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TRANSFORMATION OF AGRICULTURAL LANDS

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Summary

One of the methods of land transformation is linear programming method, which is called the simplex method. Its application allows us quickly and efficiently to build a model of optimal use of land resources and helps to find such combination of the lands, that allows us to obtain the maximum yield in money equivalent with given resources. The application of methods of remote sensing (RS) as spatial information to solve the problems of land management, including land transformation, becomes the most optimal in modern conditions.

Keywords

transformation of the land • simplex method • GIS technologies • remote sensing

1. Introduction

At this stage of organization of land relations the new character and the content of the socio-economic problems of land use are determined: formation of new land ownership, its division and augmentation, transferring of rights on the land plots (shares) to the land users, transferring of land to lease, land protection and rational land use. New land-uses are arising or arrangement of existing ones is occurring constantly. Nowadays there is a need to meet the maximum satisfaction of the economic interests of landowners and land users, the most complete and effective utilization of productive capacity of farms and lands which are associated with them, in strict compliance with the special regimes and the conditions of land resources use [Tretyak et al. 2011]. Therefore, for the quick and efficient resolution of the problems of land management, including land transformation, we should use modern space, computer and terrestrial technologies that greatly facilitate this process.

Increasingly new methods of automated execution of land transformation using modern GIS technologies are developing. An urgent task is to solve the problem of development of methodological and algorithmic mechanism for providing by information technologies the field of land management and cadastre as also for solving a number of practical problems that arise during the creating of the projects of territorial land management and land management affairs, land protection and rational use of lands [Enemark 2005].

Every management decision about the transformation of agricultural lands has its own particular result, and the goal of management activity is to find out such forms, methods, means and decision-making tools that could help to achieve the optimal result in specific conditions and circumstances.

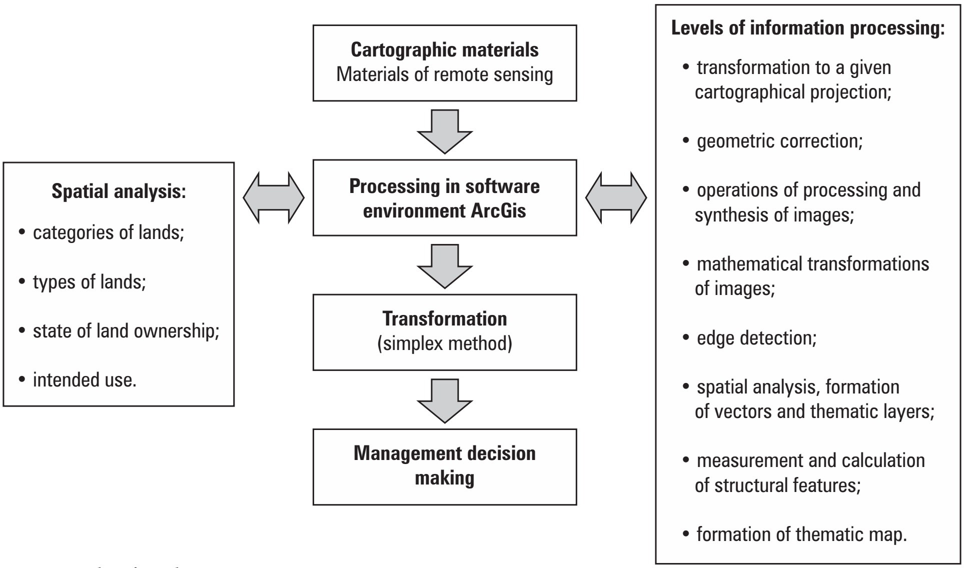
The technology of development, adoption and implementation of decisions and procedures, the implementation of logical, analytical, information retrieval, computing and other operations should provide their clear sequence. Developing managerial procedures we prescribe a procedure of implementation of certain operations which are related to the collection, movement, storage, processing, analysis of information, providing structural departments and individual working places by it, and we determine other actions, arising from the need to solve economic problems.

2. Material and methods

2.1. Block diagram of the implementation of the research

In the world of the new requirements the theoretical and methodological providing of land management production by using computer technologies based on the graphical land use planning is relevant [Becek 2011]. Geoinformation systems (GIS) allow to interpret spatially coordinated information, related to a particular area, for the purpose of creating new units of landholdings.

