80px;
}

ul li a{
     text-decoration: none;
     color: white;
```

```
}

/* SLIIIIIIIIIDERRRRRRRRRRRRRRRRRRRRRRRRRRR */
     #container-img {
          width:800px;
          height: 500px;
          overflow:hidden;
          margin: 0 auto;
          }
     #slideshow {
          height:600px;
          width:800px;
          position:relative;
          margin: 0 auto;
          border-radius:5px;
          }
     #slideshow img {
          height:95%;
          text-align:center;
          position:relative;
          margin: 10px 10px;
          float: left;
          cursor: pointer;
          }
                              Css3
-------------------------------------------------------------------------------
body{
     padding: 0px;
     margin:0 0 0 0;
     background-attachment: fixed;
     background-position: -500px -50px;
     width:1000px;
}
body.active{
     overflow: hidden;
}
header{

}
#header{
     width: 1000px;
     height: 140px;
     background: rgba(255, 255, 255, 0.6);
     z-index: 99;
     position: fixed;
     margin: 140px 0 0 0;
```

```
}
#header:hover{
     background: rgba(255, 255, 255, 0.9);
}

#logo{
     width: 351px;
     height: 140px;
     background:url(images/logo.png);
     background-size: contain;
     background-repeat: no-repeat;
     z-index: 100;
     margin:0 auto 0 auto;
}

#gallery{
     width: 1000px;
     height: 700px;
     background: url(images/header.jpg);
     background-position: 0px -800px;
     background-size: cover;
     background-repeat: no-repeat;
     margin-top: -140px;
     z-index: -1;
     position: relative;
}
.containers{

}
#con1{
     width: 1000px;
     height: 700px;
     background: white;
     transition: 1s cubic-bezier(0.175, 0.885, 0.32,
1.275);
      -o-transition: background 0.5s linear; /* Opera */
}
#con1.active{
     height: 100%;
}
#con2{
     width: 1000px;
     height: 700px;
     background: orange;
     transition: 1s cubic-bezier(0.175, 0.885, 0.32,
1.275);
      -o-transition: background 0.5s linear; /* Opera */
```

```
}
#con2.active{
     height: 100%;
}
#con3{
     width: 1000px;
     height: 700px;
     background: yellow;
     transition: 1s cubic-bezier(0.175, 0.885, 0.32,
1.275);
      -o-transition: background 0.5s linear; /* Opera */
      overflow: auto;
}
#con3.active{
     height: 100%;
}

#con4{
     width: 1000px;
     height: 700px;
     background: lightgreen;
     padding: 0px;
     transition: 1s cubic-bezier(0.175, 0.885, 0.32,
1.275);
      -o-transition: background 0.5s linear; /* Opera */
}
#con4.active{
     height: 100%;
}
.box{
     height: 0px;
     width: 1000px;
     margin: 20px auto 0 auto;
     background: red;
     float: left;
     transition: .5s cubic-bezier(0.175, 0.885, 0.32,
1.275);
}
.box.active{
     height: 100px;
     padding:0 1px;
}
#logo2{
     height: 300px;
     width: 1000px;
     background: url(images/logo2.png);
     background-position: center;
```

```
     background-repeat: no-repeat;
     background-size: contain;
     float: left;
     margin: 100px 0 0 0;
}
#SLICE{
     width: 1000px;
     min-height: 700px;
     float: left;
     overflow: auto;

}
#con1 p{
     font-family: Anton;
     font-size: 100px;
     text-align: center;
     margin: 350px auto 0 auto;

}
#intro{
     height: 0px;
     position: relative;
     overflow: auto;
     width: 750px;
     margin: auto;
     text-align: justify;
     transition: 1.5s cubic-bezier(0.175, 0.885, 0.32,
1.275);
}
#intro.active{
     height: 1050px;
     padding: 0 1px;
}

#proponents{
     height: 10px;
     width: 900px;
     position: relative;
}
#con2 p{
     font-family: Anton;
     font-size: 100px;
     color: #813F0B;
     text-align: center;
     margin: 350px auto 0 auto;

}
```

```
.propcon{
     width: 600px;
     height: 0px;
     margin: 40px auto 50px auto;
     overflow-y: hidden;
     overflow-x: auto;
     white-space: nowrap;
     transition: .5s cubic-bezier(0.175, 0.885, 0.32,
1.275);
}
.propcon.active{
     height: 900px;
}
#picture{
     width: 500px;
     height: 500px;
     position: inherit;
     margin: 40px auto;
     background: blue;
}


