

## Mathematical approaches of alternative types of land use determination for well-proportioned development of rural areas

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**Summary.** Systemic crisis and the decline of rural areas lead to a decrease in the level of life of rural population, the decrease in agricultural production. This number of problems determines the ways of rural development.

Based on a comprehensive approach and combining three components, environmental, economic and social, we have proposed the methodical approach of the main trends of land use development in rural areas by an example of Berehiv district the Transcarpathian region. It is expected to achieve an optimal balance between economically feasible and environmentally safe uses of land and to facilitate the economic increase of the material and social needs of the population (sustainable development). This technique is based on the analytic hierarchy process, which was developed by Thomas L. Saaty. Calculations were made with the help of the Mathcad software environment 14.

**Key words:** rural areas, land use, trend of development, the method of Saaty.

### ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Works of scientists like D. Babmindra, I. Bystriakov, S. Bulyhin, V. Holian, A. Danylenko, D. Dobriak, A. Dorosh, A. Kanash, A. Martyn, H. Loiiik, L. Novakivskyi, S. Osypchuk, P. Rusnak, A. Tretiak, M. Stupen, A. Sokhnych, P. Sabluk, M. Khvesyk, V. Trehobchuk, M. Fedorov, and others were dedicated to the problems of land use studying in rural areas in view of their rational use and protection. However, the peculiarities of land use are not fully described in them, particularly in the area of the Carpathians and the Transcarpathian region. An extremely wide variety of farming forms, the differentiation of natural conditions and resources, differences in the development of individual districts, as well as changes in environmental conditions require a detailed studying [16].

### PROBLEM STATEMENT

For decades rural development in our country based on the narrow specialization of the agrarian approach. This has led to the decline not only of the social infrastructure in rural areas, but also to the decline of the Ukrainian village. In the last years, the following trends in the land tenure system of our country were defined: the reformation of the land tenure system has led to a decrease in the efficiency of agricultural production, worsening in land use as the main means of production; while using the land the environmental situation continues deteriorating; there is a decline in living standards of rural residents, the demographic situation in rural areas has deteriorated sharply [2].

Systemic crisis and the decline of rural areas lead to a decline in living standards of the rural population, and the decrease of agricultural output.

This number of problems identifies the trends of rural development.

### TASK SETTING

To ensure sustainable development of economic system is an important but not well studied problem concerning rural development. This research aims at determining the trends of rural development by an example of Berehiv district the Transcarpathian region.

### THE MAIN MATERIAL

It is possible to solve problems of the economic development and people's welfare improvement only due to the development of sustainable land use in rural areas. Today the Ukrainian village is in a state of transformation caused by the development of new technologies in agriculture and structural changes in the economy of Ukraine. Currently, such problems like the employment of rural residents, en-

couraging small business development in rural areas and improvement of the rural residents' quality of life are the most vital ones. In addition, the Ukrainian village during the last decade is suffering from the poor infrastructure. To solve these and other problems of the Ukrainian village it is necessary to find realistic ways of rural development, which are based on modern approaches and principles, and place emphasis on rural development and meeting the farmers' needs. Trends of rural development of Ukraine must combine existing Ukrainian experience as well as the experience of countries which are the members of the European Union. Under modern conditions of development, there is an urgent need to develop not only strategies and programs of rural development, but also to develop and introduce effective mechanisms and tools for their implementation [5].

Based on a comprehensive approach and combining three components ( environmental, economic and social), we have proposed the methodical approach of the main trends of rural land use development by an example of Berehiv district the Transcarpathian region. It is expected to achieve an optimal balance between economically feasible and environmentally safe uses of land and to facilitate the economic increase of the material and social needs of the population (sustainable development). This technique is based on the analytic hierarchy process, which was developed by Thomas L. Saaty [19, 20, 15]. Calculations were made with the help of the Mathcad software environment 14.

The main trends of rural land use and land use forming have been determined. They concern the development of:

1. Households land tenure.
2. Land use with the recreational purpose.
3. Land use in agricultural production.
4. Land use in animal husbandry.

The criteria for assessment of the trends of development have been determined. They are:

1. Profitability.
2. Natural resource base: land, forest, water, mineral resources, landscape and biodiversity, and human potential.
3. Investment in the sphere.

Determination of the major trends and criteria for sustainable land use development is based on the analysis of the investment potential of land and natural resources use in rural areas, planning for sustainable rural development, development of institutions of civil society, the formation of a new structure of households, which will continue to be crucial in the lifestyle of farmers. The main trends of development define the land use in rural areas, leading to changes in the structure of farms. Determining the trends of sustainable land use in rural areas is based on the analysis of economic and social indicators such as profitability, resource potential and so on.

For making calculations there has been determined the score for each criterion, which shows the priority relative to each other. It should be noted that during the comparative assessment of the criteria, due to which the trends of sustainable land use in rural areas of the region are evaluated, the expert assessment has been used. The group of experts included representatives of the Department of the State Agency of Land Resources, local governments and heads of households and individual experts.

