PADDY GROWTH ANALYSIS AND DISEASE PREDICTION USING FUZZY LOGIC CONTROLLER SYSTEM

***K. Raja**
Assistant Professor, Department of Mathematics,
Sri Manakula Vinayagar Engineering College, Puducherry, India.
raja.rajth@gmail.com

Dr.S.Ramathilagam
Assistant Professor, Department of Mathematics,
Periyar Govt Arts College,
Tamilnadu, India.
thilagaiitm@mail.com

Abstract

Agriculture is the primary source of livelihood for about 60% of Indian population. Indian agriculture needs set of solutions for improvisation of both the farmers and the agricultural land. Agriculture contributes only 16% GDP for the country but it is the largest sector for employment. Apart from economy, Indian agriculture needs sustainable, efficient, technical and mainly productive farming. In this project, Paddy is taken as the field to be improvised. Paddy is categorized as 3 different varieties. Using the basic parameters of an agricultural land has membership function inputs such as temperature, humidity, sunlight and soil moisture, the respective membership outputs viz., water irrigation, plant growth and plant diseases are to be found. Membership functions come under the concept of fuzzy logic. Fuzzy logic basically uses membership functions to determine outputs for all calculations. Using IR cameras, plant growth can be easily monitored and analysed. Using this technique, basic necessities of an agricultural land can be satisfied and is also useful for productive farming. The main concentration of this idea is based on the cultivation of three different varieties of paddy.

Keywords: Agriculture, Fuzzy logic, Rule base, MATLAB, disease prediction, irrigation, paddy, sensors.

1. Introduction

Nowadays development in all the fields is increasing its progression day by day. Agriculture is also propagating its way towards technological development. But in India, it has not been popular mainly because it is not affordable by Indian Farmers.

Nearly 65% percent of world's arable land has been cultivated by farmers. Among all countries India lies in the second position in agricultural production. Also, India lies in the first position with most agricultural suicidal deaths amongst all countries. This project is basically implemented using the idea of fuzzy logic. Fuzzy logic is an idea which involves the logic that truth values of variables may be any real number between 0 and 1. This logic is used to handle the theory of partial truth where the truth value may range between completely true and completely false. Fuzzy logic is implemented in this project as the range for all the values produced by every reading from the sensors used. This project consists of various sensors for all the parameters that agricultural land contain. The sensors listed are –

temperature sensor, humidity sensor, moisture sensor, sunlight sensor. Using these sensors, the output values can be found successfully.

The varieties of paddy taken are Short duration variety, Medium duration variety and Long duration variety and some example for those varieties are NK-3325, NK-5017 and NK-6302 respectively.

The moisture in the field of paddy is required for determining the irrigation scheduling and also water resource allocation. Thus, soil moisture affects the variation patterns of evapotranspiration in paddy field and soil moisture will be determined by water irrigation and precipitation[2].

2. Fuzzy Expert System

Fuzzy logics are used in smart machines like washing machine, air conditioner and etc. It is stated that, "Researchers are converting crisp phenomena to fuzzy" [3].

Professor Lotfi A.Zadeh first introduced fuzzy logic in the year 1965 in University of California [4]. Powerful design technology is developed using fuzzy logic. Engineers use this system to solve complex problems in simple method [5].

The fuzzy logic accepts various inputs and it develops a natural way of system [6]. These fuzzy logic controllers are similar to classical logic controllers which used knowledge of human thoughts. Gas heaters were also designed using fuzzy logic behavioural model [7].The embedded automatic controller controls the fuzzy logic performances [8].

The simulation of the fuzzy logic controller system is done using the software called MATLAB. It is a toolbox which can be used to design fuzzy logic controller [9]**.** It is most used simulation software for simulation of any kind of input to read the output and we can compare it with our expected result. It is being used by many engineers and scientists across the world.

These fuzzy logic simulations can be done in the software MATLAB

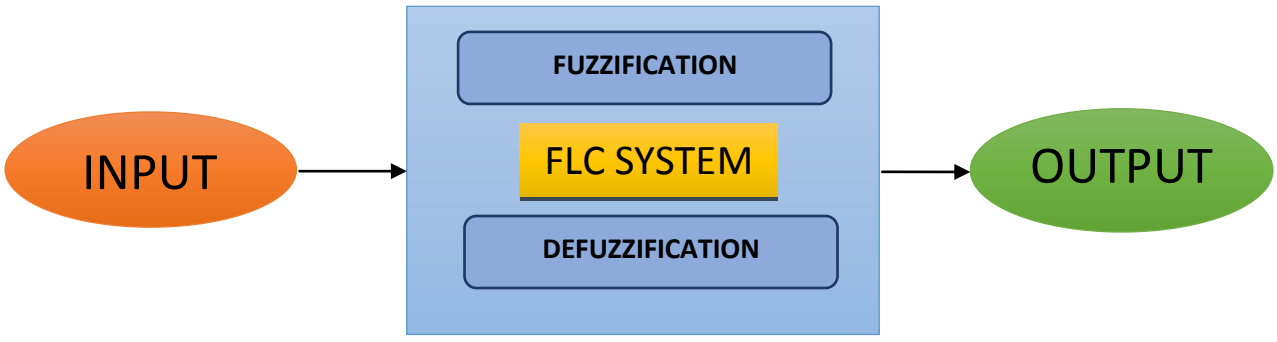

Fig 1. Fuzzy Logic Control System

2.1 Fuzzy expert system in agriculture:

While solving problems, experts relay on composure. Some agricultural experts state, even if soil condition is good, rainfall plays an important role in deciding crop production. Others understand this statement easily, because they have experienced by hearing these problem frequently.

The question is how we might show knowledge of agriculture experts that utilize vague and ambiguous terms in system.

Fuzzy logic (Zadeh, 1965), is set of mathematical principles intended for representation of knowledge contingent on membership degree. It is a supreme tool to deal with vagueness and ambiguity. It was found to enhance strength, malleability and low-priced results for real world issues.

Fuzzy logic has been implemented in various real-life instances, where uncertainty acts as critical role wherever agriculture diagnosis is prominent case of ambiguity, uncertainty and vagueness.

In agricultural domain, Fuzzy logic might make resolutions where information is imprecise, uncertain and incomplete. Fuzzy logic observes various diseases in agricultural production because it takes human decisions.

The main objective is to analyse chances of occurrence of plant diseases in beforehand to perform necessary arrangements in advance, based on risk factors and symptoms, water irrigation level and plant growth based on the input factors such as paddy type, sunlight, moisture content of soil, atmospheric temperature and humidity.

Fuzzy logic is a practice that can get necessary knowledge of agricultural domain.

(Pandey et al., 2013; Pandey et al., 2015; Kalpana and Kumar, 2012; Pandey et al., 2017; Harvinder et al., 2002 [1]; Amelio et al., 2017; Pandey et al., 2013), (Sumathi and Kumar, 2014).

3. Sensors Required

3.1 Humidity Sensor

Humidity sensors are used to find out the moisture content of water vapor in the air. It can be used for the analysis of plant for irrigation.

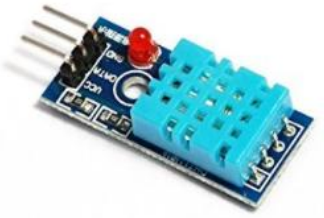

Fig 2. Temperature and Humidity Sensor

3.2 Temperature Sensor

Temperature sensor is used to measure the temperature of the surrounding environment in the paddy field which can be used for the analysis of water irrigation level and maintenance.

