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

Nilo M. Arago[1], John William F. Orillo[1,2], Jenskie Jerlin Haban[1], Jomer Juan[1], John Carlo Puno[1], Jay Fel Quijano[1], Gian Matthew Tuazon[1]
[1]*Technological University of the Philippines, Manila, Philippines.*
[2]*De La Salle University, Manila 1004, Philippines.*
nilo_arago@tup.edu.ph

***Abstract*—In this study, digital image processing technique was used to efficiently identify the Macronutrients and pH level of Soil in the farmland of Philippines: (1) Nitrogen, (2) Phosphorus, (3) Potassium and (4) pH. The composition of the system is made of four sections namely, image acquisition, image processing, training system, and result. The Artificial neural network was applied in this study for its features that make it well suited in offering fast and accurate performance for the image processing. The system will base on 448 captured image data, 70% for training, 15% for testing and 15% for validation. Based on the result, the program will generate a report in printed form. Overall, this study identifies the soil macronutrient and pH level of the soil and gives fertilizer recommendation for inbred rice plant and was proven 98.33% accurate.**

***Index Terms*—Soil, Digital Image Processing, Artificial Neural Network.**

I. Introduction

Soil has a direct impact on yield and quality of crops since it is a natural medium for plants. According to the book, Practical Guidelines in Predicting Fertility Status of Lowland Rice Soil by PhilRice [1], Soil fertility is the inherent capability of the soil to supply adequate amounts of nutrients to the plants. Therefore, it is a significant factor for the proper growth of plants for a productive yield. In the Philippines, Rice or Palay is one of the essential crops consumed by the Filipinos. According to the article, Nutritional Recommendation for Rice by International Rice Research Institute (IRRI) [2], one factor on achieving higher yields and associated higher profitability for rice is the effective use of inputs (mainly plant and soil nutrients, seed, and pesticide). Hence, these inputs should be considered for better harvest of rice.

Soil Nutrients is divided into two groups, macronutrients and micronutrients. Macronutrients consists Nitrogen, Potassium and Phosphorus. These elements are the basis of the N-P-K label on commercial fertilizer bags. As a result, the management of these nutrients is essential. Nitrogen is necessary to plant growth because it is the fundamental part of the chlorophyll molecule and vital element in the formation of amino acids and proteins in the plant. It must be mineralized by soil micro-organisms before it releases its nitrogen content for plant use. Phosphorus is unique among the anions in that it has low mobility and availability in soils. It is used for growth, nitrogen fixation, photosynthesis, and root development. Potassium is element needed in many enzymes. It regulates the opening and closing of the plant stomata, also important for disease resistance and photosynthesis. Exchangeable potassium can readily interchange with the soil solution to buffer changes. Plants consume a lot of potassium and this means that soil can experience scarcity of this element. To determine these soil primary nutrients, soil analysis or soil test is performed [3].

Soil Test is a way in which the elements of each soil nutrients are removed from the soil through laboratory chemical analysis and soil test kits. The conventional chemical analysis takes a couple of hours to analyze the nutrients of soil. The Soil Test Kit of Bureau of Soil and Water Management (BSWM) takes a few minutes to determine the NPK and pH level, but the analysis of the result is done manually by comparing the color of the soil with chemical reagents to the standard color chart [4].

This study aims to provide more efficient analysis of soil Nitrogen, Phosphorus and Potassium and pH level since the project will do the analysis digitally using image processing supported by different algorithms through Artificial Neural Network (ANN).

II. Methodology

The composition of the system is made of four sections namely the image acquisition, image processing, training system, and result as shown in Figure 1.

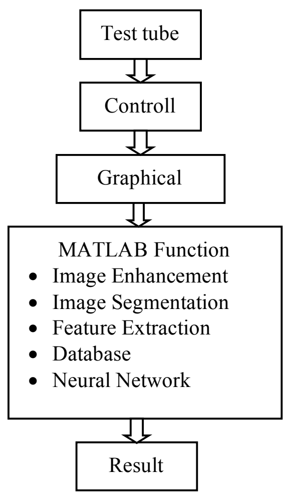


Figure 1: Main Block Diagram

A. Image Acquisition

The image acquisition is responsible for obtaining image using a 1080p Full-HD Webcam shown in Figure 2(b) with sixteen megapixels, and a controlled-light module box.

