Application of Fuzzy Logic in Land Consolidation Activities

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INTRODUCTION

Land consolidation (LC) is a tool for improving the effectiveness of land cultivation and for supporting rural development. As an important approach to achieve the sustainable utilization of land resource, land consolidation not only need to regard the amount of the farm land for the sake of achieve thing homeostasis of farmland, but also need display the active effect in other aspects, such as improve the quality of farmland, reform the ecological condition and promote the adjustment of the economic formation etc.

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INTRODUCTION

Land reallocation is the most important and a time-consuming stage of land consolidation studies, as quite many criteria are evaluated at this stage. Conducting land reallocation studies in a way that meets the wishes of farmers and also the principles of equity and justice is crucial in terms of ensuring social peace.

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INTRODUCTION

The problem encountered in land consolidation studies can be defined as allocating “n” number of cadastral parcels to “m” number of blocks. To this end, optimization studies based on many mathematical models for the process of land reallocation have been conducted. However, many different solutions have been suggested, since no single accurate mathematical model for the land reallocation process exists. The success of the suggested mathematical models has been indicated to be low, as linguistic statements and human considerations that affect the reallocation could not be embedded in them.

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INTRODUCTION

Thus, the fuzzy logic (FL) method can be utilized at the reallocation stage of land consolidation projects, as this method is able to incorporate human experiences that can be expressed linguistic but which are difficult to express mathematically. In engineering and other disciplines, events and systems are defined by using accurate mathematical models. By using these created models, an attempt is made to predict the status or course of action that will be taken by the event or system. However, such mathematical approaches are not well suited to accurately representing variations or expressions inherent in the majority of problems or situations encountered in daily life. The FL approach can be utilized in analyzing and solving such problems.

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INTRODUCTION

In the present study, FL was applied at the reallocation stage of a land consolidation study, for which an accurate mathematical model has not been found. The Konya Ilgın-Agalar district in Turkey was chosen as the project site. Local residents were interviewed to establish their views on land allocation. The results of the interview-based land reallocation model and fuzzy logic-based land reallocation models were compared. Comparison criteria were chosen as: The number of parcels and shares; average size of parcels; average number of parcels per landholding; production times of new parceling plans; the cost of the project; the status of landholdings with their close relatives (partner, father, mother, siblings and other landholdings whose land it uses), and; to what extent do the results comply with the wishes stated in interviews. In addition, a questionnaire was developed to establish farmers' preferred land reallocation model.

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MATERIAL AND METHOD

Agalar village in Ilgin county of Konya city was chosen as the research site.

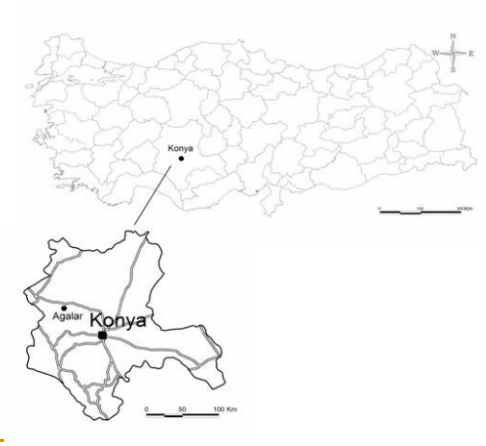

Figure 1. Study Area

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MATERIAL AND METHOD

The area of the Agalar Village land consolidation project is 1403 hectares. 1388 hectares of it is under arrangement. 989,4 hectares of this area is agricultural land, 288,7 hectares of it is pasture and 109.9 hectares is an expropriation area created previously by the Directorate General of State Water Affairs. There are 715 farmers (landholdings) present in the consolidation field and 1536 cadastral parcels available (Figure 2). 383 of these cadastral parcels are shared parcels. The average size of cadastral parcels is 0,6441 hectares.

Figure 2. Cadastral Status of Agalar Village and conditions of the cadastral parcels belonging to the 24th landholding

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Interview-based land reallocation model

The method through which the land reallocation is carried out in accordance with the farmers' preferences during the LC is called an "interview-based land reallocation model". First, parcels are placed in the blocks according to the first preferences of the landholdings by looking at the interview forms. The surpluses and the shortages in the blocks are corrected regarding the second and/or third choices of the landholdings. Finally, the parcelling procedure is carried out according to the location of the landholdings in the block.

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Fuzzy Logic-based Land Reallocation Model

Within the process of land reallocation, it is of utmost importance that the farmers do not suffer any injustice and are granted equivalent parcels. The satisfaction of the farmers directly affects the success of the land consolidation studies.

