Geodesy and Cartography
ISSN 2029-6991 / eISSN 2029-7009
2018 Volume 44 Issue 3: 106–112
https://doi.org/10.3846/gac.2018.2049

UDK 528.063.3

THE LAND REALLOCATION MODEL IN THE COURSE OF AGRICULTURAL LAND CONSOLIDATION IN UKRAINE

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Received 28 May 2018; accepted 20 September 2018

Abstract. The issue of the effectiveness of agricultural land consolidation in the environment of land relations being reshaped, with Ukraine as the example has been scrutinized in the research. Land reallocation as the key constituent of land consolidation has been considered according to the existing approaches. Necessity for substantiation of the peerness of land plots to be reallocated has been singled out. Key factors influencing the peer agricultural land exchange in the process of reallocation have been defined. It is offered to define the peerness of agricultural land plots by a set of qualitative and spatial and technological characteristics. The improvement of the existing approaches to land reallocation by limiting for the reallocated land plots peerness by the preset characteristics has been suggested. The gist of the modelling is the minimization of distance from land plot to the farmhouse. Technical data characterizing the qualitative and spatial and technological characteristics of land plots at the reallotment have been defined. The assessment of the provided reallocation model with the example of the agricultural land mass has been provided. Land reallocation is accomplished by the voluntary land plot exchange. The analysis of the reallocation results using the provided model has been executed.

Keywords: land exchange, land reallotment, peer land plots, land consolidation, optimization model, landholding.

Introduction

The improvement of the existing land tenure and land ownership system in accordance to the social and economic and environmental challenges is an important issue of the modern land management.

The spatial land tenure and land ownership factors predefine the effectiveness of the economic activity, safety and convenience for the local community. The optimization of land tenure and land ownership area, placement and configuration is usually carried out in the framework of land consolidation projects. These projects gain various goals like agricultural productivity, village development, infrastructure objects placement (Attenberger, 2002; Hendricks & Lisec, 2013) and nature conservation (FAO, 2003; Thomas, 2012).

For Ukraine and most Eastern Europe states, the need for land consolidation is to a great extent predefined by the need for the improvement of agricultural land tenure and land ownership parameters, formed in the result of land reform (Hartvigsen, 2014). With the cancelling of the agricultural land sale moratorium which is now in effect in Ukraine, the increased need for land management of the existing land tenure and land ownership is anticipated. According to UN Food Agricultural Organization (FAO), land market in Ukraine will cause the increase of fragmentation of both land tenure and land ownership (FAO, 2017).

Defining of land reallocation mechanisms as the main constituent of respective projects is the key issue for measures on land consolidation (Lemmen, Jansen, & Rosman, 2012; Thomas, 2006). Today, the critical path of the reallocation is in focus: land redistribution and land portioning (Demetriou, Stillwell, & See, 2012). Heuristic and optimization approach to land reallocation modeling are used. The following algorithms are singled out: the stepping stone algorithm, the system for Automation of the Re-allotment Plan for Land Consolidation, the Allocation and Adjustment Model, etc. (Lemmen et al., 2012; Yimer, 2014).

The European design experience witnesses, land reallocation design process has no universal mechanism, needs to consider existing land tenure conditions, processual aspects, norms and rules, designer experience, etc. (Lemmen et al., 2012). The key aspect is the possibility for the change of the existing land tenure and land ownership

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parameters without changing the right of ownership and land tenure conflicts removal (Thomas, 2006). Land reallocation coordinates the existing land usage and issues of land ownership right with demands on land usage and removes obstacles at the transition to the project plan (Seele, 1992).

Demands for the reallocation substantiation increase the need for considering a set of factors which will provide the optimal change of data and the peerness of reallocated land plots.

The research is based on the practice of land exchange in the course of land consolidation (FAO, 2003; Yimer, 2014), the experience of the existing land tenure improvement in Ukraine (Malashevskyi, Mosiichuk, & Bugaienko, 2014; Malashevskyi & Bugaienko, 2016). The reallocation model based on demands on the peerness of reallocated land plots by qualitative and spatial and technological characteristics is suggested.