Due to this the need to improve the theory and methods of land management using new information technologies is increased. Block diagram of the research, carried out by us, is shown in Figure 1.



Source: authors' study

Fig. 1. Block diagram of the research

2.2. The cartographic material

The initial stage of conduction of land transformation is a compilation of cartographic material on which basis the research and scientific study of the transformation from one type of agricultural lands to another are conducted. This cartographic material is obtained as a result of processing of in situ data, data of aerial photography, of satellite methods of earth remote sensing (RS) for obtaining spatial information and solving the problems of land management, including land transformation. Currently, the question of exploring the possibility of using satellite images to create this material remains very relevant.

2.3. Software for data processing

For solution of this problem the technological procedures of processing of data using existing software occupy an important role.

In particular, software for processing of remote sensing data are the packages for obtaining the coordinates of points in the selected coordinate system, processing of space and air photo images provided by various mathematical apparatus that allows to conduct various operations with incoming information [Sverdljuk 2006]. This is a fairly wide range of operations, from all kinds of correction (optical, geometric), through the geographical bridging of the images, down to the processing of stereo pairs with the issuance of the results in the form of actualized topographical drawing.

For the creation and processing of cartographic material for the purpose of conducting land cadastre the full-featured GIS are used most frequently. ArcGis, Erdas, Envi, AutoCad are the most widespread software systems [Kalantari 2003].

Among the many GIS software the ArcGIS, a set of software products developed by the corporation ESRI (USA) [www.esri.com/industries/cadastre], which is the most common GIS in Ukraine, is shown up with its fullness, high functionality and effectiveness. ArcGIS is an integrated collection of GIS software products for the development of a fully functional data processing system that allows users to deploy functionality of GIS in a place where it is needed: in the desktop version (ArcGIS Desktop), server (Server) or in the form of specially created program; for web or for working in the field conditions, mobile versions (Mobile).

An integrated suite of such software modules is included in the content of desktop products of ArcGiS Desktop: ArcCatalog – organization of the structure, spatial data storage and creating the databases for recording, viewing and management of metadata; ArcMap – performing of all works on mapping and editing, cartographic analysis and ortho-transformation of satellite images; ArcToolbox – data management, conversions, layers processing, vector analysis, geocoding and statistical analysis; ArcBuilder – visual graphical modeling during the construction and implementation of geo processing models that can include tools, scripts and data. Models are presented as the diagrams of data processing, they are binding the tool sets and data, which are necessary to perform complex analytical procedures and for the implementation of workflows.

With the help of these software modules and their interfaces we can perform mapping, geographic analysis, data editing and compilation, geo processing and data management.

2.4. Land transformation by simplex method

To ensure effective and efficient use of land resources it is necessary to conduct transformation of land, i.e. there is a need to change their intended use [Pongratz et al. 2008].

Transformation of lands is conducting for the purposes:

1) to increase the area of other lands,
2) to change of land allocation, taking into account soils, terrain, soil conservation,
3) to create large masses of homogeneous use, to improve or to straight land borders,
4) close-together arrangement of the specified mass of required size.

The criterion of feasibility of the planned transformation of the lands is to increase economic efficiency and to obtain the net profit based on the preservation and protection of the soils and the environment [Ludchak 2010].

There are two main methods to transform the land from one type to another – graphical and mathematical. In this case, we propose to perform transformation of the lands by linear programming method, and specifically by the simplex method. This is a widespread method of optimizing the use of limited resources which is rather effective [Fourer 2014].

The method of linear programming using the simplex method for solving the problems of land management, including land transformation, consists in finding such combination of lands, which are projecting, in order to obtain a maximum yield in monetary terms with given resources.

To solve the problem by this method it is necessary that the situation described therein should meet three basic conditions:

- it must be related to limited resources, otherwise this problem would simply not exist,
- an exact aim of the research must be formulated (profit maximization or cost minimization),
- the problem should met the criteria of linearity and homogeneity.

The process of solving the problem by the simplex method has an iterative character: computational procedures (iterations) of the same type are repeated in a certain sequence until the optimal plan of the problem is received or it is found that it does not exist [Vitlinskiy et al. 2001].