Below are the factors that farmers and applicators pay attention to in land reallocation, as indicated by research:

- The location where the farmer has the largest parcel,
- The location where the farmer's parcel density is,
- The location of the farmer's fixed facility (house, stable, hayloft, well, cluster of trees etc.)
- The location where the farmer has the second largest parcel

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Fuzzy Logic-based Land Reallocation Model

The general structure of FL model is shown in Figure 3. The MATLAB – Fuzzy Logic Toolbox Program was used for the fuzzy model solution. This program provides users with ease-of-use. For instance, users can select the numbers of input and output variables, the type and number of membership and methods of inference and defuzzification.

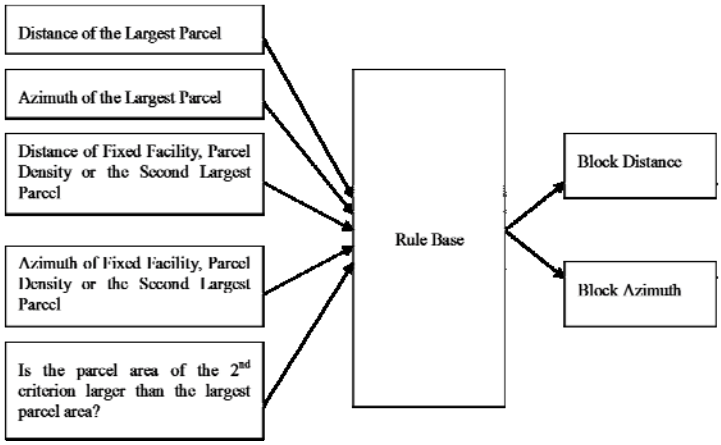

Figure 3. General Structure of Fuzzy Logic Model

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Determination of Membership Functions:

Membership functions of input and output variables were determined by benefiting from the knowledge and experience of experts and farmers, land consolidation law. The membership functions and pillar widths must be the same, except for the 5th input because the distance and azimuth will be the same for the study area.

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Determination of Membership Functions:

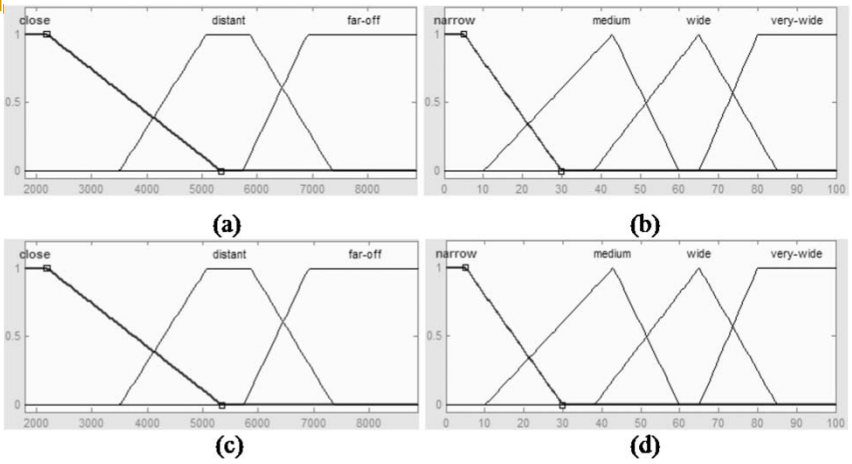

Figure 4. Schema of membership degrees of input variables **a)** Distance of the Largest Parcel (EPM) **b)** Azimuth of the Largest Parcel (EPS) **c)** Distance of Fixed Facility, Parcel Density or the Second Largest Parcel (SP2PM) **d)** Azimuth of Fixed Facility, Parcel Density or the Second Largest Parcel (SP2PS)

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Determination of Membership Functions:

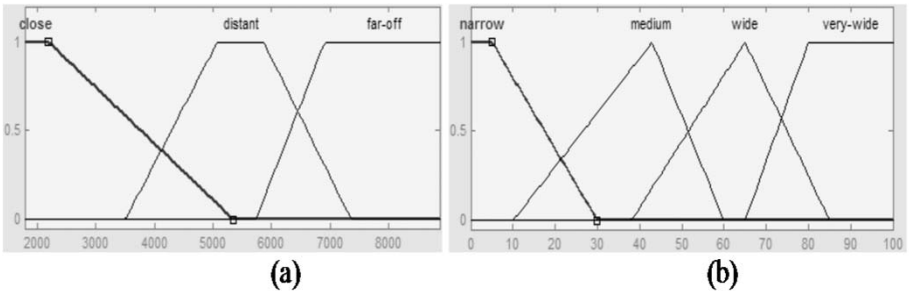

Figure 5. Schema of membership degrees of output variables

a) Block Distance (BM) **b)** Block Azimuth (BS)

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Creating the Fuzzy Logic Rule Base :

In this study, there are 3 membership functions for "the distance of the largest parcel", 4 for the "azimuth" and 2 membership functions for the variable of "Is the parcel area of 2nd criterion larger than the largest parcel area?" In addition, there are 2 output variables. A set of 288 rules (3×4×3×4×2=288) were created, considering the numbers of membership function. The 288 rules created in order to receive the results of the fuzzy system are connected with the conjunction [AND]. At this point, the Mamdani inference mechanism is utilized. These created rules were entered in the relevant part of the MATLAB Program Fuzzy Logic Toolbox to create the fuzzy rule base.