3.3 IR camera

IR camera has many uses over plant maintenance and analysis. It is majorly used for detection of disease, water content in the plant, temperature, pest prediction, soil properties and etc. Hence it is the most important instrument taken for the plant disease prediction and analysis.

Fig 3. IR Camera

3.4 Soil Moisture Sensor

Soil moisture sensor uses capacitance of the dielectric permittivity of the soil medium and hence the water content in the soil acts as dielectric medium and the percentage of water content is measured, which will be useful for the crop irrigation maintenance and disease prediction systems.

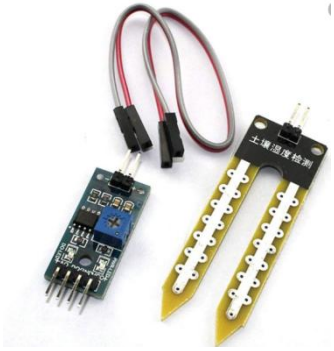

Fig 4. Soil moisture sensor

3.5 Light Sensor

Light sensor is a photoelectric device which converts the light energy into electrical energy that can be used for calculation of the light/ Luminous intensity of the sunlight falling on the field and with which the amount of light required for the plant growth can be easily detected.

Fig 5. Light Sensor

4. Proposed Design

The fuzzy logic controller system for the agricultural paddy analysis is determined by using fuzzy inputs and fuzzy outputs. The main theme of the project is to provide easy way of plant analysis for disease prediction and water irrigation level prediction, plant growth analysis for the farmers to make decisions easier. There are 45 rules for input and outputin smart paddy analysis and disease prediction which are used for the fuzzy logic. The fuzzy inputs for paddy analysis are:

1. Paddy Type
2. Temperature
3. Humidity
4. Sunlight
5. Soil Moisture

The output analysed for the given input are:

1. Water irrigation level
2. Plant growth level
3. Disease prediction

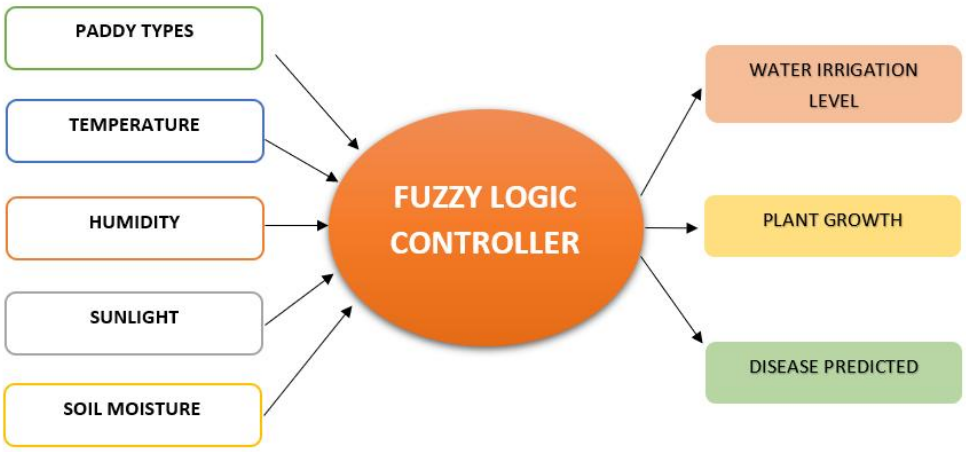

Fig 6. Fuzzy logic Inputs and Outputs System

5. Membership function for Fuzzy logic inputs and outputs

5.1 Fuzzy Input

Fuzzy logic controller system uses a set of crisp input values. These input values can be represented in the terms of fuzzy membership inputs or values. The values are selected on the basis of the linguistic inputs which uses a range from a low value to high value or vice versa. For the Paddy types such as short duration variety, medium duration variety and long duration variety, the membership functions are [71-105],[96-125] and [126-150] respectively. For the second input, temperature, for the ranges such as cold, warm and hot, the membership functions are [20*C-26*C], [27*C-35*C] and [35*C-45*C] respectively. For the range value of humidity such as less, medium and high, the membership functions are [0-25%], [25-60%] and [60-100%] respectively. For the input Sunlight ranging from foggy, cloudy and sunny, the membership functions are [16-24*C], [25-30*C] and [31-40*C]. And for the last input, soil moisture ranging from dry soil, wet soil, flooded, the membership functions are [0-30%], [30-60%] and [60-100%] respectively. These values can be represented using triangular membership functions and graph to notify the values of the outputs generated. All these membership functions can be plotted as below:

5.1.1 Paddy Type

Paddy types are divided into three varieties such as Short duration, Medium duration and Long duration variety and each of it has its own duration of the growth period.

Fuzzy Input	FUZZY	FUZZY RANGE
Paddy Type	Short duration variety	71-105 Days
	Medium duration variety	96-125 Days
	Long duration variety	115-150 Days

$$\Psi_{Short}(x) = \begin{cases} 1, & x<96 \\ \frac{115-x}{19}, & 96\leq x\leq 115 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{Medium}(x) = \begin{cases} \frac{x-96}{9}, & 96\leq x\leq 105 \\ \frac{125-x}{20}, & 105\leq x\leq 125 \end{cases}$$

$$\Psi_{Long}(x) = \begin{cases} \frac{x-105}{20}, & 105\leq x\leq 125 \\ 1, & 125\leq x\leq 150 \\ 0, & \text{otherwise} \end{cases}$$

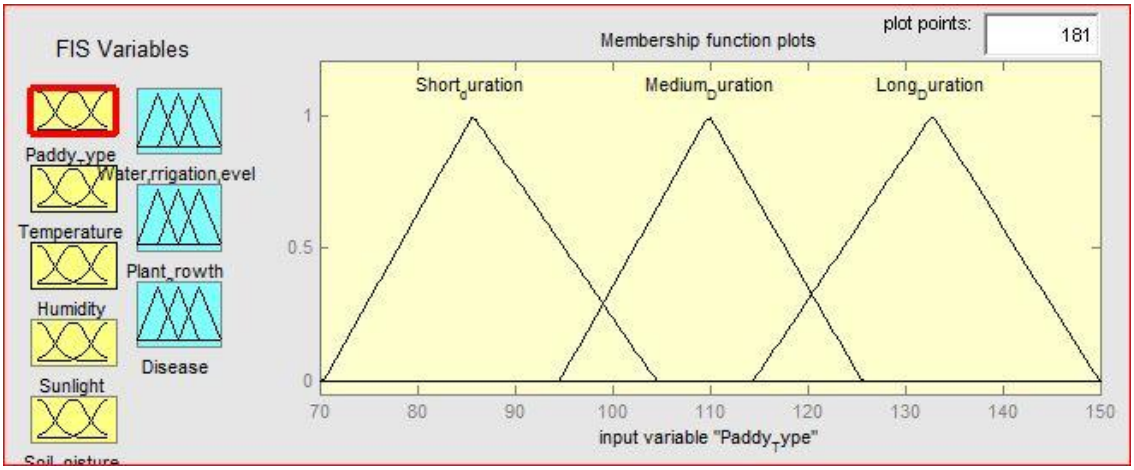

Fig 7. Membership function plot for Paddy type

5.1.2 Temperature

Temperature of the plant is main component for a plant growth. It can be divided into cold, warm and hot. These temperature levels are so much important for the growth of any variety paddy.