The main economic and mathematical model of the problem is presented in expanded form:

To find out:

$$F_{\max} = c_1 X_1 + c_2 X_2 + c_3 X_3 + c_4 X_4 + \ldots + c_n X_n, \tag{1}$$

with restrictive conditions:

$$\left.\begin{array}{l} a_{11}X_1 + a_{12}X_2 + \ldots. + a_{1n}X_n \leq B_1 \\ a_{21}X_1 + \mathrm{a}_{22}X_2 + \ldots.+ a_{2n}\mathrm{X}_n \leq B_2 \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ a_{\mathrm{m}1}X_1 + a_{\mathrm{m}2}X_2+\ldots. + a_{mn}X_n \leq B_m \end{array}\right\} \quad (2)$$

where:

$F_{\max}$ – linear objective function (is subjected to maximization),
c_n, a_{mn}, B_m – specified constants,
X_n – parameters of the optimal use.

3. Results and discussion

The practical implementation of the research technology we will show on the example of the territory of the separate village council (Figure 2).

Thematic maps, which are created as a result of field measurements, were accepted as a basic cartographic material.

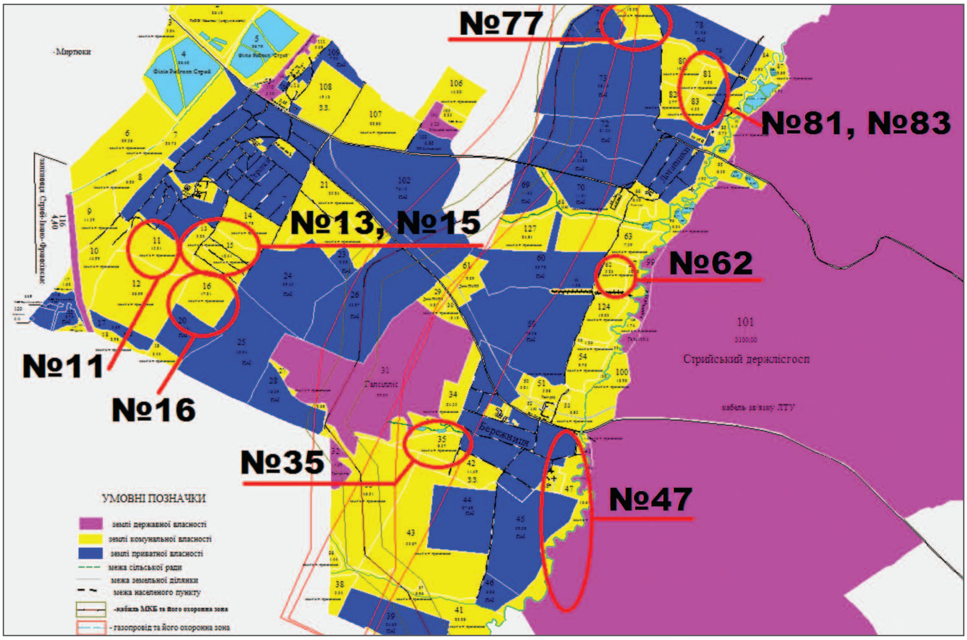
Pre-processing of initial data involves converting of collected data into a format which ArcGIS supports. If cartographic materials are made in different epochs and in different coordinate systems, then on the cartographic materials we can select typical uniquely identified contours whose coordinates we will define in a chosen unified coordinate system that will allow for the further to implement the transformation of all coordinate systems (if it exists on the different maps) to a unified system [Kazachenko et al. 2009].

On the thematic map we defined and analyzed those land plots (parcels) which would be advisably transformed from one type of the lands to another for their efficient and effective use.

The necessity in transforming of the agricultural lands is caused mainly by the fact that this village council is planning the development of meat and dairy industry, horticulture, so it is advisable to increase the number of perennial plantings, grasslands and to create a pasture for these purposes.

Chosen land plots which are offered to transform from one type of agricultural lands to another are depicted in Figure 2.

For the creation of the pasture (lands with adverse geographical conditions – such as swamp, high groundwater, high grass vegetation, etc.) we should allot a land plot no. 47 with an area of 16.65 ha which is currently occupied by the grassland. It is also advisable land plots no. 62, 81, 83 (total area – 14.8 ha) to transform from grasslands to arable lands, as they are near the limits of the settlement and have regular geometric shape – so in the future it will be easier to follow the plow. For the creation of the grasslands it is expedient to transform land plots no. 11, 16, 35, 77 which now are arable lands with a total area of 41.09 ha. Land plots no. and 15 (arable lands) with a total area of 15.64 ha are proposed to be transformed into perennial plantings in this paper.