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Defuzzification:

The center of gravity method (centroid), which is the most common method for defuzzification, is used in order to defuzzy fuzzy output. While the centroid method is among the alternatives of MATLAB program, it is principally made with the mathematical formula below.

$$z^* = \frac{\int u_c(z).z dz}{\int u_c(z) dz}$$

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Obtaining the Results

In order to find which landholding is placed in which block, data are entered in Simulink block. Some of the data are given in Table 3.

Table 3. Fuzzy System Data

No	Landholding No	EPM	EPS	SP2PM	SP2PS	1/0
1	3	3069.55	59.47	1784.00	0.00	0
2	4	3069.55	59.47	1784.00	0.00	0
3	7	3069.55	59.47	1784.00	0.00	0
4	8	7239.98	47.36	1784.00	0.00	0
5	9	7239.98	47.36	1784.00	0.00	0
6	17	4341.35	64.71	5973.70	69.47	1
7	18	3771.33	66.45	1784.00	0.00	0
8	19	7960.02	60.01	7392.43	57.44	1
9	20	6728.11	81.04	5960.31	51.91	0
10	21	6232.55	53.71	6232.55	53.71	1
…	…	…	…	…	…	…
…	…	…	…	…	…	…

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Obtaining the Results

To determine the blocks in which the landholdings are reallocated, a grid system is organized in the project field (Figure 6). The grid system is organized by a 20×21 grid network in X and Y direction at 250 meters distances.

As seen in Figure 6, values derived from the FL system are in a convenient range. However; it can be seen that, in some regions, landholdings are intense, in some they are rare.

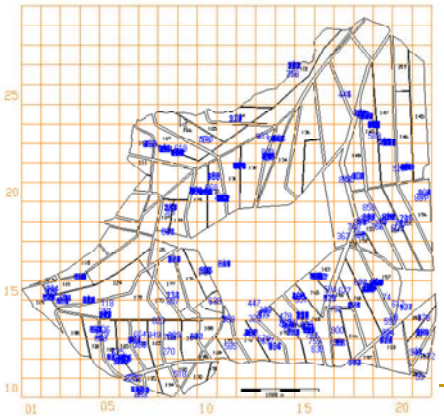

Figure 6. Grid System

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Obtaining the Results

Blocks numbered 130, 147, 152, 154, 160, 162, 163, 183 and 184 are extremely full. This is a result of the sizes of landholdings reallocated to blocks. The landholdings that are not completely filled are certainly placed in the same blocks after the first fuzzy land reallocation. The number of landholdings which are certainly placed is 390. However, some of the landholdings in full blocks need to be certainly reallocated. Landholdings with a single parcel and fixed facility can be given as examples. The number of this kind of landholding is 120. Therefore, the number of the certainly reallocated landholdings is 510. According to this, 71.33% (510/715) of the landholdings are successfully placed after the first land reallocation.

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Obtaining the Results

The land reallocation of the rest of landholdings is made via block balancing. In other words, landholdings in full blocks are placed in empty ones. To achieve this, 4 criteria below are taken into account in landholdings that can not be reallocated:

- Block with largest parcel,
- Block with fixed facility, parcel density or the second largest parcel,
- Block with the third largest parcel,
- Block with same parcel classification.

Land reallocation is completed using these criteria and parceling of landholdings in blocks is done.

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DISCUSSION

Number of Parcels:

The current and previous situations of the parcels belong to the landholdings in terms of the number of parcels in the study area are shown in Table 4.

Table 4. Examination of Models in Terms of Number of Parcel

Parcel size (da)	Cadastral situation	Interview-based model	Fuzzy logic-based model
	Number of Parcels	Number of Parcels	Number of Parcels
0-5	831	140	264
5-10	436	244	168
10-20	194	240	133
20-30	45	79	66
30+	30	51	81
Toplam	**1536**	**754**	**712**

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DISCUSSION

Average Parcel Size:

Table 5. The examination of the models in terms of average parcel sizes.