1. Peer land exchange at land reallocation

One of the most important principles influencing the effectiveness of reallocation is the land owners' losses avoiding. In FAO researches (FAO, 2003), it has been indicated the "equal value" of land is predefined by the soil quality and all the factors essentially impacting land use. Necessity for considering the land plot placement relative to other plots, roads, households and farm houses is singled out. It is suggested to consider land exchange to be peer in case land plots to be exchanged are equal by a set of general natural and acquired properties and have the same value from the point of view of its main functional role.

Considering the above mentioned facts, characteristics of agricultural land plots as the production factor should be considered at their exchange. Useful properties of the land plot like soil quality in accordance to demands on cultivation of crops and existence of improvements should be taken into consideration. Technological processing conditions predefine the production capability in case of the equal fertility. The placement of the land plot predefines the profit from land usage in case of equal production capability. The existence of easements or servitudes can cause agricultural production losses (Figure 1).

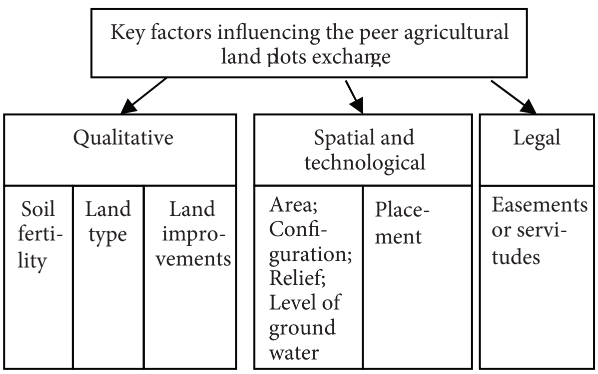

Figure 1. The peer agricultural land exchange factors classification

At agricultural land plot exchange, characteristics of land plots as the production means should be taken into consideration. It is necessary to consider the acreage type and soil quality in accordance to the demands on agricultural crop cultivation and the existence of improvements. Technological conditions for cultivation (provided productivity is the same) predefine the production capability. Land plot placement (provided the production capability is the same) predefines the land usage profit. Legal restraints and restrictions can cause agricultural production losses (Bugaienko, 2015).

It is suggested to consider land improvements, acreage type, hydrographic characteristics, placement, easements and usage limitations and restrictions at block forming and defining the suitable for reallotment land plots as in the approach (Yimer, 2014).

2. Land reallocation optimization model

Let us suggest, areas of land plots formed after reallocation are defined as variables x_{ij}.

Following constraints formed on the basis of the reallotted land plots peerness demands are offered:

The exchanged land plots should be peer at the readjustment:

$$\sum_{i=1}^{n} K_{ij} B_{ij} x_{ij} = \sum_{k=1}^{l} K_{kj} B_{jk} S_{jk}, \quad j = 1, 2, ..., m, \qquad (1)$$

where K_{ij} is the coefficient characterizing the combined impact of qualitative and spatial and technological characteristics of the land plot after readjustment; B_{ij} is the coefficient characterizing the land plot soil quality by the core natural and acquired properties from the point of view of growing basic crops ("ball-bonitet" in Ukraine) after readjustment; K_{jk} is the coefficient characterizing the combined impact of qualitative and spatial and technological characteristics of the land plot before readjustment; B_{jk} is the coefficient characterizing the land plot soil quality by the core natural and acquired properties from the point of view of growing basic crops before the readjustment; S_{jk} is the area of the land plot k belonging to the owner j before the readjustment; l is the quantity of land plots belonging to the owner j before the readjustment; n is the quantity of blocks involved to the project; m is the quantity of land owners involved to the project.

Value K is calculated as the product of separate factors depending on the presence of the corresponding factors by the equation:

$$K_i = K_{qi} \times K_{li} \times K_{imi} \times K_{fi} \times K_{ri} \times K_{gi} \times K_{mi} \times K_{oi}, \qquad (2)$$

where K_q is the coefficient characterizing the lowering of the soil quality as the result of contamination, erosion, etc.; K_l is the coefficient characterizing the type of agricultural land; K_{im} is the coefficient characterizing the land improvements; K_f is the coefficient characterizes configuration; K_r is the coefficient characterizing relief; K_g is the coefficient of the hydrographic characteristics of land plot;

K_m is the correction coefficient for land plot placement; K_o is the coefficient characterizing the existence of easements or servitudes.

Coefficients are calculated according to methodology (Chibiriakov, Malashevskyi, & Bugaienko, 2015).

