International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(13s) 2026 pp. 907-926
https://doi.org/10.70917/ijcisim-2026-4132
Article

OPTIMIZING PADDY CULTIVATION: A FUZZY LOGIC APPROACH TO PADDY GROWTH ANALYSIS AND DISEASE DETECTION

K. Mathevan Pillai[1], K. Raja[2], S. Thiruvazhimarba Pillai[3], V. S. Mathu Suresh[4]*

[1]Department of Mathematics, Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India.
Email: madhevanpillai@francisxavier.ac.in
[2]Department of Mathematics, Sri Manakula Vinayagar Engineering College, Puducherry, India.
Email: raja.rajth@gmail.com
[3]Loyola Institute of Technology and Science, Thovalai, Tamil Nadu, India.
Email: thiruvazhi69@gmail.com
[4]Rohini College of Engineering and Technology, Palkulam, Kanyakumari, Tamil Nadu, India.
Email: sreeuthrad@gmail.com
Corresponding Author: K. Raja

Abstract: Agriculture is the primary livelihood for around 60% of India's population, yet it contributes only 16% to the country's GDP. Despite being the largest employment sector, Indian agriculture requires innovative solutions to improve both the welfare of farmers and the productivity of agricultural land. The sector faces a pressing need for sustainable, efficient, and technology-driven farming practices. This project focuses on improving paddy cultivation, which is divided into three different varieties. By utilizing key parameters of agricultural land, such as temperature, humidity, sunlight, and soil moisture, we apply fuzzy logic membership functions to generate outputs like water irrigation, plant growth monitoring, and disease detection. Fuzzy logic is employed to calculate these outputs based on the input parameters. Additionally, IR cameras are used to monitor and analyse plant growth effectively. This approach addresses the fundamental needs of agricultural land and promotes more productive farming practices. The central objective of this project is to enhance the cultivation of three distinct paddy varieties through advanced monitoring and decision-making tools.

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

1. INTRODUCTION

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

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. FUZZY EXPERT SYSTEM

The fuzzy logic accepts various inputs and it develops a natural way of system. These fuzzy logic controllers are similar to classical logic controllers which use knowledge of human thoughts. The embedded automatic controller controls the fuzzy logic performance.

A Fuzzy Expert System (FES) is an expert system that substitutes fuzzy logic for Boolean logic. It is a group of membership functions and rules that are applied to data analysis. They are focused on numerical processing, as opposed to traditional expert systems, which are primarily symbolic reasoning engines.

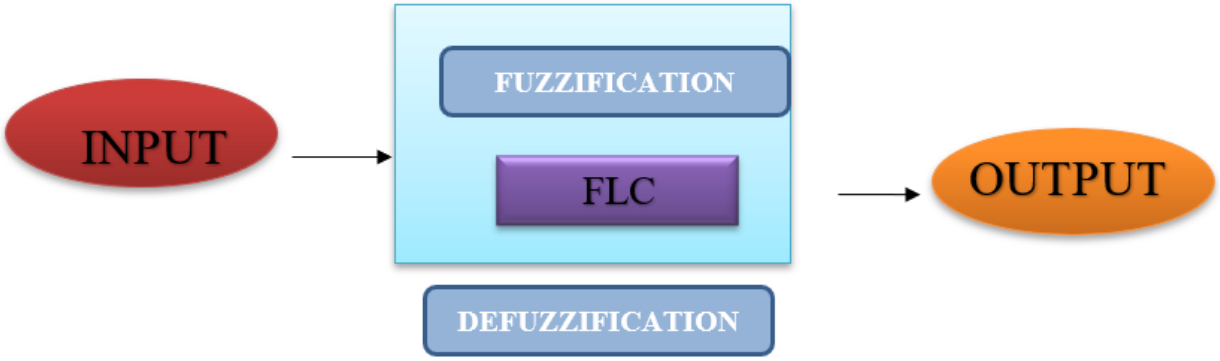


Figure 1 Fuzzy logic control system workflow

2.1 Fuzzy expert system in agriculture

While solving problems, experts relay on composure. Some agricultural experts state that, 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 problems frequently. The question is that how the knowledge of agriculture experts utilize vague and ambiguous terms in system shows.

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 analyze chances of occurrence of plant diseases 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.

2.2 Sensors Required

2.2.1 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 plants for irrigation.

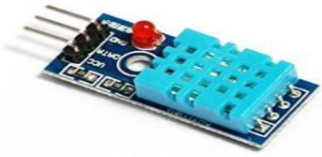


Figure 2 Temperature and humidity sensor

2.2.2 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.

2.2.3 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 etc. Hence it is the most important instrument taken for the plant disease prediction and analysis.

Figure 3 IR Camera

2.2.4 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.

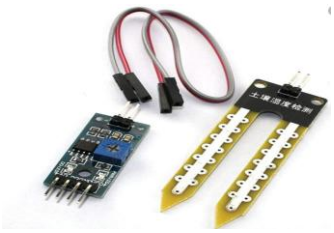


Figure 4 Soil moisture sensor

2.2.5 Light Sensor

Light sensor is a photoelectric device which converts 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.

Figure 5 Light sensor

3. PROPOSED DESIGN

The fuzzy expert 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 output in 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 fuzzy output analyzed for the given input are:

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

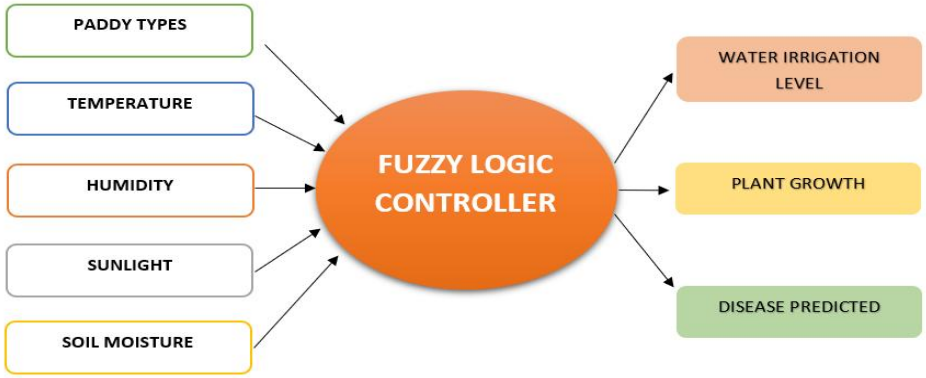


Figure 6 Fuzzy logic inputs and outputs diagram for paddy analysis

4. MEMBERSHIP FUNCTIONS FOR FUZZY LOGIC INPUTS AND OUTPUTS

4.1 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 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 days -105 days], [96 days -125 days] and [126 days - 150 days] 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°C - 24°C], [25°C - 30°C] and [31°C - 40°C]. And for the last input, soil moisture ranging from dry soil, wet soil and 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. These membership functions are plotted as given in the figures from 7.7 to 7.14.

