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LAND GRADING ANALYSIS BASED ON FARMER OPINIONS USING FUZZY AHP

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Abstract: In land consolidation (LC) projects, grading is one of the most critical stages in determining parcel values fairly and accurately. The fact that the grading process is based on scientific methods, can be proven with mathematical calculations, and reflects farmers' opinions, increases the application's reliability and acceptability. In this study, as part of the LC project in Boyalılar village, Daday district, Kastamonu province, an expert team of farmers familiar with the LC area evaluated the parcels using the pairwise comparison method. These comparisons were analyzed using the Fuzzy Analytical Hierarchy Process (AHP). Agricultural advantages on the land were determined based on the farmer's knowledge, and the results were compared with grading maps prepared by the State Hydraulic Works (DSI). The study's findings revealed that the agricultural assessments of expert farmers and the soil index maps produced by the official institution were largely consistent. This demonstrates the parallelism between local knowledge and scientific data. However, differences were identified in the spatial assessments. While the DSI method only considers the administrative unit center and roads, farmer experts emphasized that proximity to the district center and neighboring villages should also be considered among the factors affecting parcel values. It was determined that location scoring should consider not only the administrative centers of the LC area but also proximity to all surrounding administrative units. In conclusion, the study demonstrates that interviews with farmers familiar with the application area can be reliable in rating studies, saving both time and reducing costs.

Keywords: Land consolidation, Rating, Farmer opinions, Fuzzy AHP

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1. Introduction

Land consolidation (LC) studies are an important tool used to increase land productivity, protect the ecological structure, improve farmers' living conditions, reduce land fragmentation, and ensure food security (Korthals Altes and Bong Im, 2011; Çay and Acar, 2022; Rao, 2022). They also support rural development (Acar and Bengin, 2018; Pašakarnis and Maliene, 2010) and contribute to the national economy (Bengin and Acar, 2018; Nguyen and Warr, 2020). LC is the process of re-registering and consolidating fragmented lands through inheritance, sale, or the opening of agricultural irrigation canals (Çay and İşcan, 2004; Acar and Akdeniz, 2023). Used as a well-established land management tool, especially in Europe and South Asia, LC has a history of over 100 years in Western European countries. Traditionally, its primary purpose is to reduce land fragmentation, support agricultural development, and facilitate voluntary farm expansion (Akdeniz and Acar, 2023; Akdeniz et al., 2023; Çay and Acar, 2025; Çay et al., 2025). Furthermore, the process is closely linked to developing agricultural infrastructure such as irrigation, transportation, and drainage, and is shaped by regional needs (Veršinskas et al., 2020). The Food and Agriculture Organization of the United Nations (FAO), in its 2020 Legal Guidelines on Land Consolidation, defined land consolidation as a legally based land management process implemented in rural areas to reduce land fragmentation, facilitate farm expansion, and achieve public interest objectives such as nature restoration and infrastructure construction (Hartvigsen and Gorgan, 2020). LC processes should be implemented per the Voluntary Guidelines for the Responsible Management of Land, Fisheries and Forests in the Context of Local Food Security (VGGT). One of the fundamental principles of VGGT is the protection of legitimate property rights. In this context, landowners and farmers participating in LC projects are expected to be guaranteed to have at least the same conditions as before the project (FAO, 2012). Rating studies are being conducted to prevent loss of rights during the redistribution of parcels. The first LC applications in Türkiye began in 1961, and different rating methods were developed based on various laws and regulations. Farmers familiar with the project area also serve on the rating committees established within this scope and contribute to the preparation of the rating maps. According to the regulation that came into effect in 2019, the commission's contribution is set at 15% of the total score (Anonymous, 2019).

However, in some projects, farmer feedback was found to be inconsistent with the rating maps prepared by the institution. This study examined the land consolidation application in Boyalılar village, Daday district, Kastamonu province. Using fuzzy logic methods, the superiority of all parcels was compared, taking only farmer feedback into account. Based on farmer feedback, the rating map was compared with the official rating map prepared for the Project. As a result of the comparison, location, soil, and parcel-focused analyses were conducted to investigate the differences and advantages of the rating maps.