The total of all land plots within a block before and after the reallocation should be equal:

$$\sum_{j=1}^{m} x_{ij} = S_{0i}, \quad i = 1, 2, \dots n, \tag{3}$$

where S_{oi} is the area of block i involved to the project.

The total land area within the project before and after readjustment should be equal:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij} = \sum_{i=1}^{n} S_{0i}. \tag{4}$$

Variable x_{ij} are nonnegative values only:

$$x_{ij} \geq 0. \tag{5}$$

Objective function:

$$F = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij} x_{ij} \rightarrow \max, \tag{6}$$

where c is the objective function coefficient; n is the quantity of blocks involved to the project; m is the quantity of land owners involved to the project.

It is offered to use objective function according to approach (Kik, 1980), which suggests minimization of the average distance between farmhouses and reallotted land plots:

$$F = \sum_{i=1}^{n}\sum_{j=1}^{m} \frac{1}{d_{ij}} x_{ij} \rightarrow \max, \tag{7}$$

where d_{ij} is the distance from the centre of block i to the holder yards of landowner j. Distances are calculated on roads.

3. Model approbation example

Provided model is tested on the project territory with the area of 131 075 sq. m. in Kyiv region. Project areas include agricultural land (plough-land) and in accordance to State Land Cadastre of Ukraine are privately owned and distributed for individual peasant agriculture. Land plots formed in the process of land mass parceling have a form close to rectangular with the side ratio 1:1.5 to 1:3. There is a path to every plot.

The project territory includes soil of two soil suitability groups: soddy non-gleic soil (B = 17) and sod-podzolic non-gleic soil (B = 19). Relief of the project territory is plain; irrigation is not needed, there are no land improvements, easements or servitudes.

Twenty landowners take part in the reallotment, their households are formed by stripped land plots (see Figure 2, Table 1).

Calculations were conducted with the simplex method, regrouping was conducted with MATLAB and ArcGis. As the result of redistribution (see Figure 3, Table 2), the quantity of overlapped land plots of the involved to the project land owners was reduced from 54 to 29, the average size more than twice.

Figure 2. The land tenure and land ownership system before reallotment

Table 1. The involved land ownership characteristics before reallotment

Land owner	Quantity of the stripped plots of the owner	The total area of land ownership, sq. m.	The area of land plots, sq. m.	Average area of land plots, sq. m.	Distance from households to land plots, m	The total distance from households to land plots, m	Reduced area, *KBS*
1	1	2665	2665,3	2665	1688	1688	45 310
2	2	4370	1570,5	2185	0651	1556	77 429
			2799,4		0905		
3	2	3232	2556,9	1616	1155	2165	54 945
			675,1		1010		
4	4	9887	2026,4	2472	389	3441	172 126
			2638,1		802		
			2556,9		1031		
			2665,3		1219		
5	2	5382	2583,1	2691	777	1429	96 669
			2799,4		652		
6	4	7616	1614,5	1904	687	3302	132 699
			2638,1		757		
			2700,6		853		
			662,8		1005		
7	2	4452	1653,0	2226	540	1163	78 996
			2799,4		623		
8	3	7899	2638,1	2633	1213	4287	134 284
			2651,2		1459		
			2609,8		1615		
9	3	6786	1614,5	2262	484	2005	123 649
			2533,0		712		
			2638,0		808		
10	3	8546	3109,0	2849	538	2757	151 509
			2638,1		1065		
			2799,4		1154		
11	4	8826	1965,0	2207	728	3377	157 278
			1653,0		720		
			2556,9		677		
			2651,2		1252		
12	3	8330	3039,6	2777	688	2444	147 686
			2638,8		534		
			2651,3		1222		
13	4	9526	2583,1	2382	428	3151	170 482
			1685,6		789		
			2556,9		842		
			2700,6		1092		
14	1	2610	2609,8	2610	428	428	44 367
15	3	7809	2519,6	2603	1033	2555	137 792
			2638,0		713		
			2651,3		808		
16	3	7859	2519,6	2620	336	2305	138 642
			2638,8		900		
			2700,6		1070		
17	1	3040	3039,6	3040	1485	1485	57 753
18	3	7341	2775,9	2447	1382	4157	134 148
			1899,8		1393		
			2665,3		1382		
19	3	7889	2533,0	2630	1127	2173	139 184
			2556,9		408		
			2799,4		639		
20	3	7009	1665,6	2336	686	3097	122 493
			2638,8		1304		
			2705,1		1107		
Total	54	131 075	131 075,0	24 577	48 963	48 963	23 174 421

