DESIGN AND IMPLEMENTATION OF FUZZY LOGIC BASED EXPERT SYSTEM IN AGRICULTURE

21303007 Shreya Gupta

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INTRODUCTION

Water automation is about managing, monitoring and even accounting for water consumption in various places such as hotels, home, land irrigation and industry. Scientists have done water automation based on different purposes using different types of hardware and technologies.

The imperfect management of water resources can lead to droughts and famines especially in rural areas. Such uncontrolled circumstances contribute to a huge loss for farmers and in most cases attempts to control such conditions by manual means are futile.

India's history with agriculture is very significant. India is currently rated second in the world for farm output. Due to a lack of initiatives, agriculture has gradually decreased with India's GDP growth throughout the course of the year. Numerous developments and studies have been conducted in this area over the years. One of them is fuzzy expert systems, which are utilised in agriculture for a variety of tasks, including temperature, moisture, humidity, soil type, soil quality, water level, paddy stage, and depth of water, among others. A group of membership functions and rules that are applied to data analysis make up a fuzzy expert system. Fuzzy expert systems are focused on numerical processing, as opposed to traditional expert systems, which are mostly symbolic reasoning engines.

One significant application-focused subfield of artificial intelligence is fuzzy expert systems. The expert systems approach makes an effort to simulate the subject-matter expertise of experts in their individual fields of expertise, such as diagnosis, planning, forecasting, etc. Expert systems are built on knowledge that emphasises domain experts' experiences more than just models and data. An expert system is a computer programme that resolves challenging issues that would often need a great deal of human skill. It can be used in a particular field of knowledge by a novice or someone with less education.

A fuzzy set is essentially a set whose members may have membership degrees ranging from 0 to 1, as opposed to classical sets, where each element must have a membership degree of either 0 or 1—if it is 0, the element is entirely outside the set; if it is 1, the element is entirely inside the set. Instead of using traditional Boolean logic and a set of membership functions and rules to make decisions about data, fuzzy expert systems use fuzzy logic. They manage unclear or imprecise information and are focused on numerical processing. A fuzzy expert system uses fuzzy logic to make decisions regarding data in the inference mechanism and is made up of the subsystems of fuzzification, inference, knowledge base, and defuzzification. Knowledge base and base of facts are passive data structures, but the inference module is made up of a group of working algorithms that carry out the procedural part of the expert system. Knowledge engineers gather information from subject matter experts, convert it into production rules, and build knowledge bases.

DOMAIN

Agriculture/IOT

MOTIVATION AND CHALLENGES

The fuzzy expert system for agriculture uses rules based on which the knowledge and experience of a human expert are captured in the form of IF-THEN rules and facts that are utilised to solve problems. This is similar to other knowledge-based systems. The following are some advantages of the expert system for agriculture:

1. Its capacity for comprehension and transparency improves the usability of relationships.
2. It is capable of mimicking human thought and reasoning.
3. The expert system very easily accommodates variations in knowledge.
4. The proper information may be quickly and effectively provided by using machine learning techniques, which can be directly and automatically learned from experimental data and current examples.
5. It is capable of handling ambiguous data.

Pros

- Accessibility: Any computer hardware may easily accommodate an expert system.
- Information Cost: The cost of giving knowledgeable counsel to each user is significantly decreased.

- Reliability Expert System: Dependable Except in cases where an expert makes a mistake when supplying data, expert systems produce reliable outcomes since concepts contain expert advice.
- Responsive: For some applications, we need a quick or real-time reaction, and an expert system might do it more quickly than a human expert.

Challenges

- Adaptability: Expert systems have a difficult time adjusting to new information that is unexpected or unknowable to their knowledge base.
- Difficulty: If a non-expert makes a mistake when utilising the system and the advice that results is inaccurate, it might be challenging to use.
- Hardware: Unlike a human, who may be able to recognise or spot problems that computer hardware may not be able to, these systems lack common sense.

RESEARCH PROBLEM

Fuzzy logic based expert system for Agriculture

OBJECTIVE

In order to help agriculturalists, make decisions on water management that are advantageous to both farmers and the environment, we plan to create an expert system.

- Our objective is to determine and monitoring the moisture, humidity, temperature, soil quality, water level etc. so as to ensure effective use of water resources, better crop productivity and pre-planning of water structures.
- The aim of the proposal is to develop an automatic system based on sensor actuator technology that can automatically predict the supply, treatment and storage of water. It offers a solution to both water scarcity and the use of abundant water resources intelligently, at the same time.