(a) (b)

Figure 2: (a) Actual Photo of the controlled-light module box (b) 1080p Full-HD Webcam

The controlled light box uses white LED strips to give enough light to the test samples. The dimensions of the controlled light box as shown in Figure 2(a), are as follows: 9.5 inches in length, 8 inches in width and 5 inches in height. The proponents came up to the said measurements based on experimentation and research. The length of the box is measured to capture the desired distance of object from lens with acceptable focus from web camera. The height of the box is approximated based on the height of the test tube and the position of the webcam. The width of the box is calculated to provide proper and sufficient space for the light on the four test tubes.

B. Image Processing

The image processing section is subdivided in four techniques, namely: image acquisition, image preprocessing, image segmentation, and feature extraction [5]. In image acquisition, image is retrieve from the camera. In image preprocessing, noise reduction and contrast/brightness adjustment will be executed. Cropping region, thresholding and masking will be included in image segmentation. Meanwhile in feature extraction or in main image processing, color analysis was performed. Two features are extracted to analyze the macronutrients and pH level: (1) mean values for the H, S and V of the image and; (2) mean values of the Lab color space. Lastly, the results will be compared to the features of the standard image.

C. Training System

For the training system section, the processed images will serve as input. The macronutrients level and pH level assessment will base on the standards given by the supporting institution and this will serve as a database for the system. The input will be processed in this section and the system is trained using the backpropagation neural network architecture to improve the accuracy of the program [6].