The methodical approach of Land Governance Assessment Framework – LGAF, used by the experts of the World Bank, was taken as the basis while defining the figures of indicators. Experts estimate the criteria in terms of priority of indicators: the most important – 71-100% important – 41-70%, significant – up to 40%. Table 1 shows the average scoring according to the above mentioned methodical approach.

**Table 1.** Expert assessment of the criteria

Criteria	Score
Profitability	100
Natural resource base	70
Investments in the sphere	40

According to the figures of the table we conclude that the group of experts suggests profitability as a priority criterion for sustainable land use in rural areas.

Based on individual experts reviews, which are provided in Table 1, we range factors influencing the choice of the ways of land use in rural areas. The most important criteria (factors) should be laid the greatest weight on, the most comparative assessment. To range factors according to their importance it is reasonable to attract all the information about the object of studying – the studied area, its natural, spatial, social, economic and household characteristics, and thorough analysis of this information.

According to expert assessments the pairwise comparison of factors is performed in the form of a matrix. Members of the matrix are represented as a fraction. Based on expert criteria we make up the comparative matrix of criteria (Table 2).

**Table 2.** Comparative matrix of criteria

Criteria		Profita- bility	Resource base	Investments in the sphere	$\Sigma a_i$
		$a_1$	$a_2$	$a_3$	$a_4$
Profitability	$a_1$	1	100/70	100/40	4,929
Resource base	$a_2$	70/100	1	70/40	3,450
Investments in the sphere	$a_3$	40/100	40/70	1	1,971
$\Sigma a_j$		2,100	3,000	5,250	10,350

$$\Sigma a_i = \Sigma a_j = 10,350. \quad (1)$$

where:

$a_i$ ;  $a_j$  – members of the matrix with an index indicating the serial number of a line and a column.

By means of the MathCAD software environment we determine the eigenvalues of the matrix (2) using the appropriate matrix function eigenvals:

$$\text{eigenvals} \left( \begin{pmatrix} 1 & \frac{100}{70} & \frac{100}{40} \\ \frac{70}{100} & 1 & \frac{70}{40} \\ \frac{40}{100} & \frac{40}{70} & 1 \end{pmatrix} \right) = \begin{pmatrix} 0 \\ 3 \\ 0 \end{pmatrix}. \quad (2)$$

The analysis of the eigenvalues of the matrix shows that the maximum eigenvalue of the matrix  $Z_{max} = 3$ , i.e. the same as the size of the matrix  $m = n = 3$ , where  $m$  – the number of lines;  $n$  – the number of columns.

We should define a score for specific criteria of development of sustainable land use in rural areas by the formula (3):

$$B = X_i * 100 / \sum X_i, \tag{3}$$

where:

$B$  – scoring,

$X_i$  – indicator.

Scoring of trends of sustainable land use development as for the criterion of profitability is calculated by the economic indicator – income from the activity of each of the branches. Scoring as for criterion on the natural resource base is calculated on the basis of providing with land-resource potential each trend of sustainable land use development in rural areas.

Accordingly, the development of households land tenure is ensured if there is the built-up land; the development of land use with the recreational purpose is ensured if there are recreation lands; the development of land use in agricultural production is ensured if there is agricultural land, including arable land, and the development of land use in animal husbandry is ensured by the presence of grasslands (Table 3).

Based on scoring as for the criteria of profitability, the availability of the resource base and the investment we make comparative matrices (Table 4).

Similarly we make the calculation for the other criteria.

We determine the eigenvalues of the matrix on criterion of profitability (4), using the corresponding matrix function eigenvals:

$$\text{eigenvals} \left( \begin{pmatrix} 1 & \frac{33}{19} & \frac{33}{35} & \frac{33}{13} \\ \frac{19}{33} & 1 & \frac{19}{35} & \frac{19}{13} \\ \frac{35}{33} & \frac{35}{19} & 1 & \frac{35}{13} \\ \frac{13}{33} & \frac{13}{19} & \frac{13}{35} & 1 \end{pmatrix} \right) = \begin{pmatrix} 0 \\ 4 \\ 0 \\ 0 \end{pmatrix}. \tag{4}$$

Similarly, we define the eigenvalues of the matrix of the criteria of the resource base and investment in the development of the branch for each base area, using the appropriate matrix function eigenvals.

On determining the eigenvalues of all matrices of pairwise comparison of options for each individual factor in accordance with the program MathCAD, it was determined that in all cases the maximum eigenvalue of the matrix  $Z_{max} = 4$ , i.e., it coincides with the size of the matrix  $m = n = 4$ .

The value of  $n$  and  $Z_{max}$  in all cases is the same, indicating the full consistency of expert review, as for the criteria of rural development and strategies separately for each of the defined factors.