#rescon{
     min-height: 0px;
     width: 1000px;
     overflow: auto;
}
#results{
     height: 10px;
     width: 900px;
     position: relative;
}
#con3 p{
     font-family: Anton;
     font-size: 100px;
     color: #813F0B;
     text-align: center;
     margin: 350px auto 0 auto;
}
#prop1{
     background: url(images/id/aloria.png);
}
#prop2{
     background: url(images/id/castillo.png);
}
#prop3{
     background: url(images/id/colocado.png);
```

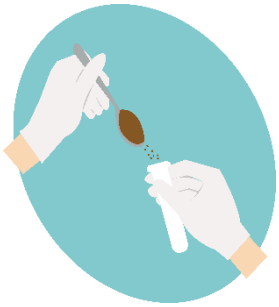
```
}
#prop4{
     background: url(images/id/pepanio.png);
}
#prop5{
     background: url(images/id/ramos.png);
}
#prop6{
     background: url(images/id/regala.png);
}
#prop7{
     background: url(images/id/padilla.png);
}
.proppp{
     width: 100%;
     height: 100%;
     display: inline-block;
}
.propbox{
     width: 10px;
     height: 10px;
     margin: auto;
     background-color: black;
     float: left;
}
```

Appendix C

Setting up SLICE

Instruction

Setting up the sample solution

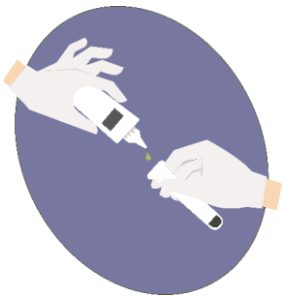


1. Put 1mg of air-dried soil in each 4 test tubes
2. For pH
   - 2.1 Add 36 drops of CPR solution unto the first test tube, mix it well then let it stand for 5 minutes.

3. For Nitrogen
   - 3.1 Add 48 drops of N solution unto the second test tube, mix it well for 5 minutes then let it settle for 30 minutes.

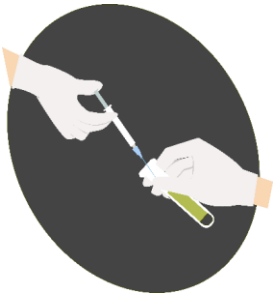
4. For Phosphorous
   - 4.1 Add 48 drops of P solution unto the 3rd test tube, mix it well then let it stand for 5 minutes
   - 4.2 Get a thin foil then wrap it firmly on the tip of the mixer stick
   - 4.3 Stir the solution without disturbing the soil for about 3 minutes

5. For Potassium
   - 5.1 Add 36 drops of K solution unto the 4th test tube, also add 10 drops of K1 then mix it well, let it stand until the soil particles settles on the bottom of the test tube.
   - 5.2 Slowly add 12 drops of K2 solution. One drop at a time
   - 5.3 DO NOT MIX OR SHAKE THE SOLUTION. Let it stand for 2 minutes
   - 5.4 Observe the cloudy yellowish layer on the top of the solution.
   - 5.5 It indicates that P is SUFFICIENT



6. Place the 4 test tubes in a rack.

7. Use disposable syringe for transferring the solution to the container.



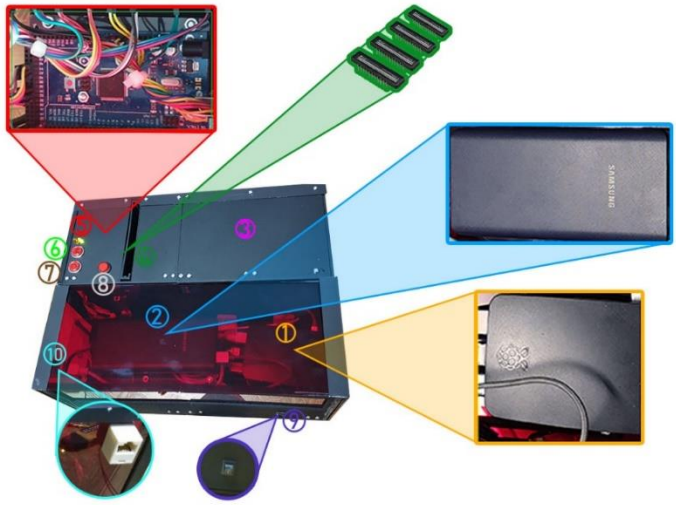
How the SLICE works:

1. Make sure that the Power bank is inside the prototype, then turn on the device
2. Pull the mount and place the sample solution using disposable syringe into the container.
3. Put the mount in the device, make sure that the container was placed properly
4. Choose whether you are testing macronutrients or contaminants, then push the button once.
5. Connect to the slice webserver, results will be shown at the website.
6. Dispose the solution properly and wash the container with distilled water.

Warnings on using SLICE:

1. Wear Personal Protective Equipment (PPE) in preparing/handling the solutions like gloves.
2. Handle the device with care. Always put it in a place where it can maintain its balance
3. Since SLICE is portable, make sure it will not be exposed to the rain.
4. Refrain from pushing the buttons repeatedly and forcefully.
5. Do not open the part where spectrometer is located for it may be misaligned that may cause error and affect the result of the SLICE.

Parts of SLICE



1.Raspberry Pi 3

2. Power bank

3. Spectrometer

4. TCD1304AP (Linear CCD Sensor)

5. Arduino MEGA 2560

6. Button M

7. Button C

8. Mount

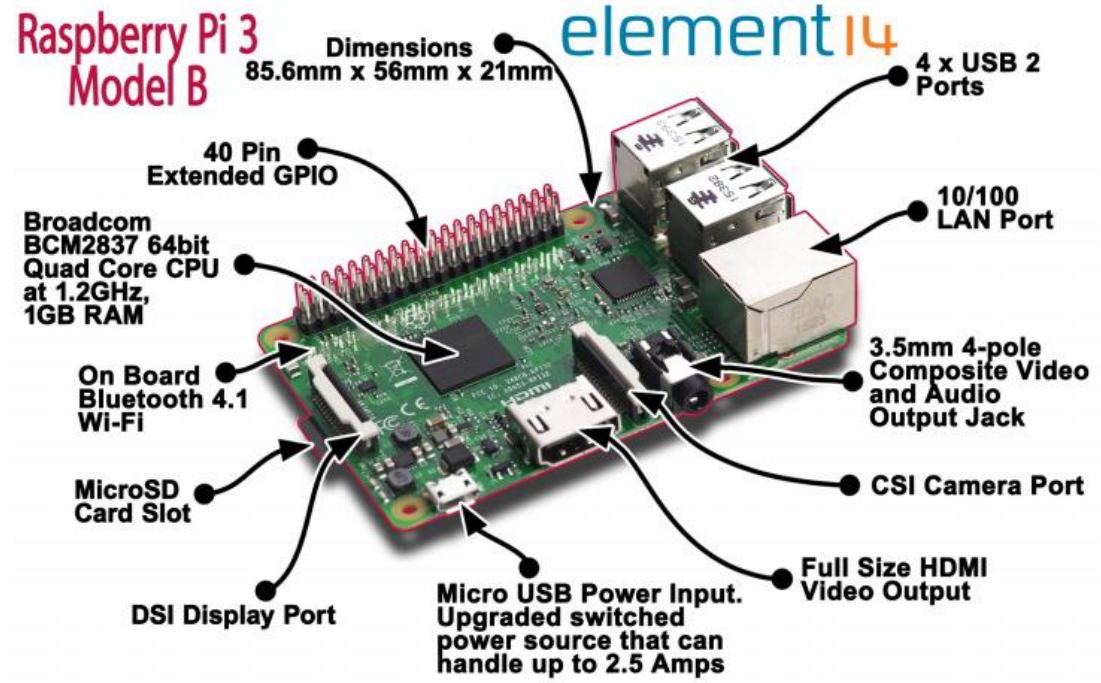
9. Switch

10. Ethernet Hub (To configure Raspberry Pi 3b)

Appendix D

Data Sheets

Raspberry Pi 3 Model B Datasheet



	Raspberryb Pi 3 Model B	Raspberry Pi 2 Model B	Model B+	Model A+	Model A
Processor Chipset	Broadcom BCM2837 64Bit ARMv7 Quad Core Processor powered Single Board Computer running at 1250MHz	Broadcom BCM2836 32Bit ARMv7 Quad Core Processor powered Single Board Computer running at 900MHz	Broadcom BCM2835 32Bit ARMv6 SoC full HD multimedia applications processor	Broadcom BCM2835 32Bit ARMv6 SoC full HD multimedia applications processor	Broadcom BCM2835 32Bit ARMv6 SoC full HD multimedia applications processor