Fuzzy Input	FUZZY	FUZZY RANGE
Temperature	Cold	20*C-26*C
	Warm	25*C-35*C
	Hot	32*C-45*C

$$\Psi_{Cold}(x) = \begin{cases} 1, & x<25 \\ \frac{32-x}{7}, & 25\le x\le 32 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{Warm}(x) = \begin{cases} \frac{x-25}{1}, & 25\le x\le 26 \\ \frac{35-x}{9}, & 26\le x\le 35 \end{cases}$$

$$\Psi_{Hot}(x) = \begin{cases} \frac{x-26}{9}, & 26\le x\le 35 \\ 1, & 35\le x\le 45 \\ 0, & \text{otherwise} \end{cases}$$

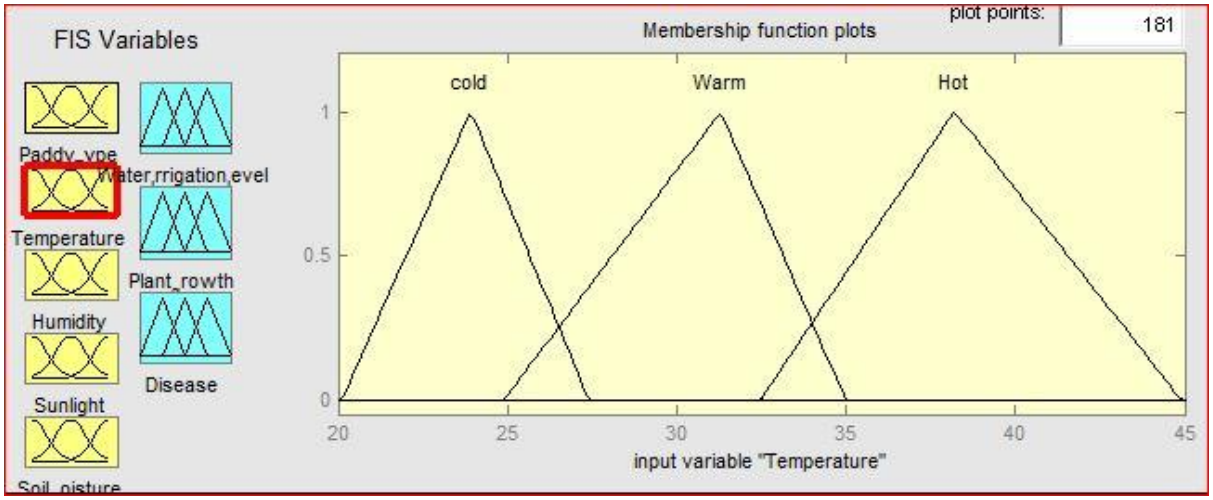

Fig 8. Membership function plot for Temperature

5.1.3 Humidity

The effect of humidity on the paddy growth is an important factor for the production and the growth of the paddy agriculture.It can be divided into low, medium and high. The humidity condition during the harvesting also plays a major role.

Fuzzy Input	FUZZY	FUZZY RANGE
Humidity	Low	0-35%
	Medium	25-65%
	High	55-100%

$$\Psi_{Low}(x) = \begin{cases} 1, & x<25 \\ \frac{55-x}{30}, & 25\leq x\leq 55 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{Medium}(x) = \begin{cases} \frac{x-25}{10}, & 25\leq x\leq 35 \\ \frac{65-x}{30}, & 35\leq x\leq 65 \end{cases}$$

$$\Psi_{High}(x) = \begin{cases} \frac{x-35}{13}, & 35\leq x\leq 65 \\ 1, & 65\leq x\leq 100 \\ 0, & \text{otherwise} \end{cases}$$

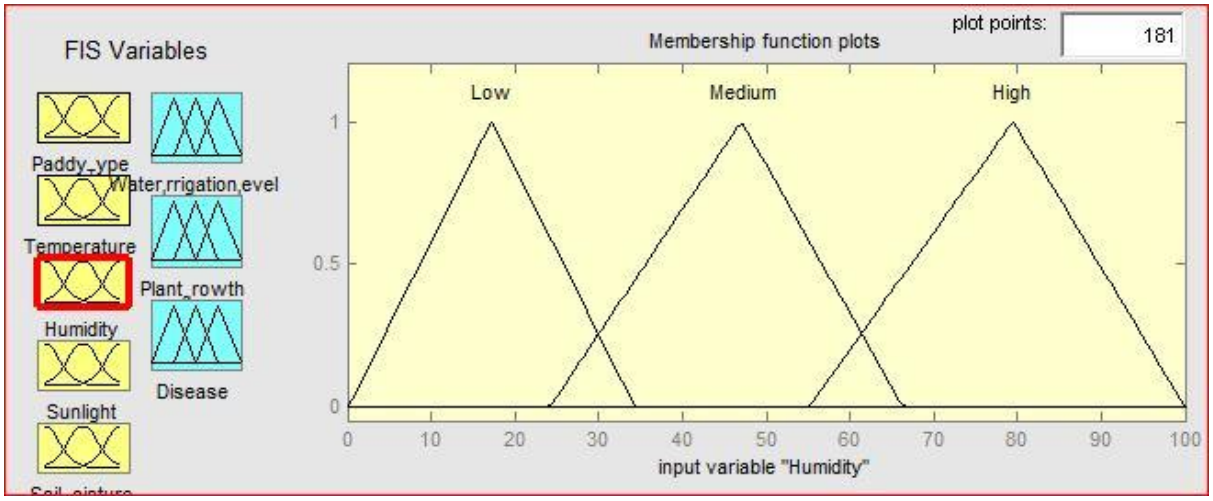

Fig 9. Membership function plot for Humidity

5.1.4 Sunlight

Sunlight is the primary resource for the processing of the green plants and paddy to transform water, minerals and carbon-di-oxide into fiber, food and biomass using the process of photosynthesis. It can be differentiated into hazy, cloudy, sunny according to the varying Celsius range.

Fuzzy Input	FUZZY	FUZZY RANGE
Sunlight	Hazy	16-25*C
	Cloudy	22-33*C
	Sunny	30-40*C

$$\Psi_{Hazy}(x) = \begin{cases} 1, & x<22 \\ \frac{30-x}{8}, & 22\leq x\leq 30 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{cloudy}(x) = \begin{cases} \frac{x-22}{3}, & 22\leq x\leq 25 \\ \frac{33-x}{8}, & 25\leq x\leq 33 \end{cases}$$

$$\Psi_{Sunny}(x) = \begin{cases} \frac{x-25}{8}, & 25\leq x\leq 33 \\ 1, & 33\leq x\leq 40 \\ 0, & \text{otherwise} \end{cases}$$