- We are also developing a Fuzzy logic based Expert system for the purpose of training the data. We are focused mainly on collection of more precise and authentic data directly from the farmers or people engaged in the process.
- To study and analyse the level and causes of water shortage in agricultural setups.
- To automate the irrigation process and restrict the loss caused to farmers due to badly managed water supply.
- This research proposed an agricultural water management system based on the Internet of Things and data analysis, and provides an intelligent analysis model of the system using the technique of time series forecasting to enhance the effectiveness of agricultural water management.

METHODOLGY

Data collection

Farmers, research institutions, and agricultural institutes are some of the sources from which the data is gathered. This is the standout quality that aids the expert system.

Management

Three steps can be identified in the water management system process. The initial stage gathers information from online sources and expert knowledge about the various parts of the crop that are visible, then moves on to determine the soil type, moisture, temperature, etc., that contributes to Paddy crop. Finally, suggestions and recommendations are made to protect the paddy from further harm.

Knowledge Acquisition

It takes a lot of time and effort to gather the necessary information from a variety of sources, including journals, papers, domain experts, and websites, and to combine it into knowledge. An agriculture officer's expert knowledge was taken out and reflected in the IF-THEN rules using the confidence factor.

- *Climatic Requirements*:

In India, rice is grown under very different conditions of altitude and climate. Rice cultivation in India extends from 8 to 35º north latitude and from sea level to an altitude of 3000 meters. Rice cultivation needs a hot and humid climate. It is best suited to areas with high humidity, long-term sunlight and a guaranteed water supply. The average temperature required throughout the life of the crop ranges from 21 to 37 °C. The maximum temperature that the crop can tolerate is 40°C to 42°C.

- *Selection of Seeds:*

The use of quality seeds in rice cultivation is an important factor in achieving better crop yields. Due care must therefore be taken to select the best quality seeds. Much of the success in growing healthy seedlings depends on the quality of the seed. Seeds intended for sowing should meet the following requirements:

- The seed should be of the correct variety that is designed to be grown.
- The seed should be clean and without obvious admixtures of other seeds.
- The seed should be mature, well developed and plump.The seeds should be free of obvious signs of age or poor storage.
- The seed should have high germination.

Before sowing, the seed should be treated with fungicides, which protect the seed against soil fungi and also give support to the seedling. We will be considering the above facts to generate a survey that can provide authentic results.

- *Land preparation*:

The field is prepared by ploughing the paddy fields with a soil turning plough followed by harrowing. The paddy field is filled with water and leached twice by paddy paddler or once by rotavator. If a green manure crop like dhaincha or mung has been obtained, it can be mixed with the rotavator during leaching and subsequent planning.

- *Regions:*

Rice crops are grown all over India. We are considering Uttar Pradesh state for developing our expert system. Rice cultivation in Uttar Pradesh can be divided into following regions:

1. The Shivalik foothills
2. Terai in the North
3. The Gangetic Plain in the centre - Highly fertile alluvial soils; flat topography broken by numerous ponds, lakes, and rivers; slope 2 m/km
4. The Vindhya Hills and plateau in the south - Hard rock Strata; varied topography of mountains, hills, plains, valleys, and plateau; limited water availability.
5. The Shivalik Range, which forms the southern foothills of the Himalayas, slopes down into a boulder bed called Bhabar.

We are further taking Gangetic plains' region for developing our rule base in order to make it more precise and efficient. This system deals within central plains of Uttar Pradesh that includes cities like Lucknow, Kanpur and Allahabad (regions excluding Pratapgarh)

- *Irrigation:*

Crop water requirement is the water required by the plants for its survival, growth, development and to produce economic parts. This requirement is applied either naturally by precipitation or artificially by irrigation.

Average Water requirement – 1100 mm

Average Water requirement (SRI) – 700 mm

The daily consumptive use of rice varies from 6-10 mm and total water is ranges from 1100 to 1250 mm depending upon the Agro climatic situation, duration of variety and characteristics of the soils.