2. Materials and Methods

In this study, the LC project in Boyalılar Village, Daday District, Kastamonu Province, completed in 2016 using the new rating method prepared per the Land Consolidation Directive, was selected as the application area (Figure 1). The parcel index in the LC project was calculated using the following equation 1 (Anonymous, 2010):

New Rating = Soil Index (40) + Location Index (20) + Asset Score (30) + Commission Score (10) (1)

Figure 1. Boyalılar village settlement map.

The total number of parcels subject to regulation in Boyalılar village is 209. The total number of parcels subject to regulation in Boyalılar village was 208. After the regulation, the number of parcels decreased to 178. The average parcel size increased from 3.68 decares before the regulation to 3.85. In the area where the LC study was conducted, the village headman and three farmers familiar with the area were selected as experts. In this context, interviews were conducted with the experts regarding the general structure of the village. Following these interviews, the rating map was reconstructed by comparing the lands of Boyalılar village using the pairwise comparison method. Chang's (1996) fuzzy scale was used for pairwise comparisons in this study (Table 1) (Cheng, 1997).

2.1. Fuzzy AHP Method

The fuzzy AHP method consists of the following steps: developing the problem hierarchy, obtaining fuzzy comparison matrices, calculating fuzzy synthetic scopes, comparing fuzzy synthetic scopes, evaluating the minimum probability degree, and normalizing the weight vector (Table 1).

Table 1. Triangular fuzzy scale table

Linguistic Variables	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
Equally important	(1, 1, 1)	(1, 1, 1)
Moderately important	(2/3, 1, 3/2)	(2/3, 1, 3/2)
Important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Extremely important	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

This study selected three experienced farmers and the village headman, well-versed in the local land structure in Boyalılar Village, Daday District, Kastamonu Province, as experts. Comprehensive face-to-face interviews were conducted with these individuals. The interviews provided detailed information at both the parcel level and in terms of topographic and agricultural characteristics, and the findings were used in the re-grading process of the village lands.

In this context, all parcels were evaluated using the pairwise comparison method, and the relative value of each parcel compared to neighboring parcels was determined. The comparison process was based on the fuzzy comparison scale proposed by Chang (1996), and Chang (1996) was used as a reference in the implementation (Table 1).

These groups, created based on expert opinions, are presented in detail below:

Equal Value Parcels: Experts stated that parcels with parcel numbers 214, 215, 216, 217, 218, 219, 220, 221, and 222 are of equal value.

Better Parcels: Parcels with parcel numbers 212, 211, 203, 202, 201, 200, and 199 are better valued than the previous group due to their closer location to the village square.

Much Better Parcels: Experts have emphasized that parcel numbers 197, 198, 205, 223, 210, 209, 225, 226, 227, 228, 229, 230, 90, 91, 92, and 213 are in the much better value group due to their proximity to the village square and their frontage on the Daday district road. Parcels with the Same Value: Parcels with parcel numbers 157, 169, 168, 167, 166, 165, 164, 163, 162, 172, 173, 174, 175, 176, 177, 300, 302, 303, 304, 305, 306, 307, 178, 179, 180, 181, 182, 184, 185, 186, 187, 191, 192, 193, 194, 195, and 196 are classified as having the same value because they have similar locations and agricultural structures. Worse Parcels: Parcel numbers 146, 147, 148, 149, 150, 151, 152, 153, 154, 158, 159, 160, and 161 are reported to be of lower value due to their location away from the village center and lower productivity.

