International Journal of
Intelligent Systems and Applications in Engineering

ISSN:2147-6799 www.ijisae.org Original Research Paper

Application of Fuzzy Logic in Land Consolidation-Classification Studies

Ela Ertunç[*1], Tayfun Çay[2]

Accepted 3rd September 2016

Abstract: Land classification is one of the most important stages of consolidation projects. The success and timely completion of this project depends on that this classification is useful and fair and are accepted by landowners. Different methods have been developed for the classification. Effects on the success of the land consolidation of the results of these methods are being investigated. In this study, fuzzy logic method has been used for land classification according to Law No. 5403. In Mamdani Type Fuzzy Logic, Values of soil index, productivity index and the location index, which are used to determine the value of the parcel index, have been defined as input, whereas the value of parcel index have been defined as the output. Inputs and outputs have been converted to the linguistic terms (*such as very efficient, inefficient, somewhat efficient, remote, near*) by creating membership functions. Rule base has been created for calculating of the parcel index. As a result of fuzzy inference and defuzzification process, the model formed by Mamdani Type Fuzzy Logic gives the value of parcel index. By giving random input values to test generated model, results has been compared with results obtained manually.

Keywords: Fuzzy logic, Land consolidation, Land classification, Fuzzy systems, Soft computing

1. Introduction

Land consolidation studies have a set of technical services in order to increase productivity in agriculture regulating agricultural space along with a variety of infrastructure services (road-irrigation network, drainage, soil leveling, construction of village settlements etc.) [1].

To give lands equal to their previous lands to landowners after the consolidation process in land consolidation area, classification process based on specific criteria of their existing plots must be made [2].

Land classification according to Soil Conservation and Land Use Law (Law No. 5403) has been defined as values found based on soil and productivity etudes and been basis to the change of land with soil's natural and permanent features and the distance to settlement or business center of land. The aim of classification is obtained according to certain criteria of the previous value from land consolidation of lands belonging to businesses.

Land classification, which is the process to estimate the ability of the land yield, includes studies relied that the soil, topography and other features of the land are interpreted and carried out in order to make comparisons between certain forms of evaluation [2].

Land classification is one of the most important stages of consolidation projects. The success and timely completion of this project depends on that this classification is useful and fair and are accepted by landowners. In order to classify lands in many countries of the world, various methods have been developed and have been put into practice [2].

Values of soil index, productivity index and location index is determined when the classification maps for land consolidation are generated, 70% of the index obtained the results of the soil etudes (SI) is taken. By adding the index scores determined for productivity (PrI) and location (LI) to this value, value of parcel index (PI) is determined. Obtained values of parcel index are evaluated in particular group ranges, and thus, map of classification is formed.

Classifications of parcels according to determined the parcel index are made according to Table 1.

Parcel index (PI) = SI*70% + V + k

Table 1. Classifications of parcels

Classification	Parcel Index	Classification	Parcel Index
1	91-100	6	41-50
2	81-90	7	31-40
3	71-80	8	21-30
4	61-70	9	11-20
5	51-60	10	0-10

Discovered fuzzy sets, logic and system concepts by Zadeh in 1965 have occured the result that much nonlinear equations are used, method is complicated and solution becomes difficult in order to working of this researcher for many years in the control area and obtaining the control he wants [3].

The concept of fuzzy logic generally tries to modelling the thinking style of people. It is communicable that turbidity signify the tentative information as a concept, in other words uncertainty. Fuzzy logic is defined as an artificial intelligence technique which run with uncertainties instead of certainties by using verbal variables. Typical value of the verbal variable is expressed with words, such as “hot” or “cold”, also, these values are represented by membership functions of fuzzy sets. The difference from standart mathematical methods of fuzzy logic is runnig with uncertainties instead of certainties and allowing the qualitative

[1, 2] *Selcuk University, Engineering Faculty, Department of Geomatics Engineering, Konya, Turkey*
** Corresponding Author: Email: elaertunc@selcuk.edu.tr*
Note: This paper has been presented at the 3rd International Conference on Advanced Technology & Sciences (ICAT'16) held in Konya (Turkey), September 01-03, 2016.

definition. That uncertainties are expressed mathematically is evaluated as the greatest convenience which is brought by fuzzy logic the modeling of complex systems [4].