Stage-wise water requirement for paddy

Stages of growth	Water requirement (mm)	Precentage of total water requirement
Nursery	40	3.22
Main field preparation	200	16.12
Planting to panicle initiation	458	37.00
Panicle initiation to flowering	417	33.66
Flowering to maturity	125	10.00

Operation wise water requirement of paddy

Operation	Water requirement (mm)
Nursery	40
Land preparation	200
Field irrigation	1000
Total	1240

Depth of submergence at different stages

Stages of crop growth	Depth of submergence (cm)
At transplanting	2
After transplanting for 3 days	5
Three days after transplanting upto maximum tillering	2
At maximum tillering (in fertile fields only)	Drain water for three days
Maximum tillering to panicle initiation	2
Panicle initiation to 21 days after flowering	5
Twenty one days after flowering	Withhold irrigation

Knowledge Representation

The acquired knowledge needs to be translated into a useful representation that the inference engine can work with in order to support reasoning. Rules, frames, and semantic networks are some of the several methods for representing knowledge. We believe that expressing information as rules is the easiest and most practical way to do so. It has the same structure as a typical If-then statement used in computer languages.

- *Data Sets*

1. SOIL STRUCTURE

Potential problem	**Units**	**No problem**	**Slight – Moderate problem**	**Severe problem**
pH	No uni	6.5-8.5 (Ideal)	<6.5: >8.5 (okay)	<6.5: >8.5 (worst)
Salinity ECw (water)	Ds / m=m Mol/cm	<2.0	2.0 - 2.6	>2.6

Salinity ECe (soil)	Ds/m	<3.0	3.0 - 3.8	>8.3
TDS	Mg/l	<450	450 – 2000	>2000
Specific ion toxicity	No units	<3	3 – 9	>9
Chloride	Me/l	<4	4 – 10	>10
Boron	Me/l	<0.7	0.7 – 3.0	>3
Bicarbonate	Me/l	<4	>4	>>4

2. SOIL TEXTURE

Particular	**Clay loam**	**Silty clay**	**Loam**	**Sandy loam**
Water requirement	1583	1602	1995	2261
Irrigation (mm)	1125	1200	1500	1775
Runoff (mm)	207	191	193	161
Percolation	893 (56%)	870 (54%)	1187 (60%)	1515 (67%)
Evapotranspiration	690 (44%)	732 (46%)	808 (40%)	745 (33%)

3. IRRIGATION SCHEDULE BASIS VARIETY

Short Duration Variety			**Medium Duration Variety**			**Long Duration Variety**		
Days	**No. of Irrigation**	**Water level (cm)**	**Days**	**No. of Irrigation**	**Water level (cm)**	**Days**	**No. of Irrigation**	**Water level (cm)**
1 – 25	5 – 7	2 – 3	1 – 30	5 – 7	2 – 3	1 – 35	6 – 8	2 – 3
25	-	Thin film of water	30	-	Thin film of water	35	-	Thin film of water

28	-	Life irrigation	33	-	Life irrigation	38	-	Life irrigation
29 – 50	6	2 - 5	34 - 65	6 - 8	2 - 5	39 – 90 or 95	12 - 15	2 - 5
51 - 70	5 - 6	2 - 5	66 – 95	8 - 10	2 - 5	96 - 125	7 - 9	2 - 5
71 – 105	5 - 6	2 - 5	96 - 125	6 - 8	2 - 5	126 - 150	5 - 6	2 -

CONTRIBUTION

Expert systems using fuzzy logic to handle incomplete information The field of agriculture has proven successful and valuable. Therefore, in the proposed research, we would create an expert system that would help agriculturalists make decisions on the management of fertiliser and would be advantageous for both farmers and the environment. Expert systems using fuzzy logic to handle incomplete information The field of agriculture has been useful and can produce good outcomes.

RELATED FRAMEWORK AND TOOLS

The proposed fuzzy expert system's performance was created in MATLAB. We developed the criteria based on professional understanding, and we selected these rules to analyse the data set. The data analysis is automatically supported by the suggested approach. The learned information is then transformed into knowledge, and the suggested technique eventually delivers them as descriptions of people. The findings of the approach suggested are then presented in a way that is easily understood by humans after the information collected is converted into knowledge.

MATLAB

The MathWorks company created the proprietary multi-paradigm programming language and computer environment known as MATLAB. Matrix manipulation, function and data visualisation, algorithm implementation, user interface building, and connecting with other programming languages are all possible with MATLAB.