Improved Valuable Parcels: Parcel numbers 93, 94, 95, 96, 97, 98, 99, 100, 101, 112, 110, 111, 144, 143, 142, 140, 141, 145, 125, 124, 113, 361, and 116 are reported to be in better condition compared to the previous group due to their frontage on the Daday road. Parcels Close to Daday: Parcels with parcel numbers 102, 103, 104, 105, 106, 107, 109, 360, and 115 are classified as more valuable due to their proximity to the Daday district center and road connections.

Parcels with the Same Value: Experts have stated that parcels with parcel numbers 117, 118, 120, 123, 122, 39, and 140 are in the same value group due to their similar characteristics.

Far Less Valuable Parcels: Parcel numbers 36, 35, 34, 30, 75, 74, 73, 72, 88, 61, and 65, located north of the Daday road in Boyalılar Plain and considered agriculturally unproductive by experts, are classified as being in the lowest value group. In addition, parcels numbered 85, 84, 83, 82, 81, 80, 79, 51, 52, and 42, close to the borders of Görük Village and facing the cadastral road, were stated to be better than other parcels due to their locational advantages.

Furthermore, experts noted that parcel number 1 had a superior agricultural structure to neighboring parcels.

Consequently, based on expert opinions, this classification was simplified by grouping parcels of similar value to ensure the applicability of the paired comparison method proposed by Chang (1996).

Thus, the analysis of 209 cadastral parcels revealed five different degree groups. The paired comparison matrix is shown in the Table 2, 3, 4, 5, 6, 7.

This methodological approach aims to provide decision support through weighting based on expert opinions and to integrate farmer-based local knowledge into the rating process. The developed rating method also applies to other agricultural areas with similar characteristics.

Five different ratings were identified in the rating map prepared based on farmer feedback. The rating map created in this context is shown in Figure 2.

3. Results

The rating map obtained in the study conducted in Boyalılar village and the rating maps prepared by the State Hydraulic Works (DSI) according to the ATT (Land Consolidation Instructions) are shown in the Figure 5. The rating map, obtained after consultations with experts, is not based on numerical data but was generated through pairwise comparisons. The parcel index for this map was set at 100 points as the highest value, and then calculated using weights derived from the fuzzy AHP (Agricultural Research Council) and included in the calculations: Grade 2: 86.79 points, Grade 3: 72.36 points, Grade 4: 62.33 points, and Grade 5: 50.29 points (Figure 2).

A rating commission was established to consider the opinions of local farmers when creating the rating maps. The commission score for the rating formula based on the ATT is 10 points. A significant difference is observed between the two rating maps. This indicates that the rating map prepared according to the ATT does not meet farmers' expectations.

Table 2. Representation of pairwise comparisons by farmers with fuzzy triangular numbers

	1			2			3			4			5	
1	1	1	1	0.67	1	1.5	0.67	1	1.5	1.5	2	2.5	1.5	2	2.5
2	0.67	1	1.49	1	1	1	0.67	1	1.5	0.67	1	1.5	1.5	2	2.5
3	0.67	1	1.49	0.67	1	1.49	1	1	1	0.67	1	1.5	0.67	1	1.5
4	0.4	0.5	0.67	0.67	1	1.49	0.67	1	1.49	1	1	1	0.67	1	1.5
5	0.4	0.5	0.67	0.4	0.5	0.67	0.67	1	1.49	0.67	1	1.49	1	1	1

Table 3. Fuzzy triangle number values of criteria

1	5.34	7	9
2	4.51	6	7.99
3	3.67	5	6.99
4	3.4	4.5	6.15
5	3.13	4	5.32

Table 4. Normalized weights of criteria

	l	m	u
S1	0.15	0.26	0.45
S2	0.13	0.23	0.4
S3	0.1	0.19	0.35
S4	0.1	0.17	0.31
S5	0.09	0.15	0.27

l= lower limit, m= most likely, u= upper limit, S_1, S_2, S_3, S_4, S_5= fuzzy synthetic extent value.