In classical set theory, any object is a member of a cluster or not. This object only has the value of "0" or "1". The medium of these values is not possible. In fuzzy logic unlike classical logic, members belong to partially the fuzzy cluster and is used in values between '0' and '1'. In the following Figure 1, the difference of binary (classical) logic and fuzzy logic is schematically shown. In Figure 1 it is shown that intermediate values do not exist in classical logic.

The processes of fuzzy logic consists of stages which the problem is analyzed and is defined, sets and logical relationships are formed, available information is converted into fuzzy sets and model is interpreted. By using a lot of prerequisites, it can be decided whether fuzzy logic solves the problem or not. Originally for the problem to be solved, it is decided whether fuzzy logic approach is the right choice or not. If the system's behavior to be applied can be expressed with rules or it requires a complex mathematical operation, fuzzy logic approach can be applied. Otherwise, The results obtained by the fuzzy logic will not give the desired values most likely [5].

In Figure 2, it is shown bluring defuzzification fuzzy system with unit.

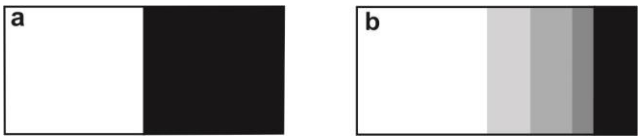

Figure 1. Representation of the difference between fuzzy logic (**a**) and classical logic (**b**)

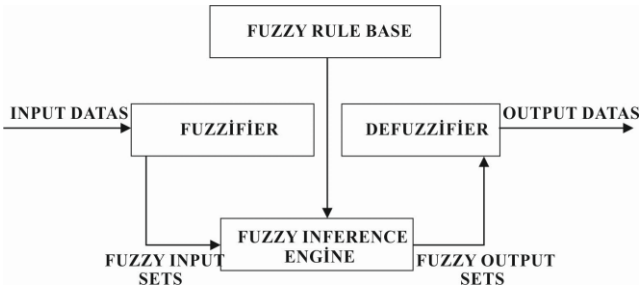

Figure 2. Blurring defuzzification fuzzy system with unit

1) General Information Base Unit: It contains the input variables which are affected of event which will be examined and all informations about these. The reason which it is called as the general data base is numerical and / or verbal of the informations here.

2) Fuzzifier: This is a processor that assigns to membership degrees in fuzzy sets that has been described as verbal to the digital input values.

3) Fuzzy Rule Base Unit: This includes all of rules that connect to output variables to inputs in the database and that can be written in logical IF – IF type. While these rules are written, all intermediate (fuzzy set) connections which may be only between input datas and outputs is considered. Thus, each rule logically connects to the output space to a part of the input space. All of this contexts creates a rule base.

4) Fuzzy Inference Engine Unit: This is a mechanism that contains processes community that provide that the system behaves with output by collecting together all of the piece relationship established between the input fuzzy sets and the output fuzzy sets. This engine benefits that How to give an output under inputs of whole system is determined by huddling together the implications of each rule.

5) Defuzzifier: This converts to sharp digital output values to results of fuzzy inference obtained result of fuzzy processes.

6) Output Unit: This unit specifies community of the output values obtained by the interaction by means of fuzzy inference engine of information and fuzzy rule bases [6].

In this study, fuzzy logic method has been used for land classification according to Law No. 5403. In Mamdani Type Fuzzy Logic, Values of soil index, productivity index and the location index, which are used to determine the value of the parcel index, have been defined as input, whereas the value of parcel index have been defined as the output. Inputs and outputs have been converted to the linguistic terms (*such as very efficient, inefficient, somewhat efficient, remote, near*) by creating membership functions. Rule base has been created for calculating of the parcel index. In order to benefit from fuzzy informations obtained, this informations have to be defuzzification. Centroid method has been used as defuzzification method. As a result of fuzzy inference and defuzzification process, the model formed by Mamdani Type Fuzzy Logic gives the value of parcel index. By giving random input values to test generated model, results has been compared with results obtained manually.