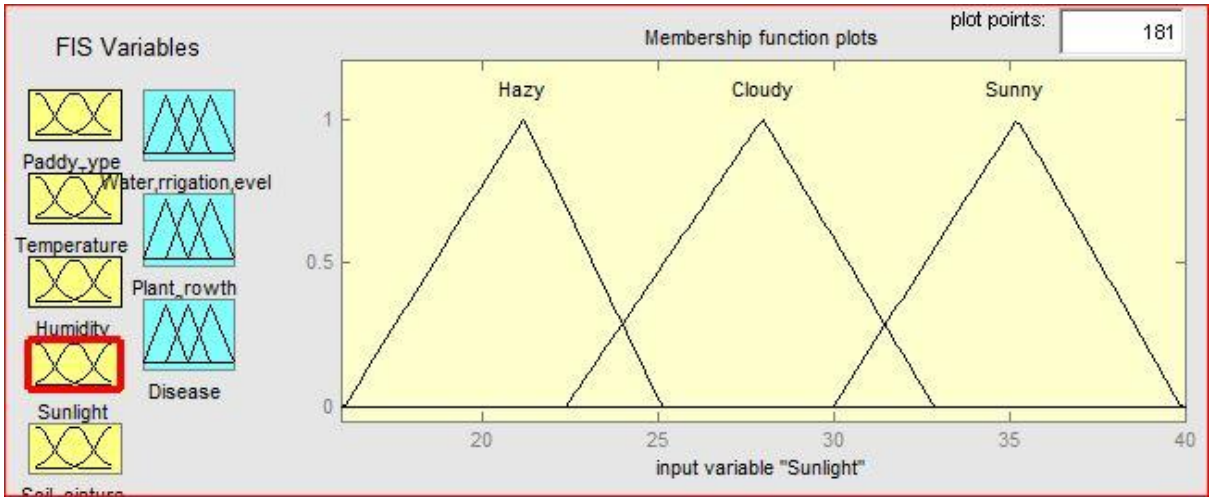

Fig 10. Membership function plot for Sunlight

5.1.5 Soil Moisture

Soil moisture is the main component in the maintenance of the absorption of soil nutrients and the water content based on the range of content of the moisture present in the soil. It ranges from the 0-100% based on the ranging from Dry soil to Wet soil to Muddy soil.

Fuzzy Input	FUZZY	FUZZY RANGE
Soil Moisture	Dry soil	0-35%
	Wet soil	25-65%
	Muddy soil	55-100%

$$\Psi_{\text{Dry soil}}(x) = \begin{cases} 1, & x<25 \\ \frac{55-x}{30}, & 25\le x\le 55 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{\text{Wet soil}}(x) = \begin{cases} \frac{x-25}{10}, & 25\le x\le 35 \\ \frac{65-x}{30}, & 35\le x\le 65 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{\text{Muddy soil}}(x) = \begin{cases} \frac{x-35}{30}, & 35\le x\le 65 \\ 1, & 65\le x\le 100 \\ 0, & \text{otherwise} \end{cases}$$

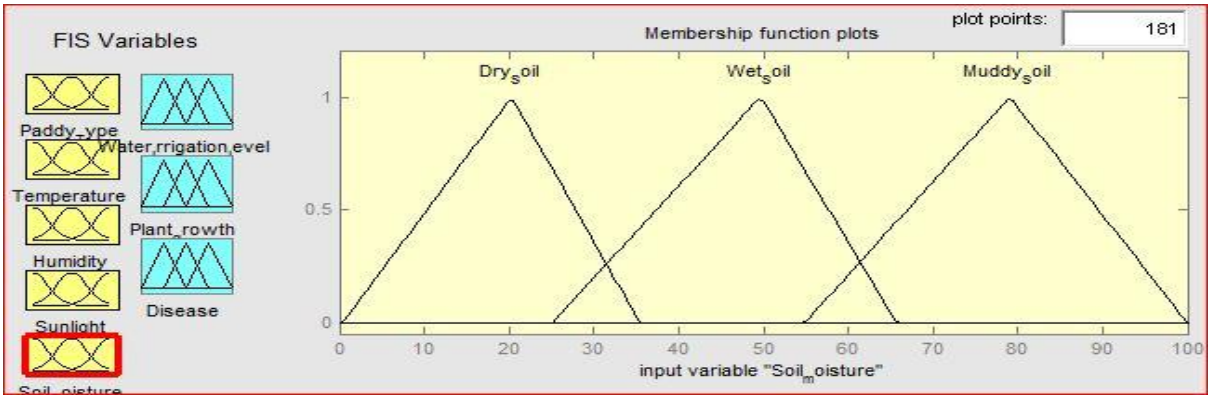

Fig 11. Membership function plot for Soil moisture

5.2 Fuzzy Output

As we have mentioned before for fuzzy inputs, the membership outputs for those inputs can be categorized here. For the output water irrigation level ranging from thin film, medium film and thick film, the membership functions are [2-3 cm], [3-4 cm] and [4-5 cm] respectively. Similarly, for the output plant growth ranging from short, medium and tall, the membership functions are [90-105 cm], [100-110 cm] and [110-115 cm] respectively. And for the final output, disease prediction ranging from mild, medium and heavy, the membership functions are [0-30%], [30-60%] and [60-100%] respectively.

5.2.1 Water irrigation level

Every crop has its own amount of water level to be maintained at a particular growth of plant. For paddy it can be divided into Thin film, Medium film and Thick film with the range of water level from 2-5cm.

Fuzzy Output	FUZZY	FUZZY RANGE
Water irrigation level	Thin film	2-3 cm
	Medium film	2.5-4 cm
	Thick film	4-5 cm

$$\Psi_{\text{Thin film}}(x) = \begin{cases} 1, & x<2.5 \\ \frac{4-x}{1.5}, & 2.5\leq x\leq 4 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{\text{Medium film}}(x) = \begin{cases} \frac{x-2.5}{0.5}, & 2.5\leq x\leq 3 \\ \frac{60-x}{30}, & 3\leq x\leq 4 \end{cases}$$

$$\Psi_{\text{Thick film}}(x) = \begin{cases} \frac{x-3}{1}, & 3\leq x\leq 4 \\ 1 & 4\leq x\leq 5 \\ 0, & \text{otherwise} \end{cases}$$

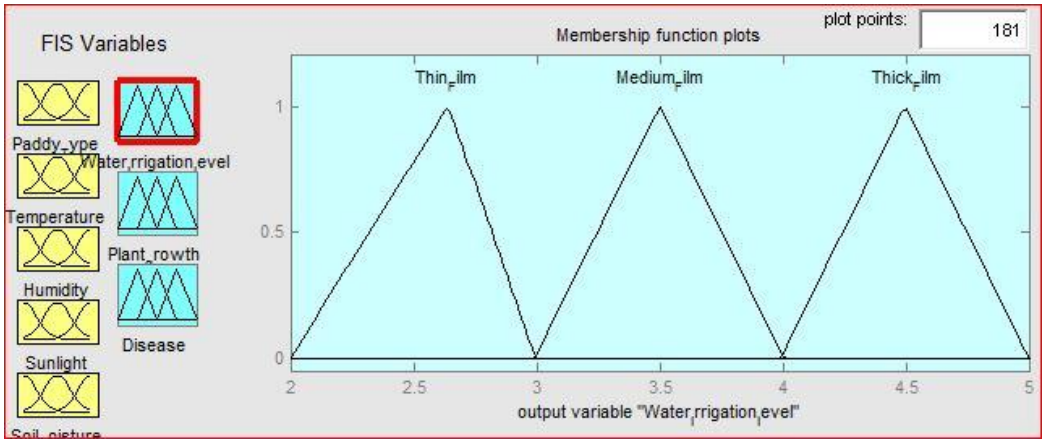

Fig 12. Membership function plot for Water irrigation level

5.2.2 Plant growth

For paddy growth, the plant growth can be determined on the basis of short, medium and tall with the series of growth ranging from 90-115cm.