Source: authors' study

Fig. 2. Highlighted land plots which are offered to transform from one type of agricultural lands to another

For better visualization all the data needed for transformation we can read in Table 1.

Table 1. Data for transformation

Agricultural lands, which are subjected to transformation	Projected lands				Areal size of agricultural lands suitable for transformation [ha]
	Cultivated pastures	Arable lands	Perennial plantings	Grasslands	
Grasslands	$\frac{350^{*}}{2.4}$	$\frac{200}{2.8}$			31.45 (32)
Arable lands			$\frac{1100}{160}$	$\frac{120}{4.5}$	56.73 (57)
The value of gross output from 1 ha of agricultural lands, which are projecting, [$ per ha]	42.40	109.55	142.53	45.90	

Source: authors' study

* In the numerator – the financial resources spent on the transformation of 1 ha of agricultural lands [$ per ha], the denominator – the expenditure of labor [man-day per ha] spent on the transformation of 1 ha, which are obtained experimentally.

For this territory of village council there are restrictions in areas, so according to conditions of economic activity, the area of perennial plantings shall not exceed 200.00 ha and cultivated pastures' area – 140.00 ha. There are also restrictions in expenditures – agricultural enterprise in order to carry out the works related to the transformation of one agricultural lands to another can allocate $ 574 000 of financial resources and 135 000 man-days of labor resources.

Our task is to find such combination of lands, which are projecting, in order to obtain a maximum yield in monetary terms with given resources.

The main economic and mathematical model of specifically given to us problem is presented in expanded form:

To find out:

$$F_{max} = c_1X_1 + c_2X_2 + c_3X_3 + c_4X_{4,} \tag{3}$$

with restrictive conditions:

$$\left.\begin{aligned} & a_{11}X_1 + a_{12}X_2 \leq B_1 \\ & a_{23}X_3 + a_{24}X_4 \leq B_2 \\ & a_{31}X_1 \leq B_3 \\ & a_{43}X_3 \leq B_4 \\ & a_{51}X_1 + a_{52}X_2 + a_{53}X_3 + a_{54}X_4 \leq B_5 \\ & a_{61}X_1 + a_{62}X_2 + \mathrm{a}_{63}X_3 + a_{64}X_4 \leq B_6 \end{aligned}\right\} \tag{4}$$

$$X_1 >= 0; X_2 >= 0; X_3 >= 0; X_4 >= 0 \tag{5}$$

where:

F_{max} – linear objective function (is subjected to maximization),
X_1 – area of grasslands that can be transformed to the cultivated pasture,
X_2 – area of grasslands that can be transformed to the arable lands,
X_3 – area of arable lands that can be transformed to the perennial plantings,
X_4 – area of arable lands that can be transformed to the grasslands,
B_1, B_2, B_3, B_4 – the maximum allowable areal sizes of transformation of each type of agricultural lands,
B_5, B_6 – monetary and human resources allocated for the purposes of transformation;
a_{ij} – expenditures for the purposes of transformation of *i*-type of land,
c_1, c_2, c_3, c_4 – gross income per unit area of transformed agricultural lands respectively.

In expanded form of economic and mathematical model (formulas 3, 4) we substitute the value of technical and economic factors and resources that we took from the project of transformation of agricultural lands for this territory of village council.

To find out:

$$F_{max} = 42{,}4\ X_1 + 109{,}55\ X_2 + 142{,}53\ X_3 + 45{,}9\ X_4 \qquad (6)$$

with restrictive conditions:

$$\left.\begin{array}{l} X_1 + X_2 \leq 32 \\ X_3 + X_4 \leq 57 \\ X_1 \leq 140 \\ X_3 \leq 200 \\ 350\ X_1 + 200\ X_2 + 1100\ X_3 + 120\ X_4 \leq 574\ 000 \\ 2{,}4\ X_1 + 2{,}8\ X_2 + 160\ X_3 + 4{,}5\ X_4 \leq 135\ 000 \end{array}\right\} \qquad (7)$$

$$X_1 > = 0;\ X_2 > = 0;\ X_3 > = 0;\ X_4 > = 0 \qquad (8)$$

In order to find the economic optimum we have to solve this system of inequalities and, for this, we should lead it into canonical form where all conditions are presented in the form of equations [Nakonechniy and Savina 2003]. For this purpose, to the left part of the system of inequalities (7) the positive variables x_{n+1}, called complement unknown values, are added. In the objective function the complement variables are introduced with zero coefficients.