2. Materials and Methods

While fuzzy system is established, the soil index (SI), the productivity index (PrI) and the location index (LI) has been defined as the input values of system, whereas, parcel index (PI) has been defined as the output value of system. The general structure of the fuzzy model is shown in Figure 3.

Firstly, while fuzzy model is created, it must be determined that values of soil index, productivity index and location index will be divided how many sub-regions and that what kind of membership function (such as triangular, trapezoidal, Gaussian curve etc.) will be used. In this study, the seven sub-regions for soil index, the five sub-regions for productivity index and the four sub-regions for location index have been determined and triangular membership function has been used.

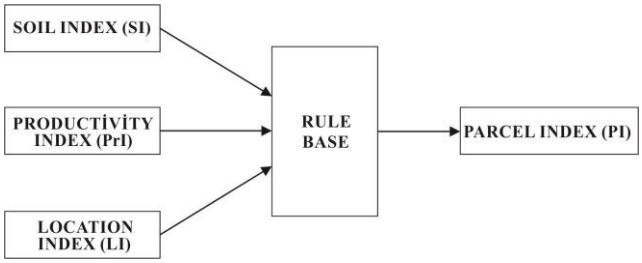

Figure 3. The general structure of Fuzzy Logic Model

2.1. Membership Function

While the fuzzy model is established, different membership functions have been formed for soil index (SI), productivity index (PrI) and location index (LI). The membership functions for input and output variables are shown in Figure 4, 5, 6 and 7. Units of factors used are: SI (unit), PrI (unit), LI (unit) and PI (unit). As shown in Equations. 1 to 4, SI membership function is in the range of 0-100, PrI membership function is in the range of 0-10, LI membership function is in the range of 0-20 and PI membership function is in the range of 0-100.

That the factors used are blurred are carried out with help of the following functions determined by benefiting from an expert's opinions and informations.

SI (A) = {a; 0 < a < 100 (1)

PrI (B) = {b; 0 < b < 10 (2)

LI (C) = {c; 0 < c < 20 (3)

PI (D) = {d; 0 < d < 100 (4)

Such as, the mathematical representation of each membership function of the location index (LI) is as follows (Equations. 5 to 8):

$$\mu_{far(C)}=\begin{cases}\frac{5-a}{5}; \mathbf{0} < a < \mathbf{5}\\ \mathbf{0}; \boldsymbol{in\ different\ conditions}\end{cases} \quad (5)$$

$$\mu_{near\ (C)} = \begin{cases}0; & \\ \frac{a-3.5}{1.5} & a \le 3.5; \\ \frac{10-a}{4} & 3.5 < a \le 5; \\ 0; & 6 < a < 10; \\ & a \ge 10; \end{cases} \quad (6)$$

$$\mu_{nearer\ (C)} = \begin{cases}0; & \\ \frac{a-10}{1.52} & a \le 10; \\ \frac{18-a}{6} & 10 < a \le 12; \\ 0; & 12 < a < 18; \\ & a \ge 12; \end{cases} \quad (7)$$

$$\mu_{thenearest(C)}=\begin{cases}\frac{17-a}{3}; 17 < a < 20\\ 0; in\ different\ conditions\end{cases} \quad (8)$$

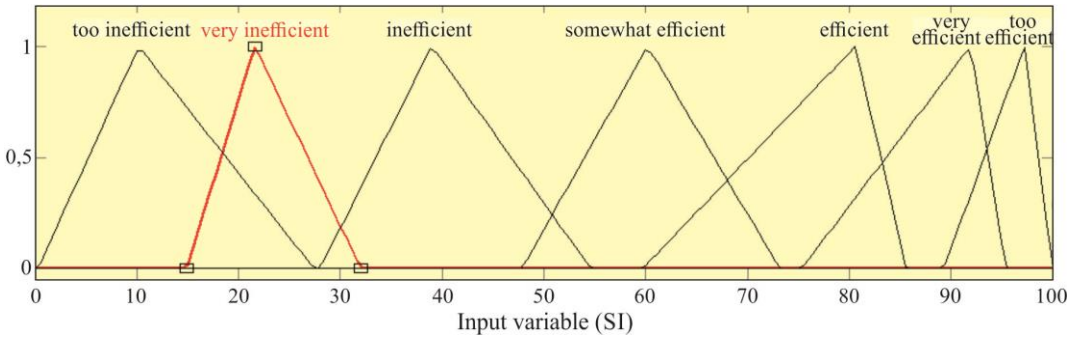

Figure 4. The membership function of soil index (SI)

