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Soil Fertilizer Recommendation System using Fuzzy Logic

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***Abstract*— Soil nutrients and season have direct impact on the growth and yield of a crop. Deficiency on the nutrient level of the soil may result to plant disease while applying excessive amount of soil fertilizer on the other hand, may also cause negative results to the development of the crop. Nutrients on the soil also changes as the season changes from wet season to dry season. This study aims to develop a fuzzy logic-based program that will provide an appropriate amount of fertilizer to soil. The parameters such as season, nitrogen, phosphorus and potassium level are the inputs used on the fuzzy logic system. The researchers proposed four kinds of fertilizer to use in this paper such as Complete, Urea, Solophos and Muriate of Potash. Combination and amount of these fertilizers will be based on the input parameters and fuzzy rules. These soil fertilizer recommendations can be used for rice in an inbred light soil.**

Keywords*— *fuzzy logic, fertilizer recommendation, soil nutrients, season, soil fertilizer

I. INTRODUCTION

Soil plays a vital role in agriculture and the nutrients on the soil has a direct impact on quality of crops growing on it [1]. Every crop needs an appropriate combination of nutrients to live and grow healthy. Excessive amount in fertilizer can be toxic to plant development while insufficient nutrient level may cause disease to plants [2].

Nutrients in soil is classified in to two categories: macronutrients and micronutrients. Macronutrients includes Nitrogen, Phosphorus and Potassium as primary elements and Sulfur, Calcium and Magnesium as secondary elements [3]. These are the elements that are needed in relatively large amounts. While micronutrients include iron, boron, manganese, zinc, copper, chlorine and molybdenum. These are also known as trace elements because trace amount of these elements is needed by plants [2]. Macronutrients specially Nitrogen, Phosphorus and Potassium or NPK is commonly the basis of the fertilizers as the three numbers that can be seen on a fertilizer label, indicates the proportion of each macronutrient that the fertilizer contains.

Soil test is conducted to identify the nutrient level of the soil. There are different soil test techniques used and results of this test can be analyzed to come up with a fertilizer recommendation appropriate for a certain crop. The nutrient deficiency of the soil must be addressed by relating the result to the expected level of nutrient. Nutrient level also changes as the weather changes on dry or wet season [4].

The objective of this paper is to design a fuzzy logic program that will provide fertilizer recommendation based on the season and Nitrogen-Phosphorus-Potassium (NPK) level of the soil. The range of values of the NPK parameters used in this study is based on [5] and shown in Table 1.

TABLE I. NPK PARAMETERS

N				P				K	
L	*ML*	*MH*	*H*	*L*	*ML*	*MH*	*H*	*D*	*S*
0 to 2	2.1 to 3.5	3.6 to 4.5	4.6 to 5.5	0 to 6	6.1 to 10	10.1 to 15	15.1 to 20	0 to 25	25 to 50

Note: L – Low, ML – Moderately Low, MH – Moderately High, H – High, D – Deficient, S – Sufficient

II. RELATED WORKS

Fuzzy logic is one of the techniques often use by researchers for agricultural advancement and precision farming. Developing agriculture with technology improves the crop production significantly [6] and guaranteeing the quality of the crop [7]. In the previous study [8], applications of fuzzy logic in agro-industrial engineering are discussed. These includes assessment of land sustainability [9], crop management [10], prediction of climate [11] and digital soil mapping [12]. Fuzzy can also be used in classifying soil moisture [13]. Another study uses fuzzy logic to control lighting intensity for soil pH based on the temperature, humidity and lighting in the plant area [14].

There are several studies that uses different technologies for identifying soil nutrients [15]. In [16], nutrients of the soil were detected using optical transducer. NPK soil nutrients in [17] are measured based on the textural characteristics and evaluated with local binary pattern and back-propagation neural network. Another study uses embedded systems to analyze the macronutrients in soil [18]. There are also papers with colorimetric analysis [19] [20] and vision system with fuzzy logic [21] that uses Soil Test Kit to determine the level of soil nutrients. In [22], fuzzy system is used to optimize the fertilizer rates for wheat crop. However, application of the fertilizer is not discussed in the study. Also, fertilizer is only based on the NPK level of the soil.

