TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 5576 - 5581

Microcontroller-Based Soil Nutrients Analyzer for Plant Applicability using Adaptive Neuro-Fuzzy Inference System

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Article Info
Volume 82
Page Number: *5576 - 5581*
Publication Issue:
January-February 2020

Article History
Article Received*: 18 May 2019*
Revised*: 14 July 2019*
Accepted*: 22 December 2019*
Publication*: 27 January 2020*

Abstract:
Philippines has a large agricultural land, but the agriculturists and farmers can't be easily determine the condition of the soil in the agricultural land. Soil nutrients analysis is necessary to determine the fertility of the soil. The present paper aims to develop a microcontroller-based soil nutrients analyzer that will predict soil nutrient contents such as Nitrogen, Phosphorous and Potassium that are primarily needed for the development of the crops. Soil pH will be the main soil parameter in determining the nutrient contents of the soil by using a pH meter sensor. The study will also integrate the adaptive fuzzy inference system (ANFIS) in the microcontroller to predict suitable crops to be planted.

Keywords: *soil nutrients, soil pH, microcontroller, ANFIS*

I. INTRODUCTION

Philippines has a rich agricultural land and agriculture plays significant role in the Philippine economy as it accounts for an employment of 40 percent of Filipino workforces and contributing an average of 20 percent to the gross domestic product (GDP). The country's primary agricultural crops include corn, rice, sugarcane, coconut, pineapple, bananas, coffee, tobacco, mangoes, abaca and tobacco. Secondary crops grown in the Philippines are peanut, cassava, camote, onion, garlic, cabbage, eggplant, and tomato. [1]

With the recent advancement of technology, numerouskinds of tools have been invented and develop to simplify the day-to-day activities of man. Specifically, in agricultural technology, a number of machines and devices are invented to help agriculturists improve farming activities and produce sufficient and quality crops.In able to produce sufficient harvest, one of the necessary things to ensure is that the land they cultivate contains adequate and sufficient soil nutrients. Adequate nutrients in soil can help produce good yields and harvest. To improve the quality and quantity of crop production, soil must containnecessary nutrients, particularly Nitrogen (N), Phosphorous (P) and Potassium (K). These primary nutrient components promote effective plant development in different ways: nitrogen helps leaf and vegetation development, phosphorus promotes root development, and potassium is necessary for flowering, fruiting, maintaining nutrient and water control in plant cells.[2]

To ensure the application of correct amount fertilizer to meet the requirements of the crop while taking advantage of the nutrients already present in the soil, a proper soil test is needed. Too much application of commercial

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fertilizers or lacking of necessary nutrients has a significant effect to the crop yield.[3]

One parameter in the determination ofsoil nutrient contents is through soil pH analysis. Soil pH is referred as the degree of the acidity or alkalinity of the soil. Soil is said to be acidic if it measures below pH 7.0 and alkaline if it contains more than pH 7.0. It is neutral if the pH level measures 7.0.[4]

Determining the acidity and alkalinity of the soil is necessary to analyze the amount of nutrients present in the soil particularly the Nitrogen (N), Phosphorous (P) and Potassium (K), which crops needed in order to develop, thrive and combat diseases in particular quantities. If the soil pH is ranging between 6.0 and 7.0 then the phosphorous will be also available to the crops.[5]

In the study of [4], it reveals that most of the farmers in the Philippines are still using the traditional method of farming due to high cost of agricultural machines and they lack enough knowledge with the use of soil test kit. There is no enough training for farmers in using the soil test kit particularly in the interpretation of the result provided by soil test and the proper fertilizer that it recommends.The farmers also have a traditional way of preparing their field, which they have learned from their ancestors without realizing that the soil's nutrients shift from time to time, resulting in different crops.

In this proposed study, soil nutrients' parameter will be analyzed using a pH sensor that will generate data to a microcontroller. All the data set gathered from Bureau Soil and Water Management (BSWM) of the Department of Agriculture will be processed using the adaptive neuro fuzzy inference system (ANFIS) to forecast plant applicability. ANFIS will be used as alternative to statistical tool for developing predictive models for soil nutrients analysis.