Fuzzy Output	FUZZY	FUZZY RANGE
Plant growth	Short	90-105 cm
	Medium	100-110 cm
	Tall	107-115 cm

$$\Psi_{Short}(x) = \begin{cases} 1, & x<100 \\ \frac{107-x}{7}, & 100\le x\le 107 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{Medium}(x) = \begin{cases} \frac{x-100}{5}, & 100\le x\le 105 \\ \frac{110-x}{5}, & 105\le x\le 110 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{Tall}(x) = \begin{cases} \frac{x-105}{5}, & 105\le x\le 110 \\ 1, & 110\le x\le 115 \\ 0, & \text{otherwise} \end{cases}$$

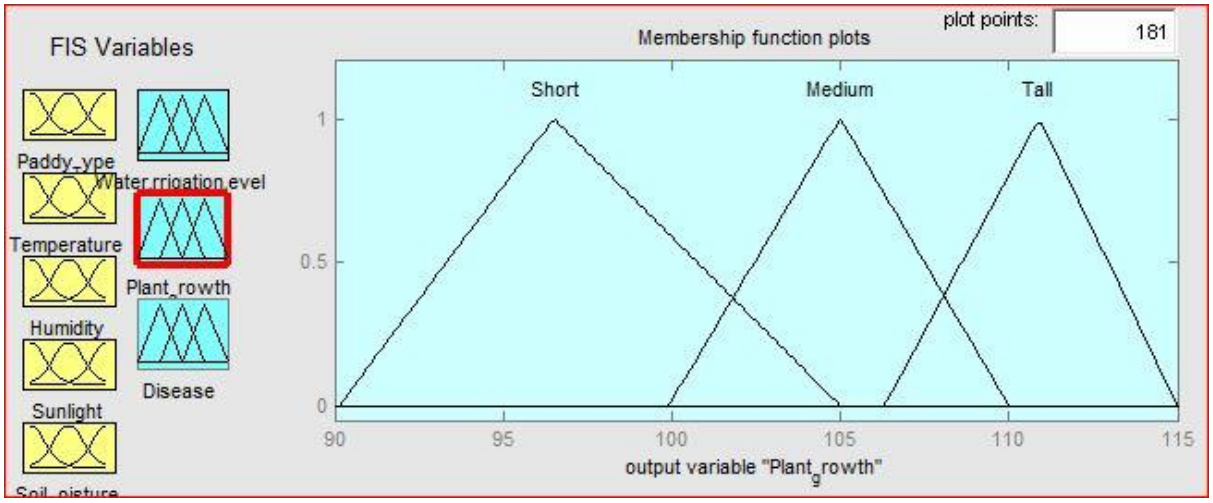

Fig 13. Membership function plot for Plant growth

5.2.3 Disease prediction

Fuzzy Output	FUZZY	FUZZY RANGE
Disease	Mild	0-30%
	Moderate	25-65%
	Severe	55-100%

$$\Psi_{Mild}(x) = \begin{cases} 1, & x<25 \\ \frac{55-x}{30}, & 25\leq x\leq 55 \\ 0, & \text{otherwise} \end{cases}$$

$$\Psi_{Moderate}(x) = \begin{cases} \frac{x-25}{5}, & 25\leq x\leq 30 \\ \frac{65-x}{35}, & 30\leq x\leq 65 \end{cases}$$

$$\Psi_{Severe}(x) = \begin{cases} \frac{x-30}{35}, & 30\leq x\leq 65 \\ 1, & 65\leq x\leq 100 \\ 0, & \text{otherwise} \end{cases}$$

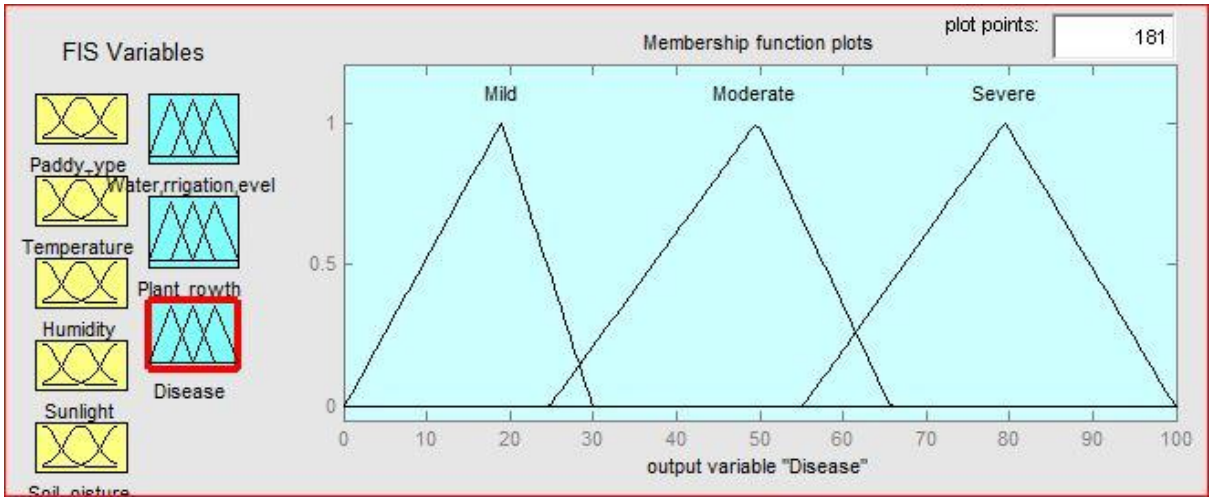

Fig 14. Membership function plot for Disease prediction

6. Rule base for the Fuzzy logic input and output

- If (Paddy_Type is Short_duration) and (Temperature is cold) and (Humidity is Low) and (Sunlight is Hazy) and (Soil_moisture is Dry_Soil) then (Water_irrigation_level is Thin_Film)(Plant_growth is Tall)(Disease is Mild)
- If (Paddy_Type is Short_duration) and (Temperature is Warm) and (Humidity is Medium) and (Sunlight is Cloudy) and (Soil_moisture is Wet_Soil) then (Water_irrigation_level is Medium_Film)(Plant_growth is Medium)(Disease is Moderate)
- If (Paddy_Type is Short_duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Sunny) and (Soil_moisture is Muddy_Soil) then (Water_irrigation_level is Thick_Film)(Plant_growth is Short)(Disease is Severe)
- If (Paddy_Type is Long_Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Sunny) and (Soil_moisture is Wet_Soil) then (Water_irrigation_level is Thick_Film)(Plant_growth is Short)(Disease is Severe)
- If (Paddy_Type is Short_duration) and (Temperature is cold) and (Humidity is Low) and (Sunlight is Hazy) and (Soil_moisture is Muddy_Soil) then (Water_irrigation_level is Thin_Film)(Plant_growth is Tall)(Disease is Mild)
- If (Paddy_Type is Medium_Duration) and (Temperature is Warm) and (Humidity is Medium) and (Sunlight is Cloudy) and (Soil_moisture is Muddy_Soil) then (Water_irrigation_level is Thick_Film)(Plant_growth is Short)(Disease is Moderate)
- If (Paddy_Type is Long_Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Sunny) and (Soil_moisture is Muddy_Soil) then (Water_irrigation_level is Thick_Film)(Plant_growth is Short)(Disease is Severe)