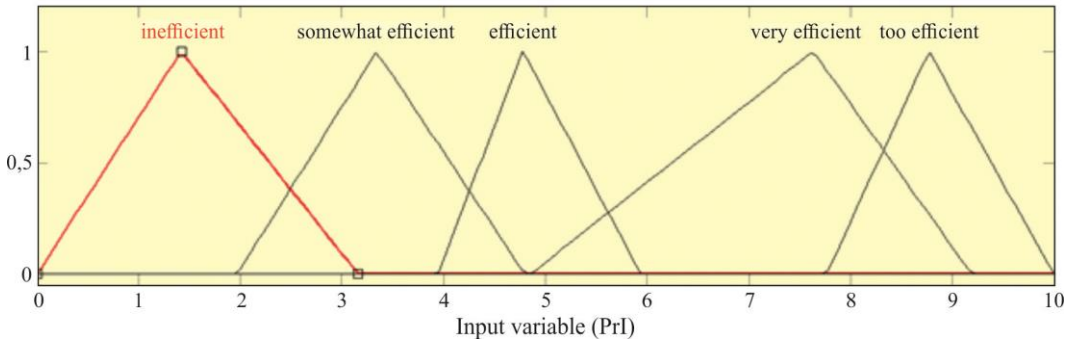

Figure 5. The membership function of productivity index (PrI)

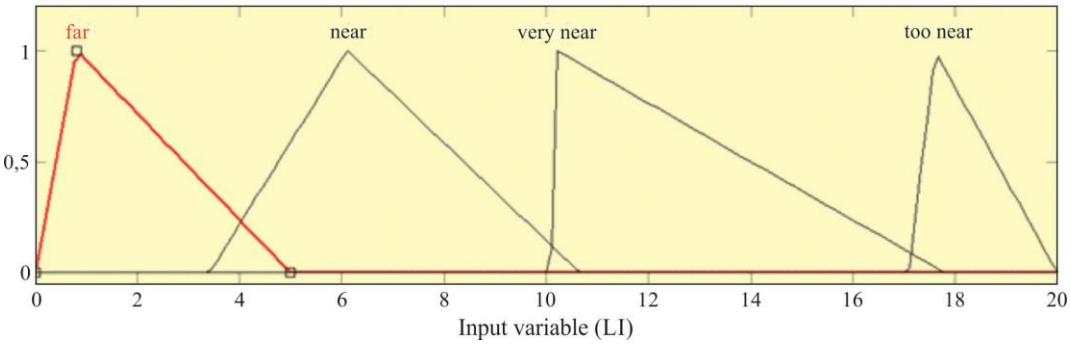

Figure 6. The membership function of location index (LI)

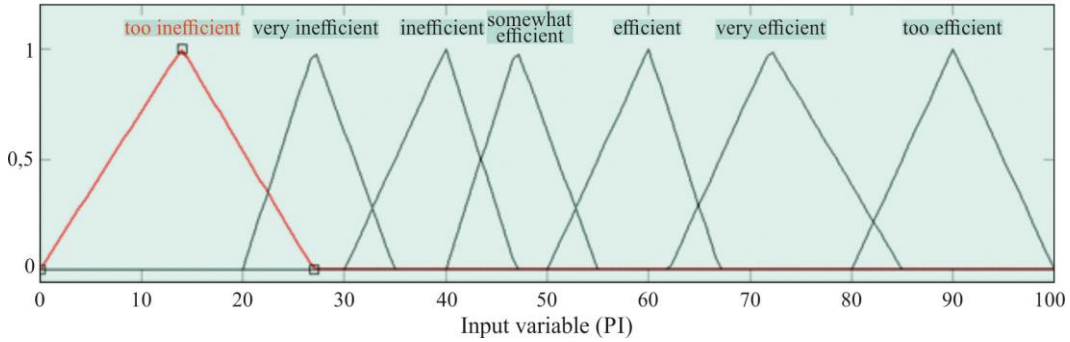

Figure 7. The membership function of parcel index (PI)

2.2. Rule Base

An appropriate rule base is required for fuzzy logic system. The total of 140 rules have been written for fuzzy system in this study. The portion of them is seen in Table 2.