4.1.1 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 as given in table 7.1.

Table 1 Range of days for different varieties of paddy type

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

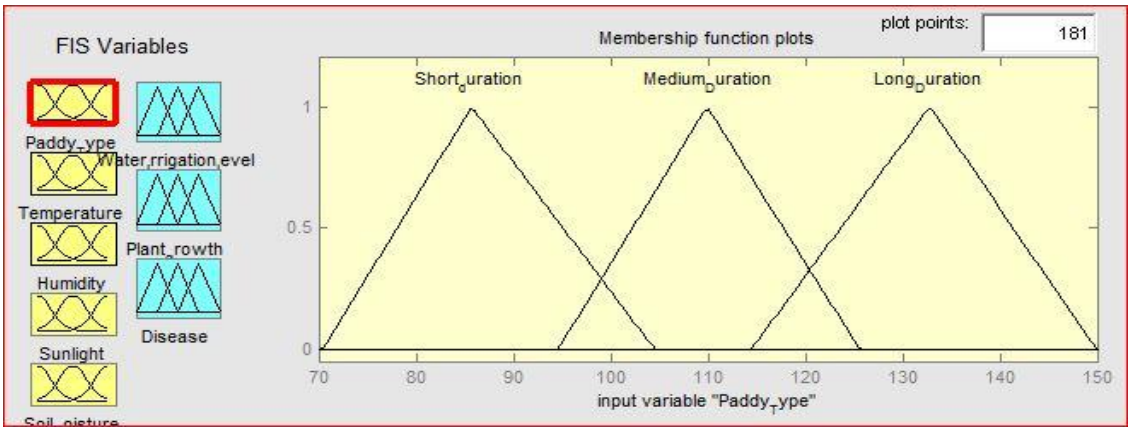


Figure 7 Membership function plot for paddy type

4.1.2 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 paddy variety as given in table 7.2.

Table 7.2 Range of temperature for different climate conditions

FUZZY INPUT	FUZZY	FUZZY RANGE
Temperature	Cold	20°C - 26°C
	Warm	25°C - 35°C
	Hot	32°C - 45°C

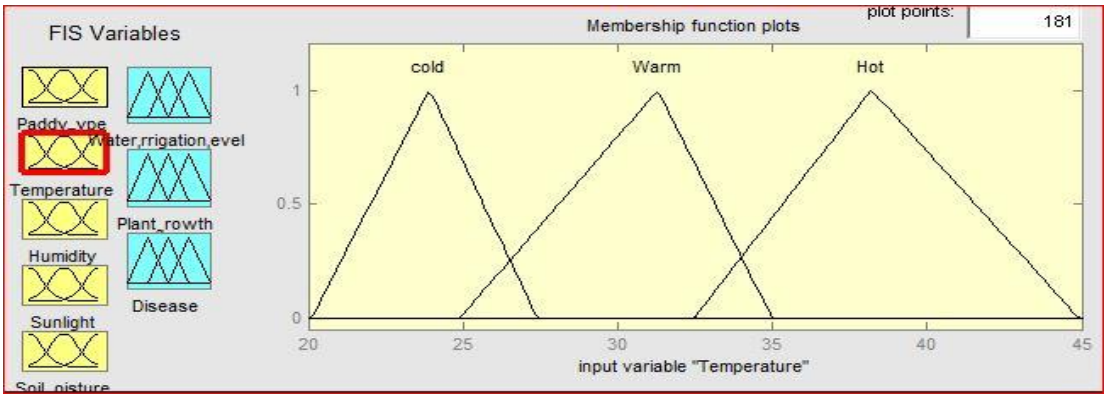


Figure 7.8 Membership function plot for temperature

4.1.3 Humidity

The effect of humidity on the paddy growth is an important factor for the production and the growth of paddy agriculture. It can be divided into low, medium and high as given in the table 7.3. The humidity condition during the harvesting also plays a major role.

Table 7.3 Growth percentage for different humidity content

FUZZY INPUT	FUZZY	FUZZY RANGE
Humidity	Low	0% - 35%
	Medium	25% - 65%

	High	55% - 100%

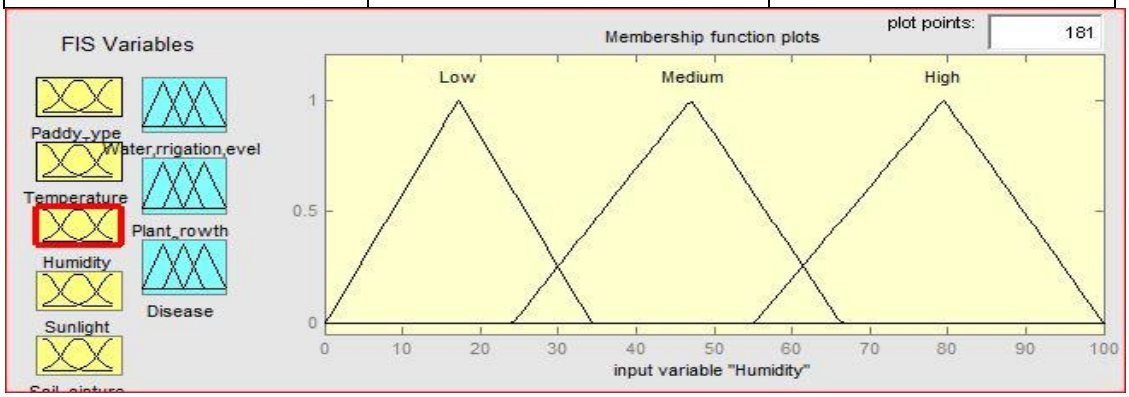


Figure 9 Membership function plot for humidity

4.1.4 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 and sunny according to the varying Celsius range as given in the table 7.4.

