GENETIC-FUZZY SYSTEM FOR THE INTELLIGENT RECOGNITION OF SOIL FERTILITY FOR AGRICULTURAL PRODUCTION

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ABSTRACT: In terms of importance and usage, soil is the second most important earth material ensuing water. Its usage and availability cannot be quantified. However, due to natural and man-made disasters, its quality has been on the steady decline over the years. It is important not only to recognize soil fertility within a geographical area but also to maintain and nurture it. Genetic-fuzzy system for the recognition of soil fertility is geared towards this direction. Utilizing a set of fuzzy sets or parameters, a soil within a particular area can be recognized as "Not fertile soil, Might be fertile soil and "Fertile soil". Genetic algorithm was used to optimize both fuzzy sets and fuzzy rule base while fuzzy logic on the other hand was used to handle vague, ambiguity and imprecision within the fuzzy sets to arrive at our conclusion of recognizing fertile soil for agricultural production.

INTRODUCTION

The science of pedology emphasizes the study of soil as a natural phenomenon on the surface of the Earth. Therefore, the pedologist is interested in the appearance of the soil, mode of formation, chemical and biological composition, classification and distribution (Brdges, 1997, Han, 1994, Kristofer, 2004). The pedosphere is the areas of the earth, where soil is occurring and soil forming factors are active (Hangsheng, 2003). The pedosphere only develops when there is a dynamic interaction between the atmosphere, biosphere, lithosphere and hydrosphere. The pore space in soil is either filled with air or water, while the solid phase consists of mineral and organic living and nonliving components.

The focal point of this research is on recognizing fertile soil within an area using Geno-fuzzy system (fusion of genetic algorithm and fuzzy logic).

METHODOLOGY

Genetic Algorithm (GA) is a useful tool for optimization and search problem while Fuzzy logic (FL) help to deal with uncertainties and impreciseness associated with certain parameters of fuzzy set. Genetic-fuzzy system is handled both optimization and uncertainties associated with fuzzy sets. The first step in designing a Genetic Fuzzy System (GFS) is to decide which parts of the knowledge base (KB) are subject to optimization by the GA. The KB of a fuzzy system does not constitute a homogeneous structure but is rather the union of qualitatively different components.

The system parades two input variables X_1 and X_2 which are parameters of soil. The training data are categorized by two classes C_1 and C_2. Each input is represented by the two linguistic terms, thus we have four rules.

Layer 1**:** The output of the node is the degree to which the given input satisfies the linguistic label associated to this node. This is governed by the bell-shaped membership functions;

$$A_i(u) = \exp[-1/2 (u-a_{i1}/b_{i1})^2],$$
$$B_i(v) = \exp[-1/2 (v-a_{i2}/b_{i2})^2],$$

which represent the linguistic terms, where $\{a_{i1}, a_{i2}, b_{i1}, b_{i2}\}$ is the parameter set.

As the values of these parameters change, the bell-shaped functions vary accordingly, thus exhibiting various forms of membership functions on linguistic labels A_i and B_i. In fact, any continuum, such as trapezoidal and triangular-shaped membership functions are also quantified candidates for node functions in this layer. The initial values of the parameters are set in such a way that the membership functions along each axis satisfy:-completeness, normality and convexity. The parameters are then tuned with a descent-type method.

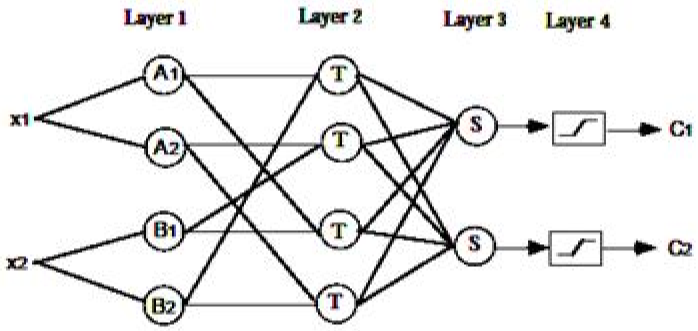

Figure 1: Fuzzy Classifier System for soil fertility recognition

Layer 2**:** Each node generates the signal corresponding to the conjunctive combination of individual degrees of match of soil parameters. The output signal is the firing strength of the fuzzy rule with respect to soil.