Although MATLAB is primarily designed for numeric computation, symbolic computation capabilities are accessible through an optional toolbox that uses the MuPAD symbolic engine. Graphical multi-domain simulation and model-based design for embedded and dynamic systems are added via an additional programme called Simulink. The MATLAB programming language serves as the foundation of the MATLAB application. The MATLAB programme is frequently used to run text files containing MATLAB code or to use the "Command Window" as an interactive mathematical shell.

LITERATURE REVIEW

S. No.	Authors	Journal Name, Year of Publication	Summary
1	Harsimranjit Singh1, Narinder Sharma2	International Journal of Engineering Sciences & Research Technology, 2014	One of these is fuzzy expert systems, which are utilised in agriculture for a variety of tasks with the goal of improving results and crop productivity. A group of membership functions and rules that are applied to data analysis make up a fuzzy expert system. Fuzzy expert systems are focused on numerical processing, as opposed to traditional expert systems, which are primarily symbolic reasoning engines. This project will describe the function of fuzzy expert systems, as well as many agricultural trials and research.

2	Sonal Dubey, R.K. Pandey, S.S. Gautam	International Journal of Soft Computing and Engineering (IJSCE), 2013	Transferring the most recent information to farmers is one of the industry's major concerns. Traditional systems should be replaced with expert systems. Fuzzy logic has proven to be effective in expert systems when handling uncertain information in the agricultural area. The fact that many agricultural decision-making processes are sometimes hazy or rely on intuition adds to this uncertainty. To deal with uncertainty, ambiguity, and insufficient knowledge, fuzzy logic is used. Expert systems can function at their best with ambiguous or uncertain knowledge and data because to fuzzy logic. As opposed to conventional Boolean logic, fuzzy expert systems use fuzzy logic. They are focused on processing numerical data.
3	Savita Kolhe, Raj Kamal, Harvinder S. Saini, G.K. Gupta b	Journal paper from ELSEVIER, 2011	The paper describes an interface for three subsystems: an intelligent disease diagnosis subsystem with an object-oriented intelligent-inference model, an intelligent tutor for crop disease with an audio-visual graphical user web interface, and the knowledge acquisition subsystem

			with a dynamic knowledge base. The paper discusses the functionality, design, and creation of an intelligent multimedia web interface. Additionally, the evaluation's findings are revealed. The system for making intelligent inferences for agricultural disease management employs a novel approach of rule promotion based on fuzzy logic. It offers significant assistance and quick fixes for plant pathological issues.
4	Hemanta Kalita, Ridip Dev Choudhary, Shikhar kr. Sarma	IEEE 2016 International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT)-Pune, India.	This research describes the design and creation of an expert system that aims to supply rice plants with appropriate water. The knowledge base, inference mechanism, or control structure, and user interface make up the proposed system. Here, in this system, users or farmers have issues with illnesses and water management that affect rice plants during the course of their lives. The users input these issues through a user interface, and the knowledge base, which takes the form of rules and detects the likely disease, compares them to the input.

5	Pinaki Chakraborty, Dilip Kumar Chakrabarti	Journal paper from Elsevier, 2007	The crop protection expert systems need special mention among all agricultural expert systems. These expert systems are designed for use by farmers and other people with little computer skills. Therefore, particular consideration must be given to their development. The current research creates a taxonomy for crop protection expert systems and briefly describes four such crop protection expert systems utilised in India.
6	M. Safdar Munir, Imran Sarwar Bajwa, Sehrish Munawar Cheemaa	Journal paper from Elsevier, 2019	This research presents an intelligent Smart Watering System (SWS) that is helped by an Android application for smart water consumption in small and medium-scale gardens and fields. The suggested system relies on a collection of affordable and widely available sensors that record information about plants and environmental variables in real-time, such as temperature, humidity, light intensity, and soil moisture level. The suggested SWS evaluates the data once it has been gathered from sensors on a server and uses fuzzy logic to decide on the watering plan. Here, the use of fuzzy logic assists in

			making wise decisions regarding the need for watering, and block-chain offers the necessary security in an Internet of Things (IoT) enabled system by allowing only the trustworthy devices to access and administer the proposed system.

