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Finding least fragmented holdings with factor analysis and a new methodology: a case study of kargılı land consolidation project from Turkey

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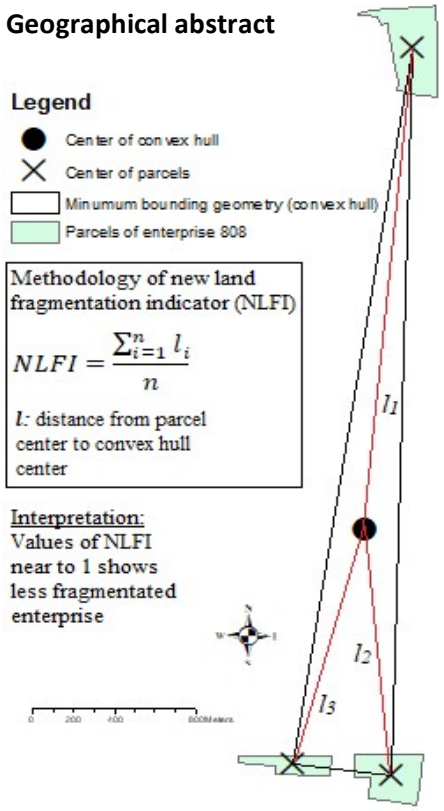
Abstract. Land fragmentation (LF) is a problem restrain agricultural activities and decrease mechanization level, production. Land consolidation (LC) projects are done in the World as well as Turkey to solve LF issues. Researchers created indicators to measure land fragmentation which is important to see success level of LC projects. The use of these indicators is controversial or not accurate. The core aim of the present study is to find new land fragmentation index and to find least fragmented holding with factor analysis using the other indicators which are Simmons, Januszevski, number of parcels, Shmook and Igbozurike besides new land fragmentation index. Kargılı Village land consolidation project in Mersin, Turkey was chosen as a material. Cadastral data before land consolidation, was used to calculate value of indicators, where number of parcels was 932, total area was 1,741.9 ha, the average parcel size was 1.9 ha, number of holdings was 542 and the average parcel size was village had 932 parcels. Data processing were performed with ArcMAP 10.6.1 and SPSS. A total of 18 holdings were identified randomly as sample size which were sufficient to carry out factor analysis including principle component to rank holdings ($P < 0.01$).As a result, new land fragmentation index found correlated with others ($P < 0.01$) and ranking according to new indicator performed better than ranking considering all indicators. In this context, it is possible to use new land fragmentation indicator to determine priority areas for land consolidation.



Key words: GIS, factor analysis, land consolidation, land fragmentation indicators.

INTRODUCTION

The best criteria of agricultural is the high production efficiency increase with low cost. Land fragmentation is the one of problem restrain good agricultural practices to reach the goal (Gonzales, 2004; Hristov, 2009; Vijulie et al., 2012; Kirmikil & Arici, 2013; Küsek, 2014; Looga et al., 2018). For this reason, measuring the land fragmentation level is of considerable importance (Kadigi et al., 2017). In accordance with this purpose, rural areas have been developed under the name land consolidation, land reform and land administration in the world (Burton & King, 1982; Agrawal 1999; Sabates-Wheeler 2002; Niroula & Thapa 2005; Miranda et al., 2006; Sikor et al., 2009; Hartvigsen 2014; Li et al., 2018; Stańczuk-Gałwiaczek et al., 2018). In Turkey, land consolidation projects have been done with investments in high amounts to demolish land fragmentation and irregular shaped parcels. Approximately 5.1 million ha area was consolidated and these projects are conducted on 1.9 million ha in the country. Moreover, it is planned to finish land consolidation projects on 14 million ha until 2023 (TAGEM, 2017). The land consolidation projects have been carried out in Turkey, increases the importance of monitoring and evaluating these projects. One of one important output is decreasing land fragmentation related with agricultural production (Kumbasaroğlu et al., 2007; Tuğay, 2012; Looga et al., 2018), fuel consumption (Polat & Manavbaşı, 2012), rural roads (Kuzu et al., 2019), carbon dioxide emissions (Değirmenci et al., 2017) and mechanization (Küsek, 2014). For the purpose of monitoring and evaluating land management, many indexes have been developed and used to measure land fragmentation (Simmons, 1964; Januszewski, 1968; Ibgozurike, 1974; Schmook, 1976; Demetriou et al., 2011; Looga et al., 2018). In the study of Demetriou et al.(2013) mentioned that land fragmentation indices don't serve the purpose and the new index of Demetriou et al.(2011) may meet the demands for a specific project. Measurement of land fragmentation with existing indices does not give accurate result or have a lot of factors which are spatial distribution of parcels, size of parcels, shape of parcels, accessibility of parcels, type of ownership and shared ownership. For this reason, there is a need for new indexes to measure land fragmentation quickly, easily applicable and effectively.