Table 4 Range of temperature for various forms of sunlight

FUZZY INPUT	FUZZY	FUZZY RANGE
Sunlight	Hazy	16°C - 25°C
	Cloudy	22°C - 33°C
	Sunny	30°C - 40°C

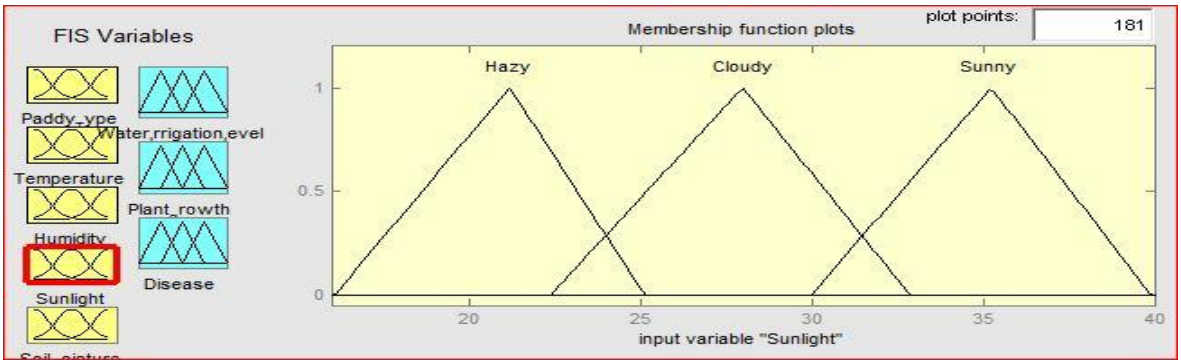


Figure 7.10 Membership function plot for sunlight

4.1.5 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 moisture content in the soil. It ranges from 0-100% based on different ranges such as from dry soil to wet soil to muddy soil as given in the table 7.5.

Table 7.5 Growth percentage for amount of soil moisture

FUZZY INPUT	FUZZY	FUZZY RANGE
Soil Moisture	Dry soil	0% - 35%
	Wet soil	25% - 65%

	Muddy soil	55% - 100%

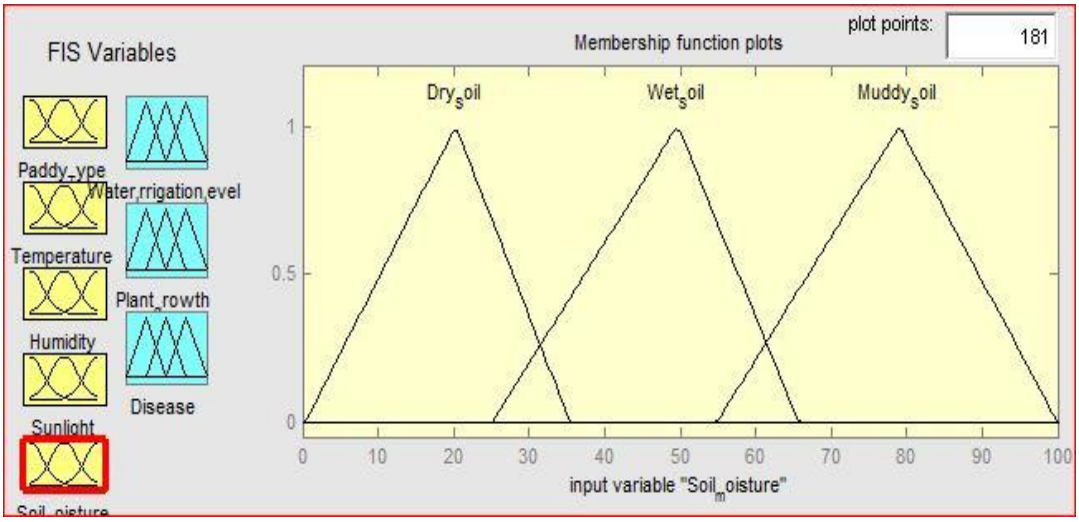


Figure 11 Membership function plot for soil moisture

4.2 Fuzzy Output

As 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 cm - 3 cm], [3 cm - 4 cm] and [4 cm - 5 cm] respectively. Similarly, for the output plant growth ranging from short, medium and tall, the membership functions are [90 cm - 105 cm], [100 cm - 110 cm] and [110 cm - 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.

4.2.1 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 cm - 5cm as given in the table 7.6.

Table 6 Range of water for different films of paddy

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

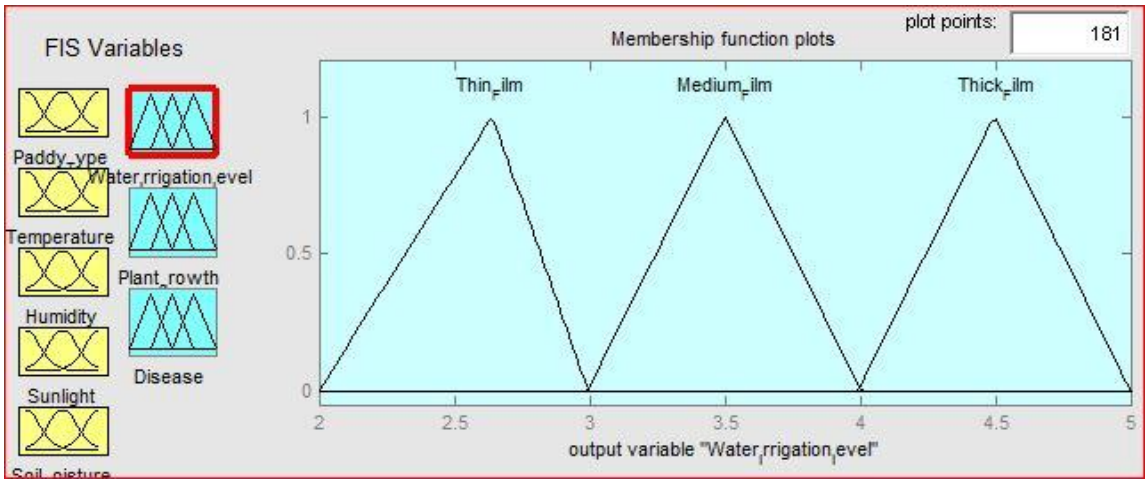


Figure 7.12 Membership function plot for water irrigation level

4.2.2 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 cm -115 cm as given in the table 7.7.

