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Re-Allocation Aspects in Land Consolidation: A New Model and its Application

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Abstract: It is presented, in this study, a mathematical optimization model suitable for designing the new re-allotment plans in LC and its application to a hypothetical area about 26.371 ha comprising 6 holdings. The most important feature of the model is a cost factor which into account the parameters of road time index, ratio of area, landowner preferences and fixed installations in optimization process. It is seen that its results will be useful and acceptable by the farmers.

Key words: Land consolidation, mathematical optimization model, re-allotment plan

INTRODUCTION

The farm lands in many countries is scattered into a large number of small plots. This situation is unfavorable for an efficient agriculture (Van Huylenbroeck and Martens, 1987). Land consolidation (LC) for agricultural purposes is an activity or an instrument that is implemented in order to consolidate fragmented agricultural holdings or, in other words, to unite the scattered parcels of the distinct farms (Cay and Iscan, 2004).

LC is a tool for improving the effectiveness of land cultivation and for supporting rural development (Sklenicka, 2006). In other words, LC can be considered as the reorganization of rural area with the aim of to improve the agrarian structure, the infrastructure and the regional economy of the country. This can be achieved by work and living conditions (De Vos, 1982), redistribution of land, farm enlargement, building of new roads and watercourses, improvement of land protection or recreation of nature and landscape (Polman, 1974).

Though the intensity of the measures taken in LC projects (LCP's) can vary widely, LCP's can be described as comprehensive investment projects for rural development. Generally LCP's include measures to improve the parcellation, improving the water control, improving the accessibility and, safeguard and enhance natural and scenic values (Bosma, 1985).

Preparation and implementation of LCP's are generally time consuming process. Many of necessary administrative and arithmetic operations are labor-intensive. It is desirable to computerize these operations and if possible to take advantage of operational research techniques (Ayranci and Girgin, 2000).

The recent development of computers has opened up new possibilities for land consolidation. One of these is the computer-aided allocation of plots, using mathematical programming (Tenkanen, 1987). The computer is involved in three main activities in land consolidation, i.e., administration, allocation and mapping (Polman, 1974).

In some countries where LC was widely applied, possible applications of operational research techniques have been investigated and put into practice in land activities (Polman, 1974; De Vos, 1982; Lemmen and Sonnenberg, 1986; Tenkanen, 1987, 1990; Girgin and Kik, 1989; Tuomaala, 1989; Kik and Sprik, 1990; Moolenaar, 1990). Following earlier applications of computer resources to various aspects of the land consolidation process (Kik, 1990; Monke *et al*., 1992; Gonzales *et al*., 2004, 2006), the development of Geographical Information Systems (GIS), which integrate geographical databases with map visualization and generation capabilities, has created enormous potential for improvement of land consolidation process (Gonzales *et al*., 2004, 2006).

Turkish LC regulations is provides for landscape renovation within LC areas, which focuses, among other things, on the planting of shrubs and trees, the creation of small parks/recreation/areas, in non-agricultural land and the protection/conservation of the cultural heritage and physical environment within LC areas, such as the restoration of traditional foundations, old water mills and railway lines (Cay and Iscan, 2004).

The LC studies in Turkey are being conducted on the village basis, but some of LCPs are spread over an area of 70,000 km^2. The LC and land use planning works are being carried out under the supervision of Agrarian Agency with the contributions of governmental institutions of State Hydraulic Works, Cadastre and Registration and the Rural Services (Girgin *et al*., 1992).

On the other hand, some methods are developed on the use of operational research techniques for determining optimum parcellation plan in LC (Girgin, 1984; Avci and Balci, 1988; 1990; Girgin and Kik, 1989; Avci, 1990; Buker *et al*., 1990). A computer based land information system called ARA-LIS from now has been developed by a group of experts and put into implementation in order to facilitate the works. About 20000 ha of land of the Southeastern Anatolian Project (GAP) area which is the most important development project of the Turkey has been consolidated and prepared a land use plan by using this system. Beside, a rough digital terrain model has been set up to determine the requirements of drainage and leveling works (Girgin *et al*., 1992).

In this study, a mathematical optimization model (MM) (a modified form of the model developed by Ayranci (1997) (OM) which is suitable for designing the new re-allotment plan in LC) and its application to a hypothetical area together with the OM has been described.