The core aim of the present study is to develop a new approach to measure land fragmentation for land consolidation projects in terms of spatial distribution of the parcels belong the holdings. We compare the new index with commonly used land fragmentation indices using factor analysis and correlation. The new index is calculated with the help of geographic information systems and is based on land fragmentation level decrease as the distance decrease between the parcels belong the holding.

MATERIALS AND METHODS

Material

Kargılı land consolidation project, which was finished project in Mersin, Turkey, was chosen as a material in the study. Cadastral data before LC, given in Fig. 1, was used to measure land fragmentation indices. Kargılı LC project covers 1,741.9 ha including 932 parcels belong 542 holdings. Data, containing holdings information and map, was obtained from the state-run private company made the project.

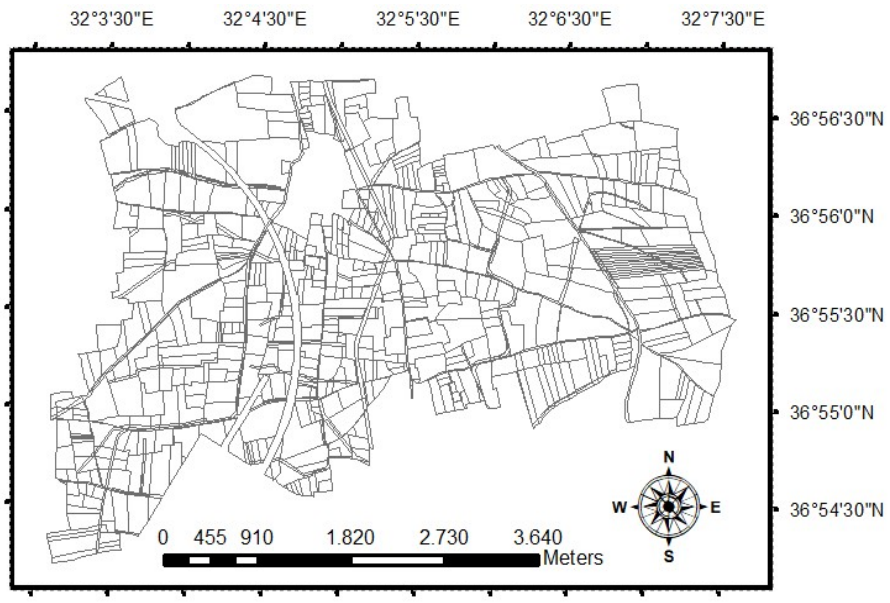


Figure 1. Cadastral map of Kargılı land consolidation project.

Generally, a program NetCAD is used to conduct land consolidation process in Turkey. Land fragmentation level was measured for a number of holdings due data available for calculation methods. The holdings evaluated were chosen randomly. The adequacy of this sample size was measured with Kaiser-Meyer-Olkin (KMO) test which is first step of the factor analysis. Detail of factor analysis stages are given in the methodology part. The features of the holdings evaluated are given in Table 1.

Table 1. Main features of the holdings evaluated

Holdings no*	Total area (ha)	Number parcel
1009	48.83	8
1034	6.3	3
147	0.02	3
209	0.29	2
256	0.05	2
300	34.65	3
369	0.02	2
503	0.01	2
647	734.52	12
717	11.47	4
755	29.30	4
780	6.96	6
785	539.73	15
808	30.73	3
896	326.07	6
919	290.14	21
966	29.17	3
969	1,013.02	15

*Original holding no in the project was used to avoid confusion in the calculations and the rank.