We take the linear combination of the firing strengths of the rules at Layer 3 and apply sigmoidal function at Layer 4 to calculate the degree of belonging to a certain class. Given training set $\{(x^k, y^k), k = 1, \ldots, K\}$ where x^k refers to the k^{th} input pattern then

$$Y^K = \begin{cases} (1, 0)^T \text{ If } X^K \text{ belongs to Class 1} \\ (0, 1)^T \text{ If } X^K \text{ belongs to Class 2} \end{cases}$$

The error function for pattern k can be defined by $E_K = 1/2 [(0_1^K - Y_1^K)^2 + (0_2^K - Y_2^K)^2]$

where y^k is the desired output and o^k is the computed output.

Using fuzzy IF-THEN rules to describe a classifier**,** assume that K patterns $x_p = (x_{p1}, x_{pn})$, p = 1, . . . , K are given from two classes, where x_p is an n-dimensional crisp vector. Typical fuzzy classification rules for n = 2 are like

IF x_{p1} is small and x_{p2} is very large THEN $x_p = (x_{p1}, x_{p2})$ belongs to Class C_1
IF x_{p1} is large and x_{p2} is very small THEN $x_p = (x_{p1}, x_{p2})$ belongs to Class C_2

where x_{p1} and x_{p2} are the features of pattern (or object) p, small and very large are linguistic terms characterized by appropriate membership functions.

Genetic Algorithm is used for optimizing the knowledgebase, which houses both the database and Fuzzy rule-base. Genetic algorithm comprises five components which are fitness function, selection, mutation, reproduction and crossover. **The fitness function**, also called evaluation function, is the genetic algorithm component that rates a potential solution by calculating how good they are relative to the current problem domain. **Selection** is a way for the genetic algorithm to move towards promising regions in the search space. The individuals with high fitness are selected and they will have a higher probability of survival to the next generation. With too much selection pressure, genetic search will terminate prematurely; while with too little selection pressure, evolutionary progress will be slower than necessary. A lower selection pressure is recommended in the start of the genetic search; while a higher selection pressure is recommended at the end in order to narrow the search space. Reproduction is one thing that all evolution algorithms have in common is that they have a population that in one way or another must evolve and become better and better. In genetic algorithms this is done primarily using two operations -mutation and crossover. **Mutation** is a genetic operator that changes one or more gene values in a chromosome. Mutation is an important part of the genetic search, which helps to prevent the population from stagnating at any local optima. Mutation means that you take one or more random chromosomes from the DNA string and change it (e.g. 0 become 1 and vice versa). **Crossover,** is exchanging chromosome portions of genetic material. The result is that a large variety of genetic combinations will be produced. In most genetic algorithms, recombination is implemented by the means of a crossover operator which operate on pairs of chromosomes to produce new offspring by exchanging segments of the genetic material from the parent's. In other words, crossover takes two of the fittest genetic strings in a population and combines the two of them to generate new genetic strings.

Figure 2 shows the fundamental block diagram of a FRBS. The inference procedure of the system is presented in Figure 2. The genetic fuzzy system for recognition of soil fertility is in Figure 3

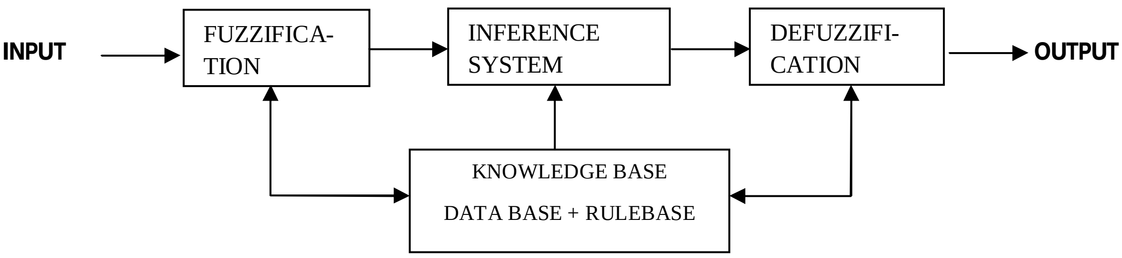

Fig. 2: Fuzzy Rule Based System (FRBS)