MATERIALS AND METHODS

Parcellation design in LC, a very complex problem is to determine that which parcel of any holding will be allocated at which block (the area where the new parcels will be settled on). This process is being conducted with a mathematical optimization model. The model depends on the transport model which is one of the operational research techniques.

The transport model is useful when needed some distributions from some sources to some demand places (Karayalcin, 1993).

For developing the model it is assumed that all parcels of area are internally homogeneous as regards soil quality and other related characteristics that affect productivity. Cereal and sugar beet will be grown on all parcels and crop pattern will be 25 and 75%, respectively and all parcels will be cultivated by the machinery of similar characteristics. The working time in a day is 10 h and every agricultural activity is independent from each other.

The basic aim of the modified model (MM) is designing a new re-allocation plan in LC. The equation of this algorithm employs the minimization of the product of the land to be allocated and the cost factor (C_{ij}). The cost factor of the proposed re-allocation model takes into consideration the parameters of road time index, ratio of area, landowner preferences and fixed installations. By using equation of $Min(\Sigma\Sigma C_{ij}.X_{ij})$, it is possible to determine how much on which land block will be allocated to each holding (X_{ij}). The expression of these parameters is as follows.

Road time index: Road time index, Irt that implies the necessity of decreasing the time spent to reach from farmer's residence to their parcels in a daily working time can be express as follows basically;

$$Irt = At/Tt \tag{1}$$

Arrival time: Generally, collected settlement is seen in Turkey and the settlement areas are surrounded by the agricultural lands. Moreover, farmers have fairly fragmented parcels all over the agricultural area.

If the parcels of a holding are rather fragmented, the time spent for arriving to the parcels is more than the collected ones. To calculate the arrival time, the distance between the block (the area where the new parcels will be settled on) entry point and the farmer's residence where all the machinery are kept and the distance between the parcels in a block of the same holding are considered.

It is assumed that all the farmers will use the same route until they reach to the block entry point. The distance between the entry point of the block and the centroid of the parcels owned by the same farmer are accounted as the crow flies. Arrival time (At) can be calculated as follows;

$$At_{ij} = \frac{2k(L_{ij} + \sum_{1}^{p} l_{ijp})}{Vt} \tag{2}$$

Numbers of k coefficients are shown in Table 1. Values of l_{ijp} can be extract from the vertex coordinate data that define it in the GIS data base and for example, it can be seen for 2nd holding at nr 101 and nr 102 block in Fig. 3. The average velocity to reach from farmer's residence to the parcels has been taken 12 km h^{-1} in Turkish conditions (Dincer, 1973). The number of the travels between the farmer's residence and the parcel is related to the plot size. As the plot size increases, the number of the travels also increases.

Tillage time: Tillage time can be calculated by the following formula;

Table 1: k coefficients according to the parcel size (Ayranci, 1997)

	Parcel size (ha)							
	0-3.75	3.76-6.80	6.81-7.46	7.47-8.40	8.41-9.73	9.74-10.66	10.67-11.20	11.21-13.60
k	16	18	19	20	21	23	24	25

$$Tt_{ij} = A_{ij}\sum_{t}^{T} Gr_t.Tc_t \quad (3)$$

The annual tillage time (Tt_{ij}) includes the time spent for tillage, smoothing, fertilizing, harvesting etc. and it is accepted as 16 h ha^{-1} for cereals and 79 h ha^{-1} for sugar beet (Evcim, 1990) per unit area (ha) in Turkish conditions.

The rate of area: It is assumed as a rule in LC that the parcels of a farmer must be gathered together around the largest parcel. To evaluate this concept, the model has a parameter named as rate of area Ra, which means the rate of area of any holding in any block and it can be accounted as follows;

$$Ra_{ij} = 1\text{-}A_{ij}/A_j \quad (4)$$

Preference factor: LC includes some arrangements on the farmer's lands. The acceptability of the LCPs is related to the farmer's satisfaction about LCPs. The farmers give in a hearing their preference in which block they would like to have their new parcels located.