Table 7 Range of plant growth for paddy

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

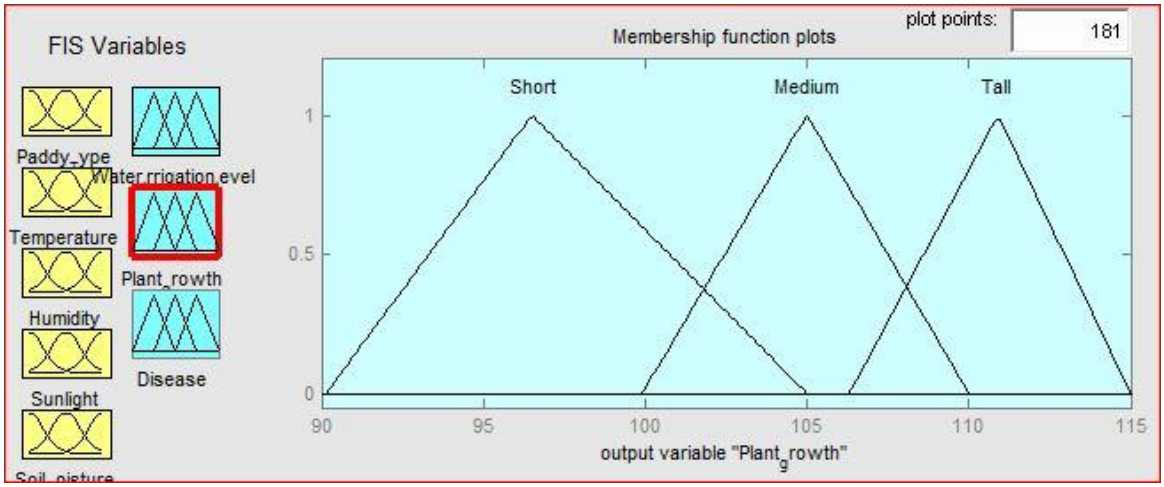


Figure 7.13 Membership function plot for plant growth

4.2.3 Disease prediction

The disease prediction of crops can be classified on the basis of mild, moderate and severe as given in the table 7.8.

Table 7.8 Different ranges of disease prediction

FUZZY OUTPUT	FUZZY	FUZZY RANGE

Disease	Mild	0% - 30%
	Moderate	25% - 65%
	Severe	55% - 100%

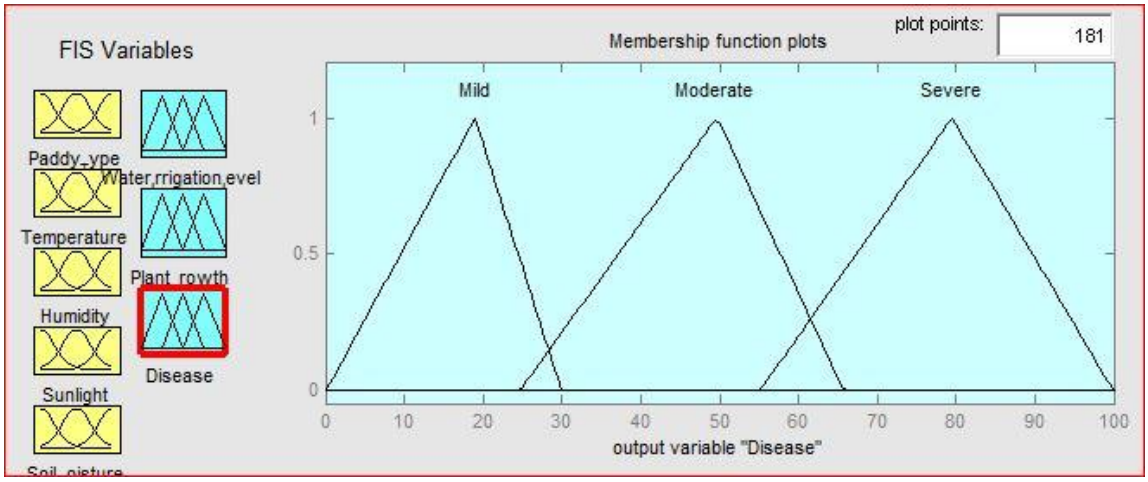


Figure 14 Membership function plot for disease prediction

5. RULE BASE FOR THE FUZZY LOGIC INPUTS AND OUTPUTS

Rule 1: 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)

Rule 2: 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)

Rule 3: 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)

Rule 4: If (Paddy Type is Medium 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)

Rule 5: If (Paddy Type is Medium 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)

Rule 6: If (Paddy Type is Medium 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)

Rule 7: If (Paddy Type is Long 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)

Rule 8: If (Paddy Type is Long 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)

Rule 9: 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)

Rule 10: 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)

Rule 11: If (Paddy Type is Medium Duration) and (Temperature is cold) 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)

Rule 12: If (Paddy Type is Long Duration) and (Temperature is cold) 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).