III. FUZZY LOGIC

Fuzzy Logic (FL) was firstly introduced by L. A. Zadeh at the theory [23] which characterized each object of a set by a degree of membership functions from the interval [0,1]. Degree of similarity of an object to the fuzzy subset is defined by the membership function [24]. In FL concepts like slow, fast or very fast can be formulated mathematically and processed by the computers based on how human brain thinks and able to rationalize [25].

A Fuzzy logic system has four components namely, fuzzifier, rule base, inference engine, and defuzzifier. This system is represented in Figure 1.

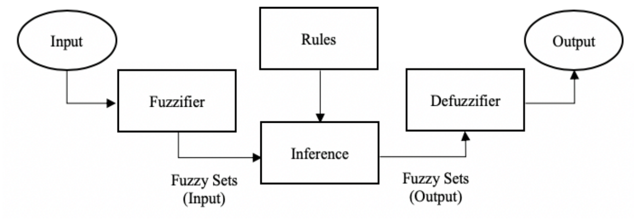

Fig. 1. Fuzzy Logic System

The first component is the fuzzifier. This converts crisp inputs into fuzzy sets. Rules can be acquired from data or may be provided by an expert. These are expressed as a group of *If Then* statements. The inference engine combines these rules and the membership function to produce a fuzzy output [24]. The shape of membership function such as triangular, trapezoidal, Gaussian, sigmoid, hyperbola, triangular, etc. can be chosen arbitrarily.

In this study, the researchers develop a fuzzy logic-based program that will provide an appropriate amount of fertilizer to soil considering the parameters such as nitrogen (N), phosphorus (P), potassium (K) level and season (S). The triangular membership function is used in this study. The parameters N, P, K and S were assessed in the fuzzification process. The range of the values for these parameters are based on [5]. The membership functions for N are Low (L), Moderately Low (ML), Moderately High (MH) and High (H) and equations representing this are written in (1-4).

$$\mu_{N\_L}(x) = \begin{cases} 0, & x \le -0.1 \\ \dfrac{x+0.1}{0.9} & -0.1 \le x \le 1 \\ \dfrac{2.1-x}{1.1} & 1 \le x \le 2.1 \\ 0 & 2.1 \le x \end{cases} \tag{1}$$

$$\mu_{N\_ML}(x) = \begin{cases} 0, & x \le 2 \\ \dfrac{x-2}{0.8} & 2 \le x \le 2.8 \\ \dfrac{3.6-x}{1.2} & 2.8 \le x \le 3.6 \\ 0 & 3.6 \le x \end{cases} \tag{2}$$

$$\mu_{N\_MH}(x) = \begin{cases} 0, & x \le 3.5 \\ \dfrac{x-3.5}{0.5} & 3.5 \le x \le 4 \\ \dfrac{4-x}{0.6} & 4 \le x \le 4.6 \\ 0 & 4.6 \le x \end{cases} \tag{3}$$

$$\mu_{N\_H}(x) = \begin{cases} 0, & x \le 4.5 \\ \dfrac{x-4.5}{0.5} & 4.5 \le x \le 5 \\ \dfrac{4-x}{0.6} & 4 \le x \le 5.6 \\ 0 & 5.6 \le x \end{cases} \tag{4}$$

Phosphorus have four membership functions;Low (L), Moderately Low (ML), Moderately High (MH) and High (H) and equations representing this are written in (5-8).