In this context, three preference alternatives were given to the farmers to choose the block which will be settled of their parcels after LC. The preferences are determined during the interviews with the farmers. That gives the farmers a right for designing the LC area. Yet, the factor must have a numerical expression and to give a numerical expression is a hard work.

But, there are some ways of incorporating the landowners' wishes into the allocation procedure. For example, the objective of maximizing productive values of land and that of maximizing the implementation degree of the priorities presented by the landowners may be combined into one objective function by using various weights. Another way to take landowners' wishes into account is to express them as a constraint describing the degree of their implementation (Tenkanen, 1987).

In the developing of the model, to cope with this problem a simple way is followed: The numerical values of three preferences have been divided into the numerical value of total preferences (i.e., 1/3, 2/3 and 3/3). In this way, it is obtained 0.33 for 1st preference, 0.66 for 2nd preference and 1 for 3rd preference.

After all, the following expression can be used for determining the cost factor of ith holding at the jth block.

$$C_{ij} = Irt_{ij}.Ra_{ij}.Fp_{ij} \quad (5)$$

Fixed installations: Each project contains non-exchangeable parcels. Non-exchangeable parcels are excluded from the re-allotment calculation (Kik, 1990).

The model includes another component named as fixed installations. If there are some facilities like farm building, well, perennial crop and glasshouse on a parcel, this parcel is accepted as important and it should be given to its owner after LC. In the model, to obtain this, the parcels where the installations are established, have been allocated in the name of the relevant holding before optimization. This area has been subtracted from the area of the relevant holding and block, so the matrix has been balanced again. Then the optimization process is started.

Consequently, the optimization process can be done by the Eq. 6.

$$Z_{min} = \sum_{1}^{m}\sum_{1}^{n} X_{ij}.C_{ij} \quad (6)$$

RESULTS AND DISCUSSION

Under this headline, the application of the model mentioned above to the hypothetical area seen in Fig. 1 has been described. The aim of the test was twofold namely; to acquire insight into the reality value of the application of the model and to acquire insight into the possibility of the implementing the model.

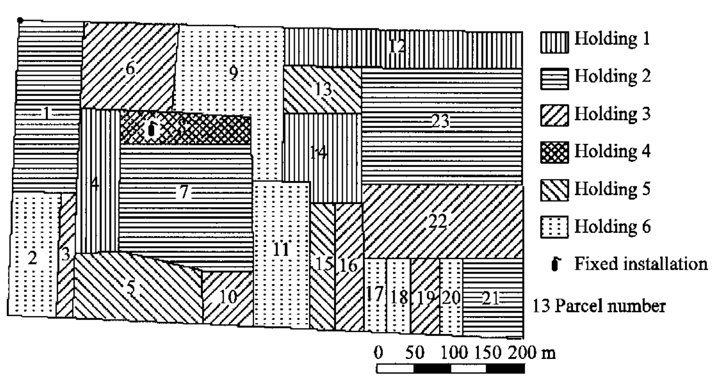

Fig. 1: The hypothetical area

It is assumed that, the area includes 23 parcels belonging to 6 holdings whose partners live in the same village. Holding 4 has a fixed installation on its parcel. Total area is 26.371 ha. Parcel sizes were range from about 0.3 to 3.0 ha and the holdings had a wide range of sizes (Table 2). Average parcel size is about 1.147 ha and mean parcel number per holding is 3.83.

To apply the method and to locate the land available, the study area has to be split up into blocks (Kik, 1990; Tenkanen, 1990). A block comprises the land that can be reached from one road-segment (Kik, 1990).

In this study, the consolidation area has been divided into two blocks named as block 101 and block 102 (Fig. 2). One of them is 13.156 ha and the other one is 12.130 ha. The rest of area is separated as common use for road, water and drainage canals. The interrupted area is 1.085 ha and it is about 4.2% of all area. This area was divided among all of the holdings at the same ratio according to the size of their area. Henceforth the new area of the holdings has reached to 25.286 ha. The entry point of the first (nr 101) and second (nr 102) blocks 2.800 and 3.018 km away from the houses of the farmers.

To calculate some parameters of the model it is needed to overlap the original site plan and the block plan (Fig. 3).

