Land rating as basis for spatio-temporal scenarios of land organization

E V Cherkashina, D A Shapovalov, S I Komarov
State University of Land Use Planning, 15, Kazakova str., Moscow, 105064, Russia
E-mail: cherkashina@infokad.ru

Abstract. One of the most important issues of land management design is land and crop rotations organization. Its solution not only determines the mode of each land plot use but also organizes a system of crop rotations with their placement on the arable land. The crop rotations are placed with regards to the quality of soils, relief, land plots configuration, location, market potential and site potential. The calculation of the total resource potential enables to determine land plots rating, which forms the basis for the design of the crop rotation system. The rating is formed on the basis of an improved concept for assessing the investment and resource potential of the land use of an agricultural organization, which contributed to regarding the entire set of resources inherent in this land use, land tenure. The article presents the research findings on the organization of crop rotation in agricultural enterprises based on the rating. Design of crop rotation including land plots of equal quality, enables to predict crop yields, gross output, production costs, which invariably leads to an increase in the economic efficiency of production.

1. Introduction
The organization of land and crop rotations is one of the most complicated tasks of land management design. Its solution requires regarding the complex of conditions characterizing the soil, relief, climate, territorial and productive land properties, specialization and prospects for the development of the economy, its production capacity, investment climate, market situation, etc. A scientifically grounded system of land organization and crop rotation becomes more important in conditions when the amount of land suitable for agricultural production decreases annually by tens of millions hectares [1, 2]. Agricultural lands are removed from circulation. The load on the remaining land plots increases. Consequently, the processes of land degradation intensify and the quality of soils deteriorates [3]. As noted in many publications [4–6], in such conditions, studies on the territory planning (organization) improvement, including the ones which involve new indicators in the known methods of land valuation, become especially important.

The authors have developed a concept for assessing the investment and resource potential of land use [7, 8], which enables to regard the entire set of resources inherent in a given agricultural enterprise (land use, land tenure). Typically, the potential for agricultural land use is understood as soil fertility due to soil characteristics, or more broadly understood natural characteristics [9,10]. The novelty of the author’s perception of the resource potential lies in its more expanded interpretation. The investment and resource potential in this study was formed by the cumulative method of five private potentials reflecting the ability of land use to generate income.
2. Materials and methods

Aggregate resources can be subdivided into soil, natural, production, market and location potential. The soil potential is formed by the aggregate of soil varieties as well as the agrochemical parameters of soils. These factors affect the fertility of the site and are the main characteristics that affect the expected cash flows from agricultural production. Mathematically, soil potential is the sum of soil and agrochemical characteristics, normalized for comparability in the following way:

\[ SP_i = \sum_{j=1}^{k} Y_j \]  

where: \( SP_i \) is soil potential of the \( i \)th object (field, land plot, land use, municipality, region); \( Y_j \) is the normalized value of the \( j \)th characteristic being part of the soil potential. The calculation of the soil potential (fragment) is shown on the example of the integrated agricultural production company “Gladyshevsky”, Tokarevsky district of the Tambov region (Table 1).

| Land plot                        | 1   | 2   | 3   |
|----------------------------------|-----|-----|-----|
| Normalized humus content         | 0.55| 0.44| 0.44|
| Normalized thickness of the humus horizon | 0.46| 0.36| 0.36|
| Normalized thickness of the humus horizon | 0.58| 0.69| 0.69|
| Normalized mineral forms of nitrogen | 0.28| 0.52| 0.44|
| Normalized content of mobile phosphorus | 0.66| 0.60| 0.56|
| Normalized content of exchangeable potassium | 0.89| 0.90| 0.79|
| Normalized pH                    | 0.92| 0.90| 0.85|
| Normalized indicator of hydrolytic acidity | 0.28| 0.16| 0.19|
| Normalized degree of erosion     | 0.80| 0.61| 0.61|
| Normalized amount of calcium in the soil | 1.00| 0.36| 0.17|
| Normalized amount of magnesium in the soil | 0.34| 0.23| 0.23|
| Normalized amount of zinc in soil | 0.12| 1.00| 0.78|
| Normalized amount of manganese in soil | 0.27| 0.41| 0.67|
| Normalized amount of copper in soil | 0.29| 0.86| 0.68|
| Normalized amount of boron in soil | 0.13| 0.28| 0.59|
| Normalized amount of sulfur in the soil | 0.34| 0.19| 0.78|
| Normalized soil fertility rate   | 0.71| 0.69| 0.65|
| Normalized sum of absorbed bases | 1.00| 0.37| 0.20|
| “absorbed bases together with hydrolytic acidity” | 1.00| 0.38| 0.21|
| Normalized degree of soil saturation with bases | 0.36| 0.29| 0.26|
| **Soil potential**               | **10.98**| **10.23**| **10.17**|

Natural potential arises under the influence of climatic, relief and other natural factors that affect yield, growing costs and other components of the cash flow. This indicator should be calculated using the following formula:

\[ NP_i = \sum_{j=1}^{l} T_j \]  

where: \( NP_i \) is natural potential of the \( i \)th object (field, land plot, land use, municipality, region); \( T_j \) is the normalized value of the \( j \)th characteristic included in the natural potential (Table 2)