Figure 3. The land tenure and land ownership system after reallotment

Table 2. The involved land ownership characteristics after reallotment

Land owner	Quantity of the stripped plots of the owner	The total area of land ownership, sq. m.	The area of land plots, sq. m.	Average area of land plots, sq. m.	Distance from households to land plots, m	The total distance from households to land plots, m	Reduced area, *KBS*
1	1	2385	2385	2385	834	834	45310
2	1	4075	4075	4075	1069	1069	77429
3	1	2892	2892	2892	591	591	54945
4	1	9059	9059	9059	529	529	17,2126
5	2	5088	1967	2544	649	1456	96 669
			3120		807		
6	2	6984	1191	3492	866	1801	132 699
			5793		936		
7	1	4158	4158	4158	851	851	78997
8	2	7495	3435	3747	1015	2215	134 284
			4060		1201		
9	2	6508	2602	3254	658	1307	123 649
			3906		648		
10	2	8912	7350	4456	652	1445	151 508
			1562		793		
11	2	9252	1927	4626	1299	2481	157 278
			7325		1182		
12	1	8687	8687	8687	407	407	147 686
13	2	10028	8478	5014	857	1934	170482
			1550		1076		
14	1	2610	2610	2610	438	438	44367
15	1	8105	8105	8105	583	583	137 792
16	1	8155	8155	8155	736	736	138642

End of Table 2

Land owner	Quantity of the stripped plots of the owner	The total area of land ownership, sq. m.	The area of land plots, sq. m.	Average area of land plots, sq. m.	Distance from households to land plots, m	The total distance from households to land plots, m	Reduced area, *KBS*
17	1	3397	3397	3397	841	841	57 753
18	2	7891	2576	3946	1333	2585	134 149
			5315		1252		
19	2	8187	3067	4094	417	0871	139 184
			5121		454		
20	1	7205	7205	7205	770	770	122 493
Total	29	131 075	131 075	4795	23 747	23 747	2 317 442

The quantity of the overlapping land plots of any land owner wasn't increased after reallocation and the remoteness of the overlapped land plots was reduced by an average factor of 2.5 for each land owner. The largest quantity of overlapped land plots was reduced to two plots per owner. One of the most important principles influencing the effectiveness of reallocation is the land owners losses avoiding.

Taking into consideration the demands on the peer value of land plots by a set of predefined characteristics is an alternative to the acceptable range of land plot value loss after reallocation, offered by Mihajlovic, Miladinovic, and Šoškic (2011). Thus, the provided model reflects the general tendencies (Ayranci, 2007; Yilmaz & Demir, 2015) on taking into consideration the advanced list of factors as contrasted to single factor models of reallotment. The simplification of the modeling process at the stage of block forming is also the advantage of the model.

There is a need to emphasize, the suggested approach complies with the FAO recommendations (FAO, 2003) concerning the application of the relative value at land reallocation in cases there is no need for compensation, and land market is slow of underdeveloped.

The results can be used: at land consolidation in the modern environment and in particular in the case of the launching of the agricultural land market in Ukraine; rented land improvement by means of the secondary leasing; in case of land allocation within the previously formed mass of agricultural land tenure aiming at the placement of infrastructure facilities, nature conservation of other measures demanding the change of the existing land tenure and land ownership parameters; for future scientific studies.

Conclusions

The formation of demands on the peerness of reallocated land plots is the key aspect of land reallocation substantiation in the course of land relations reforming. An approach to defining the peerness of land plots at reallocation based on qualitative and spatial and technological characteristics as the key aspect of reallocation substantiation has been suggested. A model of land reallocation aiming at land consolidation at the core of which is the approach to the minimization of distance from land plot to the holder's yard has been suggested. The approach has been improved by forming of restrictions based on the demands for the peerness of reallocated plots by qualitative and spatial and technological demands.

The effectiveness of the model has been approved by practical evaluation. As the result of reallocation of the overlapping plots within the project area, the increase of land plot area, the reduction of distance between overlapping land plots and the reduction of the quantity of the overlapping land plots was achieved. After the reallocation, spatial characteristics of land tenures the optimization of which the provided model is aiming at, have not been deteriorated.

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