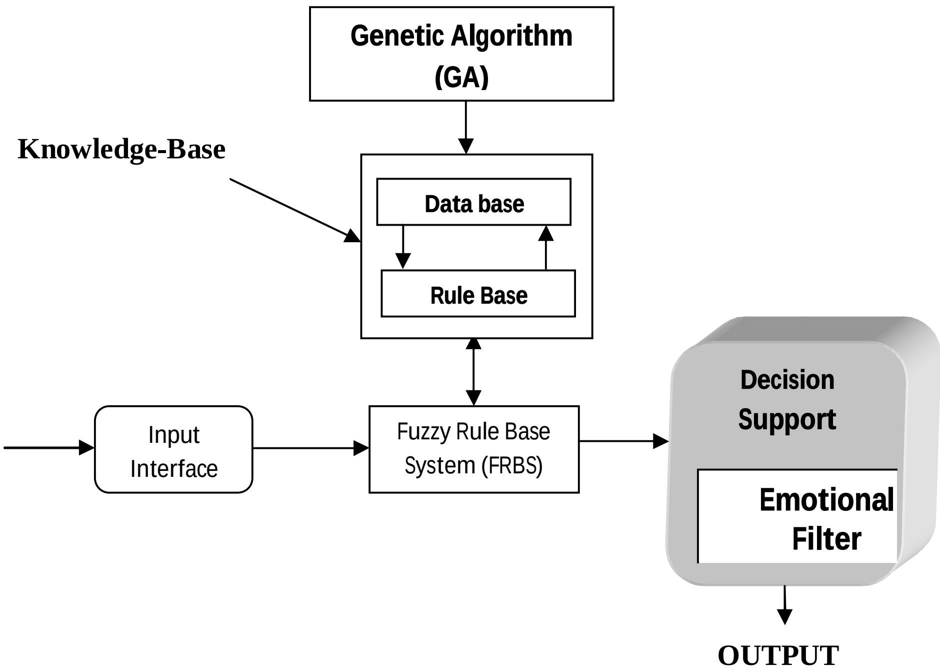

Figure 3: Genetic-fuzzy system for recognition of soil fertility

RESULT AND DISCUSSION

To design the *Genetic-Fuzzy* system for the recognition of soil fertility, we designed a system which consists of the set of parameters needed for the recognition of soil fertility.

The fuzzy partition for each input feature consists of the parameters of fertile soil. However, it can occur that if the fuzzy partition of soil fertility is not set up correctly, or if the number of linguistic terms for the input features is not large enough, then some patterns will be misclassified. The rules that can be generated from the initial fuzzy partitions of the classification of soil fertility are thus:

Not fertile soil (Class: C_1)

Might be fertile soil (Class: C_2)

Fertile soil (Class: C_3)

If the soil area is experiencing three or less parameters *THEN* (C_1), if the soil area is experiencing at least four parameters *THEN* (C_2) and if the soils area is experiencing five or more parameters *THEN* (C_3)

The Fuzzy IF-THEN Rules (R_i) for soil fertility is

R1: IF the soil area is experiencing presence of parent materials rich in soluble ions THEN it is in class C_1.

R2: IF the soil area is experiencing presence of parent materials rich in soluble ions and presence of climatic condition based on precipitation THEN it is in class C_1.

R3: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation and soil topography based on horizontal layout THEN it is in class C_1.

R4: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout and presence of hill slope position (runoff and erosion) THEN it is in class C_2.

R5: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion) and presence of microclimatic effects THEN it is in class C_3.

R6: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion), presence of microclimatic effects and presence of micro-organisms THEN it is in class C_3.

R7: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion), presence of microclimatic effects, presence of micro-organisms and regular nutrient cycling THEN it is in class C_3.

R8: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion), presence of microclimatic effects, presence of micro-organisms, regular nutrient cycling and lack of podzolization THEN it is in class C_3.

R9: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion), presence of microclimatic effects, presence of micro-organisms, regular nutrient cycling, lack of podzolization and lack of calcification THEN it is in class C_3.

R10: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion), presence of microclimatic effects, presence of micro-organisms, regular nutrient cycling, lack of podzolization, lack of calcification and little or no salinization presence THEN it is in class C_3.

R11: IF the soil area is experiencing presence of parent materials rich in soluble ions, presence of climatic condition based on precipitation, soil topography based on horizontal layout, presence of hill slope position (runoff and erosion), presence of microclimatic effects, presence of micro-organisms, regular nutrient cycling, lack of podzolization, lack of calcification, little or no salinization presence and lack of Gleization THEN it is in class C_3.