Methodology

Calculation of land fragmentation indicators

The various indices were used to determine land fragmentation level in the project. These indices are Simmons, Januszevski, number of parcels, Shmook, Igozuruke and new land fragmentation index. Formula of the indices, optimum values and correction factor are given below. Correction factor is a parameter which is used to do factor analysis. Indices can be corrected with +1 or -1. Indices are taken correction factor +1 are the indices we want them increase while the indices with correction factor -1 are the indices we want them decrease.

Main idea of the new land fragmentation index is 'if parcels comes closer, fragmentation level decreasing' or vice versa. Process of calculation index comprise of a number of steps in ArcMAP 10.6.1. Calculation algorithm of NLFI is given in the graphical abstract and the steps following:

1- Changing parcel feature from polygon to point (feature to point)

2- Creating minimum polygon covering all parcels (minimum bounding geometry with convex hull)

3- Changing the minimum bounding geometry from polygon to point (feature to point)

4- Calculating distance from parcel centre to minimum bounding geometry (point distance)

5- Calculating the new land fragmentation index with the formula

Factor analysis

Factor analysis is used for many purposes such as data reduction, selection of the representative variables from large data set, clustering and ranking. In the present study, factor analysis was used to rank the indices in order of the land fragmentation level. According to the analysis, the land fragmentation level of the holdings were determined using all indicators. In the factor analysis, rotational method were used with varimax which are used mostly (Özdamar, 2017). The overall performance of each holding were obtained and used to rank them.

Applying the factor analysis consist of 8 steps following (Alpar 2017):

1- Calculating min, max and mean values of the land fragmentation indices for all holdings

2- The aim of this step is to normalize the smallest value to 0, the maximum value to 1 and to spread all other data to the range of 0-1. Calculating normalized values of the indices was defined as Eq. (1):

$$NV = \frac{X - \min(X)}{\max(X) - \min(X)} \quad (1)$$

where NV: normalized value¸ X: the observation (a specific value of the land fragmentation index we are calculating for SV); min(X): minimum value of the observation; max(X): maximum value of the observation.

3- Applying principle component analysis with a statistical program to get coefficients of each land fragmentation indicator for the holdings

4- Calculating % weight of the coefficients each land fragmentation indicator for the holdings according to Eq. (2):

$$Coef\% = \frac{100 \times C_i}{\sum_{i=1}^{n} C_i} \quad (2)$$

where Coef% = % weight of the coefficient; Ci: i-th coefficient obtained from principle component analysis.

5- Corrected values of the coefficients (Coef%) according to correction factor of the indices. The correction factors of the indices was given Table 2. Corrected values are calculated with Eq. (3):

$$CV = CF \times Coef\% \quad (3)$$

where CV: corrected values of the indices; CF: correction factor; Coef%: % weight of the coefficient.

6- Calculation of the weighted indicator values for each component formed by principle component analysis according to Eq. (4) below:

$$WIV_{Ci} = \sum_{i=1}^{n} CV_i \times NV_i \quad (4)$$

where WIVCi: Weighted indice values of i-th component; Ci: i-th component formed by principle component; CVi: corrected calues i-th indice; NVi: normalized value of the i-th indicator.

Calculation of the overall holding scores according to Eq. (5):

$$S = \sum_{i=1}^{n} V_i \times WIV_{Pi} \quad (5)$$

where S: Score of a holding; Vi: % of variance explained by the component; WIVCi: Weighted indice values of i-th component; Ci: i-th component formed by principle component.

7- Ranking the holdings according to the scores calculated by the set of formula.

Shortly, in statistical evaluation, correlation was used to investigate statistical relation between indicators and factor analysis to rank the holdings according to all indices.