$$\mu_{P\_L}(x) = \begin{cases} 0, & x \le -0.1 \\ \dfrac{x+0.1}{2.9} & -0.1 \le x \le 3 \\ \dfrac{3-x}{3} & 3 \le x \le 6.1 \\ 0 & 6.1 \le x \end{cases} \tag{5}$$

$$\mu_{P\_ML}(x) = \begin{cases} 0, & x \le 6 \\ \dfrac{x-6}{2} & 6 \le x \le 8 \\ \dfrac{8-x}{2.1} & 8 \le x \le 10.1 \\ 0 & 10.1 \le x \end{cases} \tag{6}$$

$$\mu_{P\_MH}(x) = \begin{cases} 0, & x \le 10 \\ \dfrac{x-10}{2.5} & 10 \le x \le 12.5 \\ \dfrac{12.5-x}{2.6} & 12.5 \le x \le 15.1 \\ 0 & 15.1 \le x \end{cases} \tag{7}$$

$$\mu_{P\_H}(x) = \begin{cases} 0, & x \le 15 \\ \dfrac{x-15}{2.5} & 15 \le x \le 17.5 \\ \dfrac{17.5-x}{2.6} & 17.5 \le x \le 20.1 \\ 0 & 20.1 \le x \end{cases} \tag{8}$$

Potassium have two membership functions such as Sufficient (S) and Deficient (D) and equations representing this are written in (8-10).

$$\mu_{K\_D}(x) = \begin{cases} 0, & x \le -0.1 \\ \dfrac{x+0.1}{12.9} & -0.1 \le x \le 13 \\ \dfrac{13-x}{12.1} & 13 \le x \le 25.1 \\ 0 & 25.1 \le x \end{cases} \tag{9}$$

$$\mu_{K\_S}(x) = \begin{cases} 0, & x \le 25 \\ \dfrac{x-25}{12} & 25 \le x \le 37 \\ \dfrac{37-x}{13.1} & 37 \le x \le 50.1 \\ 0 & 50.1 \le x \end{cases} \tag{10}$$

Season is divided in to two; Wet and Dry. Values coresponds to the months, 1-7 for Wet season and 8-12 for Dry season. Equations representing this are written in (11-12).

$$\mu_{S\_W}(x) = \begin{cases} 0, & x \le 0 \\ \dfrac{x}{4} & 0 \le x \le 4 \\ \dfrac{4-x}{7.5} & 4 \le x \le 7.5 \\ 0 & 7.5 \le x \end{cases} \tag{11}$$

$$\mu_{S\_D}(x) = \begin{cases} 0, & x \le 7.5 \\ \dfrac{x-7.5}{1.5} & 7.5 \le x \le 9 \\ \dfrac{9-x}{3.1} & 9 \le x \le 12.1 \\ 0 & 12.1 \le x \end{cases} \tag{12}$$

Rules are created after setting the values for the membership functions to determine the recommended fertilizer based on season and NPK level of the soil. 64 rules are created and some of them are shown in table 2. Figure 2-4 shows the fuzzy rules surfaces pairing 2 parameters against the output.

TABLE II. FUZZY RULES

No	Fuzzy Rules
1	If (N_Level is L) and (P_Level is L) and (K_Level is D) and (Season is W) then (N_Fertilizer is L_W)(P_Fertilizer is L)(K_Fertilizer is D) (1)
2	If (N_Level is L) and (P_Level is L) and (K_Level is D) and (Season is D) then (N_Fertilizer is L_D)(P_Fertilizer is L)(K_Fertilizer is D) (1)
3	If (N_Level is L) and (P_Level is L) and (K_Level is S) and (Season is W) then (N_Fertilizer is L_W)(P_Fertilizer is L)(K_Fertilizer is S) (1)
4	If (N_Level is L) and (P_Level is L) and (K_Level is S) and (Season is D) then (N_Fertilizer is L_D)(P_Fertilizer is L)(K_Fertilizer is S) (1)
5	If (N_Level is L) and (P_Level is ML) and (K_Level is D) and (Season is W) then (N_Fertilizer is L_W)(P_Fertilizer is ML)(K_Fertilizer is D) (1)
6	If (N_Level is L) and (P_Level is ML) and (K_Level is D) and (Season is D) then (N_Fertilizer is L_D)(P_Fertilizer is ML)(K_Fertilizer is D) (1)
7	If (N_Level is L) and (P_Level is ML) and (K_Level is S) and (Season is W) then (N_Fertilizer is L_W)(P_Fertilizer is ML)(K_Fertilizer is S) (1)
8	If (N_Level is L) and (P_Level is ML) and (K_Level is S) and (Season is D) then (N_Fertilizer is L_D)(P_Fertilizer is ML)(K_Fertilizer is S) (1)
9	If (N_Level is L) and (P_Level is MH) and (K_Level is D) and (Season is W) then (N_Fertilizer is L_W)(P_Fertilizer is MH)(K_Fertilizer is D) (1)
10	If (N_Level is L) and (P_Level is MH) and (K_Level is D) and (Season is D) then (N_Fertilizer is L_D)(P_Fertilizer is MH)(K_Fertilizer is D) (1)