Table 1: Degree of membership of Soil fertility

PARAMETERS OR FUZZY SETS	**CODES (P01- P11)**	**DEGREE OF MEMBERSHIP OF SOIL FERTILITY**		
		Cluster 1 (C_1)	**Cluster 2 (C_2)**	**Cluster 3 (C_3)**
Presence of parent materials rich in soluble Ions	P01	0.10	0.10	0.80
Presence of climatic Condition Based on Precipitation	P02	0.10	0.10	0.80
Soil Topography based on horizontal layout	P03	0.50	0.00	0.50
Presence of hill slope position (runoff and erosion)	P04	0.50	0.50	0.00
Presence of microclimatic effects	P05	0.29	0.59	0.12
Presence of micro-organisms	P06	0.00	0.50	0.50
Regular nutrient cycling	P07	0.18	0.70	0.12
Lack of podzolization	P08	0.80	0.10	0.10
Lack of Calcification	P09	0.10	0.10	0.80
Little or no salinization presence	P10	0.10	0.13	0.77
Lack of Gleization	P11	0.20	0.20	0.60
RESULTS		**NOT FERTILE SOIL**	**MIGHT BE FERTILE SOIL**	**FERTILE SOIL**

The degree of membership of fertile soil ordered in the following classes for a typical scenario is presented in Table 1. The graphical representation in Figure 4 is a representation of Table 1 with degree of membership ranging from *0.00-1.00 (below 0.5, low degree of membership and 0.5 and above high degree of membership)*. The graph clearly show three parameters with high degree of "Not Fertile soil" in Cluster 1, four parameters with high degree of "Might be fertile soil" in Cluster 2 and seven parameters with high degree of "Fertile soil" in Cluster 3.

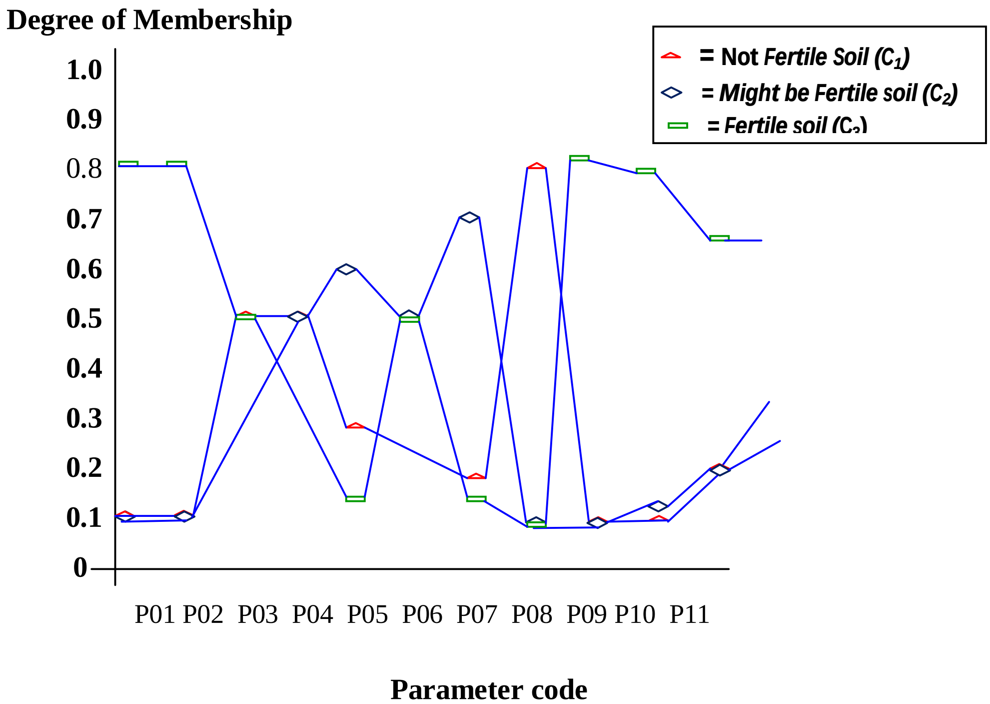

Figure 4: Graphical representation of Membership Grades of Soil Fertility

CONCLUSION

Apart from water soil is the next important earth material. The need to design a system that would assist human in general to recognize soil fertility cannot be over emphasized. This paper which demonstrates the practical application of genetic algorithm and fuzzy logic (Geno-fuzzy system) for soil recognition utilizing a set of fuzzy sets. This model which uses a set of fuzzified data set incorporated into genetic algorithm system is more precise than the traditional system. The system designed is an interactive system that tells an individual the current condition of a particular soil area. A system of this nature should be introduced in the agricultural sector to assist farmer in food production.

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