Table 2. Calculation methods of land fragmentation indices

Index	Formula	Resource	Optimum values	Correction factor	Parameters needed
Simmons	$Simmons = \frac{\sum_{i=1}^{n} A_i^2}{A}$	Simmons (1964)	1	+1	**A_i:** Area of *i*th parcel
Januszewski	$Januszewski = \frac{\sqrt{A}}{\sum_{i=1}^{n} \sqrt{A_i}}$	Januszewski (1968)	1	+1	**A:** Total size of the holding
Number of parcels	Total number of parcels of the holding	Anonymous	1	-1	**n:** number of parcels belong the holding
Schmook	$Schmook = \frac{\sum_{i=1}^{n} A_i}{A}$	Schmook (1976)	0	-1	**Dt:** Total length of round trip distance covering all parcels belong the holding
Igbozurike	$Igbozurike = \frac{\sum_{i=1}^{n} (\frac{A_i}{100}) \times Dt}{n}$	Igbozurike (1974)	1	+1	**l_i:** Distance from *i*th parcel centre to convex hull centre
New land fragmentation index	$NLFI = \frac{\sum_{i=1}^{n} l_i}{n}$	-	0	-1	

RESULTS AND DISCUSSION

The descriptive statistics of the indices are given Table 3. The indices have different range. Variation coefficient shows the distribution function of Schmook and Igbozurike indices calculated for the holdings is more heterogeneous than the other indices.

Table 3. Descriptive statistics of the indices

	Minimum	Maximum	Mean	Std. Deviation	Variation coeff (%)
Simmons	0.24	0.83	0.50	0.18	36.00
Januszewski	0.09	0.90	0.37	0.22	59.00
NoP	2.00	21.00	6.33	5.65	89.26
Schmook	0.00	0.13	0.04	0.06	150.00
Igbozurike	0.53	147.00	30.72	35.31	114.94
NLFI	25.21	1,813.30	858.27	594.33	69.25

The correlation matrix given in Table 4 show the index Igbozurike is only correlated negatively with the index and significant at 0.05 level. Igbozurike which calculated with the parameters area and total length of round trip distance covering all parcels belong the holding is differ from the other indices with this parameters. Simmons and Januszewski were found positively correlated and very similar as in the previous studies (Değirmenci et al., 2017; Demetriou et al., 2013). Schmook and NLFI are the only indices correlated with the other indices. As a result, the correlation between the new fragmentation index and other indices is a positive result for its usability.

Table 4. Pearson correlation coefficient matrix

Indicators	Simmons	Januszewski	NoP	Schmook	Igbozurike	NLFI
Simmons	1					
Januszewski	.943**	1				
NoP	-.721**	-.576*	1			
Schmook	.801**	.811**	-.473*	1		
Igbozurike	-.316	-.388	.299	-.530*	1	
NLFI	-.593**	-.560*	.629**	-.715**	.615**	1

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

Sample adequacy of the factor analysis was measured with Kaiser Meyer Olkin and Barlett test and was found 0.68 and 86.50, respectively ($P < 0.01$). As a result of factor analysis, 3 components were formed explain 92% of the total variance. The rotated component matrix is given Table 5.

Table 5. Rotated component matrix

Index code	Index	PC1	PC2	PC3
A	Simmons	0.454	0.384	0.117
B	Januszewski	0.443	0.289	0.357
C	NoP	-0.374	-0.242	0.763
D	NLFI	-0.412	0.336	0.315
E	Schmook	0.443	-0.05	0.418
F	Ibgozurike	-0.301	0.771	-0.063
Variation explained (%)		0.67	0.15	0.10

We can see from Fig. 2, the fragmentation indices with principle component coefficients close each other are cumulated together in terms of similar values of land fragmentation indices. For instance, the holdings with no 147, 369 and 503 are cumulated and have similar values of land fragmentation. The distance increase between the holdings means their values of land fragmentation differ while distance decrease between the holdings means they have more similar features.

The holdings closer to tip of the index line illustrate they related more each other. And it also means they have more optimum value in terms of the indices which they are closer to the end of the index lines (blue). In the graph, on the left side number of parcels, new land fragmentation index and Ibgozurike are more similar than the indices on the right side (Simmons, Januszewski and Schmook). Another feature the graph is that we can easily examine the correlation between the indicators supporting Table 5. The acute angle between indicators show positive linear correlation while the wide angles show relation between the indices decrease. The holdings close each other have similar values, the holdings asunder have different values. We can also see from success rating, these holdings are also close each other (Table 5).

