# A Study of Applications of Fuzzy Logic in Various Domains of Agricultural Sciences

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## ABSTRACT
Fuzzy logic (FL) has emerged as an important branch of Expert system which has proved to provide solution to real life problems that had remained unsolvable otherwise. It has found wide range of applications in diversified areas. In this paper, we study how the methods of fuzzy logic have been effectively used to solve a myriad of problems in the field of agricultural sciences.

This paper reviews a few of the applications of fuzzy logic integrated with expert systems which had been applied in the field of agricultural sciences. This study could be considered as a part of the literature survey done for research work in future for developing expert system for a particular crop for a given region in our country. It can serve as the baseline for further work to be carried out in this domain.

## Keywords
Expert System, Fuzzy Logic, Soft Computing

## 1. INTRODUCTION
Expert System – branch of artificial intelligence, is a program that aims to simulate the decision making process done by human. Such programs are domain-specific i.e., applicable to solve only a particular problem. The architecture of an expert system consists of knowledge base, knowledge engineer, inference engine and user interface. The knowledge base forms the life line of any expert system which contains facts, rules as well as heuristics information represented in the form of if- then structure known as "production rules". Knowledge engineer is the programmer who confides complex knowledge into a knowledge base. Inference engine is the module which derives new knowledge from the existing knowledge base. It is the reasoning mechanism which searches and locates the appropriate knowledge that is required to arrive at a new knowledge. User interface is the window through which the end-user converses with the expert system.

Many expert systems have been developed in medical field (MYCIN), civil engineering (PREDICTE), automobile engineering (ALTREX), and mineral locations (PROSPECTOR).

In particular, many expert systems had been developed in the agricultural field – for maximizing the yields and minimizing the loss. A rule based system combined with fuzzy logic had provided better results to achieve optimal yield.

## 2. NEED FOR FUZZY LOGIC
Fuzzy Logic is a method to solve problems in expert systems which can be viewed as an extension of the classic set theory that deals with membership of the elements and the inferences that can be arrived. It also extensively uses the concept of probability theory to handle data that are uncertain and ambiguous. Using FL, imprecision data as well as vague images can be interpreted and analyzed. It is rich in operations which are based upon the set membership operations. The method encompasses of the fuzzy inference system as listed by Jang (1993):

1. a fuzzification interface that transforms the crisp inputs into degrees of match with linguistic values;
2. a knowledge base that includes :
    i. a rule base containing a number of fuzzy 'If–Then' rules;
    ii. a database that defines the membership functions of the fuzzy sets used in the fuzzy rules;
3. a decision-making unit that performs the inference operations on the rules; and
4. a defuzzification interface that transforms the fuzzy results of the inference into a crisp output.

Though the above mentioned units forms as basic, however, more advancements had been made in the recent past which are more sophisticated and handles data that are most often considered to be as inputs for soft computing.

## 3. FUZZY LOGIC AND PROBLEMS IN AGRICULTURAL SCIENCE
The domain of agricultural science has varied branches such as soil and seed management, water and irrigation, disease and pest control, weed management, fertilizers etc., The problems that are faced in each of these areas are complex as it involves many factors that constitutes and influence them such as geographical location, climatic conditions, weather changes and other organisms that infect them (plant pathology). All these makes the problem encountered, to be very difficult to formulate it in a particular model and devise a method to solve it in a traditional way.

Since fuzzy logic uses the unconventional values i.e., values that are neither 0 (false) nor 1 (true), but lies between the interval of 0 and 1, it takes the probabilistic measure to quantify the parameters. Hence many problems whose parameters are difficult to be quantified, have also been solved, that would have been otherwise impossible if conventional methods had to be applied.

Let us now review a few of the many areas where fuzzy logic had been successfully applied in the field of agricultural sciences.

## 3.1 Review of the Design, Development and Application of Fuzzy Logic

### *3.1.1 Application of Fuzzy logic in disease management*

In the paper titled "Design and Development of Fuzzy Expert System for Integrated Disease Management in Finger Millets" [2], an approach to disease management combines an rule-based expert system being developed and fuzzy logics applied to evaluate the severeness of the disease that had been identified using the symptoms and appearance. According to the statistics a loss of 8% is due to the diseases that attack the crop at various stages of its growth. Hence, it is crucial to devise an efficient way to tackle the problem. Combined with the expertise of the agricultural scientist and experience of the farmers, technology can be blended to revolutionize the agronomic practices [3][5].

'Integrated Disease Management' involves the selection and application of a harmonious range of disease control strategies that minimize losses and maximizes returns [4].

Various stages are been discussed in the identification of the disease and the treatments recommended and is shown in Table 1

**Table 1. Identification of disease and treatment recommended**

| RANK | PERCENTAGE OF LEAF AFFECTED AREA | REACTION |
|---|---|---|
| 0 | No symptoms on the leaves | Immune |
| 1 | <1% | Highly resistant |
| 2 | 1-5% | Resistant |
| 3 | 5-25% | Moderately resistant/susceptible |
| 4 | 25-50% | Susceptible |
| 5 | >50% | Highly susceptible |

The expert system uses fuzzification and defuzzification process to reason out which was otherwise done only by the experience gained by the farmers or the expertise of the agricultural scholars.

### *3.1.2 Application of Fuzzy logic in pest management*

A review of the paper "Integrated Pest management system using fuzzy expert system" the loss of crop due to pest is estimated to be about 55% before harvest [3]. The expert system developed FuzzyXPest is rule-based and applies fuzzy logic to infer conclusion.