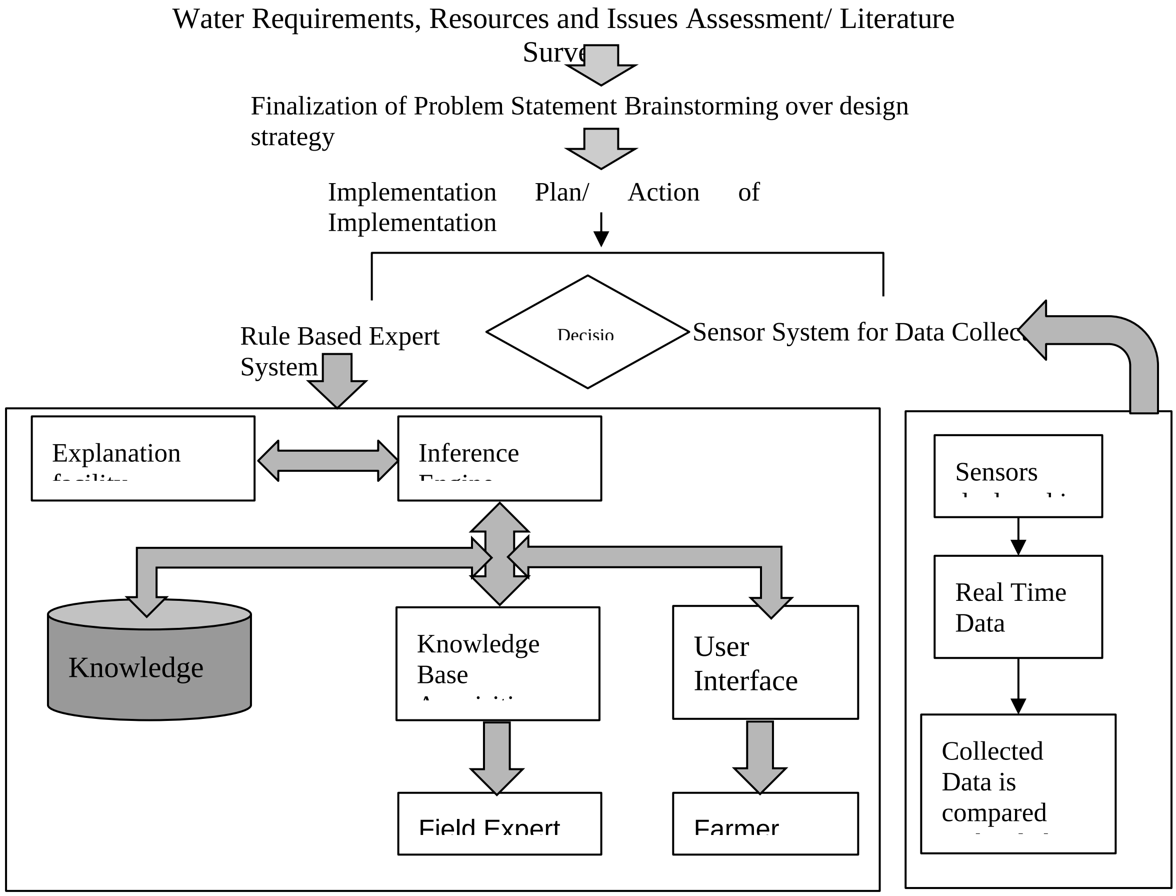
OVERVIEW OF THE DESIGN

We are developing a Rule-based Expert system for the purpose of providing assistance to farmers. We are focused mainly on collection of more precise and authentic data directly from the farmers or people engaged in the process. In an expert system development, knowledge base development is the most important part. The quality of an expert system depends on its knowledge base. Hence, here main focus is on developing a powerful knowledge base.

The steps for developing knowledge base in this system are identification of the input problem, knowledge acquisition and representation of knowledge into the knowledge base. We have already completed the first and second steps. Following is the description of work done yet:

Input Problem:

Rice is the crop considered for development of rule base. Our project aims at determining and monitoring the rainfall, moisture, humidity, temperature, soil quality, water level etc. so as to ensure effective use of water resources, better crop productivity and pre-planning of water structures.