II. RELATED WORKS

The authors[6]use image processing technique in designing a vision system that can successfully detect soil nutrients. In this study, the vision system utilizes image capturing, image processing and feature extraction of data. The effectiveness of the vision system experiment was calculated based on the reliability of the fuzzy logic model from the features extracted.

The study of[2], apply optical transducer in measuring and detecting the presence of primary soil nutrients. They utilize transducer to calculate the amount of nutrients (NPK) that should be added to soil to increase its fertility, boost soil quality and reduce the excessive application of fertilizers. The sample's of NPK value is determined by each nutrient's absorption of light. The optical transducer serves as sensor for detection which consists of three light emitting diodes as a light source and a light detection photo diode. It also uses a microcontroller to acquire input data that converts the transducer results into digital display reading. Results of the experiment revealed that the optical transducer can calculate the amount of nutrients present in soilcategorizing it as low, medium and high level.

In a similar study, the authors[7] presented the paper that can detect the NPK of the soil by using fiber optic sensor. This paper identified measurement of nutrient contents in order to determine the amount of additional nutrient content should be applied to soil in order to upsurge plant productiveness. This increases soil value, resulting in a good quality of crops in exchange. In the present work, a color sensor based on optic fiber was established to determine values of nitrogen, phosphorous and potassium. Color analysis of the liquified soil solution was conducted here.

The study of[8][9]presented an experimental research which determine the primary nutrients of the soil by applying ultraviolet spectroscopy. Finding shows that by using a series of test and through the analysis of

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the wavelength, the concentration of primary soil nutrients can be determined.

In their study, authors [10]presented a study on the use of wireless sensor technology in soil nutrients determination. The project utilizes microcontroller for the monitoring of various sensors; a built-in radio transceivertoproduce radio waves needed for transmission of data from beamsthru wireless transmission device; and power generation and power storage devices. The objective of the study was to help the farmers to identify the soil requirement, for them to correctly apply the appropriate fertilizer in the farm and to lessen the soil pollution caused by excessive application of fertilizer that contribute acidity to the soil.

The authors[11]discussed the opportunities and challenges of using potentiometer electromechanical sensors for the detection of the primary soil nutrients. The paper highlighted the advantages of using this sensor which includes multi-target simultaneous detection, automation, lower cost, and rapidness.

Authors[12]on their study determine the measurable nutrients by using available sensors to design a soil test with crop recommendation. They developed an intelligent decision-making system that recommends the suitable crops based on pH value. The paper proposes a system that uses the decision support system to build an efficient and accurate model. The proposed model works is testing of soil samples in the farm filed of soil pH along with the NPK calibration values using the Arduino mega controller which is interfaced with LCD and soil pH sensor, then feeding the gathered data of soil pH gathered through a microcontroller and feed for the decision model to select the specific crop to be grown in that condition to get better productivity and manage resistance of the crop.

The author [13] proposed the prediction of soil fertility for wheat cultivation. In this study, three methodswere used for the forecastwhile it integrates ANFIS for better prediction. They proposed the prediction of soil components (sand, silt and clay) in shallow layers based on ordinary radionuclides absorption in the soil using ANFIS. In this study, an attempt has been made to Adaptive neuro fuzzy inference system (ANFIS) to predict soil fertility using soil iron (Fe), phosphorus (P), zinc (Zn), copper (Cu), manganese (Mn), organic matter (OC) and soil potassium (K) in Fars province, southwest Iran. The paper used the Sugeno method to establish an ANFIS model. Methodology consists of selecting dependent and independent parameters of soil, fuzzification, fuzzy inference law, membership function and defuzzification method. Results show that the model with 1.6543e0.5 and -1.5941e0.5 errors for train and tested was most reliable for fertility prediction, respectively. This concluded that ANFIS is an effective method for soil fertility prediction.

The authors[14] proposed a study that will determine the primary nutrients NPK by using image processing SVM algorithm and Smart Agro Sensor System. The goal is to make agriculture intelligent through automation, image processing and the Internet of Things. The project uses sensing module, microcontroller, soil moisture sensor, temperature and humidity sensor, pH analog meter, Wifi module and Blynk app. The project proposed a classification of soil picture patterns to classify NPK with the combination of extraction of texture and color features. The study also suggests the integration of the system using mobile application for future study.