GPU	Videocore IV	Videocore IV	Videocore IV	Videocore IV	Videocore IV
Processor Speed	QUAD Core @ 1250 MHz	QUAD Core @ 900 MHz	Single Core @ 700 MHz	Single Core @ 700 MHz	Single Core @ 700 MHz
RAM	1GB SDRAM @ 400 MHz	1GB SDRAM @ 400 MHz	512 MB SDRAM @ 400 MHz	256 MB SDRAM @ 400 MHz	256 MB SDRAM @ 400 MHz
Storage	MicroSD	MicroSD	MicroSD	MicroSD	SDCard
USB 2.0	4x USB Ports	4x USB Ports	4x USB Ports	1x USB Ports	1x USB Ports
Power Draw/ Voltage	2.5A @ 5V	1.8A @ 5V	1.8A @ 5V	1.8A @ 5V	1.2A @ 5V
GPIO	40 pin	40 pin	40 pin	40 pin	26 pin
Ethernet Port	Yes	Yes	Yes	No	No
Wi-Fi	Built in	No	No	No	No
Bluetooth LE	Built in	No	No	No	No

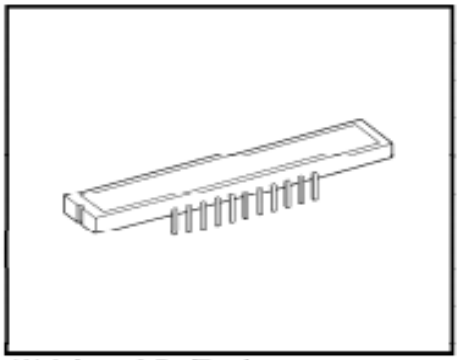
TCD1304AP

TOSHIBA TCD1304AP

TOSHIBA CCD LINEAR IMAGE SENSOR CCD(Charge Coupled Device)

TCD1304AP

The TCD1304AP is a high sensitive and low dark current 3648-elements linear image sensor. The sensor can be used for POS handscanner
The device is consist of sensitivity CCD chip.
The TCD1304AP has electronic shutter function (ICG). Electronic shutter function can keep always output voltage constant that vary with the intensity of lights.

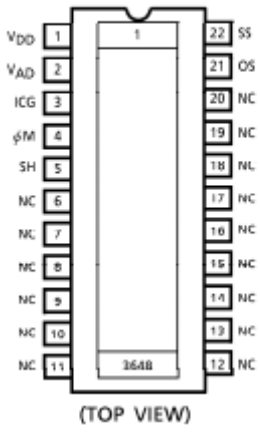


Weight : 2.7g (Typ.)

FEATURES

- Pixel Number : 3648
- Pixel Size : 8μm x 200μm
- Photo Sensing Region
  : High Sensitive & Low Dark Current pn Photodiode
- Internal Circuit : CCD Drive Circuit
- Power Supply : Only 3.0 V Drive (MIN.)
- Function : Electronic Shutter
  Sample and Hold Circuit
- Package : 22 Pin DIP (T-CAPP)
  TOSHIBA-CCD-ADVANCED-PLASTIC-PACKAGE

PIN CONNECTIONS



(TOP VIEW)

MAXIMUM RATINGS (Note 1)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Master Clock Pulse Voltage	$V_{ØM}$	-0.3~7	V
SH Pulse Voltage	V_{SH}		
ICG Pulse Voltage	V_{ICG}		
Digital Power Supply	V_{DD}		
Analog Power Supply	V_{AD}		
Operating Temperature	T_{opr}	-25~60	°C
Storage Temperature	T_{stg}	-40~100	°C

(Note) All voltage are with respect to SS terminals. (Ground)

PIN NAMES

$_{Ø}$M	Master Clock
SH	Shift Gate
ICG	Integration Clear Gate
V_{AD}	Power (Analog)
V_{DD}	Power (Digital)
SS	Ground
NC	Non Connection

FAIRCHILD SEMICONDUCTOR™

2N3906

PNP General Purpose Amplifier

This device is designed for general purpose amplifier and switching applications at collector currents of 10 µA to 100 mA.

Absolute Maximum Ratings*

T_A= 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	40	V
V_{EBO}	Emitter-Base Voltage	5.0	V
I_C	Collector Current – Continuous	200	mA
T_j , T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:

1) These ratings are based on a maximum junction temperature of 150 degrees C.

2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

3) All voltages (V) and currents (A) are negative polarity for PNP transistors.

Thermal Characteristics

T_A= 25°C unless otherwise noted

Symbol	Characteristics	Max			Units
		2N3906	*MMBT3906	**PZT3906	
P_D	Total Device Dissipation	625	350	1,000	mW
	Derate above 25°C	5.0	2.8	8.0	mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3			°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	125	°C/W

*Device mounted on FR-4 PCB 1.6" X 1.6" X 0.06."

**Device mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm; mounting pad for the collector lead min. 6 cm^2

Electrical Characteristics

T_A= 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage*	I_C = 1.0 mA, I_B = 0	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C= 10 µA, I_E= 0	40		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E= 10 µA, I_C = 0	5.0		V
I_{BL}	Base Cutoff Current	V_{CE}= 30 V, V_{BE} = 3.0 V		50	nA
I_{CEX}	Collector Cutoff Current	V_{CE}= 30 V, V_{BE}= 3.0 V		50	nA
ON CHARACTERISTICS					
h_{FE}	DC Current Gain*	I_C= 0.1 mA, V_{CE}= 1.0 V I_C= 1.0 mA, V_{CE}= 1.0 V I_C= 10 mA, V_{CE}= 1.0 V I_C= 50 mA, V_{CE}= 1.0 V I_C= 100 mA, V_{CE}= 1.0 V	60 80 100 60 30	300	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C= 10 mA, I_B= 1.0 mA I_C= 50 mA, I_B= 5.0 mA		0.25 0.4	V V
$V_{BE(sat)\_}$	Base=Emitter Saturation Voltage	I_C= 10 mA, I_B= 1.0 mA I_C= 50 mA, I_B= 5.0 mA	0.65	0.85 0.95	V V
SMALL SIGNAL CHARACTERISTICS					
f_T	Current Gain – Bandwidth Product	I_C= 10 mA, V_{CE}= 20 V, f = 100 MHz	250		MHz