The MM and OM have been applied to the hypothetical area by using the transportation method using AB: QM 4.0 packages and optimal solutions by MODI have been taken. The optimal solutions of the models are seen in Table 3 and the new re-allotment plans designed according to the optimization process are shown in Fig. 4 and 5.

Table 4 includes the comparisons of the both models according to some of their agricultural characteristics. Table 4 shows that the both models have same results on parcel number (7) and the mean parcel size (3.610 ha). In other word, mean parcel number is decreased about 69.56% and this parameter is found 75.87% by Avci (1990), 55.43% by Girgin (1984) and 71.47% by Ayranci (1997). In addition, mean parcel number per holding is decreased about 69.56% while this parameter is found 55.45% by Girgin (1984), 41.75% by Girgin and Kik, (1989) and 76.76% by Ayranci (1997). Seventeen parcels owned by the 1st, 2nd, 3rd, 4th and 5th holdings are gathered

Table 2: Describing the holdings

Holding No.	Total area (ha) Before LC	After LC	No. of parcels	Parcel No.	Farmer preferences 1st pref.	2nd pref.
1	3.649	3.499	3	4,12,14	101	102
2	7.869	7.545	4	1,7,21,23	101	102
3	5.774	5.536	6	3,6,10,16,19,22	102	101
4	0.905	0.868	1	8	101	-
5	2.752	2.639	3	5,13,15	102	101
6	5.422	5.199	6	2,9,11,17,18,20	102	101
Total	26.371	25.286	23	-	-	-

Table 3: The optimal solution of MM and OM

Block No.	Model	Parcel size(s) of the holdings 1	2	3	4	5	6	Supply (ha)
101	MM	3.499	7.545		0.868		1.244	
	OM	3.499	3.253	5.536	0.868			13.156
102	MM			5.536		2.639	3.955	
	OM		4.292			2.639	5.199	12.130
Demand (ha)		3.499	7.545	5.536	0.868	2.639	5.199	25.286