The relationship with parcel index (PI) that is the output value of soil index (SI), location index (LI) and productivity index (PrI) that are input values are shown in Figure 8, 9 and 10.

Table 2. Rule base

Rule Number	SI	PrI	LI	PI
Rule 1	very inefficient	inefficient	far	too inefficient
Rule 2	very inefficient	inefficient	near	too inefficient
Rule 3	very inefficient	inefficient	very near	very inefficient
…				
Rule 48	inefficient	somewhat efficient	too near	efficient
Rule 49	inefficient	efficient	far	inefficient
Rule 50	inefficient	efficient	near	somewhat efficient
…				
Rule 85	efficient	somewhat efficient	far	somewhat efficient
Rule 86	efficient	somewhat efficient	near	very efficient
Rule 87	too efficient	inefficient	very near	very efficient
…				
Rule 118	too efficient	inefficient	near	very efficient
Rule 119	too efficient	inefficient	very near	too efficient
Rule 120	too efficient	inefficient	too near	too efficient

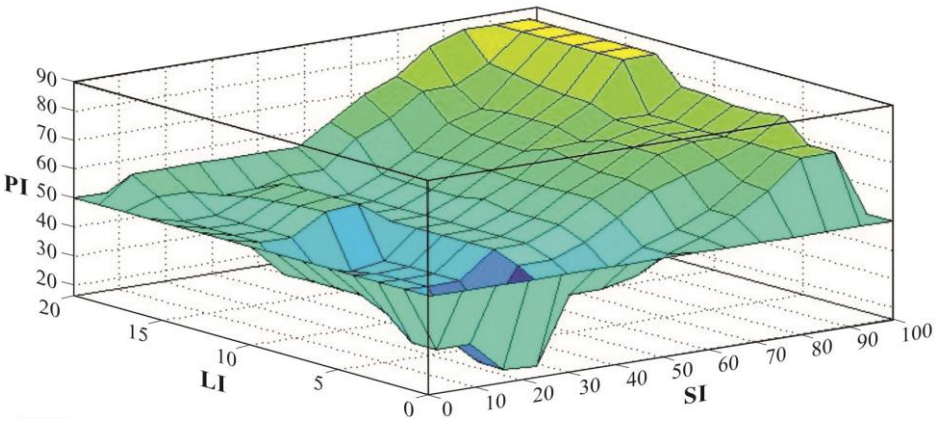

Figure 8. The relationship with PI of LI and SI

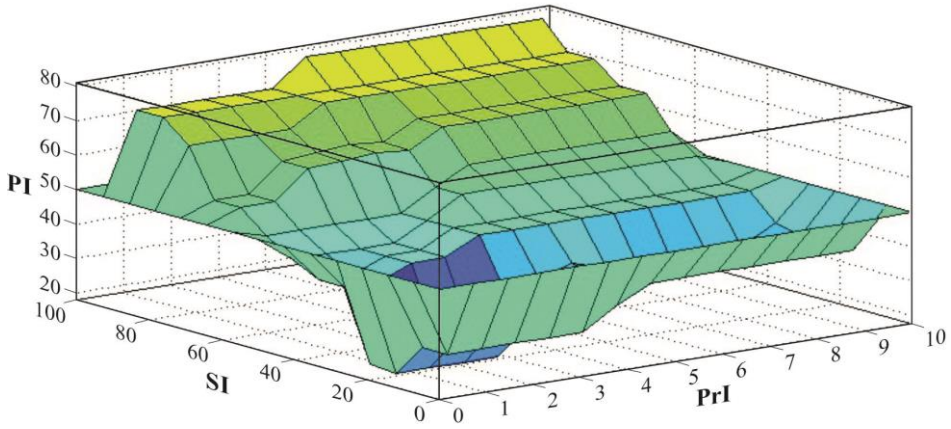

Figure 9. The relationship with PI of SI and PrI

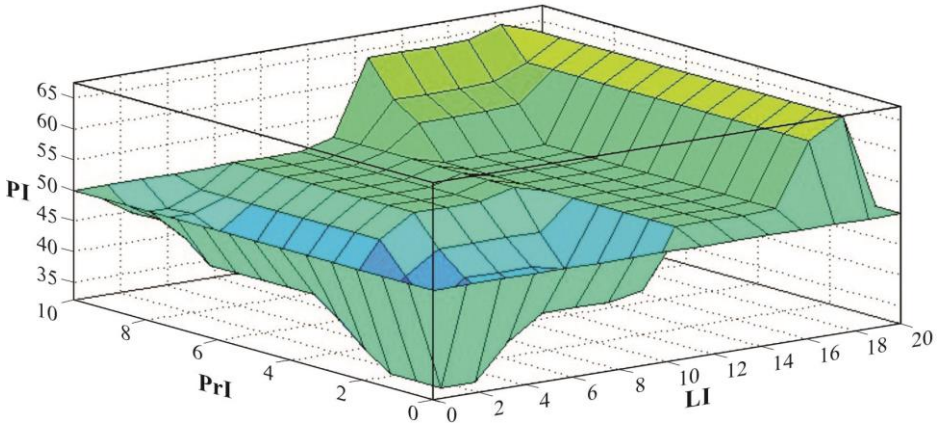

Figure 10. The relationship with PI of PrI and LI

3. Conclusion