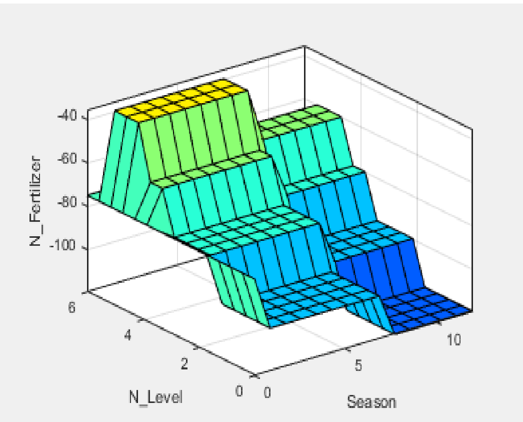

Fig. 2. Season vs Nitrogen vs N-Fertilizer

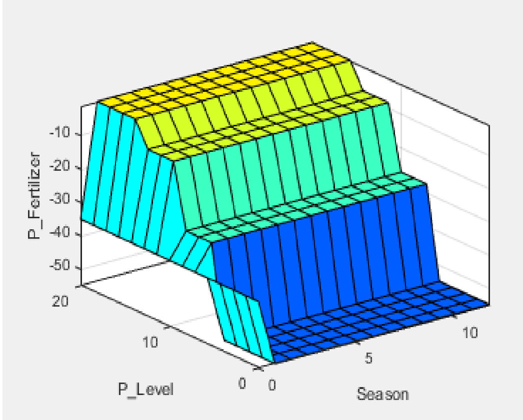

Fig. 3. Season vs Phosphorus vs P-Fertilizer

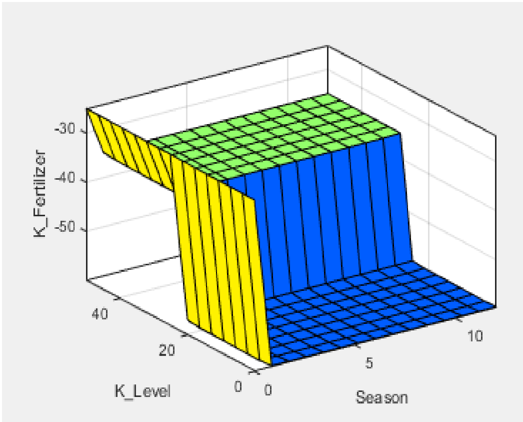

Fig. 4. Season vs Potassium vs K-Fertilizer

The defuzzifier is the last component in the Fuzzy Logic System (FLS) that converts the fuzzy controller output to a crisp output [24]. The defuzzification implemented to complete this study is the centroid defuzzifier. The equation below defined the center of gravity (COG) of any area.

$$COG = \frac{\int \mu(z)zdz}{\int \mu(z)dz} \quad (13)$$

where $\mu(z)$ represents the bounded area.

IV. Result and Discussion

In this study, different values of each parameter where used to test the program. Figure 5 shows five examples of fertilizer recommendation for wet season while figure 6 shows fertilizer recommendation for dry season. The value of the NPK and season is evaluated by the fuzzy system to compute the appropriate amount of fertilizer. The output of the fuzzy logic is used in a simple algorithm to view the results as shown in the figure.

Four kinds of fertilizer are proposed in this paper such as 14-14-14 Complete, 46-0-0 or Urea, 0-18-0 or Solophos and 0-0-60 or Muriate of Potash. In the first two example of figure 5 and 6, similar NPK values but different season is evaluated by the system.