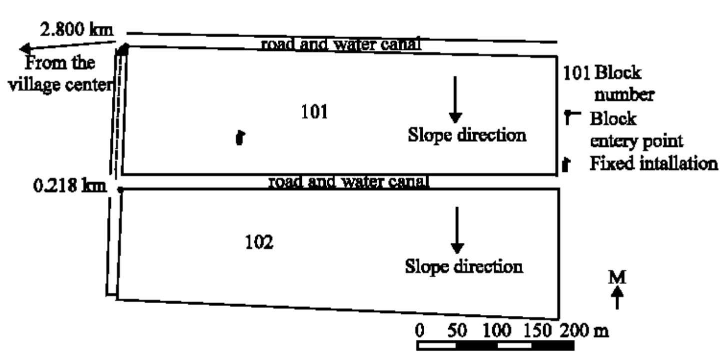

Fig. 2: The new block plan

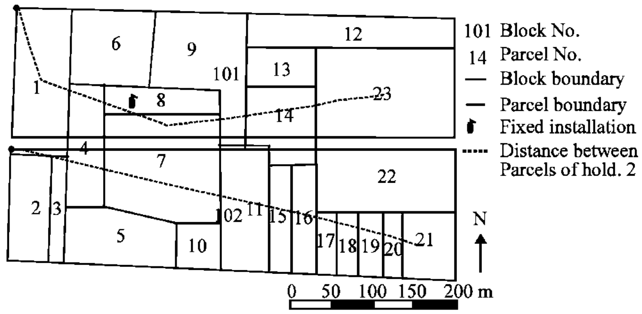

Fig. 3: Overlapping of the new block plan and original situation plan

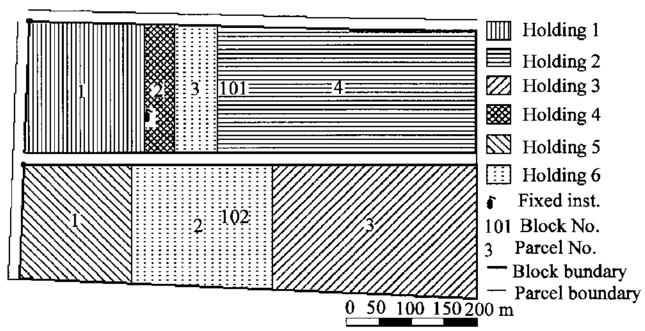

Fig. 4: Re-allotment plan according to the outputs of MM

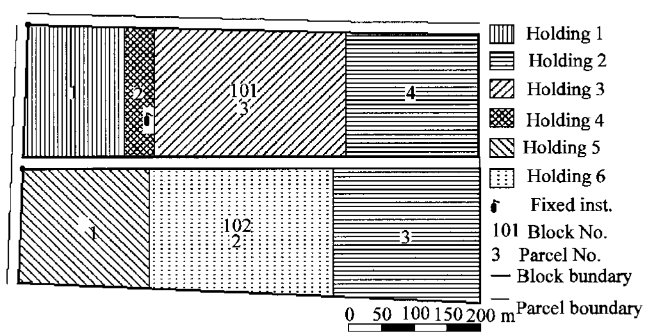

Fig. 5: Re-allotment plan according to outputs of OM

Table 4: Comparisons of the models among agricultural characteristics

	Characteristics								
	Parcel No.		Mean parcel size (ha)		Parcel(s) given according to the 1st preference of holdings		Parcel(s) given according to the 2nd preference of holdings		
Model	Before LC	After LC	Before LC	After LC	No.	Area (ha)	No.	Area (ha)	Fixed installation
MM	23	7	1.147	3.610	6	24.042	1	1.244	OK
OM	23	7	1.147	3.610	5	15.458	2	9.828	OK

together as one parcel for each holding in MM and 6 parcels owned by the 6th holding are gathered together as two parcels in blocks 101 and 102.

The 19 parcels owned by the 1st, 3rd, 4th, 5th and 6th holdings are gathered together as one parcel for each holding in OM and the 4 parcels owned by 2nd holding are gathered together as two parcels in blocks 101 and 102. The mean parcel size have increased 315% (from 1.147 to 3.610 ha) after consolidation process for both models. This value is found about 222.97% by Girgin (1984), 160%

Table 5: Comparisons by rate of area (Ra)

Holding No.	Rate of area 101	Rate of area 102	Given area (ha) MM 101	MM 102	OM 101	OM 102
1	**0.215**	0.055	**3.499**	-	3.499	-
2	**0.423**	0.163	**7.545**	-	3.253	4.292
3	0.111	**0.336**	-	**5.536**	5.536	-
4	0.066	-	0.868	-	0.868	-
5	0.050	**0.163**	-	**2.639**	-	2.639
6	0.135	**0.273**	1.244	**3.955**	-	5.199
Total	1.000	1.000	13.156	12.130	13.156	12.130

by Girgin and Kik (1989), 373.33% by Kik (1990), 353% by Avci and Balci (1990) and 324.41% by Ayranci (1997).

The distinctive diversity among the models is seen on farmer's preferences. The MM has created 6 parcels suitable for the 1st preference and 1 parcel suitable for the 2nd preference of the holdings. The holding 6 has two parcels. The parcel created suitable to the 2nd preference of the holding belongs to the holding 6 and there are no parcels gathered together as one parcel according to their 2nd preference of the holdings. The parcel size to the 1st preference of the holdings is 24.042 ha and about by 95% of total consolidation area in MM. The same area was 15.458 ha (about by 61%) in the OM. The OM has created 2 parcels suitable for the 2nd preference of the holdings. One of them belongs to the holding *2* that has two parcels after consolidation. The other parcel belongs to the holding 3 and the holding's 1st preference was at block 101. According to the results of the models, it can be said that the re-allotment plan created by MM is more acceptable by the farmers (Fig. 5). The both model outputs have been evaluated according to the rate of area Ra in each block (Table 5).

Table 5 shows that all the parcels created by MM are at the same block where the ratio of the holdings' area is the biggest. This result matches with the concept of the LC. If we look at the results of the OM, the parcel owned by holding 3 has been created in the block 101 where the ratio of the area of holding 3 is small. Another parcel owned by holding 2 has been created in the block 102 where the ratio of area of holding 2 is less than block 101.

In addition, the both models had succeeded about fixed installations because of their algorithms.