IMPLEMENTATION

MEMBERSHIP FUNCTIONS

⇒ Fuzzy Inputs

(i) pH value :

Range

0 − 6·5   6·5 − 8·5   >8·5 severe

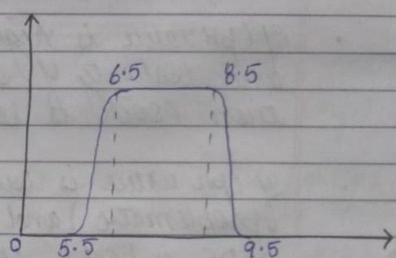
ideal

Membership functions :

0 , if $x < 6.5$

1 , if $6.5 \leq x \leq 8.5$

0 , if $x > 8.5$



- because at ≪6·5 & ≫8·5 the crop didn't sustain

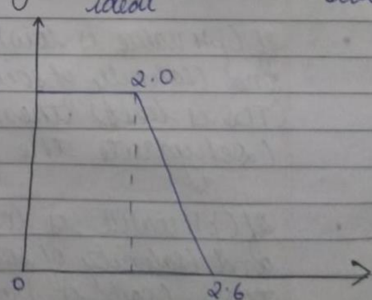
(ii) Salinity ECw(water)   Range : <2·0 , 2·0 − 2·6 , >2·6

ideal   severe

1 , if $0 \leq x \leq 2.0$

$\frac{x-2}{2.6-2.0}$, if $2.0 \leq x \leq 2.6$

0 , if $x > 2.6$

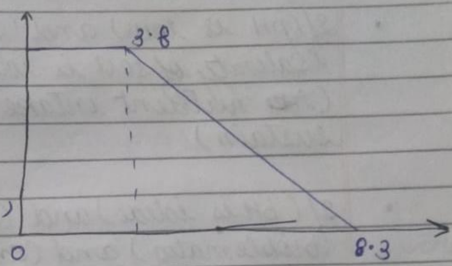


- because at $2.0 \leq x \leq 2.6$, there is slightly or moderate problem.

(iii) Salinity (soil) ECe

Range : <3.0 , 3.0 − 3.8 , > 8.3
best, severe

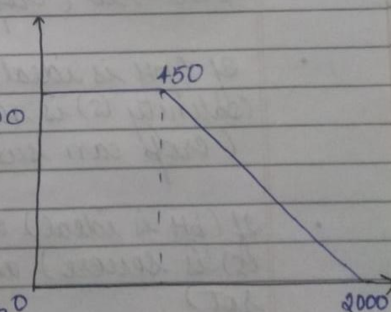
$$\mu(x) = \begin{cases} 1, & \text{if } 0 \leq x \leq 3.0 \\ \dfrac{x-3}{3.8-3}, & \text{if } 3.0 \leq x \leq 3.8 \\ 0, & \text{if } x > 8.3 \text{ (severe)} \end{cases}$$



(iv) TDS value

Range: <450 , 450−2000 , >2000
best, severe

$$\mu(x) = \begin{cases} 1, & \text{if } x < 450 \\ \dfrac{x-450}{2000-450}, & \text{if } 450 < x < 2000 \\ 0, & \text{if } x > 2000 \end{cases}$$



- because at range 450 − 2000 there is moderate problem but crop can sustain

03 AUGUST WEDNESDAY 216-150 • WEEK 32

① Ion toxicity (x) =

less	No Problem	$x<3$
Medium	Slightly moder problem	$x = 3-9$
high	severe Prob.	$x>9$

② Chloride (x) =

less	No Prob.	$x<4$
Medium	SMP	$x = 4-10$
high	SP	$x>10$

③ Boron (x) =

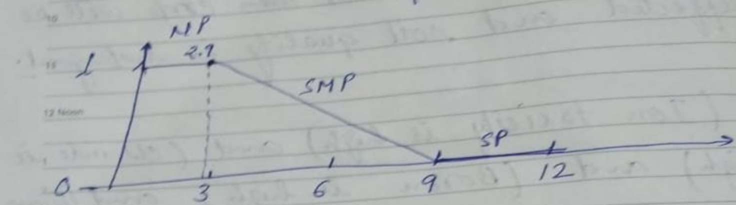
less	No Prob.	$x<0.7$
Medium	SMP	$x = 0.7-3$
high	SP	$x>3.0$

④ Bicarbonate (x) =

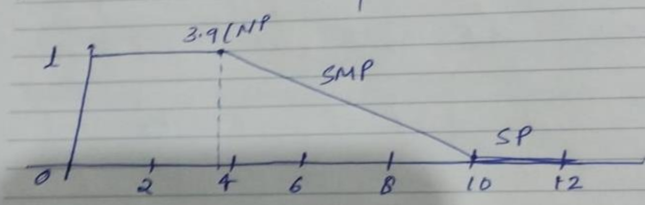
less	NP	$x<4$
Medium	SMP	$x = 4-5$
high	SP	$x>5$

