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

Olena BUGAIENKO*

Kyiv National University of Construction and Architecture, Kyiv, Ukraine

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 re-shaped, 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 reallocation 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 reallocation, 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, procedural 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
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 (Malashevskiy, Mosiichuk, & Bugaienko, 2014; Malashevskyi & Bugaіenko, 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).

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) predefines 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 reallocation 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 reallocated land plots peerness demands are offered:

The exchanged land plots should be peer at the readjustment:

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

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; $K_{kj}$ 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:

$$K_i = K_{qi} \times K_{wi} \times K_{mi} \times K_{fi} \times K_{ri} \times K_{gi} \times K_{mi} \times K_{oi},$$

where $K_{qi}$ is the coefficient characterizing the lowering of the soil quality as the result of contamination, erosion, etc.; $K_{wi}$ is the coefficient characterizing the type of agricultural land; $K_{mi}$ is the coefficient characterizing the land improvements; $K_{fi}$ is the coefficient characterizes configuration; $K_{ri}$ is the coefficient characterizing relief; $K_{gi}$ is the coefficient of the hydrographic characteristics of land plot;

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 (Malashevskiy, Mosiichuk, & Bugaienko, 2014; Malashevskyi & Bugaіenko, 2016). The reallocation model based on demands on the peerness of reallocated land plots by qualitative and spatial and technological characteristics is suggested.

**Key factors influencing the peer agricultural land plots exchange**

- **Qualitative**
  - Soil fertility
  - Land type
  - Land improvements

- **Spatial and technological**
  - Area; Configuration; Relief; Level of ground water

- **Legal**
  - Easements or servitudes

**Figure 1. The peer agricultural land exchange factors classification**
\( K_m \) 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:

\[
\sum_{j=1}^{m} x_{ij} = S_{ij}, \quad i = 1, 2, ..., n, \tag{3}
\]

where \( S_{ij} \) is the area of block \( i \) involved to the project.

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

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

Variable \( x_{ij} \) are nonnegative values only:

\[ x_{ij} \geq 0. \tag{5} \]

Objective function:

\[
F = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{1}{d_{ij}} x_{ij} \rightarrow \max, \tag{6}
\]

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 reallocated land plots:

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

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-gley soil \((B = 17)\) and sod-podzolic non-gley 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 reallocation](image-url)
Table 1. The involved land ownership characteristics before reallocation

| 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                                                       | 45310           |
| 2          | 2                                          | 4370                                   | 1570,5                        | 2185                              | 0651                                      | 1556                                                       | 77429           |
| 3          | 2                                          | 3232                                   | 2556,9                        | 1616                              | 1155                                      | 2165                                                       | 54945           |
| 4          | 4                                          | 9887                                   | 2026,4                        | 2472                              | 389                                       | 3441                                                       | 172126          |
| 5          | 2                                          | 5382                                   | 2583,1                        | 2691                              | 777                                       | 1429                                                       | 96669           |
| 6          | 4                                          | 7616                                   | 1614,5                        | 1904                              | 687                                       | 3302                                                       | 132699          |
| 7          | 2                                          | 4452                                   | 1653,0                        | 2226                              | 540                                       | 1163                                                       | 78996           |
| 8          | 3                                          | 7899                                   | 2638,1                        | 2633                              | 1213                                      | 4287                                                       | 134284          |
| 9          | 3                                          | 6786                                   | 2638,1                        | 1904                              | 687                                       | 3302                                                       | 132699          |
| 10         | 3                                          | 8546                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 11         | 4                                          | 8826                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 12         | 3                                          | 8330                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 13         | 4                                          | 9526                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 14         | 1                                          | 2610                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 15         | 3                                          | 7809                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 16         | 3                                          | 7859                                   | 3090,0                        | 2849                              | 538                                       | 151509                                                     |                 |
| 17         | 1                                          | 3040                                   | 3040                          | 3040                              | 1485                                      | 1485                                                       | 57753           |
| 18         | 3                                          | 7341                                   | 3040                          | 3040                              | 1485                                      | 1485                                                       | 57753           |
| 19         | 3                                          | 7889                                   | 3040                          | 3040                              | 1485                                      | 1485                                                       | 57753           |
| 20         | 3                                          | 7009                                   | 3040                          | 3040                              | 1485                                      | 1485                                                       | 57753           |
| **Total**  | **54**                                     | **131075**                             | **131075**                    | **24577**                         | **48963**                                  | **48963**                                                  | **23174421**    |
Figure 3. The land tenure and land ownership system after reallocation

Table 2. The involved land ownership characteristics after reallocation

| 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                           | 3120                                | 649                                    | 1456                                          | 96669           |
| 6          | 2                                      | 6984                                 | 1191                           | 3492                                | 866                                    | 1801                                          | 132699          |
| 7          | 1                                      | 4158                                 | 4158                           | 4158                                | 851                                    | 851                                           | 78997           |
| 8          | 2                                      | 7495                                 | 3435                           | 4060                                | 1015                                   | 2215                                          | 134284          |
| 9          | 2                                      | 6508                                 | 2602                           | 3906                                | 658                                    | 1307                                          | 123649          |
| 10         | 2                                      | 8912                                 | 7350                           | 1562                                | 652                                    | 1445                                          | 151508          |
| 11         | 2                                      | 9252                                 | 1927                           | 7325                                | 1299                                   | 2481                                          | 157278          |
| 12         | 1                                      | 8687                                 | 8687                           | 8687                                | 407                                    | 407                                           | 147686          |
| 13         | 2                                      | 10028                                | 8478                           | 1550                                | 857                                    | 1934                                          | 170482          |
| 14         | 1                                      | 2610                                 | 2610                           | 2610                                | 438                                    | 438                                           | 44367           |
| 15         | 1                                      | 8105                                 | 8105                           | 8105                                | 583                                    | 583                                           | 137792          |
| 16         | 1                                      | 8155                                 | 8155                           | 8155                                | 736                                    | 736                                           | 138642          |
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 Šoškić (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 reallocation. 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.