CONCLUSIONS

This study describes the modified form of Ayranci (1997) (MM) and the application of the MM and original form of Ayranci (1997) (OM) to the hypothetical area about 26.371 ha. It also includes the comparison of the outputs of the models. The OM has three parameters named as road time index, landowner's preference and fixed installations. In addition, the MM has the parameter of ratio of area and different algorithm on calculation of landowner's preference.

The road time index implies the decreasing of the arrival time in a daily working time. The ratio of area provides to give parcels from the largest parcels of the holdings. The preference factor evaluates the farmers' wishes. The last component of the models is fixed installations and it guarantees to give the parcels that include some installations like building, well etc to their true owners at the same place after LC.

After the optimization process, it is seen that the both models have similar results. The MM is more efficient on evaluating the landowner preferences and rate of area than OM. Both of the models guarantee the fixed installations owned by the holdings and they give an area to the holdings that have parcel having some installations. It can be said that the models are useful for designing re-allotment plans in LC. The advantage of method is the objective weighing of interests, which means to say that, without making allowance for the person involved, the choice between allocation or no allocation in a given block unit takes place on an objective basis. In addition, it can help the decision-makers for selecting the best alternative in the preparatory phase of LC.

The cost factor of the mathematical optimization model used designing new reallocation plan in LC has been adapted to the Turkish conditions. Unfortunately, different cost factors that take into account some other parameters may be product for different regions and countries. Application of the method in other countries would probably require a more time-consuming collection and calculation of required data.

If the parameters of the cost factor are increase and based on the true values acceptability of the results is increase.

The mathematical techniques allow for an integration of different systems in the field of re-allotment for land consolidation purposes.

NOMENCLATURE

Irt	Road time index
Tt_{ij}	The annual tillage time for ith holding at the jth block (hour)
At	The period of time spent for arriving from the farmers houses to their parcels (hour)
A_{ij}	The total parcel size of the ith holding at the jth block (ha)
Tt	The tillage time of any parcel (hour)
C_{ij}	Cost factor of ith holding at jth block
k	The number of times in a year that the farmers go to the parcels for the agricultural activities for growing the crops
l_{ijp}	The distance (as the crow flies) between centroids of the parcels (p) of the ith holding at the jth block (km)
L_j	The distance from farmer's residence to the entry point of the jth block (km)
Vt	The average velocity to reach from farmer's residence to the parcels (km h^{-1})
Gr_t	The growing ratio of the tth crop
Irt_{ij}	Road time index of ith holding at jth block
Tc_t	The annual tillage time per unit area (ha) for tth crop (h ha^{-1})
X_{ij}	The size of area which will be allocate for ith holding at jth block
Ra_{ij}	The rate of area of ith holding at jth block
Fp_{ij}	Preference factor of ith holding at jth block

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REFERENCES

Avci, M. and A. Balci, 1988. Determining of the parcellation plan in land consolidation that minimizes the class-exchange during combining of the farms' parcels that are in the different land class. Proceedings of 3rd National Kulturteknik Congress, İzmir, Turkey (In Turkish with English abstract).

Avci, M., 1990. A research to benefit from linear programming on determining optimum parcellation plan in land consolidation. Proceedings of XIIIth Operational Research and Industry Engineering National Congress, 21-22 June 1990, METU, Ankara, Turkey (In Turkish).

Avci, M. and A. Balci, 1990. A research on the use of operation research techniques for determining optimum parcellation plan in land consolidation. Journal of Applied Science Institute of Ege University, I (1), İzmir (In Turkish with English abstract).

Ayranci, Y., 1997. Geographic in formation system aided land consolidation in Yukari Candir-Tokat Village in Turkey. Ph.D Thesis, Ankara University, Graduate School of Natural and Applied Science, 1997. Ankara (In Turkish with English abstract), pp: 1-117.

Ayranci, Y. and I. Girgin, 2000. Geographic information system aided land consolidation at the YukarI ÇandIr Village in Tokat province in Turkey. Proceedings of 2nd ICGESA 2000 Int. Conference on GIS for Earth Science Applications, 11-14 Sept. Menemen-Izmir-Turkey (Published in CD format).

Bosma, H., 1985. The evaluation in advance of the effects and costs of land consolidation projects in Netherlands. Proceedings of the 8th Symposium of the EAAE., pp: 293-312.