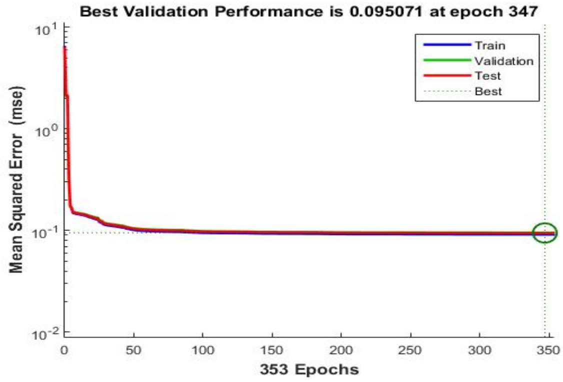


Figure 3: pH Initial Level Assessment Performance Plot

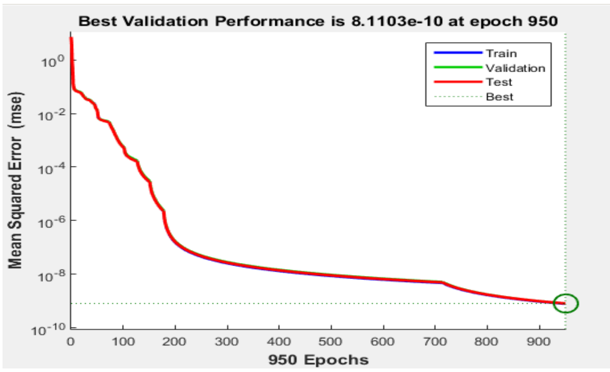


Figure 4: pH Final (BTB) Level Assessment Performance Plot

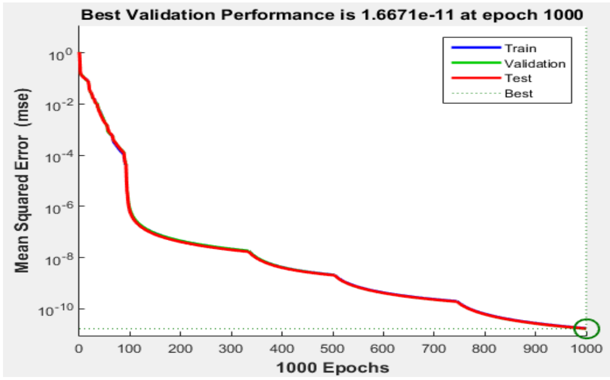


Figure 5: pH Final (BCG) Level Assessment Performance Plot

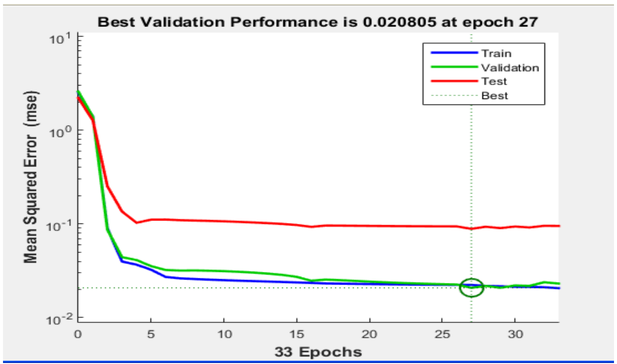


Figure 6: Nitrogen Level Assessment Performance Plot

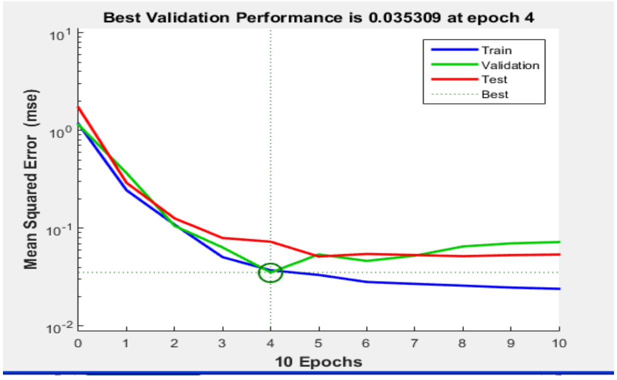


Figure 7: Phosphorus Level Assessment Performance Plot

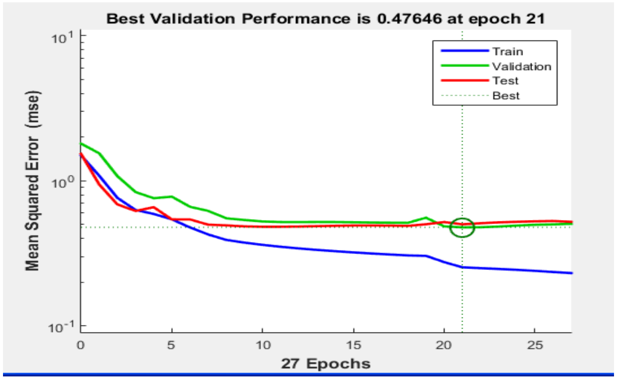


Figure 8: Potassium Level Assessment Performance Plot

The Performance Plot is shown in Figure 3 to Figure 8. The database for the network must be comprised of sufficient data examples. For macronutrients and pH Level identification, SoilMATe uses 520 captured image samples, comprised of 130 samples for each of the elements. Training and performance parameters are initialized after creating the neural network. Since Artificial Neural Network (ANN) uses an iterative learning algorithm, weights and biases are randomly initialized and the images are presented to the network one at a time. For the network to consider the data as correctly classified, at least one of the training parameters must be satisfied. From the sample, 70% was used for training, 15% for testing and 15% for validation.

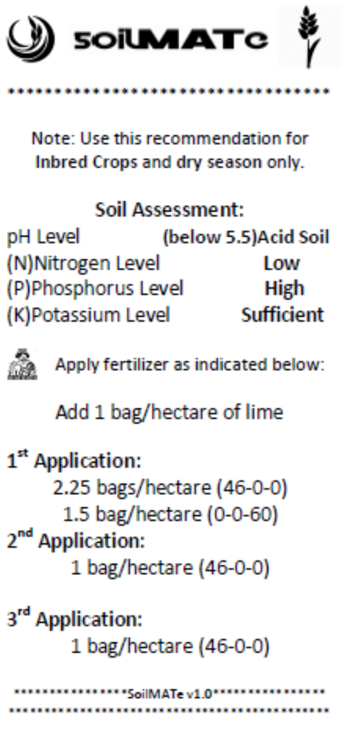
This process is repeated until the training number is reached. The learning algorithm allows the network to improve its performance and predict the next set of data correctly by modifying the weights. The training stops once the mean square error of the network is less than $1x10^{-10}$.