C_{obo}	Output Capacitance	V_{CB}= 5.0 V, I_E= 0, f = 100 kHz		4.5	pF
C_{ibo}	Input Capacitance	V_{EB}= 0.5 V, I_C= 0, f = 100 kHz		10.0	pF
NF	Noise Figure	I_C= 100 µA, V_{CE}= 5.0 V, R_S=1.0kΩ, f=10 Hz to 15.7 kHz		4.0	dB
SWITCHING CHARACTERISTICS					
t_d	Delay Time	V_{CC}= 3.0 V, V_{BE}= 0.5 V, I_C= 10 mA, I_{B1}= 1.0 mA		35	ns
t_r	Rise Time			35	ns
t_s	Storage Time	V_{CC}= 3.0 V, I_C= 10mA I_{B1}= I_{B2}= 1.0 mA		225	ns
t_f	Fall Time			75	ns

*Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%

NOTE: All voltages (V) and currents (A) are negative polarity for PNP transistors.

LM324

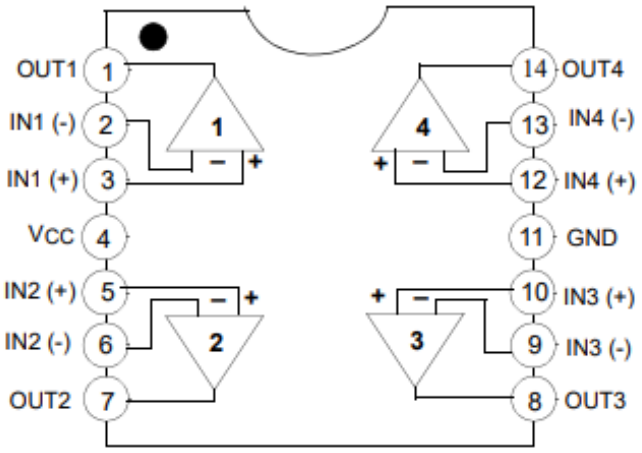
FAIRCHILD SEMICONDUCTOR®

www.fairchildsemi.com

LM2902,LM324/LM324A,LM224/ LM224A

Quad Operational Amplifier

Internal Block Diagram



Absolute Maximum Ratings

Parameter	Symbol	LM224/LM224A	LM324/LM324A	LM2902	Unit
Power Supply Voltage	V_{CC}	±16 or 32	±16 or 32	±13 or 26	V
Differential Input Voltage	$V_{I(DIFF)}$	32	32	26	V
Input Voltage	V_I	-0.3 to +32	-0.3 to +32	-0.3 to +26	V
Output Short Circuit to GND VCC≤15V, TA=25°C(one Amp)	-	Continuous	Continuous	Continuous	-
Power Dissipation, TA=25°C 14-DIP 14-SOP	P_D	 1310 640	 1310 640	 1310 640	mW
Operating Temperature Range	T_{OPR}	-25 ~ +85	0 ~ +70	-40 ~ +85	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	-65 ~ +150	-65 ~ +150	°C

ARDUINO ATMega 2560

Microcontroller	ATmega2560
Operating Voltage	5v
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	14 MHz
LED_BUILTIN	13

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode() , digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These** pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.
- **LED: 13**. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- **I2C: 20 (SDA) and 21 (SCL).** Support I2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I2C pins on the Duemilanove or Diecimila.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

IRF510

3469674 FAIRCHILD SEMICONDUCTOR 84 DE 3469674 0027934 8

FAIRCHILD
A Schlumberger Company

IRF510-513
MTP4N08/4N10
N-Channel Power MOSFETs, 5.5 A, 60-100 V

T-39-09
T-39-11

Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

TO-220AB

- **Low $R_{DS(ON)}$**
- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(ON)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

IRF510
IRF511
IRF512
IRF513
MTP4N08
MTP4N10

Maximum Ratings

Symbol	Parameter	Rating IRF510/512 MTP4N10	Rating MTP4N08	Rating IRF511/513	Unit
V_{DSS}	Drain to Source Voltage	100	80	60	V
V_{DGR}	Drain to Gate Voltage R_{GS} = 20 kΩ	100	80	60	V
V_{GS}	Gate to Source Voltage	±20	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes 1/8" From Case for 5 s	275	275	275	°C
Maximum On-State Characteristics					
		IRF510/511	**IRF512/513**	**MTP4N08/10**	
$R_{DS(ON)}$	Static Drain-to-Source On Resistance	0.60	0.80	0.80	Ω
I_D	Drain Current				A
	Continuous at T_C = 25°C	4.0	3.5	5.0	
	Continuous at T_C = 100°C	2.5	2.0	3.5	
	Pulsed	16	14	14	
Maximum Thermal Characteristics					
$R_{\theta JC}$	Thermal Resistance, Junction to Case	6.4	6.4	2.5	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	80	80	80	°C/W
P_D	Total Power Dissipation at T_C = 25°C	20	20	50	W

Appendix E

Macronutrients and Contaminants Reagents

Contaminants	**Chromogenic Reagent**
Lead (Pb)	Sulphide
Cadmium (Cd)	1% Ninhydrin solution
Arsenic	Acidified using Sulfamic acid then addition of Phosphate
Mercury	Methylthiophenyl-diazoaminoazobenzene (MTDAA) Or Cuprous Iodide (CuI) / polystyrene composite

Macronutrients	**Chromogenic Reagent**
Nitrogen	Solution N (from Soil Test Kit)
Phosphorus	Solution P, P1 and tin strip (from Soil Test Kit)
Potassium	Solution K, K1 and K2 (from Soil Test Kit)
pH level	Solution CPR, BTB and BCG (from Soil Test Kit)

Appendix F

Macronutrients Raw Data to ppm (mg/L) Conversion and Concentration Range

Macronutrients Raw Data to ppm (mg/L) Conversion Table

RAW	N	P	K	pH
1	0	1	5	5.1
2				
3				
4				
5				
6			10	
7				
8	4			
9				
10				
11			20	
12				
13				
14				
15	6			5.2
16				
17				
18		2		
19				
20				
21			30	
22	8			
23				
24				
25				5.3
26				
27				
28				
29	10			