The location potential is determined by factors affecting the logistics of agribusiness associated with land use and is directly proportional to its cost. Location potential can be determined by the following formula:

\[ LP_i = \sum_{j=1}^{m} D_j \]  

where: \( LP_i \) is the potential of the \( i \)th object (field, land plot, land use, municipality, region) location; \( D_j \) is the normalized value of the \( j \)th characteristic included in the location potential (Table 3).
Table 2. Natural potential of integrated agricultural production company “Gladyshevsky” land plots (fragment)

| Land plot | Normalized Moisture Coefficient | Normalized terrain slope | Normalized coefficient of field elongation | Natural potential |
|-----------|---------------------------------|--------------------------|-------------------------------------------|-------------------|
| 1         | 0.35                            | 0.10                     | 0.90                                      | 1.36              |
| 2         | 0.06                            | 0.34                     | 0.91                                      | 1.30              |
| 3         | 0.47                            | 0.79                     | 0.81                                      | 2.08              |

The production potential implicates the demand in the commodity markets for the products the economy specializes in as well as in the production cost. The production potential is as follows:

\[ PP_i = \sum_{j=1}^{N} B_j \] (4),

where: \( PP_i \) is the production potential of the \( i^{th} \) object (field, land plot, land use, municipality, region); \( B_j \) is the normalized value of the \( j^{th} \) characteristic included in the location potential (Table 4.).

Table 3. Location potential of integrated agricultural production company “Gladyshevsky” land plots (fragment)

| Land plot | Normalized remoteness from storage sites | Normalized distance from elevator | Normalized distance from railway station | Normalized distance from regional road | Normalized distance from federal road | Normalized distance from the place of residence of labor force | Location potential |
|-----------|-----------------------------------------|----------------------------------|-----------------------------------------|---------------------------------------|-------------------------------------|----------------------------------------|-------------------|
| 1         | 0.41                                    | 0.51                             | 0.86                                    | 0.86                                  | 0.86                                | 0.56                                    | 4.07              |
| 2         | 0.56                                    | 0.65                             | 0.79                                    | 0.79                                  | 0.79                                | 0.41                                    | 3.99              |
| 3         | 0.24                                    | 0.42                             | 0.95                                    | 0.95                                  | 0.95                                | 0.24                                    | 3.73              |

Table 4. Production potential of integrated agricultural production company “Gladyshevsky” land plots (fragment)

| Land plot | Normalized product yield | Normalized gross income | Normalized production costs | Production potential |
|-----------|--------------------------|-------------------------|-----------------------------|----------------------|
| 1         | 0.71                     | 0.12                    | 0.48                        | 1.31                 |
| 2         | 0.63                     | 0.30                    | 0.47                        | 1.41                 |
| 3         | 0.15                     | 0.20                    | 0.59                        | 0.94                 |

Market potential stipulates the value of land use in terms of the market influenced by the prevailing combinations of supply, demand, price, etc. and is the sum of the normalized criteria describing the market situation. It can be represented as follows:

\[ MP_i = \sum_{j=1}^{N} Ts_j \] (5),

where: \( MP_i \) is market potential of the \( i^{th} \) object (field, land plot, land use, municipality, region); \( Ts_j \) is the normalized value of the \( j^{th} \) characteristic being part of the location potential (Table 5.).

Table 5. Resource potential of integrated agricultural production company “Gladyshevsky” fields (fragment)

| Field | Resource potential | Zone |
|-------|--------------------|------|
| 1     | 16.97              | 5    |
| 2     | 16.87              | 5    |
| 3     | 16.28              | 4    |

Aggregate resource potential is the sum of private potentials:

\[ ARP_i = SP_i + NP_i + LP_i + PP_i + MP_i \] (6)
The resource potential calculated for a specific field enables to improve the information support of the land management design process, to most effectively organize the system of crop rotations, forage lands, etc. The resource potential of an agricultural enterprise can be used when justifying investment projects, attracting capital investments, justifying government subsidies, etc.

3. Research results

After receiving the rating results, 3 variants of spatio-temporal scenarios for organizing the crop rotation system of integrated agricultural production company “Gladyshevsky” were developed. The first option implies planning three crop rotations (three-, four- and five-field) based on the principle of forming compact arrays of crop rotations with an optimal weighted average distance from the center of the massif to the fields with the objective to reduce transport costs due to the absence of dissection of the territory by natural tracts, maximally close in sown areas structure to the desired volume of gross output of an agricultural organization (Table 6, Fig. 1). Despite the optimal combination of spatial characteristics, the average indicators of the ranking by crop rotation have differences, which will affect the volume of gross production by years.