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Example number 1

NPK value : N = 5.5, P = 20 and K = 50
Season = wet season

Recommended Fertilizer

0.58 bag of 0-0-60 Muriate of Potash Fertilizer
0.76 bag of 46-0-0 Urea Fertilizer
0.06 bag of 0-18-0 Solophos Fertilizer

Example number 2

NPK value : N = 4, P = 12.7 and K = 27.8
Season = wet season

Recommended Fertilizer

0.57 bag of 14-14-14 Complete Fertilizer
0.47 bag of 0-0-60 Muriate of Potash Fertilizer
1.13 bag of 46-0-0 Urea Fertilizer

Example number 3

NPK value : N = 3.8, P = 2.7 and K = 8.3
Season = wet season

Recommended Fertilizer

3.93 bag of 14-14-14 Complete Fertilizer
0.08 bag of 0-0-60 Muriate of Potash Fertilizer
0.11 bag of 46-0-0 Urea Fertilizer

Example number 4

NPK value : N = 5.5, P = 1 and K = 50
Season = wet season

Recommended Fertilizer

2.5 bag of 14-14-14 Complete Fertilizer
1.11 bag of 0-18-0 Solophos Fertilizer

Example number 5

NPK value : N = 5.5, P = 6 and K = 20
Season = wet season

Recommended Fertilizer

2.5 bag of 14-14-14 Complete Fertilizer
0.42 bag of 0-0-60 Muriate of Potash Fertilizer
1.11 bag of 0-18-0 Solophos Fertilizer
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Fig. 5. Sample Recommendation for Wet Season

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Example number 1

NPK value : N = 5.5, P = 20 and K = 50
Season = dry season

Recommended Fertilizer

0.58 bag of 0-0-60 Muriate of Potash Fertilizer
1.3 bag of 46-0-0 Urea Fertilizer
0.06 bag of 0-18-0 Solophos Fertilizer

Example number 2

NPK value : N = 4, P = 12.7 and K = 27.8
Season = dry season

Recommended Fertilizer

0.57 bag of 14-14-14 Complete Fertilizer
0.47 bag of 0-0-60 Muriate of Potash Fertilizer
1.57 bag of 46-0-0 Urea Fertilizer

Example number 3

NPK value : N = 5.5, P = 20 and K = 20
Season = dry season

Recommended Fertilizer

1 bag of 0-0-60 Muriate of Potash Fertilizer
1.3 bag of 46-0-0 Urea Fertilizer
0.06 bag of 0-18-0 Solophos Fertilizer

Example number 4

NPK value : N = 0.2, P = 18 and K = 40
Season = dry season

Recommended Fertilizer

0.6 bag of 0-0-60 Muriate of Potash Fertilizer
2.61 bag of 46-0-0 Urea Fertilizer
0.06 bag of 0-18-0 Solophos Fertilizer

Example number 5

NPK value : N = 3.5, P = 7.5 and K = 45
Season = dry season

Recommended Fertilizer

1.93 bag of 14-14-14 Complete Fertilizer
0.13 bag of 0-0-60 Muriate of Potash Fertilizer
1.59 bag of 46-0-0 Urea Fertilizer
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Fig. 6. Sample Recommendation for Dry Season

Noticeably, the amount of fertilizer for dry season, specifically urea is greater than the amount in wet season because the season greatly affects the nitrogen nutrient of the soil. The recommended fertilizer is suitable to use for rice in an inbred light soil

V. Conclusion and Future Works

The result shows that the fuzzy logic system is successfully developed and simulated in order to give appropriate fertilizer recommendation. Season, nitrogen, phosphorus and potassium level is used as input parameter of the fuzzy system. Different fertilizer combination is created depending on the range of input parameters used.

The program was successfully executed and done; However, the researchers would like to make the following recommendations to further improve the research; (1) Used the recommended fertilizer to identify the accuracy of the result and (2) Connect the program to a soil test analyzer.

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