Table 5. Degree of possibility

1	2	3	4	5
M1	1	1	1	1
0.87	M2	1	1	1
0.72	0.85	M3	1	1
0.62	0.76	0.91	M4	1
0.5	0.65	0.81	0.9	M5

M_1, M_2, M_3, M_4, M_5= fuzzy extent value or fuzzy judgment value.

Table 6. Weights

Minimum		Weight
1	Land	0.268986
0.87	Location	0.233444
0.72	Infrastructure	0.19465
0.62	Transportation	0.167649
0.5	Plot Shape	0.135271

Table 7. Weights to be used in the LC Project

1st Degree	100
2nd Degree	86.79
3rd Degree	72.36
4th Degree	62.33
5th Degree	50.29

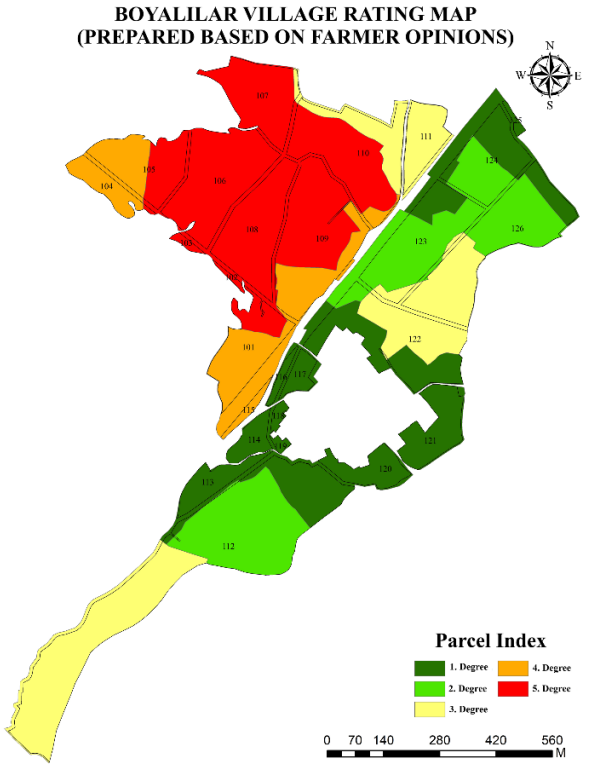

Figure 2. The Boyalılar village rating map was prepared according to farmers' opinions.

3.1. Location-Based Comparison

The LC project in Boyalılar Village was graded according to the new regulations published in 2010. The project assigned a maximum location score of 20 points. Parcels near the village center were assigned up to 10 points as part of this score.

Our experts' statements indicated that the Boyalılar village center and the Daday district road were considered valuable, similar to the DSI location map. Furthermore, unlike the DSI location map, the eastern part of Boyalılar village's land was valued due to its proximity to the Daday district center, and the northeastern part to the village center of Görük village. It was stated that the higher value of land in the eastern part of Boyalılar village compared to land in the western part is due to its proximity to the Daday district (Figure 3).