Rule 13: If (Paddy Type is short duration) and (Temperature is Warm) 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)

Rule 14: If (Paddy Type is Medium 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)

Rule 15: If (Paddy Type is Long Duration) and (Temperature is Warm) and (Humidity is High) and (Sunlight is Hazy) and (Soil moisture is Muddy Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 16: If (Paddy Type is short duration) and (Temperature is Hot) and (Humidity is Low) and (Sunlight is Cloudy) and (Soil moisture is Dry Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 17: If (Paddy Type is Medium Duration) and (Temperature is Hot) and (Humidity is Medium) and (Sunlight is Sunny) and (Soil moisture is Wet Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 18: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Hazy) and (Soil moisture is Muddy Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 19: If (Paddy Type is short duration) and (Temperature is cold) and (Humidity is Low) and (Sunlight is Cloudy) and (Soil moisture is Dry Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 20: If (Paddy Type is Medium Duration) and (Temperature is Warm) and (Humidity is Low) and (Sunlight is Sunny) and (Soil moisture is Wet Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 21: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is Low) and (Sunlight is Hazy) and (Soil moisture is Muddy Soil) then (Water irrigation level is Thin Film) (Plant growth is Short) (Disease is Severe)

Rule 22: If (Paddy Type is short duration) and (Temperature is cold) and (Humidity is Medium) and (Sunlight is Cloudy) and (Soil moisture is Dry Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 23: If (Paddy Type is Medium Duration) and (Temperature is Warm) and (Humidity is Medium) and (Sunlight is Sunny) and (Soil moisture is Wet Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 24: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is Medium) and (Sunlight is Hazy) and (Soil moisture is Muddy Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 25: If (Paddy Type is short duration) and (Temperature is cold) and (Humidity is High) and (Sunlight is Cloudy) and (Soil moisture is Dry Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 26: If (Paddy Type is Medium Duration) and (Temperature is Warm) and (Humidity is High) and (Sunlight is Sunny) and (Soil moisture is Wet Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 27: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Hazy) and (Soil moisture is Wet Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 28: 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)

Rule 29: If (Paddy Type is Medium Duration) and (Temperature is Warm) and (Humidity is Medium) and (Sunlight is Hazy) and (Soil moisture is Wet Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 30: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Hazy) and (Soil moisture is Muddy Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 31: If (Paddy Type is short duration) and (Temperature is cold) and (Humidity is Low) and (Sunlight is Cloudy) and (Soil moisture is Dry Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 32: If (Paddy Type is Medium 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)

Rule 33: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Cloudy) and (Soil moisture is Muddy Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 34: If (Paddy Type is short duration) and (Temperature is cold) and (Humidity is Low) and (Sunlight is Sunny) and (Soil moisture is Dry Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 35: If (Paddy Type is Medium Duration) and (Temperature is Warm) and (Humidity is Medium) and (Sunlight is Sunny) and (Soil moisture is Wet Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 36: 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)

Rule 37: 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)

Rule 38: If (Paddy Type is Medium Duration) and (Temperature is Warm) and (Humidity is Medium) and (Sunlight is Cloudy) and (Soil moisture is Dry Soil) then (Water irrigation level is Medium Film) (Plant growth is Medium) (Disease is Moderate)

Rule 39: If (Paddy Type is Long Duration) and (Temperature is Hot) and (Humidity is High) and (Sunlight is Sunny) and (Soil moisture is Dry Soil) then (Water irrigation level is Thick Film) (Plant growth is Short) (Disease is Severe)

Rule 40: If (Paddy Type is short duration) and (Temperature is cold) and (Humidity is Low) and (Sunlight is Hazy) and (Soil moisture is Wet Soil) then (Water irrigation level is Thin Film) (Plant growth is Tall) (Disease is Mild)

Rule 41: If (Paddy Type is Medium 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)

Rule 42: 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)

Rule 43: 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)

Rule 44: 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)

Rule 45: 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)

Table 9 Input and output rules for paddy analysis

RULE 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

6. 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 considering the paddy types such as short duration variety, medium duration variety and long duration variety, the value generated for paddy type is 108 days. For cold, warm and hot, the value generated for temperature is 32°C. For low, medium and high, the value generated for humidity is 50.6°C. For hazy, cloudy and sunny, the value generated for sunlight is 28.5°C. For dry soil, wet soil and muddy soil, the value generated for soil moisture is 49.4°C. Similarly, when considering the outputs, for thin film water, medium film water and thick film water, the value generated for water irrigation is 3.5 cm. For short, medium and tall, the value generated for plant growth is 102 cm. For mild, moderate and 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.