The method developed in this study has been applied the first time for the land classification. according to Land Law No. 5403. As shown in Table 3, the results of Fuzzy Logic Model are compared with results of traditional method. It is seen in Table 3 that both the results obtained from the fuzzy logic model and the results obtained from the traditional method are similar one another. The system is fast and is more accurate than traditional methods. This system also has a high reliability. Besides, accuracy of established fuzzy system has been shown on stabilizing right graph that its angle is 45 degrees (Figure 11).

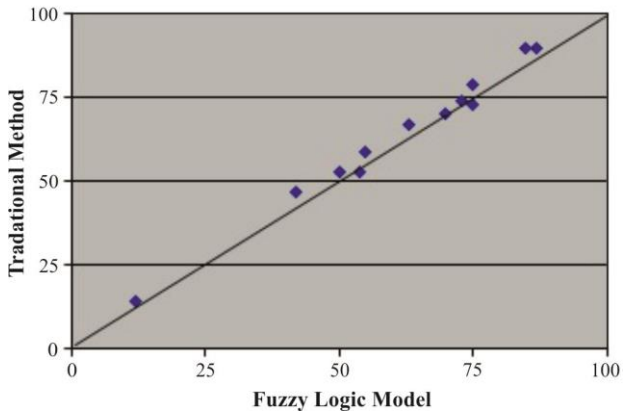

Figure 11. Accuracy of Fuzzy Logic Model with the help of 45 degrees right

Table 3. Comparison of the results of Traditional Method and Fuzzy System

SI	V	K	PI According to the Traditional Method	PI According to the Fuzzy Logic System
83	9	18	85	90
74	8	15	75	73.2
60	5	8	55	59.5
71	7	13	70	70.2
55	8	17	63.5	67.4
95	9	12	87.5	90
80	5	14	75	79
78	6	12	73	77.7
10	2	3	12	13.6
50	5	10	50	53.5
61	4	7	53.7	52.8
40	3	11	42	47.4
15	3	4	17.5	17.6
30	2	6	29	23.6
23	6	4	26.1	23.5
78	7	10	71.6	73.4

As a result of this study, it is understood that Mamdani Fuzzy Logic Method can be used for the land classification. This system can be further improved by being increased linguistic variables and the number of rules of generated Fuzzy Model.

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