30				
31				
32			35	
33				
34				
35		3		5.4
36	12			
37				
38				
39				
40				
41			40	
42				
43	14			
44				
45				

RAW	N	P	K	pH
46	14	3	40	5.5
47				
48				
49				
50	16		45	
51				
52				
53		4		
54				
55				
56				
57	18			
58				
59				
60			50	5.6
61				
62				
63				
64	20			
65				
66				
67				
68				
69		5		
70				
71	22		55	
72				
73				
74				
75				
76				
77				
78	24			5.7
79				
80				
81				
82				
83				
84			60	
85	26	6		
86				
87				
88				
89				
90				

RAW	N	P	K	pH
91	32	6	65	5.7
92				
93				5.8
94				
95				
96				
97	36			
98				
99				
100				
101			70	5.9
102	40			
103				
104		7		6
105				
106				
107	44			
108				
109				
110				
111			75	6.1
112	48			
113				
114				
115				
116	50			
117				
118				
119				6.2
120	52			
121			80	
122		8		
123				
124	54			
125				
126				
127				
128	56			6.3
129				
130				
131			85	
132	58			
133				
134				
135				

RAW	N	P	K	pH
136	60	7	85	6.3
137				
138		8		6.4
139				
140	62		90	
141				
142				
143				
144	64			
145				
146				
147				
148	66			6.5
149				
150				
151			95	
152	68			
153				
154				
155				
156	70	9		
157				
158				
159				
160				
161	72		100	6.6
162				
163				
164				
165				
166				
167	74			
168				
169				
170	76			
171				
172				
173	78		110	6.7
174				
175				
176		10		
177	80			
178				
179				
180				

RAW	N	P	K	pH
181	82	10	120	6.7
182				
183				
184				
185				
186	84			
187				
188				
189				
190		11		
191	86		130	6.8
192				
193				
194				
195				
196	88			
197				
198				
199				
200				
201	90		140	
202				
203				
204				
205				
206	92			
207				
208		12		
209				
210				
211	94		150	
212				
213				
214				
215				6.9
216	96			
217				
218				
219				
220				
221	98		160	
222				
223				
224		13		
225				

RAW	N	P	K	pH
225	100	13	160	6.9
226				
227				
228				
229				
230	102		170	
231				
232				
233				
234				
235	104			
236				
237				
238				
239				
240	106	14		7
241				
242				
243				
244				
245	108		180	
246				
247				
248				
249				
250	110			
251				
252				
253				
254				
255				

Soil Macronutrients Concentration Range

Macronutrients	Low	Medium	High
Nitrogen (N)	Less than 25	25-60	More than 60
Phosphorus (P)	Less than 6	6-10	More than 10
	Insufficient	**Sufficient**	
Potassium (K)	Less than 50	50 or more	
pH Level	Less than 6	6-7	

All values are expressed in Parts Per Million (ppm) or milligram per Liter (mg/L)

Appendix G

Laboratory Results for Contaminants

NANOTECH ANALYTICAL SERVICES AND TRAINING (NASAT) CORP.
G/F Unit 9 Block 7 Lot 2 GPS Building Southpoint Road, Southpoint Subdivision, Brgy. Banay-Banay, Cabuyao, Laguna
Tel. No.: (632) 576-8922 * Fax: (632) 576-1599 * Email: customercare@nasatcorp.com;
Website: http://www.nasatcorp.com

LABORATORY TEST REPORT

Company Name	Technological University of the Philippines		
Attention	Roland Ian Regala		
Job Order No.	LAB2006-029	**Date Received**	03/11/2020
Sample ID No.	S20-0295	**Date Started**	03/11/2020
Sample Description	1	**Date Completed**	03/16/2020
Date & Time of Sampling	N/A		

Test Description	Results	Units	Test Methods
Cadmium	0.008	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.631	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	0.027	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Sources: Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 23rd Edition.
Note: Results of examination are specifically related to samples as received.
*Method Detection Limit

Analyzed by:

Angelica C. Pagala, *RCh*
Laboratory Chemist
PRC Reg No. 0014434

Riena Jane M. Ramirez
Laboratory Analyst
PRC Reg No. 0002231

Certified Correct by:

Mark Anthony C. Esmael, *RCh*
Laboratory Head
PRC Reg No. 11236

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Website: http://www.nasatcorp.com

LABORATORY TEST REPORT

Company Name	Technological University of the Philippines		
Attention	Roland Ian Regala		
Job Order No.	LAB2006-029	**Date Received**	03/11/2020
Sample ID No.	S20-0296	**Date Started**	03/11/2020
Sample Description	2	**Date Completed**	03/16/2020
Date & Time of Sampling	N/A		

Test Description	Results	Units	Test Methods