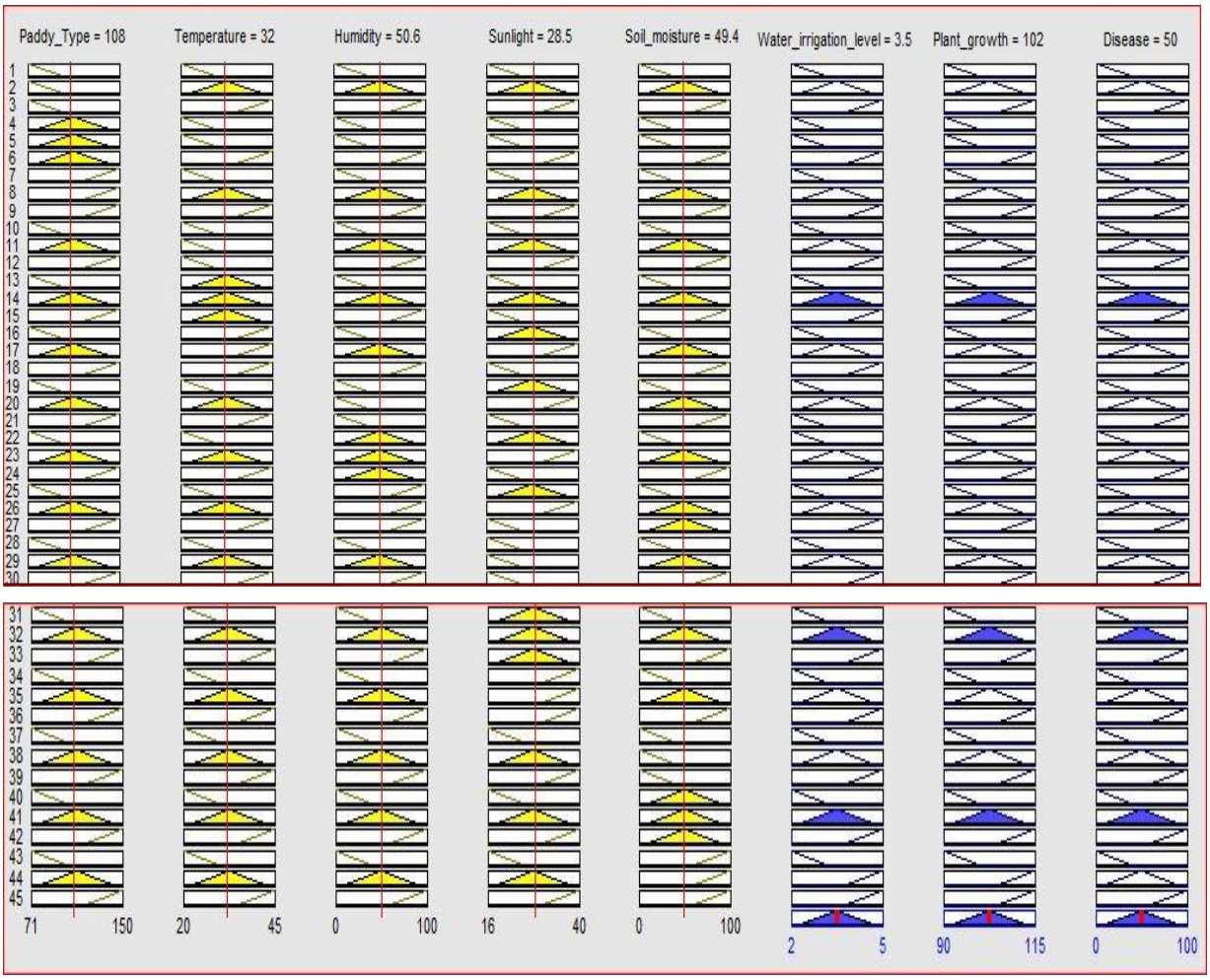


Figure 7.15 Rule viewer for fuzzy logic system of paddy analysis

7. 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 different inputs and outputs are given in the figures from 16 to 20.

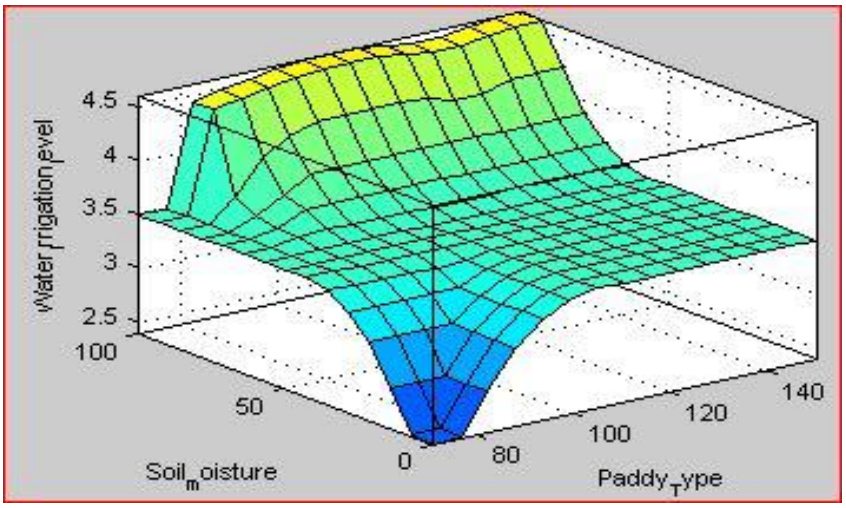


Figure 16 Surface plot for soil moisture vs. paddy type for water irrigation level