7. Fuzzy logic input and output table

S. NO	LINGUISTIC INPUTS					LINGUISTIC OUTPUTS		
	PADDY TYPE	**TEMPERATURE**	**HUMIDITY**	**SUN LIGHT**	**SOIL MOISTURE**	**WATER IRRIGATION**	**PLANT GROWTH**	**DISEASE**
1	Short Duration Variety	Cold	Low	Haze	Dry Soil	Thin Film	Short	Mild
2	Short Duration Variety	Warm	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate
3	Short Duration Variety	Hot	High	Sunny	Muddy Soil	Thick film	Tall	Severe
4	Medium Duration Variety	Cold	Low	Haze	Dry Soil	Thin Film	Short	Mild
5	Medium Duration Variety	Warm	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate
6	Medium Duration Variety	Hot	High	Sunny	Muddy Soil	Thick film	Tall	Severe
7	Long Duration Variety	Cold	Low	Haze	Dry Soil	Thin Film	Short	Mild
8	Long Duration Variety	Warm	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate
9	Long Duration Variety	Hot	High	Sunny	Muddy Soil	Thick film	Tall	Severe
10	Short Duration Variety	Cold	Low	Haze	Dry Soil	Thin Film	Short	Mild
11	Medium Duration Variety	Cold	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate
12	Long Duration Variety	Cold	High	Sunny	Muddy Soil	Thick film	Tall	Severe
13	Short Duration Variety	Warm	Low	Haze	Dry Soil	Thin Film	Short	Mild
14	Medium Duration Variety	Warm	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate
15	Long Duration Variety	Warm	High	Haze	Muddy Soil	Thick film	Tall	Severe

16	Short Duration Variety	Hot	Low	Cloudy	Dry Soil	Thin Film	Short	Mild
17	Medium Duration Variety	Hot	Medium	Sunny	Wet Soil	Medium Film	Medium	Moderate
18	Long Duration Variety	Hot	High	Haze	Muddy Soil	Thick film	Tall	Severe
19	Short Duration Variety	Cold	Low	Cloudy	Dry Soil	Thin Film	Short	Mild
20	Medium Duration Variety	Warm	Low	Sunny	Wet Soil	Medium Film	Medium	Moderate
21	Long Duration Variety	Hot	Low	Haze	Muddy Soil	Thick film	Tall	Severe
22	Short Duration Variety	Cold	Medium	Cloudy	Dry Soil	Thin Film	Short	Mild
23	Medium Duration Variety	Warm	Medium	Sunny	Wet Soil	Medium Film	Medium	Moderate
24	Long Duration Variety	Hot	Medium	Haze	Muddy Soil	Thick film	Tall	Severe
25	Short Duration Variety	Cold	High	Cloudy	Dry Soil	Thin Film	Short	Mild
26	Medium Duration Variety	Warm	High	Sunny	Wet Soil	Medium Film	Medium	Moderate
27	Long Duration Variety	Hot	High	Haze	Muddy Soil	Thick film	Tall	Severe
28	Short Duration Variety	Cold	Low	Haze	Dry Soil	Thin Film	Short	Mild
29	Medium Duration Variety	Warm	Medium	Haze	Wet Soil	Medium Film	Medium	Moderate
30	Long Duration Variety	Hot	High	Haze	Muddy Soil	Thick film	Tall	Severe
31	Short Duration Variety	Cold	Low	Cloudy	Dry Soil	Thin Film	Short	Mild
32	Medium Duration Variety	Warm	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate

33	Long Duration Variety	Hot	High	Cloudy	Muddy Soil	Thick film	Tall	Severe
34	Short Duration Variety	Cold	Low	Sunny	Dry Soil	Thin Film	Short	Mild
35	Medium Duration Variety	Warm	Medium	Sunny	Wet Soil	Medium Film	Medium	Moderate
36	Long Duration Variety	Hot	High	Sunny	Muddy Soil	Thick film	Tall	Severe
37	Short Duration Variety	Cold	Low	Haze	Dry Soil	Thin Film	Short	Mild
38	Medium Duration Variety	Warm	Medium	Cloudy	Dry Soil	Medium Film	Medium	Moderate
39	Long Duration Variety	Hot	High	Sunny	Dry Soil	Thick film	Tall	Severe
40	Short Duration Variety	Cold	Low	Haze	Wet Soil	Thin Film	Short	Mild
41	Medium Duration Variety	Warm	Medium	Cloudy	Wet Soil	Medium Film	Medium	Moderate
42	Long Duration Variety	Hot	High	Sunny	Wet Soil	Thick film	Tall	Severe
43	Short Duration Variety	Cold	Low	Haze	Muddy Soil	Thin Film	Short	Mild
44	Medium Duration Variety	Warm	Medium	Cloudy	Muddy Soil	Medium Film	Medium	Moderate
45	Long Duration Variety	Hot	High	Sunny	Muddy Soil	Thick film	Tall	Severe

8. Rule Viewer for agriculture fuzzy logic system

The graph presented using rule viewer shows how the three outputs such as water irrigation, plant growth and plant disease are obtained based on the inputs - paddy type, temperature, humidity, sunlight and soil moisture. For example, when we consider the paddy types such as short duration variety, medium duration variety and long duration variety, the value generated for paddy type is 108. For cold, warm, hot the value generated for temperature is 32. For low, medium, high, the value generated for humidity is 50.6. For hazy, cloudy, sunny, the value generated for sunlight is 28.5. For dry soil, wet soil, muddy soil, the value generated for soil moisture is 49.4. Similarly, when we consider the outputs, for thin film water, medium film

water, thick film water, the value generated for water irrigation is 3.5. For short, medium, tall, the value generated for plant growth is 102. For mild, moderate, severe, the value generated for plant disease is 50. Therefore, these results produced for the if-then rules through MATLAB are obtained using rule viewer.