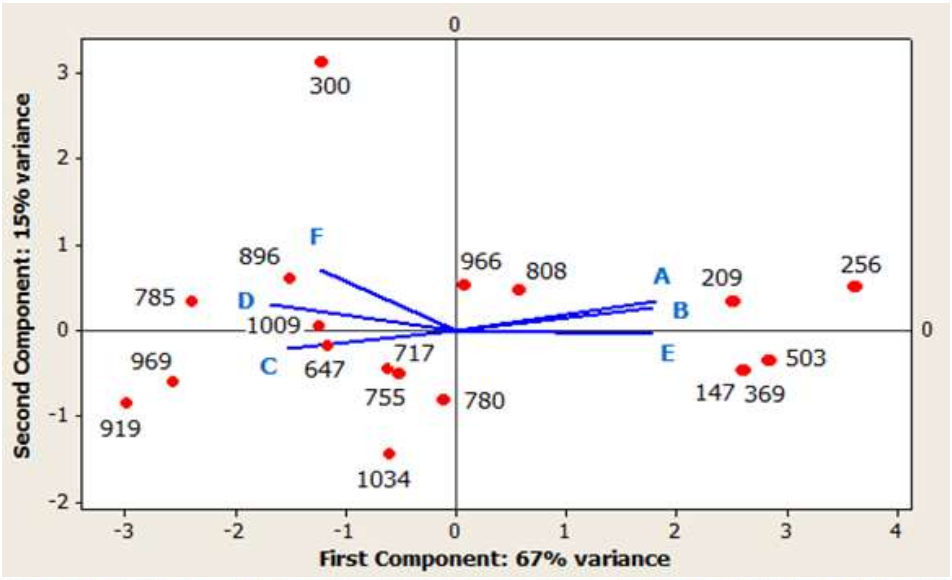


Figure 2. Biplot graph.

Table 6 clarify ranking the holdings with overall score besides new land fragmentation index. The least fragmented holdings are on the top of the list when the most are on the end of the list. The overall ranking is similar with the NLFI ranking, even the top 4 holdings are same but the order is different. The holding no 256 is top of the overall ranking when it is the 4th in the other ranking. When we investigate the parcels of the holding no 256, we can clearly see the holdings with 503, 369 and 147 are less fragmented than the holding 256. It can be said that these holdings are not fragmented due to no gap exist between the parcels. This prove NLFI perform better than the others. When we focus on the most fragmented holding with no 919 according to overall performance is not on the bottom of the NLFI rank. Indeed, the holding with no 969 which is the most fragmented holding in reference to NLFI is examined, it was more fragmented than the holding 919. According to ranking of NLFI and the overall ranking of all indices, we can say that we can use the new index instead of using a lot of factors. It may be possible use NLFI interchangeably.

Table 6. Overall ranking of the holdings and comparison with new land fragmentation

Overall			New land fragmentation index		
Holding no	Score	Rank	Holding no	NLFI	Rank
256	4,113.25	1	503	25.21	1
503	3,323.18	2	369	40.63	2
369	3,161.72	3	147	66.29	3
147	3,101.84	4	256	130.06	4
209	2,961.80	5	1034	291.14	5
808	771.69	6	780	415.47	6
966	295.46	7	717	629.15	7
780	203.78	8	209	724.46	8
717	-214.64	9	808	985.62	9
1034	-233.17	10	755	994.62	10
755	-343.53	11	966	1,061.69	11
647	-939.21	12	1,009	1,122.02	12
1009	-994.05	13	647	1,262.37	13
300	-1104.63	14	919	1,272.89	14
896	-1,305.83	15	300	1,295.40	15
785	-2,180.84	16	785	1,538.14	16
969	-2,305.62	17	896	1,780.41	17
919	-2,678.12	18	969	1,813.30	18