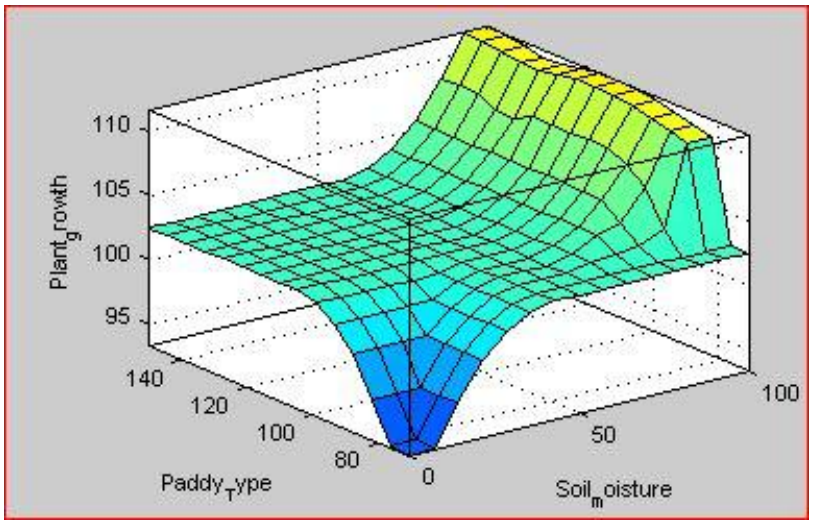


Figure 17 Surface plot for paddy type vs. soil moisture for plant growth

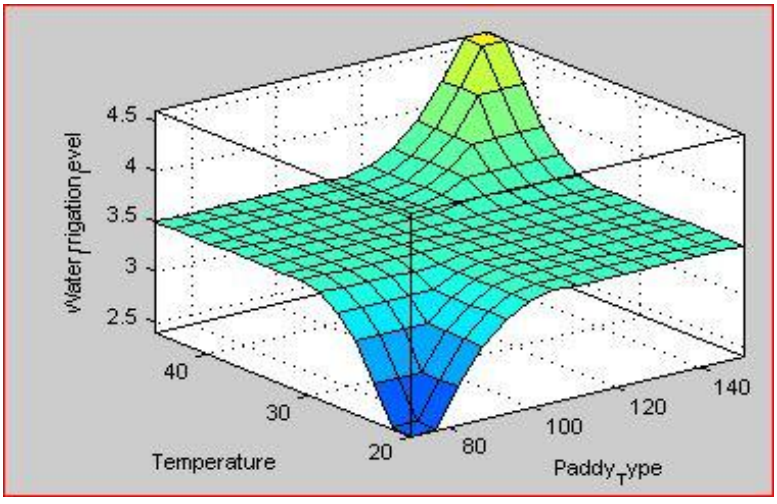


Figure 18 Surface plot for temperature vs. paddy type for water irrigation level

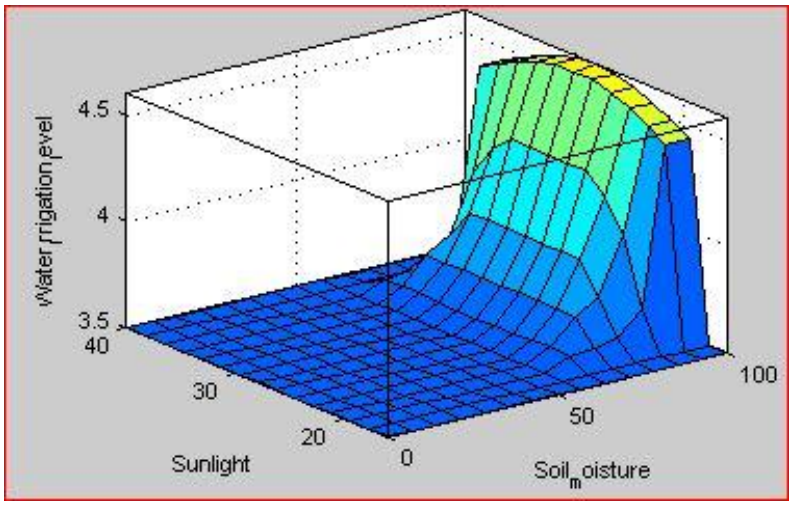


Figure 19 Surface plot for sunlight vs. soil moisture for water irrigation level

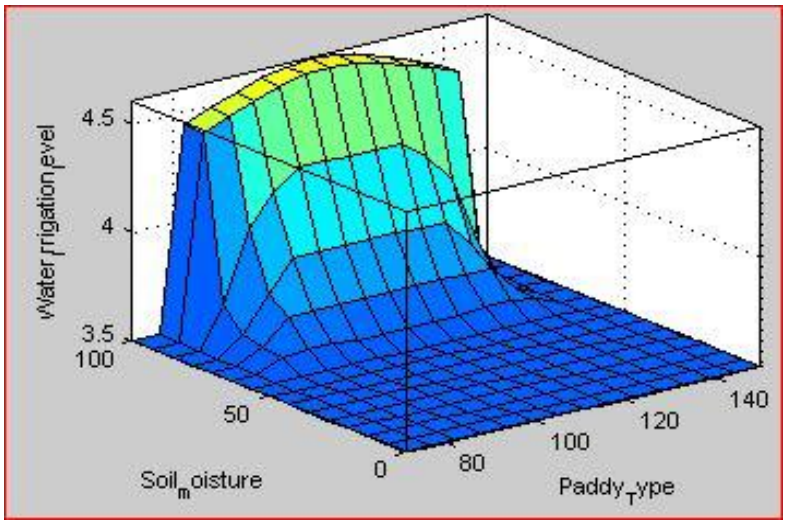
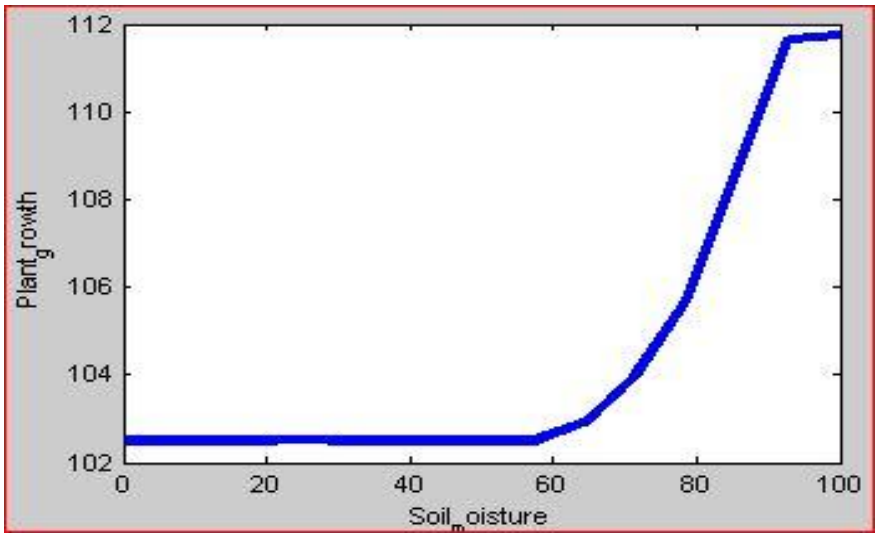


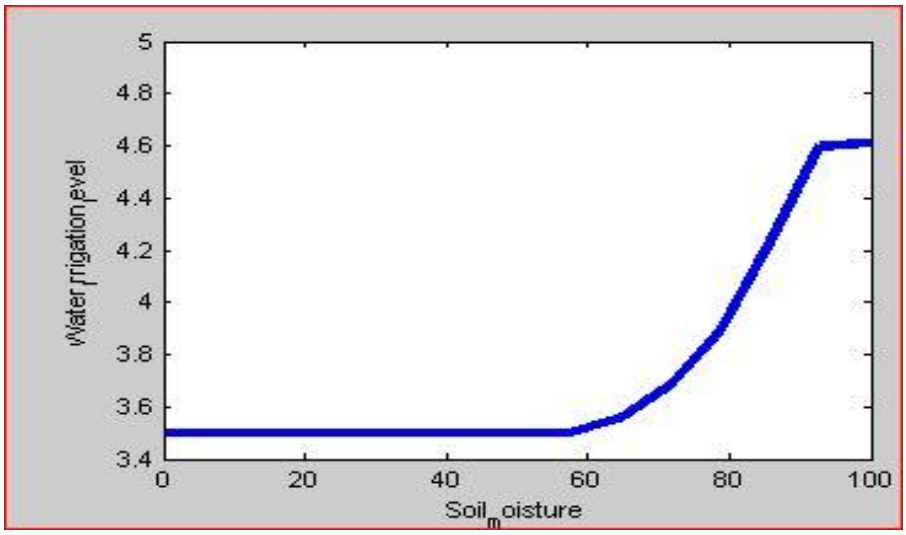
Figure 20 Surface plot for soil moisture vs. paddy type for water irrigation level