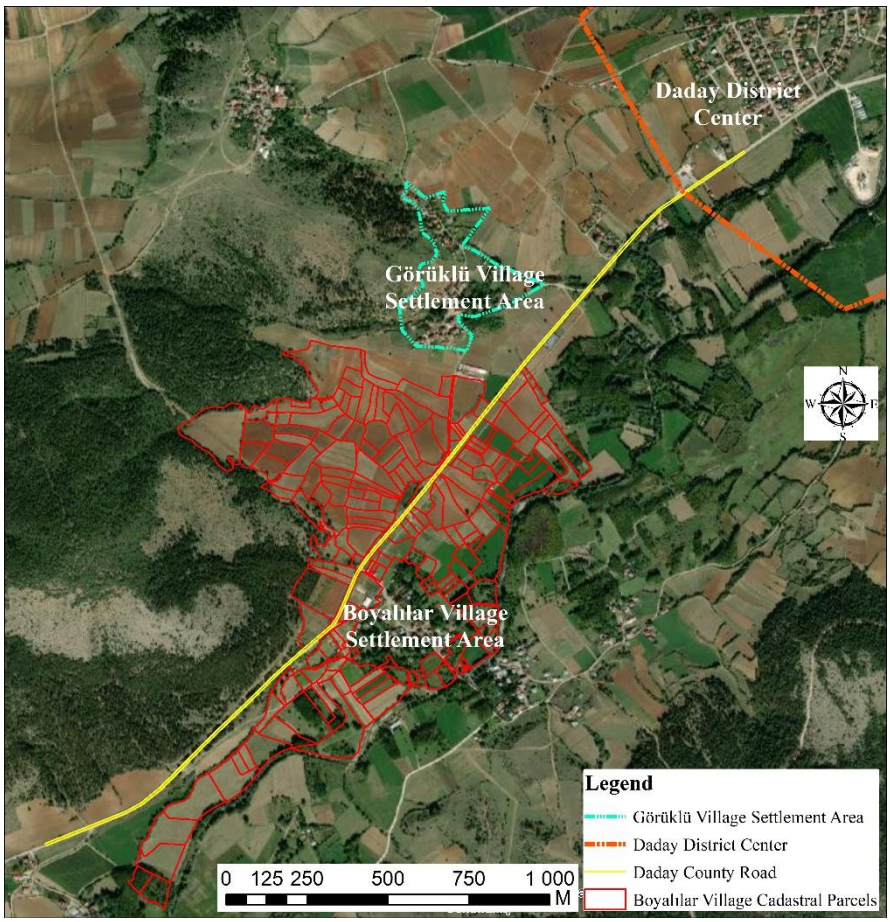

Figure 3. Boyalılar village and Görük village settlement map.

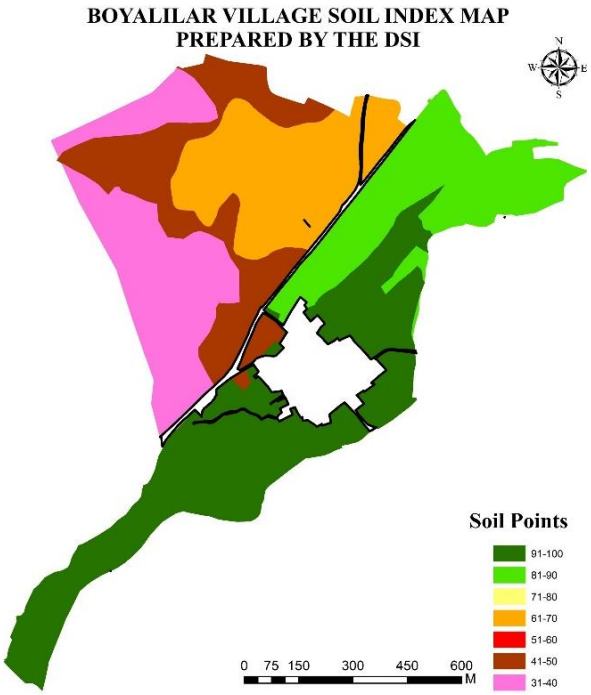

Figure 4. Boyalılar village soil index map.