Cadmium	<0.004*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	1.220	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	<0.008*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Sources: Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 23rd Edition.
Note: Results of examination are specifically related to samples as received.
*Method Detection Limit

Analyzed by:

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Laboratory Analyst
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Certified Correct by:

Mark Anthony C. Esmael, *RCh*
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Tel. No.: (632) 576-8922 * Fax: (632) 576-1599 * Email: customercare@nasatcorp.com;
Website: http://www.nasatcorp.com

LABORATORY TEST REPORT

Company Name	Technological University of the Philippines		
Attention	Roland Ian Regala		
Job Order No.	LAB2006-029	**Date Received**	03/11/2020
Sample ID No.	S20-0297	**Date Started**	03/11/2020
Sample Description	3	**Date Completed**	03/16/2020
Date & Time of Sampling	N/A		

Test Description	Results	Units	Test Methods
Cadmium	<0.004*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.578	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	<0.008*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Sources: Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 23rd Edition.
Note: Results of examination are specifically related to samples as received.
*Method Detection Limit

Analyzed by:

Angelica C. Pagala, *RCh*
Laboratory Chemist
PRC Reg No. 0014434

Riena Jane M. Ramirez
Laboratory Analyst
PRC Reg No. 0002231

Certified Correct by:

Mark Anthony C. Esmael, *RCh*
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PRC Reg No. 11236

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Website: http://www.nasatcorp.com

LABORATORY TEST REPORT

Company Name	Technological University of the Philippines		
Attention	Roland Ian Regala		
Job Order No.	LAB2006-029	**Date Received**	03/11/2020
Sample ID No.	S20-0298	**Date Started**	03/11/2020
Sample Description	4	**Date Completed**	03/16/2020
Date & Time of Sampling	N/A		

Test Description	Results	Units	Test Methods
Cadmium	0.004	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.259	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	0.015	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Sources: Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 23rd Edition.
Note: Results of examination are specifically related to samples as received.
*Method Detection Limit

Analyzed by:

Angelica C. Pagala, *RCh*
Laboratory Chemist
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Riena Jane M. Ramirez
Laboratory Analyst
PRC Reg No. 0002231

Certified Correct by:

Mark Anthony C. Esmael, *RCh*
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NANOTECH ANALYTICAL SERVICES AND TRAINING (NASAT) CORP.
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Tel. No.: (632) 576-8922 * Fax: (632) 576-1599 * Email: customercare@nasatcorp.com;
Website: http://www.nasatcorp.com

LABORATORY TEST REPORT

Company Name	Technological University of the Philippines		
Attention	Roland Ian Regala		
Job Order No.	LAB2006-029	**Date Received**	03/11/2020
Sample ID No.	S20-0299	**Date Started**	03/11/2020
Sample Description	5	**Date Completed**	03/16/2020
Date & Time of Sampling	N/A		

Test Description	Results	Units	Test Methods
Cadmium	<0.004*	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Lead	0.151	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy
Arsenic	0.032	mg/L	Inductively Coupled Plasma – Optical Emission Spectroscopy

Sources: Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 23rd Edition.
Note: Results of examination are specifically related to samples as received.
*Method Detection Limit

Analyzed by:

Angelica C. Pagala, *RCh*
Laboratory Chemist
PRC Reg No. 0014434

Riena Jane M. Ramirez
Laboratory Analyst
PRC Reg No. 0002231

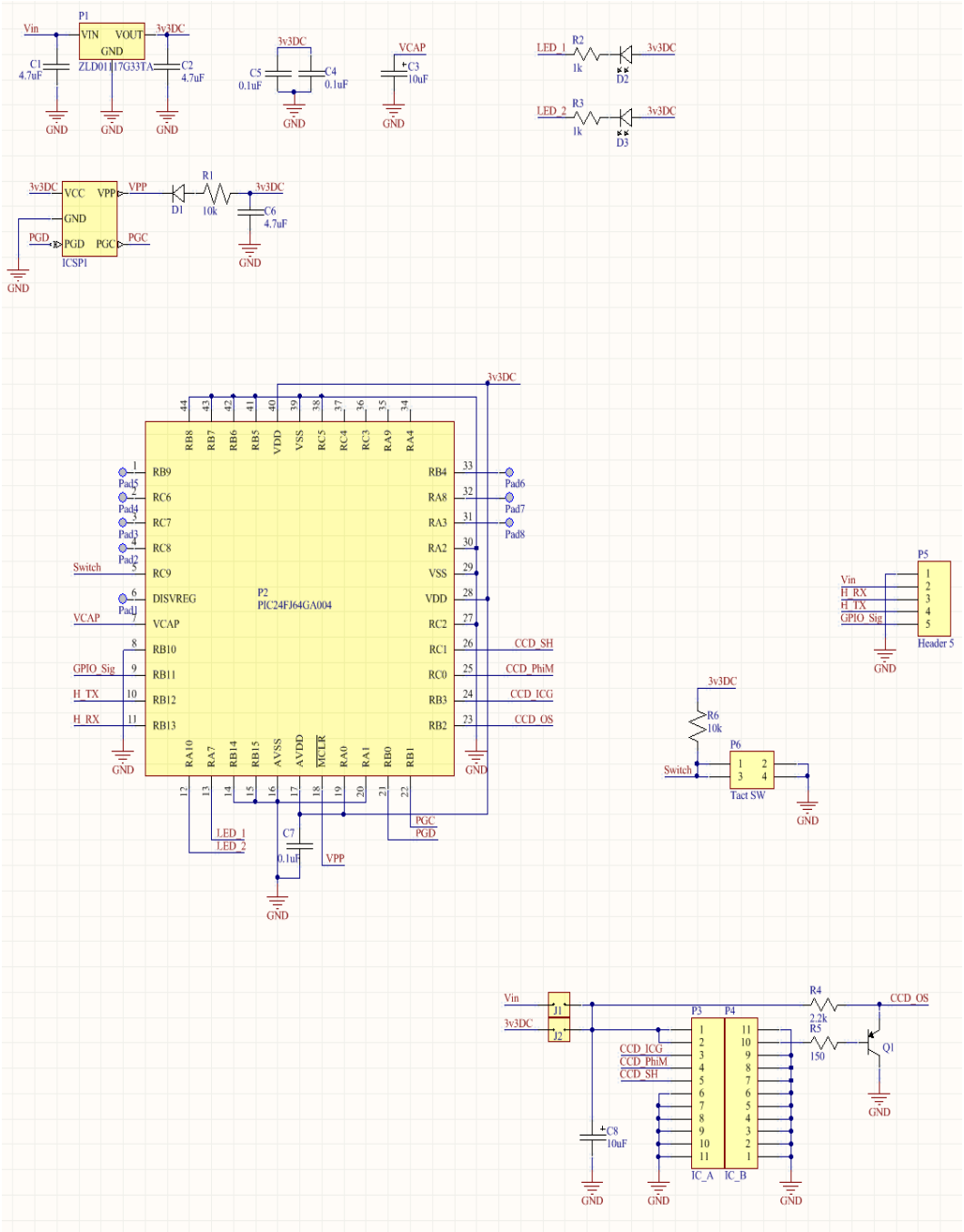
Certified Correct by:

Mark Anthony C. Esmael, *RCh*
Laboratory Head
PRC Reg No. 11236

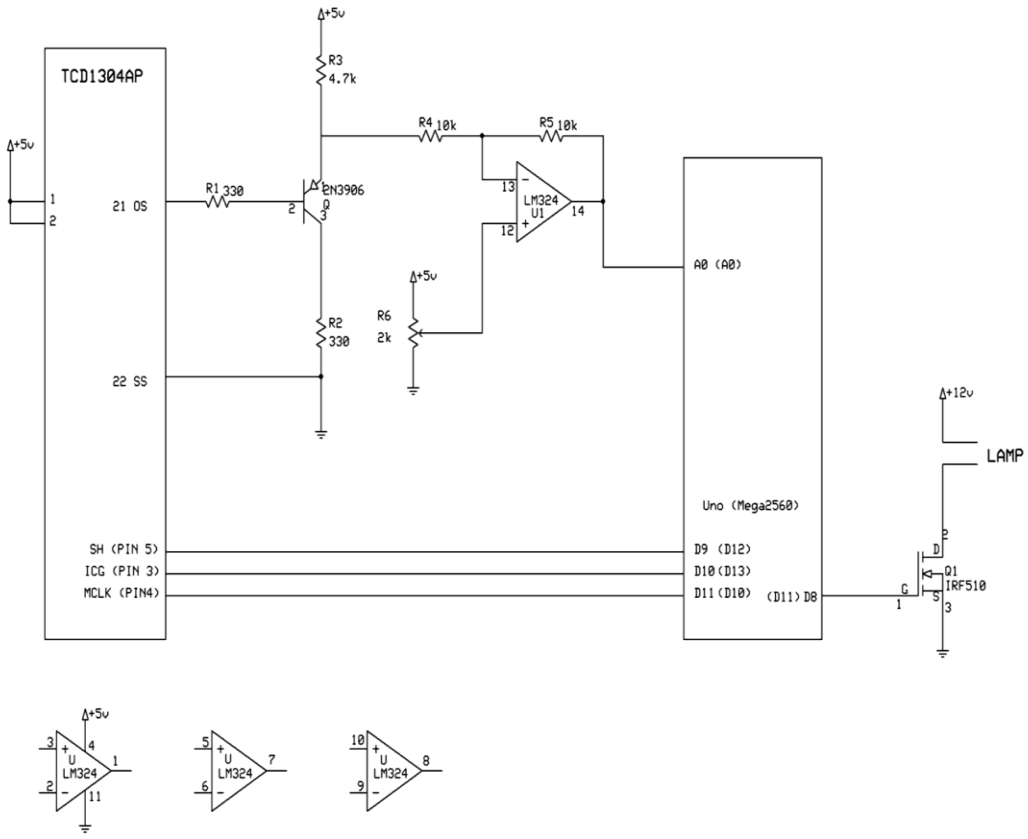
Appendix H

Circuits

Microchip Schematic Design



Sensor Design