7.1 Graph plotting

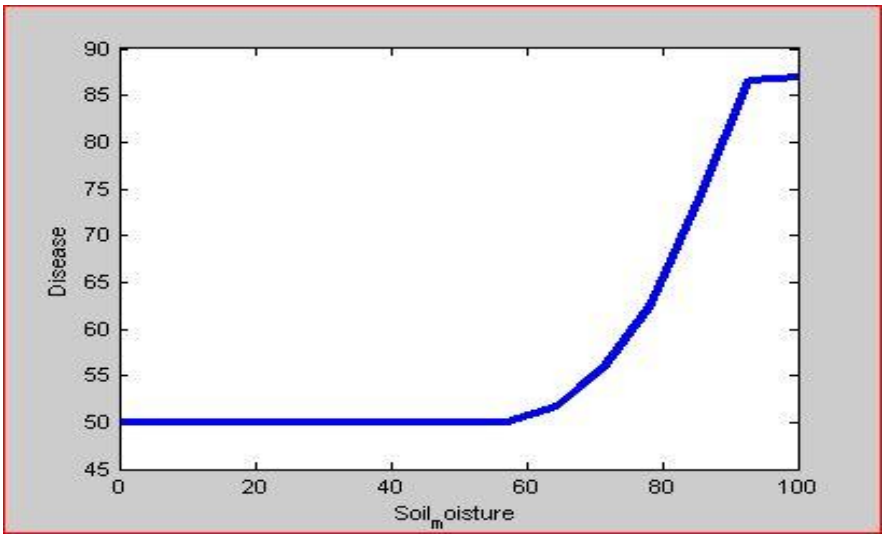
The input values such as paddy type, humidity, temperature, soil moisture, sunlight are given, the output values such as water irrigation level, plant growth and disease prediction are analyzed and it is plotted in the graphs from 7.1 to 7.3.



Graph 7.1 Surface graph for plant growth



Graph 7.2 Surface graph for water irrigation level



Graph 7.3 Surface graph for disease prediction

8. CONCLUSION

From the above analysis of paddy growth and disease prediction using fuzzy logic control system, the following results are concluded:

i.) This work is a simple measure to improvise agriculture and expand the idea for productive farming technique for the useful growth of paddy.

ii.) There are various ideas and theories 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.

iii.) 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 study states.

iv.) 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.

Ethical Approval

Any of the authors' investigations with human participants or animals are not included in this article.

Funding

The authors declare that no funding was received for this study.

Conflict of Interest

The authors have no applicable financial or non-financial interests to expose this article.

Informed Consent

Any of the authors' investigations with human participants or animals are not included in this article.

Authorship Contributions

Authors' contribution K. Raja helped in conceptualization, methodology, writing-original draft preparation; and writing-review and editing K. Raja to formal analysis and investigation and resources.

Reference:

1. L.A. Zadeh, Fuzzy Sets, Information and Control, 338–353, (1965).
2. Chusnul Arif , (IJARAI) International Journal of Advanced Research in Artificial Intelligence, Vol. 1, No. 1, 2012.
3. Shivdeep Kaur, "Use of Fuzzy Logic in Design of Smart Washing Machine and Air Conditioner: A Review", IJSRR 2019, 8(3), 296-301.
4. Harvinder S., Saini, R. K., Sharma A. N. (2002). Web based fuzzy expert system for integrated pest management in soybean. International Journal of Information Technology, Vol. 8, pp. 55-74.
5. Workman, M. Hardware requirement for Fuzzy Logic Control Systems. Lubbock, TX: Texas Tech University, (1996)
6. George J. Kilr and Bo Yuan, Fuzzy Sets and Fuzzy Logic (India: PHI, 1995).
7. Zhen. A. and Feng R. G., "The design of neural network Fuzzy controller in washing Machine," in Proc. 2012 International Conference on Computing, Measurement, Control and Sensor Network (CMCSN), Shanxi, China, 136-139, 2012.
8. Mamdani, E.H., "Application of Fuzzy Algorithms for Control of Simple Dynamic Plant", Proc. IEEE, 121(12), 1585-1588, 1974.
9. Ge Zhe-Xue, Sun Zhi-Qiang. Neural N/w Theory and the realization MATLAB (Beijing: Electronics industry publishing, 2007)
10. Zadeh LA (1965) Fuzzy sets. Info Control 8(3):338–353.
11. Raja, K., and Dr. S. Ramathilagam., (2021), Automation on washing machine using fuzzy logic controller provided with three inputs and two outputs for setting the temperature of water, Proceedings of the IEEE, ISBN: 978-1-6654-1570-5 Page 1753- 1759 (2021). ISSN NO: 0018-9219.
12. Raja, K., and Dr. S. Ramathilagam., (2019), Paddy growth analysis and disease Prediction using fuzzy logic controller system, Turkish journal of computer and mathematics education, Vol. 10(02) 573-595 (2019). ISSN NO: 1309-4653.
13. Raja, K., and Dr. S. Ramathilagam., (2021), Smart air conditioning system using fuzzy logic system and simulation using Matlab, Malaya journal of Matematik, Issue 1, 331-333 (2021). ISSN NO: 2321 – 5666.

14. Raja, K., and Dr. S. Ramathilagam., (2021), Washing machine using fuzzy logic controller to provide wash quality, Soft computing, Vol. 24 issue 15, 9957-9965 (2021).ISSN NO: 1433-7479.
15. Raja, K., (2023), Python-based fuzzy logic in Automatic Washer control system, Soft computing, Vol. 27,6159-6185 (2023). ISSN NO: 1433-7479.
16. Pandey P., Kumar S., Shrivastav S. (2013). A critical evaluation of computational methods of forecasting based on fuzzy time series. International Journal of Decision Support System Technology, Vol. 5, No. 1, pp. 24-39.
17. Pandey P., Kumar S., Shrivastav S. (2013). Forecasting using fuzzy time series for diffusion of innovation: Case of tata Nano car in India. National Academy Science Letters, Vol. 36, No. 3, pp. 299-309. http://doi.org/ 10.1007/s40009-013-0140-4
18. Pandey P., Kumar S., Shrivastav S. (2017). An efficient time series forecasting method Exploiting fuzziness and turbulence in data. International Journal of Fuzzy System Applications, Vol. 6, No. 4, pp. 83-98.
19. Kalpana M., Senthil-Kumar A. V. (2012). Design and implementation of fuzzy expert system using fuzzy assessment methodology. International Journal of Science and Applied Information Technology, Vol. 1, No. 1, pp. 39-45.