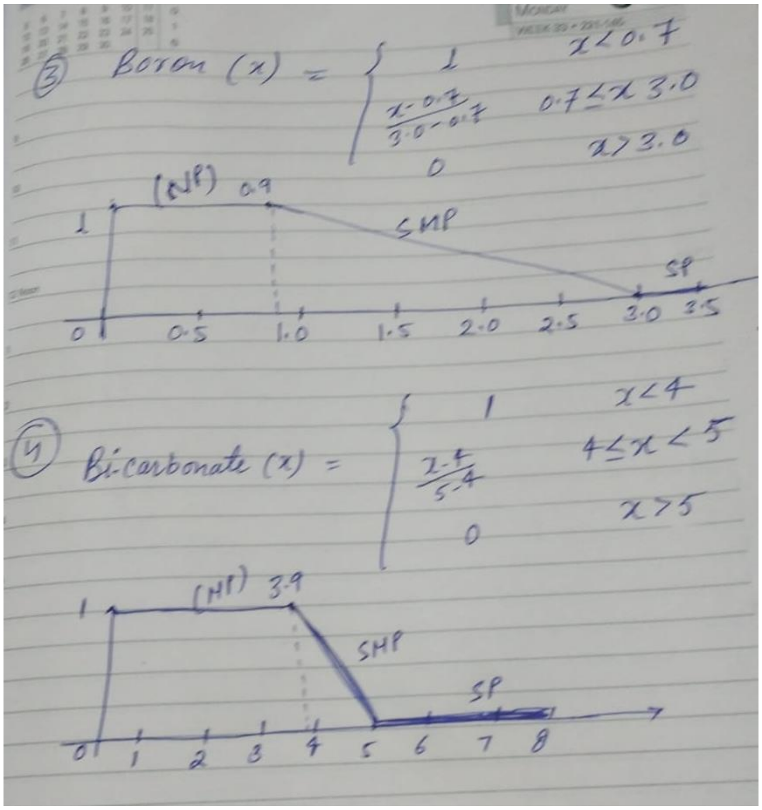
07 AUGUST SUNDAY 220-146 • WEEK 32

① Ion toxicity (x) =
$$\begin{cases} 1 & x<3 \\ \frac{x-3}{9-3} & 3\le x\le 9 \\ 0 & x>9 \end{cases}$$



② chloride (x) =
$$\begin{cases} 1 & x<4 \\ \frac{x-4}{10-4} & x\le 4\le 10 \\ 0 & x>10 \end{cases}$$





③ Boron (x) =
1   x<0.7
x-0.7 / 3.0-0.7   0.7≤x 3.0
0   x>3.0
(NP) 0.9
SMP
SP
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
④ Bi-carbonate (x) =
1   x<4
x-4 / 5-4   4≤x<5
0   x>5
(NP) 3.9
SMP
SP
0 1 2 3 4 5 6 7 8

<u>RULES</u>

Rules.

- If (pH value is low) and (salinity (water) is best) and (Salinity of soil is best) and (TDS is best) then (Soil is acidic) and (crop didn't sustain)

- If (pH value is ideal) and (Salinity of water is best) and (Salinity of soil is best) and (TDS is best) then (crop will sustain)

- If (pH value is high) and (Salinity of water is best) and (Salinity of soil is best) and (TDS is best) then (soil is basic) and (crop will not sustain)

- If (ph value is low) and (salinity of water is slightly problematic) and (salinity of soil is best) and (TDS is best) then (crop will not sustain)

- If (pH value is low) and (salinity of water is severe) and (salinity of soil is best) and (TDS is best) then (crop will rot)

- If (pH value is low) and (salinity of water is best) and (salinity of soil is slightly problematic) and (TDS is best) then (soil is acidic and patchy) and (dehydrate the plant) and (need more water)

- If (pH value is low) and (salinity of water is best) and (salinity of soil is severe) and (TDS is ideal) then (soil is patchy) and (plant will not sustai

- If (pH is low) and (Salinity of water is ideal) and (Salinity of soil is ideal) and (TDS is slightly problem-atic) then (root will not absorb nutrients)