Table 6. Rating indicators of projected crop rotations of option I of the spatial-temporal scenario of integrated agricultural production company “Gladyshevsky”

| Crop rotation                  | Number of plots in crop rotation | Rating value | Average rating |
|-------------------------------|----------------------------------|--------------|----------------|
| Field crop rotation No. 1     | 12                               | ≥15.0        | 16.53          |
|                               | 8                                | < 15.0       | 11.61          |
| Total                         | 20                               | -            | 14.56          |
| Field crop rotation No. 2     | 11                               | ≥15.0        | 16.99          |
|                               | 7                                | < 15.0       | 12.68          |
| Total                         | 18                               | -            | 15.31          |
| Field crop rotation No. 3     | 6                                | ≥15.0        | 16.30          |
|                               | 16                               | < 15.0       | 12.85          |
| Total                         | 22                               | -            | 13.79          |
| In all                        | 60                               | -            | 14.51          |

The second option implies designing two five-field crop rotations with the maximum approximation to the planned structure of sown areas of integrated agricultural production company “Gladyshevsky” being equivalent in terms of fields rating, conditions for crops concentration (Table 7, Fig. 2).

Table 7. Rating indicators of the projected crop rotations of option II of the spatial-temporal scenario of integrated agricultural production company “Gladyshevsky”

| Crop rotation                  | Number of plots in crop rotation | Rating value | Average rating |
|-------------------------------|----------------------------------|--------------|----------------|
| Field crop rotation No. 1     | 6                                | ≥15.0        | 16.30          |
|                               | 16                               | < 15.0       | 12.85          |
| Total                         | 22                               | -            | 13.79          |
| Field crop rotation No. 2     | 23                               | ≥15.0        | 16.75          |
|                               | 15                               | < 15.0       | 12.11          |
| Total                         | 38                               | -            | 14.92          |
| In all                        | 60                               | -            | 14.51          |

The third option of the spatio-temporal scenario of territory organization consists in the design of one four-field and one five-field crop rotation, which focuses on the need to create equivalent conditions for the qualitative composition of soils based on fields rating, the requirements for the
optimal size of crop rotations for a given zone, and crops concentration (Table 8, Fig. 3).

**Table 8.** Rating indicators of the projected crop rotations of option III of the spatial-temporal scenario of integrated agricultural production company “Gladyshevsky”

| Crop rotation                | Number of plots in crop rotation | Rating value | Average rating |
|------------------------------|----------------------------------|--------------|----------------|
| Field crop rotation No. 1    | 13                               | ≥15,0        | 16,74          |
|                              | 19                               | < 15,0       | 12,78          |
| Total                        | 32                               | -            | **14,39**      |
| Field crop rotation No. 2    | 16                               | ≥15,0        | 16,59          |
|                              | 12                               | < 15,0       | 12,04          |
| Total                        | 28                               | -            | **14,64**      |
| In all                       | 60                               | -            | **14,51**      |

**Figure 1.** Option 1 of spatio-temporal scenario of organizing crop rotations of integrated agricultural production company “Gladyshevsky”

**Figure 2.** Option 2 of spatio-temporal scenario of organizing crop rotations of integrated agricultural production company “Gladyshevsky”
Figure 3. Option 3 of spatio-temporal scenario of organizing crop rotations of integrated agricultural production company “Gladyshevsky”.

4. Conclusion
The analysis of the developed options is necessarily complemented by economic calculations of agricultural production efficiency. The calculation of economic efficiency showed that option 3 drawn up according to the most optimal combination of the rating of fields is a priority and is recommended for being implemented on the farm.

Thus, the calculation of the investment and resource potential reflecting the totality of resources inherent in an agricultural organization enables to choose the most efficient option for the spatio-temporal scenario for agricultural land.

References
[1] Gulan B, Stamenovic M 2015 Land Potential Eurobrand pp 23-31. doi: 10.5281/zenodo 3595635
[2] Hepperle E, Dixon-Gough R et al 2013 Land management: Potential, Problems and Stumbling Blocks. DOI: 10.3218/3480-6.
[3] Koohafkan P 2009 Land resources potential and sustainable land management: An overview Natural Resources Forum 24 69-81. DOI: 10.1111/j.1477-8947.2000.tb00933.x.
[4] Assiri M, Barone V, Silvestri F et al 2021 Planning sustainable development of local productive systems: A methodological approach for the analytical identification of Ecoregions Journal of Cleaner Production 287 125006. DOI: https://doi.org/10.1016/j.jclepro.2020.125006
[5] Siptits S O, Evdokimova N E 2020 Methods of ecological and economic optimization of land resource use in regional agri-food systems E3S Web of Conferences 222 06036. DOI:
[6] Wang Xiangdong, Liu Wei-Dong 2012 Spatial Planning System in China: Status, Problems and Reconstruction *Economic Geography* 32 7-15+29

[7] Komarov S 2020 Proposals for improving the land economic valuation *Modern problems of cadastral and economic valuation of land: a collection of scientific works* pp 37-44

[8] Komarov S 2021 Methodology for assessing the investment and resource potential of agricultural land *European Proceedings of Social and Behavioural Sciences* 115

[9] Köstner B, Berg M et al 2008 Land, Climate and Resources (LandCaRe) 2020-Foresight and Potentials in Rural Areas under Regional Climate Change *Italian Journal of Agronomy* 3 743-744

[10] Zalza B, Mutiara Raharjo 2014 Land use and land suitability analysis based on eruption hazard potential of mount Merapi *JSTI: Analisis Penggunaan Dan...(Hasmana Soewandita)* 16 8-19