Parcel Size	Square	Increase Rate (%)
Previous parcel size	0.6441 ha	-
Parcel size based on the interview-based model	1.2895 ha	100
Parcel size based on the fuzzy logic-based model	1.3656 ha	103

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DISCUSSION

Duration and Cost of the Land Reallocation:

The cost of interview studies for Agalar village consolidation field was $26500, based on the commercial rates of the Chamber of Cadastral Map Engineers. Since the fuzzy logic based land reallocation model would not require an interview study, the project cost would be $26500 less. While 45 days were previously required for the preparation of the necessary data for land reallocation, in the fuzzy logic based land reallocation model, it was completed in a 25-day-period, thereby saving 20 days. The economic value of this saving is around $7650. In total, a 3-month-time saving could obtained for the Agalar village consolidation project.

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~~Examination of interview-based and fuzzy logic-based models on the~~ basis of landholdings:

The proportion of landholdings with one parcel is 37.76%. This rate is 75.10 % in the interview-based model after land consolidation, compared to 94.94% in the fuzzy logic based model. As far as possible, landholdings are combined in one parcel after land consolidation. The fuzzy logic based land reallocation model is more successful in terms of combining landholdings within one parcel than the interview-based land reallocation model.

Table 6. Evaluations on the basis of landholdings

Landholding No	Surname, name	Number of cadastral parcels	New parcel numbers after the interview-based model	New parcel numbers after the fuzzy logic - based model
24	Akgöl Mevlüt	4	2	1
70	Arı Ethem	3	2	1
74	Arık Mustafa	5	3	1
80	Arslan Güler	2	2	1
95	Aşık Mustafa	8	4	1

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Examination of interview-based and fuzzy logic-based models on the basis of landholdings:

The conditions of the cadastral parcels belonging to the 24th landholding are shown in Figure 2, the new parcels formed after applying the interview-based model are shown in Figure 7, and the parcels formed after applying the fuzzy logic based model are shown in Figure 8.

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Figure 2

Examination of interview-based and fuzzy logic-based models on the basis of landholdings:

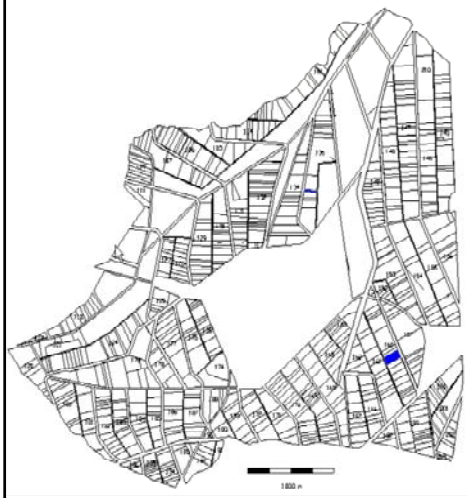

Figure 7. New Parcels of the 24th Landholding after the interview-based model

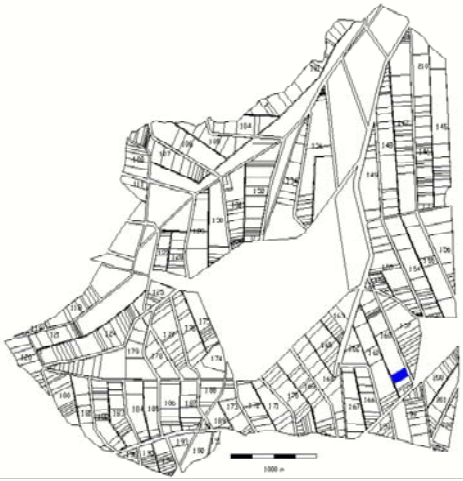

Figure 8. New parcels of the 24th landholding after the Fuzzy Logic Based Land Reallocation

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CONCLUSION

As a result of these comparisons, it has been concluded that the fuzzy logic based model was more successful in terms of *number of parcels*, *average parcel size*, *average number of parcels* per landholding, *duration of land reallocation* process, project cost and farmer satisfaction, whereas the interview-based land reallocation model proved to be more applicable in meeting the conditions set by the landholdings concerning their relatives and other landholdings.

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CONCLUSION

In the fuzzy logic based land reallocation model developed in the present study, more than half of the landholdings are given from the blocks with new parcels based on the interview-based reallocation model. When the interviews conducted with farmers to perform the interview-based land reallocation are analyzed, the fuzzy logic based land reallocation method gave quite successful results in fulfilling the requests of the landholdings. This is important, since farmer satisfaction is among the objectives of land consolidation.

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CONCLUSION

According to the results of the interviews conducted with the farmers, it appeared that they are much happier with the outcome of the fuzzy logic based land reallocation model than that of the interview-based land reallocation model. Considering the fact that farmer satisfaction is important in land consolidation projects, the fuzzy logic based land reallocation model is judged to have been successful.

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CONCLUSION

As a result of this study, a fuzzy logic based method can be recommend for the land reallocation procedure in land consolidation projects, since FL has suitable characteristics to model human processes of thinking and behavior. The application of FL to an increasing range of issues suggests that the FL method, which is currently used in areas such as engineering applications, will soon be used more widely.

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