Buker, M., I. Girgin, H. Bolukoglu, I. Arici, A. Korukcu and H. Gungor, 1990. Development of a model for accelerating land consolidation and application of this model in Alpu. Republic of Turkey, Ministry of Agric., For. and Rural Services, Gen. Direct. of Rural Services, Res. Inst. of Eskisehir publications, General Public. No. 222, Report serial No. 178, Eskisehir, Turkey (In Turkish with English abstract).

Cay, T. and F. Iscan, 2004. Algorithm developing for land consolidation software. Proceedings of XXth ISPRS Congress, 12-13 July 2004, Istanbul.

De Vos, W.H., 1982. Allocation in land consolidation projects in the netherlands with the aid of an automated system. Surveying and Mapping, 42: 339-345.

Dincer, H., 1973. A research of the working capabilities in the agriculture of the power animals that use in the Erzurum region. Publication of the Ataturk University 1973, (165), Erzurum, Turkey (In Turkish).

Evcim, U., 1990. The data base of agricultural mechanization and planning. Publication of the Ege University 1990 (495), İzmir-Turkey (In Turkish).

Girgin, I., 1984. Determining of the optimum parcellation plan in land consolidation. Proceedings of I. National Kulturteknik Congress, 15-18 May 1984, Adana-Turkey. (In Turkish with English abstract).

Girgin, I. and R. Kik, 1989. Re-allotment research in the Turkish land consolidation Project Emirhacili Village. In Proceeding 11th International Congress on Agricultural Engineering 1989, Rotterdam, The Netherlands, 4: 2711-2720.

Girgin, I., C. Celik and R. Sarsu, 1992. A land information system for LC and management. International conference on agricultural engineering, Uppsala.

Gonzalez, X.P., C.J. Alvarez and R. Crecente, 2004. Evaluation of land distributions with joint regard to plot size and shape. Agric. Syst., 82: 31-43.

Gonzalez, X.P., M.F. Marey and C.J. Alvarez, 2006. Evaluation of productive rural land patterns with joint regard to the size, shape and dispersion of plots. Agricultural Systems (Article in Press).

Karayalcin, I., 1993. Operations research techniques. Technical University of Istanbul, Faculty of Management Engineering. Mentes bookstore, Istanbul. (In Turkish).

Kik, R., 1990. A method for reallotment research in land development projects in The Netherlands. Agric. Syst., 33: 127-138.

Kik, R. and J.B. Sprik, 1990. Application of GIS in reallotment research for land development projects. Proceedings of the 1st European Conference on Geographical Information Systems. 10-13 April 1990, Amsterdam, pp: 296-308.

Lemmen, C.H.J. and J.K.B. Sonnenberg, 1986. A model for allocation and adjustment of lots in land consolidation: New developments in the Netherlands. FIG XVIII International congress, 706.5. 1-11 June 1986, Toronto, Canada, pp: 327-341.

Monke, E., F. Avillez and M. Ferro, 1992. Consolidation policies and small-farm agriculture in nortwest Portugal. Eur. Rev. Agric. Econ., 10: 67-83.

Moolenaar, M.P., 1990. Lanscape design in relation to reallotment in land consolidation projects. FIG XIXth International Congress, 10-19 June, Helsinki, pp: 296-308.

Polman, J., 1974. Automation in land consolidation in the Netherlands. International Federation of Surveyors, 304.1, Washington, USA.

Sklenicka, P., 2006. Applying evaluation criteria for the land consolidation effect to tree contrasting study areas in the Chech Republic. Land Use and Policy, 4: 502-510.

Tenkanen, J., 1987. Computer-aided allocation of plots in land consolidation. J. Surveying Sci. Finland, No. 2/1987, Published by the Finnish Society of Surveying Sciences, pp: 10-25.

Tenkanen, A., 1990. Computer-aided planning in finnish land consolidation. FIG XIXth Congress International, 10-19 June, Helsinki, pp: 325-333.

Tuomaala, J., 1989. Computer-aided land consolidation in Finland. International cartographic conference, Budapest, pp: 17-24 August 1989.

Van Huylenbroeck, G. and L. Martens, 1987. Estimating the benefits at farm level of land consolidation projects in Belgium. 5th European Congress of Agricultural Economists, Hungary.