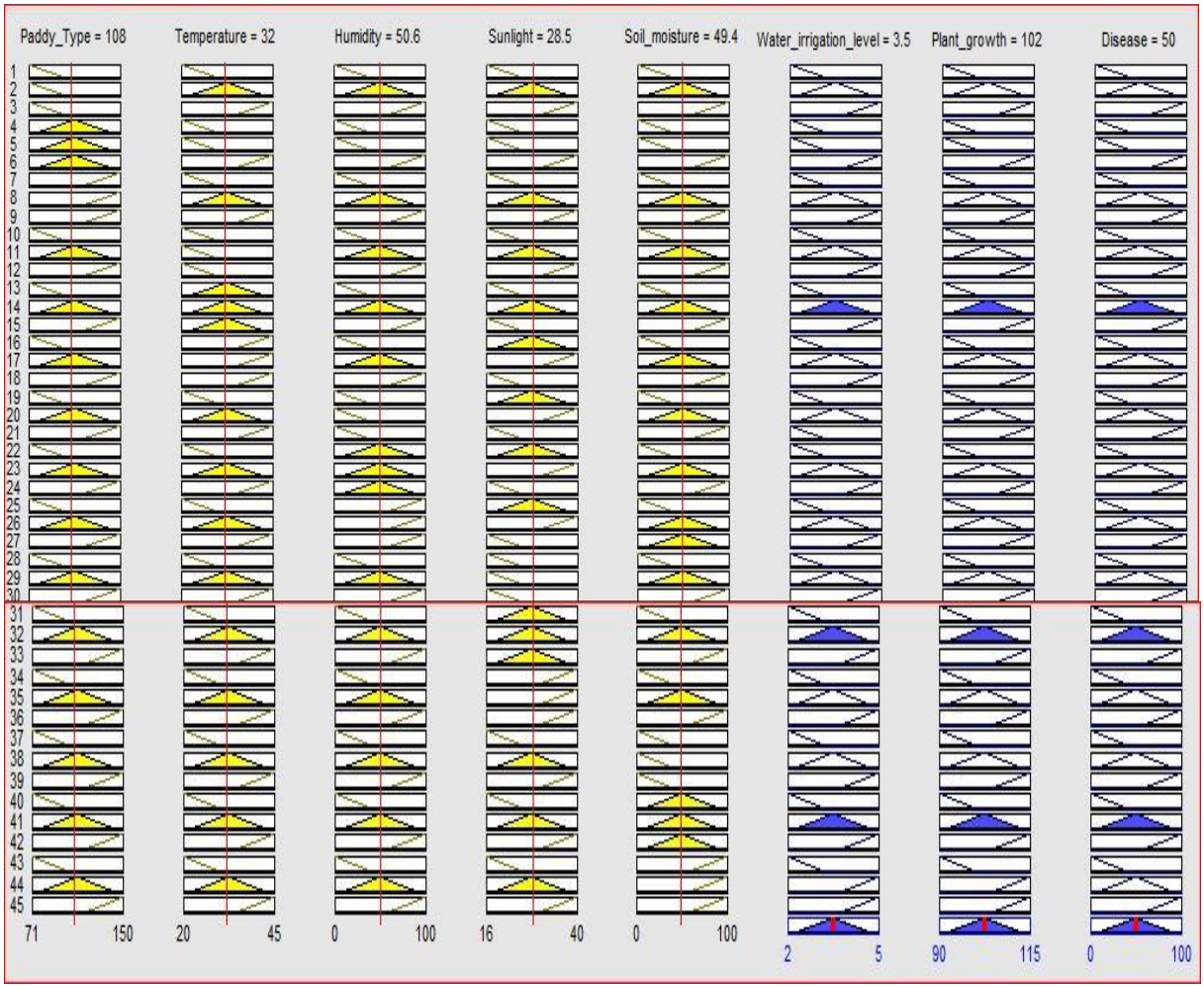

Fig 15. Rule viewer of FLC system

9. Surface viewer for fuzzy logic system of agriculture

The implementation of fuzzy logic systems is to provide outputs for the given inputs of agriculture. In MATLAB, the fuzzy logic toolbox option is used to develop the fuzzy logic system for the paddy growth analysis and disease prediction. In this circumstance, a surface viewer is used to show the relation between the membership function input and output parameters. The 3D surface viewer for the input and output are graphed as follows:

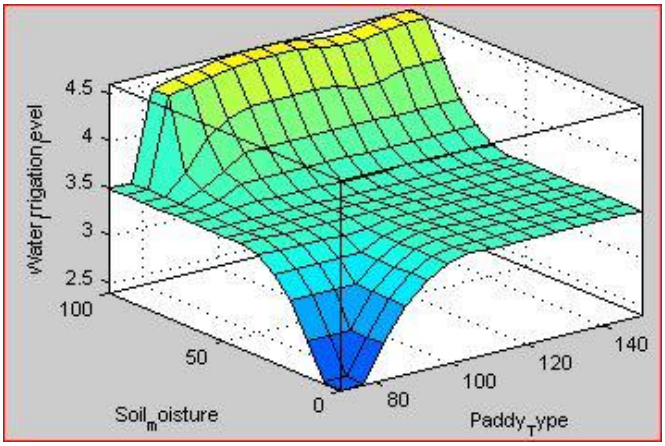

Fig 16. Surface plot for Soil moisture vs Paddy type for Water irrigation level

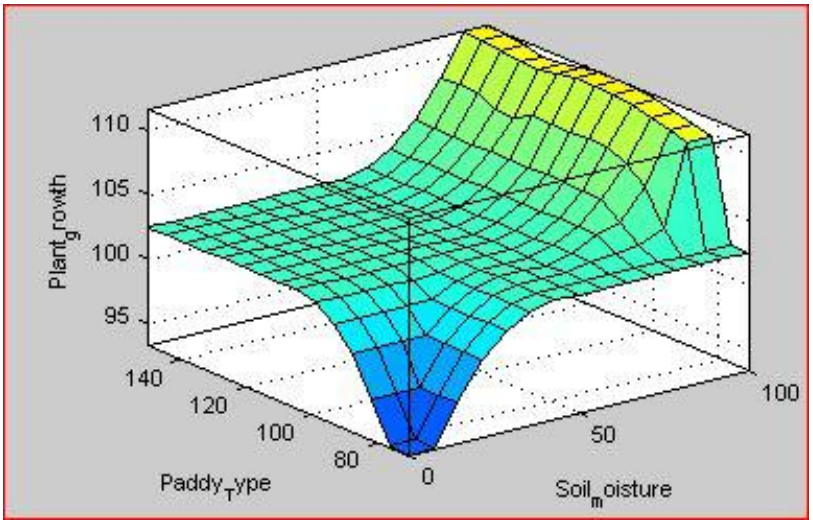

Fig 17. Surface plot for Paddy type vs Soil moisture for Plant growth

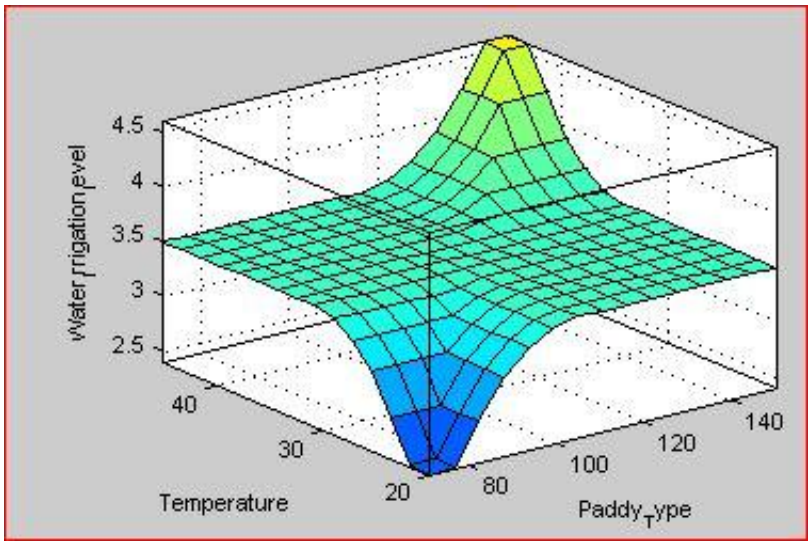

Fig 18. Surface plot for Temperature vs Paddy type for Water irrigation level

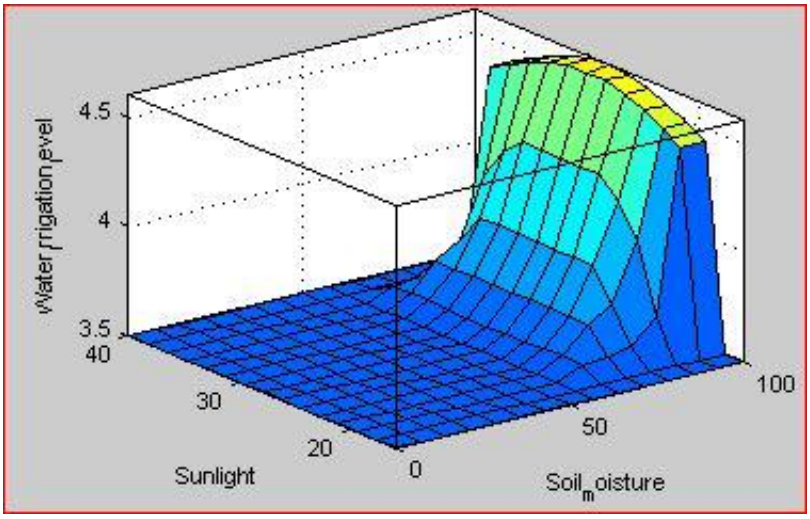

Fig 19. Surface plot for Sunlight vs Soil moisture for Water irrigation level

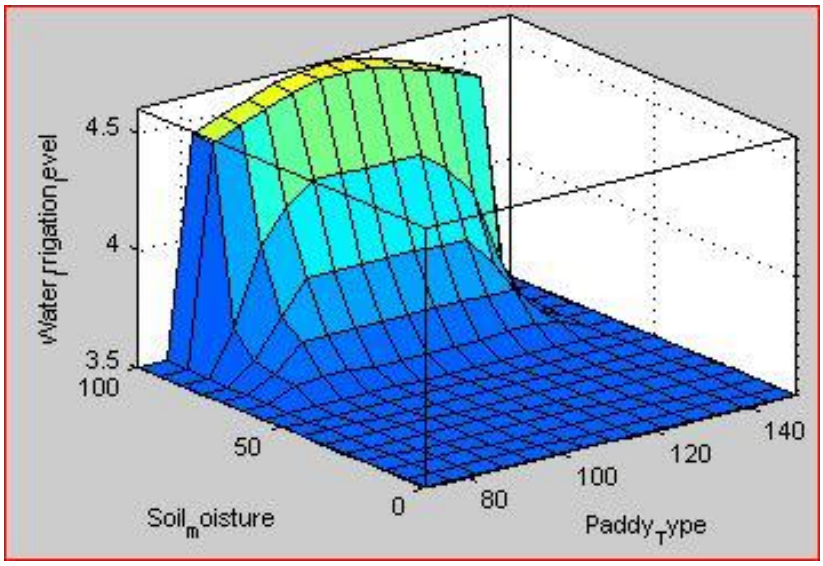

Fig 20. Surface plot for Soil moisture vs Paddy type for Water irrigation level

9.1 Graph plotting:

From the given graph, it is known that as the input values such as paddy type, humidity, temperature, soil moisture, sunlight are given, the output values such as Water irrigation level, plant growth and disease prediction are analyzed and it is shown as a graph as given below:

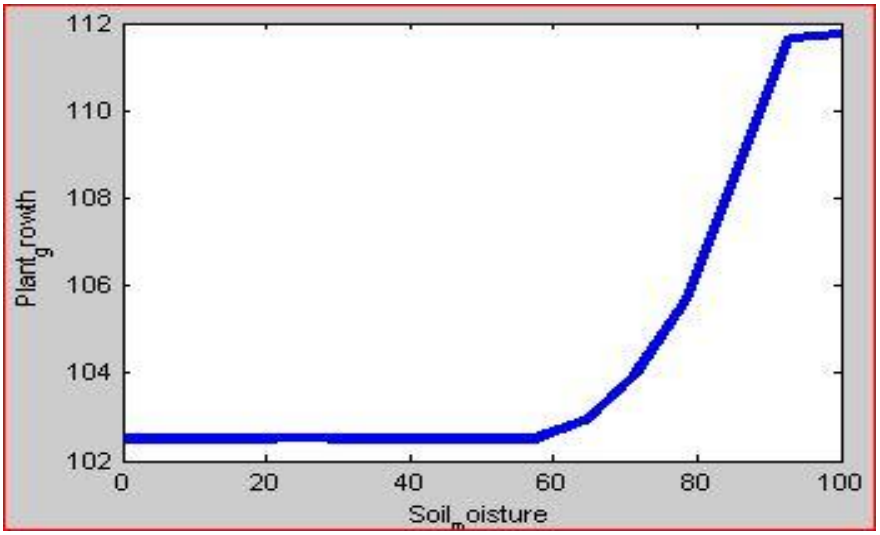

Fig 21. Surface graph for Plant growth

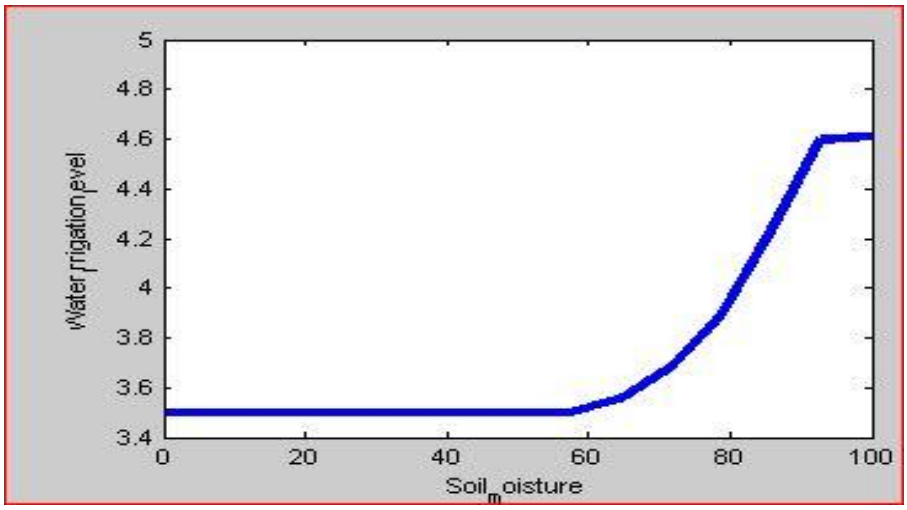

Fig 22. Surface graph for water irrigation level

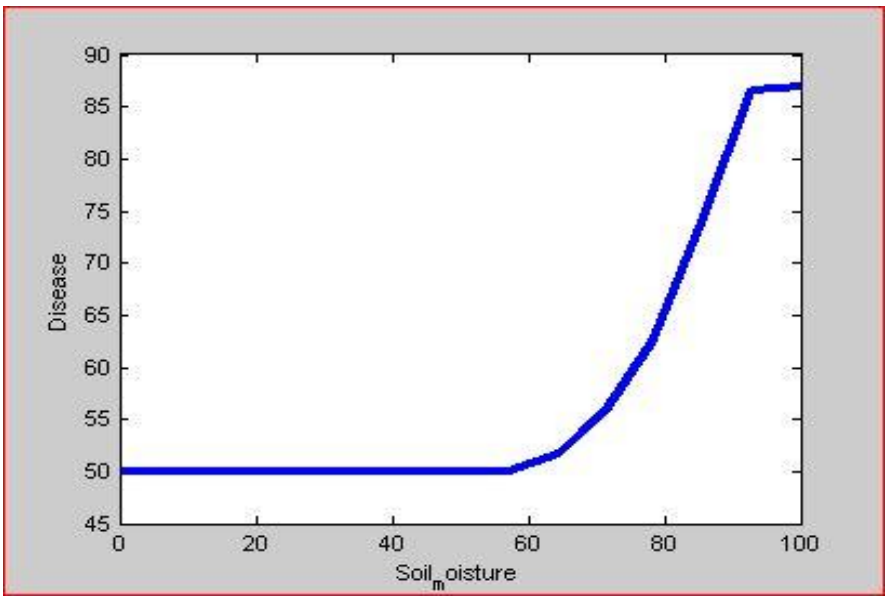

Fig 23. Surface graph for Disease prediction

Conclusion

This paper is a simple measure to improvise agriculture and expand the idea for productive farming technique for the useful growth of paddy. There are various ideas and theories about using fuzzy logic in the field of agriculture and the other technologies related to it. Also, there are many ways to implement those ideas and technologies.

By using this fuzzy technology with the linguistic inputs such as paddy type, sunlight, temperature, soil moisture and humidity to validate the outputs such as paddy growth, water irrigation level and diseases predicted. Hence this is more useful in the analysis of paddy growth and disease prediction as the paper states. Enormous methods are available to be implemented in the field of agriculture. Indian agriculture plays a vital role in world's agricultural production. This might be a step to improve agricultural processes to a new normal of technologically developed agricultural system.

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