Appendix I

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Appendix J

Proponent's Profile Layout

JOHN AZIEL M. ALORIA

To utilize my technical skills for achieving the target and developing the best performance in the company. I would like to implement my innovative, skills and ideas in ECE field and creativity for accomplishing the tasks given.

ABOUT

GENDER
Male
BIRTHDAY
October 29, 1998
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EDUCATION

Primary School
Legarda Elementary School – City of Manila
2006-2010

Secondary School
Ramon Magsaysay High School – España, Manila
2010-2014

Tertiary School
Technological University of the Philippines – Manila
Bachelor of Science in Electronics Engineering
2014-2020

AFFILIATIONS

OECES (Organization of Electronic Engineering Students)
Technological University of the Philippines- Manila
Member 2014 – Present

Institute of Electronics Engineers of the Philippines
ECT Associate Member 2018-Present

TECHNICAL SKILLS

- Computing Softwares: Python, MatLab and GNU Octave
- Computer Skills: Microsoft Office Applications
- Technical Skills: Basic Electronics and Communication; Troubleshooting
- Hard-working, quick learner, people-oriented and flexible

CARL JOHN PATRICK A. CASTILLO

To be able to share and learn with my colleagues and to provide an utmost performance and overwhelming determination to widen my knowledge, abilities and skill in the field.

ABOUT

GENDER
Male
BIRTHDAY
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EDUCATION

Primary School
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2005-2011

Secondary School
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2011-2015

Tertiary School
Technological University of the Philippines – Manila
Bachelor of Science in Electronics Engineering
2015-2020

AFFILIATIONS

OECES (Organization of Electronic Engineering Students)
Technological University of the Philippines- Manila

Member	2015 – Present
Officer	2019-2020

Institute of Electronics Engineers of the Philippines- MSC

Member	2017-Present

TECHNICAL SKILLS

- Basic Knowledge in Electronics Simulator (MultiSim, etc.) and Root-Cause Analysis
- Intermediate knowledge in program languages (eg. C++, python, Matlab, Django Framework)
- Advanced Knowledge in Web development (Html 3 and CSS 5)
- Expert in Graphics Design (Photoshop, Illustrator and After Effects)
- Proficient in Office Applications (Word, Powerpoint, Excel, etc.)

ANDREW ED COLOCADO

ABOUT

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January 22, 1999
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0956-039-1662

EDUCATION

Primary School
Naic Elementary School
2005-2011

Secondary School
Cavite National Science High School
2011-2015

Tertiary School
Technological University of the Philippines – Manila
Bachelor of Science in Electronics Engineering
2015-2020

AFFILIATIONS

OECES (Organization of Electronic Engineering Students)
Technological University of the Philippines- Manila
Member 2015 – Present

Institute of Electronics Engineers of the Philippines- MSC
Member 2017-Present

ELECTRONICS AND COMMUNICATION ENGINEERING QUIZZER
Member 2016-Present

DOST-SEI Scholar's Club
JLSS SCHOLAR 2017-Present

VARSITY PLAYER (CHESS – MALE DIVISION)
TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES – MANILA
Varsity Player 2016-2018

TECHNICAL SKILLS

- Knowledgeable in the following programming languages:
  - C / C++ (MATLAB, Arduino, etc.)
  - Python (Raspberry Pi)
- Skilled in the following circuit and hardware simulation and design: AutoCAD, SolidWorks, NI Multisim, Proteus Design Suite, etc.
- Proficient in the following word, photo, and video editors: MS Word, Excel, PowerPoint, Photoshop, Illustrator, etc.
- Fluent in Tagalog and English.

CARA LOU E. PEPANIO

To enhance my educational skills and gain professional expertise by seeking an internship position in a competent and adept workplace.
To improve and hone my skills to better myself and if given the opportunity, to contribute in the progress of the company.

ABOUT

GENDER
Female
BIRTHDAY
November 27, 1999
EMAIL