- If (pH is low) and (Salinity of water is ideal) and (salinity of soil is ideal) and (TDS is severe) then (~~ro~~ nutrient intake adversely affect) (crop didn't sustain)

- If (pH is ideal) and (Salinity of water is slightly problematic) and (salinity of soil is ideal) and (TDS is ideal) then (crop can sustain) (lower the amount of water)

- If (pH is ideal) and (salinity (w) is severe) and (salinity (s) is ideal) and (TDS is ideal) then ~~we see~~ (crop will not sustain)

- If (pH is ideal) and (Salinity (W) is ideal) and (Salinity (S) is slightly prob) and (TDS is ideal) then (crop can sustain)

- If (pH is ideal) and (salinity (W) is ideal) and (Salinity (S) is severe) and (TDS is ideal) then (crop can rot)

- If (pH is ideal) and (Salinity $_w$ is ideal) and (salinity (S) is ideal) and (TDS is slightly prob) then (crop can sustain)

- If (pH is ideal) and (Salinity W is ideal) and (Salinity (S) is ideal) and (TDS is severe) then (crop roots will rot)

If (Ion toxicity is less) and (chloride is less) and (boron is less) and (bicarbonate is less) then soil quality is good and ~~crop has no problem.~~ no impact on produced crop.

If (Ion toxicity is less) and (chloride is (medium) and (boron is medium) and (bi-carbonate is medium) then soil quality is medium and crop will sustain.

If (Ion toxicity is less) and (chloride is high) and (boron is high) and (bicarbonate is high) then soil quality not good and crop will be affected.

If (Ion toxicity is medium) and (Chloride is low) and (Boron is low) and (Bicarbonate is low) then soil quality moderate and crop will sustain.

If (Ion toxicity is high) and (Chloride is less) and (Boron is low) and (Bicarbonate is low) then soil quality is not good and crop will tolerate.

If (Ion toxicity is medium) and (chloride is medium) and (Boron is medium) and Bicarbonate is medium) then quality of soil will be moderate and Crop will tolerable in nature.

If (Ion toxicity is high) and (chloride is high) and (Boron is medium) and bicarbonate is medium) then crop will be affected and soil quality is not good.

If (Ion toxicity is high) and (chloride is high) and (Boron is high) and (bicarbonate is medium) then crop will be affected and soil quality is bad.

REFERENCES

1. Dubey, Sonal, R. K. Pandey, and S. S. Gautam. "Literature review on fuzzy expert system in agriculture." International Journal of Soft Computing and Engineering 2.6 (2013): 289-291.
2. Munir, M.S.; Bajwa, I.S.; Naeem, M.A.; Ramzan, B. Design and Implementation of an IoT System for Smart Energy Consumption and Smart Irrigation in Tunnel Farming. *Energies* 2018, *11*, 3427. https://doi.org/10.3390/en11123427
3. Roseline, Philomine & Tauro, Clarence & Ganesan, Nagesswary. (2012). Article: Design and Development of Fuzzy Expert System for Integrated Disease Management in Finger Millets. International Journal of Computer Applications. 56. 31-36. 10.5120/8857-2815.
4. Savita Kolhe; Raj Kamal; Harvinder S. Saini; G.K. Gupta (2011). An intelligent multimedia interface for fuzzy-logic based inference in crops. , 38(12), 14592–14601. doi: 10.1016/j.eswa.2011.05.023
5. Kalita, Hemanta; Sarma, Shikhar Kr.; Choudhury, Ridip Dev (2016). [IEEE 2016 International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT) - Pune, India (2016.9.9-2016.9.10)] 2016 International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT) - Expert system for diagnosis of diseases of rice plants: Prototype design and implementation. , (), 723–730. doi:10.1109/ICACDOT.2016.7877682
6. Pinaki Chakraborty; Dilip Kumar Chakrabarti (2008). A brief survey of computerized expert systems for crop protection being used in India. , 18(4), 469–473. doi: 10.1016/j.pnsc.2008.01.001
7. Munir, M. Safdar; Bajwa, Imran Sarwar; Cheema, Sehrish Munawar (2019). An intelligent and secure smart watering system using fuzzy logic and blockchain. Computers & Electrical Engineering, 77(), 109–119. doi: 10.1016/j.compeleceng.2019.05.006
8. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.348.7009&rep=rep1&type=pdf
9. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.635.400&rep=rep1&type=pdf