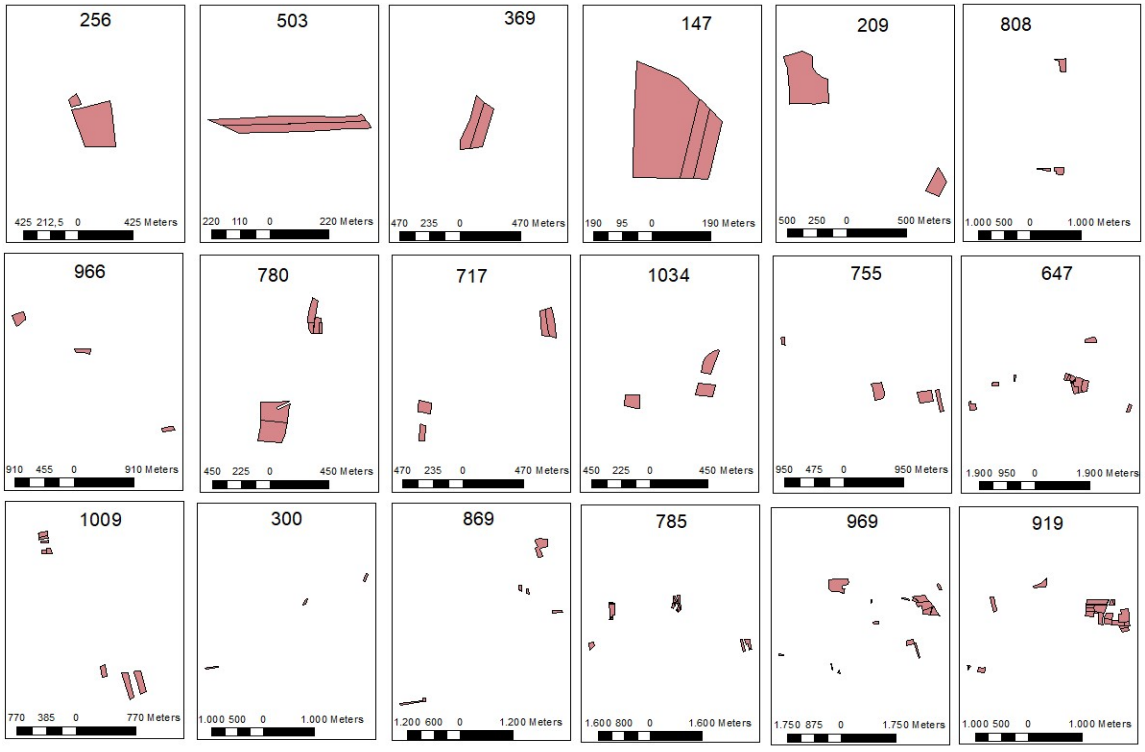


Figure 3. Spatial distribution of the parcels belongs the holdings.

Land fragmentation is effected by various parameters including holding size, number of parcels, size of parcels, shape of parcels, spatial distribution of the parcels, size distribution of parcels and internal fragmentation (Platonova et al., 2011; Demetriou et al., 2011; Aasmäe & Maasikamäe, 2014; Siik & Maasikamäe, 2015; Looga et al.,

2018; Kirmikil et al., 2017). In this studies, shortly it is explained that fragmentation measurement is the substantial matter and can be measured with many factors. The correlation, principle component results and overall rank indicate that new index can be used interchangeably. The new index doesn't show shape measurement and hidden land fragmentation but spatial distribution of the parcels belong the holdings.

CONCLUSIONS

The main purpose of the present study was to investigate a new methodology to measure land fragmentation which has various effect on agricultural production. In this context, new land fragmentation index was created and compared with the other indices including Simmons, Januszewski, number of parcels, Schmook and Ibgozurike. These indices was calculated for 18 holdings in Kargılı before land consolidation project in Turkey. The overall performance score of the previous indices was calculated with factor analysis and were used to rank the holdings. The ranking occurred as a result of factor analysis was compared with the ranking of the new index. As a conclusion, new land fragmentation index showed similar performance in some cases with the other indices and it was found correlated with the other indices. However, in most cases we may say new land fragmentation index show better performance explain scattered parcels. This new index has value in terms of measurement of agricultural productivity and priority areas of land consolidation. On the other hand, it is also need to add indices have difficulties to measure accurate land fragmentation level. Therefore, in the future studies, optimum parcel size, parcel shape and road distance from parcel residence to the parcels can be investigated according to agricultural activities depend on the crops cultivated, machinery used, irrigation and pesticide applications.

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