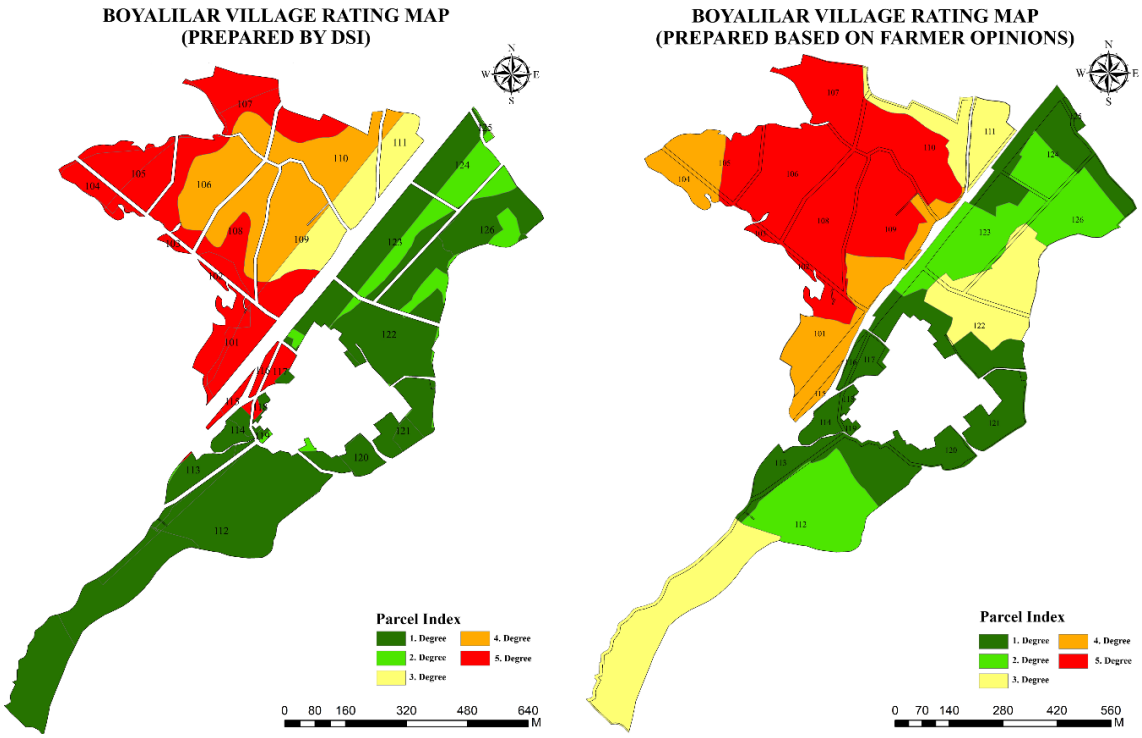

Figure 5. Boyalılar village comparison maps.

3.2. Soil-Based Comparison

According to the regulations and statutes in force in Türkiye, soil surveys are conducted according to the Storie index during grading in LC fields. The value of agricultural land is determined using the Storie index, first proposed by R.E. Storie in 1933 and later revised in 1978 (Uzunal and Arslan, 2025). The soil map shown in the Figure 4 was obtained from soil grading studies conducted in Boyalılar village. When the soil index map was compared with experts' opinions, they stated that the lands north of the Daday road were less productive than the lands south of the road. An examination of the DSI soil map reveals similar results. The soil index map shows that the lands north of the Daday road have low soil scores, while the south have high soil scores (Figure 4).

3.3. Comparison of Rating Maps

The rating map prepared by the State Hydraulic Works (DSI) for land consolidation work in Boyalılar Village is presented on the left side of the Figure 5, while the rating map based on farmer feedback is presented on the right. Comparisons reveal that parcels, particularly those around the village center, received similar rating scores. However, the vast majority of parcels located south of the highway dividing the study area into two were found to be in the 1st, second, and 3rd degree classes. In contrast, parcels located to the north were predominantly in the 3rd, fourth, and 5th degree classes (Figure 5).

While the maps are generally similar, detailed examination reveals some differences. For example, in the northeastern part of the village, in blocks 111 and 110, adjacent to Görük Village, the map prepared based on farmer feedback predicts a 3rd degree classification. In contrast, the DSI map shows these areas as 4th and 5th degrees. Similarly, block 112, located in the southwest of the village, was rated 1st degree by the DSI; the same area was classified as 3rd degree on the map based on farmer feedback. These findings suggest that the rating map produced by DSI within the ATT framework does not adequately reflect local farmers' views. Therefore, considering farmer experiences will contribute to the rating process, producing more comprehensive, realistic results that reflect field-use value (Figure 5).