III. PROPOSED METHODOLOGY

The objective of this study is to develop a microcontroller-based soil analyzer that will predict the three essentials nutrients needed for plant growth, the nitrogen, phosphorous and potassium. Soil pH is the primary parameter that will be used in analyzingthe soil nutrient contents. The proposed prototype will use Arduino microcontroller and soil pH sensor node. NPK prediction can be processed using rapid miner.

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Crops prediction can be analyzed using the Math Lab and Fuzzy Controller integrating the adaptive neuro fuzzy inference system. Figure 1 below presents the illustration of the proposed methodology.

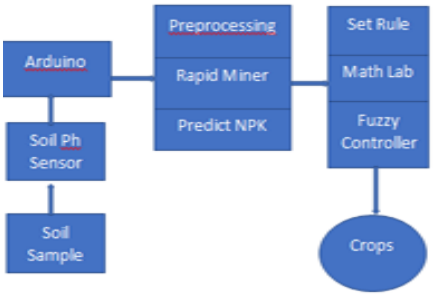

Figure 1.Block Diagram of the Proposed Methodology

In this framework, the soil acidity and alkalinity will be determined using the pH sensor. The generated data will be sent to the Arduino microcontroller. Data will undergo preprocessing using rapid miner to determine the available NPK in the soil. It will set rules using the Artificial Neuro Fuzzy Inference System (ANFIS), the combination of the fuzzy logic algorithm and artificial neural networks to predict the applicable crops that can be planted on soil based on the available soil nutrients.

a. Soil PH Sensors

In this study, soil pH sensor will be linked to Arduino Microcontroller. This will calculate the pH level of nutrients in agricultural soil. The input data will be sensed and supervised. The data generated from different soil tests will be uploaded in the microcontroller.

The reading of the pH sensor is simple which is converted into computerized utilizing ADC (Analog to Digital Converter. The framework utilizes USB A to USB B fringe link to store the incentive in datasheets and for further reference with farmers. The framework sends any sudden changes in nature of soil to the agriculturists.

Initially, pH sensor will be immersed to wet soil to get soil pH value then collaborate the pH sensor with microcontroller Arduino board using the formulas to calculate the pH value, NPK value which is derived from sensors to know the soil feature in order to grow the suitable crop. The measured pH from sensor is digitized as using the equation 1 to 3

pHv = analog value *5/1024/6 (1)

pH=5.70*pHV+calibration (2)

Calibration=Nitrogen=(pH value*10)-15
Phosphorous=(pH value*10)-22 (3)
Potassium=(pH value*10)-12

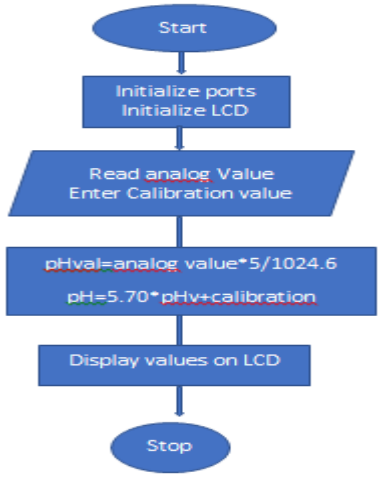

Fig. 2 Flowchart of Determining Soil pH in the Soil

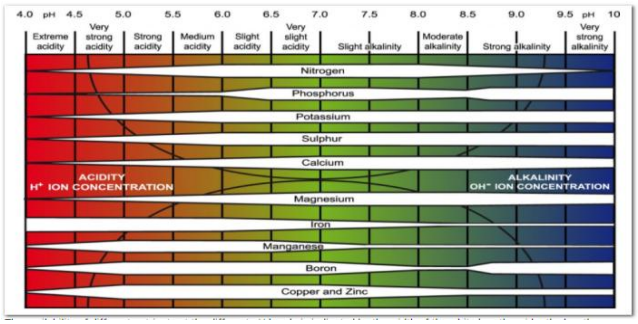

Fig 3 Chart representing nutrient content in soil

b. Arduino Uno Microcontroller

The project will use Arduino microcontroller as the main hardware component of the proposed system.

Arduino is an open source software hardware that designs and develops microcontroller-based kits to create digital devices

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and interactive objects capable of sensing and manipulating objects in the physical world. This system provides digital analog I / O pins, serial communication interfaces, USB port for personal computer charging programs.