It has been tested and proved that it had provided better results in handling pest management that attacks rice in Malaysia. The details on the forecasting module are shown in Table 2.

**Table 2. Linguistic Variables for Damage Forecasting Module**

| INPUT | LINGUISTIC VARIABLE |
|---|---|
| Number of Pests | (Few, Many, Too Many) |
| Size of Pests | (Small, Medium, Big) |
| Damages to the Plant | (Low, Medium, High) |

### *3.1.3 Application of Fuzzy logic in weed management*

The paper titled "Recognition of weeds with image processing and their use with fuzzy logic for precision farming" [4], the expert system accept the images taken as the input and analyses the affected percentage. Another problem encountered in weed management is that the plant and weed might sometimes appear in the same color. Hence identifying the weed from regular plant is easy when inspected manually but to feed the slight difference in the color needs a different mechanism.

**Figure 1: Sample Image A – Used for the recognition of weeds using image processing**

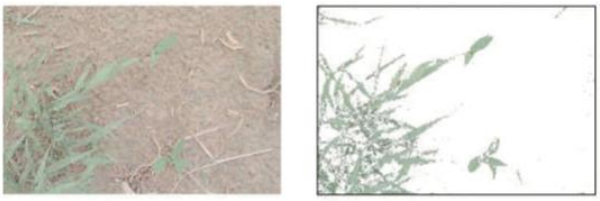

**Figure 2: Sample Image B – Used for the recognition of weeds using image processing**

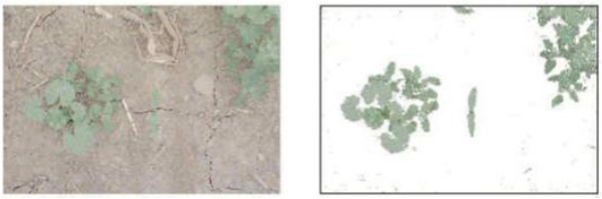

**Figure 3: Sample Image C – Used for the recognition of weeds using image processing**

The disadvantage in this could be that the system should be equipped with image processing facility

### *3.1.4 Application of Fuzzy logic to study and analyze soil*

Soil being the primary requirement of any crop to be cultivated, has a major role in the yield of any crop. The three basic constituents of soil Nitrogen, Phosphorous and Potassium known as NPK must be test before whether it is in the required ratio. Apart from these, the soil might have been polluted and depleted from its other naturally occurring minerals and micro-organisms [6][7].

A fuzzy based expert system "Design and development of Expert system for Potato Crop" analyses the soil condition using a fuzzy membership function and tabulated the results.

The decision made using the results of the findings can be of use not only to reduce the cost of fertilizers applied but also to grow the crops more organically and sustain the natural benefits of the soil [8][9].

### *3.1.5 Application of Fuzzy logic in developing expert system for various crops*

Various expert systems have been built to enhance the production of crops in different countries. Though the crops might belong to any of the category of cash crops, staple food, vegetables or fruits, the expert system developed had proved to have given better results.

A fuzzy based classification of the rice cultivation in Thailand [5] had analyzed based on the images procured from satellite and had developed a fuzzy numbers for each of their parameters and tabulated the results.

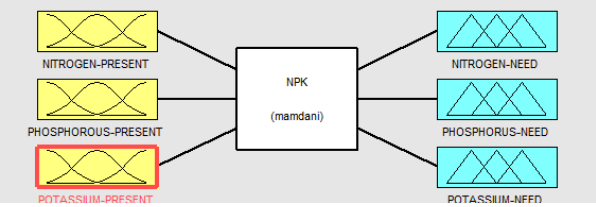


**Figure 4: Fuzzy based Fertilizer Expert system**

Many researches are in progress for increasing the production of other various crops such as for olive –"Building a fuzzy logic information network and a decision-support system for olive cultivation in Andalusia", wheat etc [10][11][12][13].

## 4. FUTURISTIC APPROACH

With the advent of soft computing- which also includes genetic computing, the techniques and methods deployed in the algorithms will be further more enhanced towards better solutions. The decisions that were made by using common sense were a great challenge to make a system exhibit the same way of reasoning. But the combination of fuzzy logic with genetic algorithms and neural networks which has emerged as soft computing has more promising future to solve more real life problems that deals with uncertainty and ambiguous data and which were difficult to model mathematically [14][15].

## 5. CONCLUSION

The prevailing scenario in agriculture of our country can be drastically improved if the research findings and development can be practically being made available for the farmers. But the technical glitches like access to the internet in the villages, availability of the software in their language and interaction between the end-user and developer for the re-engineering process are a few concerns. Encouragement through funding such researches and developing the software for almost all the crops those are cultivated in India and applying the modern technology throughout the process, right from the beginning of seed selection to till the final stage of storage management will undoubtedly make our country prominently noticeable in the global arena of agricultural sciences.

The contributions of expert system in the field of agricultural sciences are growing tremendously. With the advancement of technology – networking in particular, the expert systems built can be of great use to the farmers in tackling the problems that arise at various stages of the growth of the crop i.e., from the seed selection and crop suitability stage to till the harvest and storage management stage.

This paper throws light on the contemporary methods that can be incorporated with the age old principles (heuristic knowledge) that are traditionally followed in the field of agricultural domain for better yield thereby benefitting the farmers and our country in turn.

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