4. Discussion

One of the most critical stages of land consolidation projects is the grading of agricultural land. The literature addresses this process using various methods. For example, Demetriou (2018) developed a GIS-based automated valuation model, emphasizing the unreliability and time-consuming nature of traditional ratio-based approaches. This model evaluated parcel values and locational factors based on hedonic price functions and demonstrated that the results were superior in speed, cost, and reliability.

Similarly, Demiraslan et al. (2019) stated that the equal consideration of market value and soil class maps in existing valuation systems leads to loss of rights, undermining the sense of fairness of projects. Their study emphasized developing a more equitable and accurate valuation mechanism.

Zrobek et al. (2020) proposed a fuzzy logic-based approach to the valuation of agricultural land, demonstrating that decision-making processes can be managed more effectively with the algorithm they developed in MATLAB. In this respect, their study offers an alternative method for analyzing the agricultural real

estate market. Furthermore, Van Dijk (2003) stated that market value is not an appropriate criterion for land consolidation, but rather that soil production potential is a more accurate criterion. Furthermore, Scarelli and Venzi (2004) argued that farmers' experiences and natural and productive relationships with neighboring parcels should be considered in determining land values. Leń (2017) proposed a multidimensional, scientifically based approach for project prioritization.

Unlike approaches in the literature, this study produced a rating map based directly on farmers' opinions and compared it with the official rating map created by the State Hydraulic Works (DSI) based on the Land Consolidation Regulation (ATT). The results indicate that the DSI map does not adequately reflect farmers' experiences, with significant differences particularly evident in certain blocks (e.g., blocks 111, 110, and 112). Therefore, the unique contribution of this study is its introduction of a rating approach that solely considers the knowledge and experience of farmers in the field. This situation makes the inconsistencies between local knowledge and official practices in the land consolidation process visible and clearly demonstrates the need for a more inclusive, fair, and sustainable rating system.

4. Conclusion

The grading process is one of the most critical stages of land consolidation work. This process, based on scientific methods and verifiable through mathematical calculations and by reflecting farmer opinions, ensures that the practices are fair and applicable.

In a study conducted in Boyalılar Village, Daday district, Kastamonu province, a team of expert farmers familiar with the LC area evaluated the comparative advantages of parcels using the paired comparison method. The study findings demonstrated a general agreement between the agricultural assessments based on farmer opinions and the soil index maps prepared by the State Hydraulic Works (DSI). This demonstrates that farmers' experiences align with scientific data in the field.

However, some differences were noted in the location assessments. In the DSI maps, the location factor was determined solely based on the administrative unit center and road connections of the LC area. However, expert farmers emphasized that proximity to the Daday district center and neighboring settlements such as Görük Village influence parcel values. This finding suggests that location should be considered within a broader spatial framework.

Another important finding of the study is that the method based on farmer opinions offers advantages in terms of time and cost in implementation. This method directly reflects the knowledge of local actors with expertise in the land and offers a more practical and cost-effective evaluation opportunity than official methods.

In conclusion, this study demonstrates that the rating process in LC projects should be based not only on official criteria but also on farmers' field-related knowledge and experience. In particular, considering distances not only to the administrative center of the consolidation site but also to all surrounding settlements in determining the location criteria will contribute to developing a more realistic and comprehensive rating approach.

In future research, applying the developed method to different geographical regions, climatic conditions, and areas with different cropping patterns is crucial for assessing the model's generalizability. Such comparative studies will play a critical role in testing the method's reliability and demonstrating its adaptability to different regional conditions.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	M.N.S.	T.Ç.
C	60	40
D	60	40
S	60	40
DCP	60	40
DAI	60	40
L	60	40
W	60	40
CR	60	40
SR	60	40
PM	60	40
FA	60	40

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Approved by the Scientific Research and Publication Ethics Board of the Konya Technical University Rectorate (approval date: 05.06.2024 protocol code: 161580).

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