The complement unknown values are written as:

- X_5 – area of grasslands that cannot be transformed,
- X_6 – area of arable lands that cannot be transformed,
- X_7 – the area of cultivated pastures, which is lacking to the maximum allowable areal sizes of these cultivated pastures in the farm,
- X_8 – the area of perennial plantings, which is lacking to the maximum allowable areal sizes of these perennial plantings in the farm,
- X_9 – underused financial resources allocated for the purposes of transformation,
- X_{10} – underused labor resources allocated for the purposes of transformation.

Then, we can write the economic and mathematical model of the problem in canonical form:

$$\begin{array}{l} F_{max} = 42{,}4\ X_1 + 109{,}55\ X_2 + 142{,}53\ X_3 + 45{,}9\ X_4 + \\ \quad + k_1 X_5 + k_2 X_6 + k_3 X_7 + k_4 X_8 + k_5 X_9 + k_6 X_{10} \end{array} \qquad (9)$$

with restrictive conditions:

$$\left.\begin{array}{l} X_1 + X_2 + X_5 = 32 \\ X_3 + X_4 + X_6 = 57 \\ X_1 + X_7 = 140 \\ X_3 + X_8 = 200 \\ 350\ X_1 + 200\ X_2 + 1100\ X_3 + 120\ X_4 + X_9 = 574\ 000 \\ 2{,}4\ X_1 + 2{,}8\ X_2 + 160\ X_3 + 4{,}5\ X_4 + X_{10} = 135\ 000 \end{array}\right\} \qquad (10)$$

where:

$k_1, k_2, k_3, k_4, k_5, k_6$ – zero coefficients (every coefficient is equal to zero).

The solution of equation (9) with restrictive conditions (10) was made in simplex tables in Microsoft Excel software. The criterion for the solution of equation (9) with restrictive conditions (10) is obtaining of the positive values in the index string of simplex tables. From this solution in the final version we obtained the values of main unknowns X_1, X_2, X_3, X_4 – the parameters of the optimal use of land resources (Table 2). The solution was obtained as a result of three iterations.

Table 2. Comparison of agricultural lands' transformation [ha]

Unknown values	Initial version	Version obtained by computing
X_1 (grasslands → cultivated pasture)	16.65	16.60
X_2 (grasslands → arable lands)	14.80	11.14
X_3 (arable lands → perennial plantings)	15.64	12.69
X_4 (arable lands → grasslands)	41.09	46.03
F_{max}, [$]	5436.10	5955.26

Source: authors' study

From the data (according to Table 2) it can be seen that the maximum value of gross output has increased by 9.6% and makes up 5955.26 $. The decision about the transformation of grasslands to cultivated pasture on the area of 16.65 ha turned out to be the best and optimal, as the results of calculations are very close to the original values. As for the transformation of grasslands into arable lands, then, in accordance with the initial data, their area should have been 14.80 ha, but eventually after conducting of transformation it emerged that for the optimal use of these lands their area should be reduced by 3.66 ha. For the rational use, it is advisable to transform the arable lands in perennial plantings on the area on the 2.95 ha less than it was provided in the initial version, in other words on the area of 12.69 ha. Also, as the calculations show, that it is expedient to increase the area of transformation of arable lands to grasslands by about 5 ha to 46.03 ha.

4. Conclusions

When resolving the issues of sustainable land use new theoretical concepts and practical approaches about the optimization of agricultural land use deserve the attention and they should be based on the national legal system, economic valuation of the land and agricultural produce, local, regional and state programs of territory development, new technical and technological approaches.

The implementation of the algorithm of transformation of agricultural lands by simplex method allows to find the parameters of the optimal use of land resources and, as a result, it would lead to an increase of economic efficiency of agricultural lands and to obtaining of greater net income.

Practical implementation of transformation of agricultural lands on the territory of one of the administrative-territorial units has shown the effectiveness of this approach, which has resulted in an increasing of value of gross output by 9.6%.

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