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EDUCATION

Primary School
Muntinlupa Elementary School
2005-2011

Secondary School
Muntinlupa Science High School
2011-2015

Tertiary School
Technological University of the Philippines – Manila
Bachelor of Science in Electronics Engineering
2015-2020

AFFILIATIONS

OECES (Organization of Electronic Engineering Students)
Technological University of the Philippines- Manila

Member	2015-Present
Officer	2019-2020

Institute of Electronics Engineers of the Philippines

MSC - Member	2017-Present
Associate Member	2018-Present

TUP Student Legislative Assembly

Member	2018-Present

DOST-SEI Scholar's Club

Member	2015-Present

Annual Presentation of Project Research in Electromechanical, Civil, Information and Telecommunication Engineering

Committee Member	2018

TECHNICAL SKILLS

- Basic knowledge in Root-Cause Analysis
- Basic knowledge of Circuit Wizard and NI Multisim circuit design and simulation software
- Strong communication, interpersonal, and presentation skills
- Fast learner
- Computer Literate (MS Word, MS Excel, MS Power Point)
- Basic knowledge of Python and MATLAB programming languages

DAVIDSON L. RAMOS

I am seeking for an opportunity where I could practice the knowledge and skills I have learned from my degree program, specifically in Electronics Technology and develop my personality in a professional setting.

ABOUT

GENDER
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EDUCATION

Primary School
San Gabriel II Elementary School
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Secondary School
University of Perpetual Help System-GMA
2010-2014

Tertiary School
Technological University of the Philippines – Manila
Bachelor of Technology in Electronics Engineering Technology
2014-2017

Technological University of the Philippines – Manila
Bachelor of Science in Electronics Engineering
2017-2020

AFFILIATIONS

OECES (Organization of Electronic Engineering Students)
Technological University of the Philippines- Manila
Member 2015–Present

Institute of Electronics Engineers of the Philippines- MSC
Member 2017-Present

TECHNICAL SKILLS

- Microsoft Office (Word, Excel and PowerPoint)
- Analyze and design a circuit diagram
- Troubleshooting and repairing various applications on electronics
- Programming (Python, MATLAB)
- Root Cause Analysis

ROLAND IAN M. REGALA

Electronics and Communications Engineering student looking for an opportunity to work in a challenging environment and to provide utmost performance to widen my knowledge and skills in this field.

ABOUT

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EDUCATION

Primary School
Cupang Elementary School - Main
2005-2011

Secondary School
Muntinlupa Science High School
2011-2015

Tertiary School
Technological University of the Philippines – Manila
Bachelor of Science in Electronics Engineering
2015-2020

AFFILIATIONS

OECES (Organization of Electronic Engineering Students)
Technological University of the Philippines- Manila

Member	2015 – Present

Institute of Electronics Engineers of the Philippines

MSC - Member	2017-Present
Associate Member	2018-Present

TECHNICAL SKILLS

- Proficient in Microsoft Office
- Basic Electronics and Communications
- Intermediate knowledge in Python Programming, MATLAB, GNU Octave and HTML
- Basic knowledge in Database Management using SQL
- Basic knowledge in Adobe Photoshop, Illustrator and After Effects
- Hardware Troubleshooting
- Knowledgeable in Circuit Design and Simulation

Appendix K

Proofread Certification

C E R T I F I C A T I O N

This is to certify that the undersigned has reviewed all the pages of the research work presented in this thesis manuscript, entitled **Multifunction IoT-based Soil Contaminants and Macronutrients Analyzer** developed by *John Aziel M. Aloria, Carl John Patrick A. Castillo, Andrew Ed A. Colocado, Cara Lou E. Pepanio, Davidson L. Ramos, and Roland Ian M. Regala*, aligned with the set of structural rules that govern the composition of sentences, phrases, and words in the English language.

Ms. William Joy V. Lim, LPT
Grammarian

License No.: 1106810

February 9, 2021
Date Signed