D. Result

The result section will generate a hardcopy report (shown in Figure 9) based on the analysis of the system and will consist of the following:

For Macronutrients and pH Level Assessment:

- Qualitative Result of N, P, K and pH level
- Appropriate amount of Fertilizer to be applied per hectare
- When to apply


SoilMATe

Note: Use this recommendation for Inbred Crops and dry season only.

Soil Assessment:

pH Level	(below 5.5)Acid Soil
(N)Nitrogen Level	Low
(P)Phosphorus Level	High
(K)Potassium Level	Sufficient

Apply fertilizer as indicated below:

Add 1 bag/hectare of lime

1st Application:
2.25 bags/hectare (46-0-0)
1.5 bag/hectare (0-0-60)

2nd Application:
1 bag/hectare (46-0-0)

3rd Application:
1 bag/hectare (46-0-0)

SoilMATe v1.0

Figure 9: Generated Recommendation

III. Design Considerations

A. Implementation of MATLAB Software for Soil Macronutrient and pH level Assessment using Artificial Neural Network

The actual flow of the program in identifying the level of macronutrient and pH of the soil is detailed as follows: First, the image of the colorimetric chemical result of soil test serves as the input of the system. These images will be uploaded in Visual Basic. This will be processed using MATLAB software and will undergo several stages to achieve accurate result. Based on the result, the program will generate a report in hardcopy format.

The MATLAB will serve as an Integrated Development Environment (IDE) for image processing. This process includes the image acquisition, image enhancement, image segmentation, feature extraction, and feature comparison.

The Backpropagation Neural Network serves as a training model. This increases the accuracy of the system and decreases the computation time because it has the ability to implicitly detect complex non-linear relationships between the dependent and independent variables, and to detect all possible interactions between predictor variables.

B. Importing MATLAB functions to Graphical User Interface

The MATLAB functions and the Backpropagation Neural Network will be compiled as C/C++ libraries. The exported libraries can then be imported into Visual Basic.

A GUI (sample shown in Figure 10) made in Visual Basic will allow the user to run the program. The compiled MATLAB functions will be called to perform the image analysis. After finishing the process, a hardcopy report will be generated with recommendation provided by BSWM.

Figure 10: User Interface of SoilMATe

IV. Experimental Result

A. Result of Database Collection

The database consists of images of different level of pH and macronutrient (Nitrogen, Phosphorus and Potassium) of soil attained from the laboratory of BSWM. Using the controlled light box, the images of 130 Nitrogen (100 pictures equivalent to Low, 15 Medium and 15 High), 9000 pixels for Phosphorus (2000 pixels for Low, 3500 for Medium and 3500 for High), 130 images for Potassium (128 equivalent to sufficient and 2 for Deficient), 9023 pixels for pH CPR (1566 for 5.0, 5.3634 for 5.4, 994 for 5.8 and 2829 for 6.0), 6400 pixels for pH BTB (256 for 6.0, 2973 for 6.4, 1657 for 6.8, 873 for 7.2 and 641 for 7.6) and 2604 pixels for pH BCG (1279 for 4.0, 349 for 4.4, 678 for 4.8 and 298for 5.2) were captured and fed to the program as input. Variability in numbers of the images per level is due to the availability of soil colorimetric result that matched the STK color chart. Each photo undergoes three image processing techniques: image enhancement, image segmentation and feature extraction. All the features of the processed images are saved as a Matlab Workspace (.mat) and as an excel document (.xlsx) for backup.s.