Figure 3.Arduino Microcontroller

C. Adaptive Neuro Fuzzy Inference System (ANFIS)

Adaptive neuro fuzzy inference system will be integrated in the microcontroller to predict the suitable crops that can be planted based on the available soil nutrients.

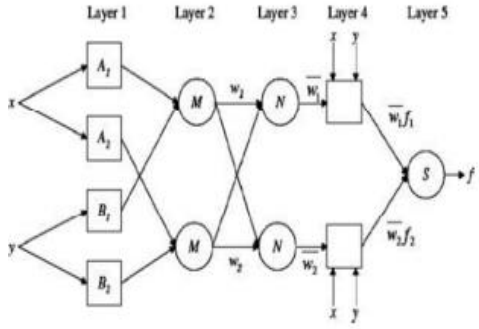

Figure 4. The ANFIS Architecture

D. Prediction of Crops

pH 4.0-6.0	pH 5.0-6.5	pH 6.0-7.5	pH 5.0-7.5	pH 6.0-8.0
Potato	Apple Blackberry Cranberry Gooseberyy Mango Melon Pineapple Pomegranate Watermelon Basil Chicory Fennel Olive Peanut Sweet potato Rice Rosemary Sage Soybean	Apricot Cherry Grapevine Grapefruit Hazelnut Hop Lemon Lychee Mulberry Nectarine Peach Plum Quince Artichoke Bean Beetroot Broccoli Brussels sprouts Cabbage Calabrese Celery Chinese cabbage Chives Lettuce Millet Mushroom Mustard Onion Pea Peppermint Radish Spinach	Banana Rhubarb Strawberry Rasberry Carrot Cauliflower Sweet corn Cucumber Garlic Lentil Parsley Pepper Pumpkin Shallot Spearmint Thyme Tomato Turnip	Avocado Asparagus Ginger Leek Mint Paprika Watercress

Table 1.Standard Values for Crop Selection

Table 1 shows different crops that can grow based on the available soil pH

Figure 5. Flowchart for Predicting Crops

IV.EXPERIMENT RESULTS

The tables below show the list of 10 samples taken using the soil kit test and the predicted possible crops suited based on the nutrients availability on the soil using the microcontroller-based soil analyzer.

NPK Prediction

Ten samples were taken randomly to determine the nutrient contents of the soil using soil kit test.

Trial	N	P	K	Ph
1	M	M	Present	7.05
2	L	M	Present	6.80
3	M	M	Present	6.63
4	M	M	Present	6.64
5	M	M	Present	6.35
6	M	H	Present	7.35
7	M	H	Present	7.49

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8	M	H	Present	7.38
9	M	H	Present	7.40
10	M	H	Present	7.25

L=Low Amount M=Moderate Amount H=High Amount

Table 2 Sample Results of Soil Kit Test

Crop Prediction

Trials	Ph	Crops
1	7.05	Tomato, garlic
2	6.80	Mongo, Tomato, Eggplant, Garlic
3	6.63	Mongo, Tomato, Eggplant
4	6.64	Mongo, Tomato, Eggplant
5	6.35	Mongo, Tomato, Eggplant
6	7.35	Tomato
7	7.49	Not Suitable
8	7.38	Not Suitable
9	7.40	Not Suitable
10	7.25	Tomato

Table 3. Sample results of predicted crops generated by microcontroller-based soil analyzer using ANFIS.

V. Conclusion

In this project, a method for determining the nutrients of the soil such as Nitrogen, Phosphorous and Potassium using soil pH as parameter is presented. It utilizes Arduino microcontroller in detecting and interpreting NPK. The study is integrated with the Adaptive Neuro-Fuzzy Inference System (ANFIS) to predict the suitable crops that can be sow using different soil pH level. This project helps the farmers in determining the soil condition and soil fertility and will guide them in using appropriate fertilizer and crops that can be planted.

VI. ACKNOWLEDGMENT

The authors would like to thank the Department of Agriculture for the assistance during the conduct of the experiment, the Commission on Higher Education for the scholarship grant, Mrs. Minerva Gusi for the fund assistance, Drs. Marietta Cantos and Julio S. Cantos of John Paul College for their strong encouragement to pursue this research.

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