| 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                                         | 57753           |
| 18         | 2                                         | 7891                                  | 2576                         | 3946                                 | 1333                                   | 1252                                        | 134149          |
| 19         | 2                                         | 8187                                  | 3067                         | 4094                                 | 417                                    | 454                                         | 139184          |
| 20         | 1                                         | 7205                                  | 7205                         | 7205                                 | 770                                    | 770                                         | 122439          |
| Total      | 29                                        | 131075                                | 131075                       | 4795                                 | 23747                                  | 23747                                        | 2317442         |

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.

References

Attenberger, J. (2002, February 25-28). The right mix of instruments – land consolidation, land management and land banking in Bavaria. Paper presented at Proceedings of International Symposium “Land Fragmentation and Land Consolidation in CEEC: A gate towards sustainable rural development in the new millennium”. Munich, Germany.

Ayranci, Y. (2007). Re-allocation aspects in land consolidation: a new model and its application. Journal of Agronomy, 6, 270-277.

Bugaienko, O. (2015). Doslidzhennia faktoriv, shcho vplyvaiut na provedennia rivnotsinnoho obminu zemelnykh dilianok silskohospodarskoho pryznachennia. Mistobuduvannia ta Terytorialne Planuvannia, 57, 48-54.

Chibiriakov, V., Malashevskyi, M., & Bugaienko, O. (2015). Vdoskonalennia metodyky rozrakhunku rivnotsinnykh zemelnykh dilianok silskohospodarskoho pryznachennia pry provedenni obminu. Inzhenerna Geodezija, 62, 85-94.

Demetriou, D., Stillwell, J., & See, L. (2012). Land consolidation in Cyprus: why is an integrated planning and decision support system required? Land Use Policy, 29(1), 131-142.

FAO. (2017). FAO advises on land consolidation legislation in Ukraine. Retrieved from http://www.fao.org/europe/news/detail-news/en/c/1068717/

FAO. (2003). The design of land consolidation pilot projects in Central and Eastern Europe. FAO Land Tenure Studies
No. 6, Rome. Retrieved from http://www.fao.org/docrep/006/Y4954E/y4954e00.htm.

Hendricks, А., & Lisec, А. (2013). Land consolidation for large-scale infrastructure projects in Germany. Geodetski Vestnik, 58(1), 46-68.

Hartvigsen, М. (2014). Land Mobility in a Central and Eastern European Land Consolidation Context. Nordic Journal of Surveying and Real Estate Research, 10(1), 23-46.

Kik, R. (1980). Reallotment of farm lands by computer. Research Digest 1980 (pp. 179-181). ICW, Wageningen.

Lemmen, C., Jansen, L. J. M., & Rosman, F. (2012, May 6-10). Informational and computational approaches to Land Consolidation. Paper presented at FIG Working Week 2012 “Knowing to manage the territory, protect the environment, evaluate the cultural heritage”. Rome, Italy.

Malashevskyi, М., & Bugaіenko, О. (2016). The substantiation of urban habitats peer land exchange in Ukraine. Geodesy and Cartography, 42(2), 53-57. https://doi.org/10.3846/20296991.2016.1198568

Malashevskyi, M., Mosiichuk, Yu., & Bugaienko, O. (2014). Doslidzhennia vichyznianoho dosvidu obminu zemel silskohospodars-коho pryznachennia. Inzhenerna Heodeziia, 61, 85-94.

Mihajlovic, R., Miladinovic, M., & Šoškic, M. (2011). Optimization of land distribution in land consolidation. Geodetski List, 2, 109-121.

Seele, W. (1992). Bodenordnerische probleme in den neuen Ländern. Vermessungswesen und Raumordnung, 54, 73.

Thomas, J. (2006). Attempt on systematization of land consolidation approaches in Europe. Fachbeitrag, 3, 156-161.

Thomas, J. (2012, February 13-16). Land consolidation as alternative to compulsory land acquisition in case of big public infrastructure projects. Paper presented at 3rd international LANDNET workshop on Land Market Development and Land Consolidation. Budapest, Hungary.

Yilmaz, A., & Demir, H. (2015). A multi-criteria optimization model for the allocation process in land readjustment projects. In Athens: Atiner’s Conference Paper Series, No: PLA2014-1509. Retrieved from https://www.atiner.gr/papers/PLA2014-1509.pdf

Yimer, F. A. (2014). Fit-for-purpose land consolidation: an innovative tool for Re-alloetween rural Ethiopia (MSc Thesis). University of Twente Faculty of Geo-Information and Earth Observation, Enschede, The Netherlands.