B. Results of Macronutrient and pH level Identification

Fifteen soil samples with different nutrient content were used for the evaluation of the program. With the supervision of Ms. Agnes Morada, Senior Agriculturist and Ms. Beatriz Magno, Supervising Agriculturist of BSWM, the samples were manually test and compared to the STK color chart. The results serve as the conventional visual test column on the evaluation sheet given to Ms. Morada and Ms. Magno. The proponents synchronized the testing between STK and SoilMATE, so after Ms. Morada and Ms. Magno was done with a certain samples, the fabricated light box was used to capture the test tube for consistency. Ms. Morada and Ms. Magno noted whether the result of SoilMATe where same to the conventional visual test. Moreover, Ms. Morada and Ms. Magno includes their comments regarding the program in the evaluation sheet provided.

The result is shown in Table 1. These values showed that the program gave an overall accuracy of 98.33% (93.33% for pH, 100% for Nitrogen, 100% for Phosphorus, and 100% for Potassium as shown in Table 2).

Table 1
Results in Identifying Nitrogen (N), Phosphorus (P), Potassium (K), initial pH (pH Init) and Final pH (pH Fin) Levels.

Sample No.	Conventional					Using SoilMATe				
	N	P	K	pH Init	pH Fin	N	P	K	pH Init	pH Fin
1	L	L	S	6	6	L	L	S	6	6
2	L	L	S	6	6.4	L	L	S	6	6.4
3	L	L	S	6	6.4	L	L	S	6	6.4
4	L	M	S	6	6.4	L	M	S	6	6.4
5	L	M	S	6	6	L	M	S	6	6
6	L	L	S	5.4	5.4	L	L	S	5.4	5.4
7	L	L	S	5.4	5.4	L	L	S	5.4	5.4
8	L	L	S	5.4	5.4	L	L	S	5.4	5.4
9	L	L	S	5.4	5.4	L	L	S	5.4	5.4
10	L	L	S	5.4	5.4	L	L	S	5.4	5.4
11	L	L	S	5.4	5.4	L	L	S	5.4	5.4
12	L	M	S	6	6	L	M	S	6	6.4
13	L	L	S	6	6.4	L	L	S	6	6.4
14	L	M	S	6	6.8	L	M	S	6	6.8
15	L	H	S	5.4	5.4	L	H	S	5.4	5.4

Note: L=Low; M=Medium; H=High; S=Sufficient

Table 2
Summary of Results

Macronutrients and pH	Accuracy
Nitrogen level	15 out of 15 - 100%
Phosphorus level	15 out of 15 - 100%
Potassium level	15 out of 15 - 100%
pH level	14 out of 15 - 93.33%

V. Conclusion

The development of the program that determines the Macronutrient and pH level of the soil for rice plant through image processing using artificial neural network was successfully implemented using MATLAB. Based on the results and findings of the research the project was found to be fully functional and proven to be 98.33% accurate.

The project was successfully implemented and done; however the proponents would like to make the following recommendations to further improve the project; (1) Collect more soil samples for the data sets which could yield on more accurate results. (2) Automate the procedural part of the soil testing.

Acknowledgments

The authors would like to acknowledge Ms. Beatriz c Magno, Ms. Agnes Morada, all the staffs of Bureau of Soils and Water Management, Ms. Maria Edda Apple Suplido and Mr. Jun Corea of International Rice Research Institute and Technological University of the Philippines, Electronics Engineering Department for their encouragement, support and cooperation in doing this project. And above all, God for His continuous guidance.

REFERENCES

[1] Practical Guidelines in Predicting Fertility Status of Lowland Rice Soil by PhilRice
[2] Nutritional Recommendation for Rice by IRRI (2008)
[3] Soil and Soil Nutrients. Retrieved by *http://www.greenlandgarden.com/*
[4] Bureau of Soils and Water Management. (2013). *Soil Analysis and Fertilizer Usage.* pp. 1-2.
[5] Image Processing. (2012). Retrieved from: *Engineersgarage.com*
[6] P. Padmasree, Maheswari. R. (June 2013). A Novel Technique for Image Compression in Hand Writted Recognition using Back Propagation in Neural Network. *International Journal of Computer Science and Engineering Technology (IJCSET).*