**Table 3.** Scoring of trends of rural land use development as for criteria of assessment

Trend of sustainable rural land use development	Criteria					
	Profitability		Resource base		Investments in the sphere	
	The financial results from sales, $X_1$	Scoring	Providing with land and resource potential, $X_2$	Scoring	Investments in the sphere, $X_3$	Scoring
Development of households land tenure	186,2	33	1376,6	3	1,1	1
Development of land use with the recreational purpose	110,5	19	27,8	1	123,5	84
Development of land use in agricultural production	200,0	35	36721,4	77	20,5	14
Development of land use in animal husbandry	75,2	13	9196,8	19	1,2	1
$\sum X_i$		100		100		

**Table 4.** Comparative matrix on criteria of profitability

Trend of sustainable rural land use development	Development of households land tenure	Development of land use with the recreational purpose	Development of land use in agricultural production	Development of land use in animal husbandry	$\sum a_i$
Development of households land tenure	1	33/19	33/35	33/13	6,218
Development of land use with the recreational purpose	19/33	1	19/35	19/13	3,580
Development of land use in agricultural production	35/33	35/19	1	35/13	6,595
Development of land use in animal husbandry	13/33	13/19	13/35	1	2,450
$\sum a_j$	3,0303	5,263	2,857	7,692	18,8429

The values of the matrix terms are interrelated and correspond to:

$$a_{ij} = 1/a_{ji}, \quad (5)$$

where:

$a_i$ ;  $a_j$  – terms of the matrix with an index indicating the serial number of lines and columns. On the diagonal of the matrix, at the intersection of similar factors or options, the terms of the matrix take the unit value.

The next step for solving the problem is to determine its own normal vector of the matrix with its maximum eigenvalue:

$$\text{eigenvec} \left[ \begin{pmatrix} 1 & \frac{100}{70} & \frac{100}{40} \\ \frac{70}{100} & 1 & \frac{70}{40} \\ \frac{40}{100} & \frac{40}{70} & 1 \end{pmatrix}, 3 \right] = \begin{pmatrix} 0.778 \\ 0.545 \\ 0.311 \end{pmatrix}. \quad (6)$$

We determine the amount in column:

0.778
0.545
<u>0.311</u>
1.634

We form the matrix of relations of normalized vectors to the total of their values and the transformed matrix by dividing the terms of the matrix to the corresponding vectors and multiplying by the characteristic number.

Then we normalize the matrix by dividing its terms by the amount of the corresponding column. The results are shown in Table 5. Calculation control shows that the sum of each column equals one.

The sum of lines gives the value of benefits of the way of sustainable land use development in rural areas – it is an integrated assessment of options.

**Table 5.** Normalized matrix

Trend of sustainable rural land use development	Profitability	Resource base	Investments in the sphere	$\Sigma$
Development of households land tenure	0,330	0,030	0,010	0,370
Development of land use with the recreational purpose	0,190	0,010	0,840	1,040
Development of land use in agricultural production	0,350	0,770	0,140	1,260
Development of land use in animal husbandry	0,130	0,190	0,010	0,330
$\Sigma$	1,000	1,000	1,000	3,000

They collectively evaluate the way of development in accordance with all the criteria. As a result, we obtain (7):

$$\begin{aligned} W1 &= 0,370; \\ W2 &= 1,040; \\ W3 &= 1,260; \\ W4 &= 0,330. \end{aligned} \quad (7)$$

## CONCLUSIONS

The research found that the priority trends of rural development for Berehiv district the Transcarpathian region are the development of land use in agricultural production ( $W3 = 1,260$ ) in order to produce environmentally-friendly products, and development of land use with the recreational purpose recreational use ( $W2 = 1,040$ ).

This approach for identifying the trends of rural development will provide a comprehensive and integrated solution to the main problems of rural areas within a single concept at various stages of government: national, regional, zonal and local – and include developed strategies, programs and techniques – organizational, economic, financial and legal techniques, provided with corresponding instruments.

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- Аннотация.** Системные кризисные явления и упадок сельских территорий приводят к снижению уровня жизни сельского населения, уменьшению объемов сельскохозяйственного производства. Такой ряд проблем обуславливает определение направлений развития сельских территорий.
- На основе комплексного подхода и сочетая три составляющие, экологическую, экономическую и социальную, нами предложен методический подход основных направлений развития землепользования сельских территорий на примере Береговского района Закарпатской области. При этом предполагается достичь оптимального соотношения между экономически целесообразным и экологически безопасными видами использования земель и обеспечить экономический рост материальных и социальных потребностей населения (устойчивое развитие). Данная методика базируется на основе метода анализа иерархий, разработанный Т. Л. Саати. Расчеты проведены с использованием программной среды Mathcad 14.
- Ключевые слова:** сельские территории, землепользования, направление развития, метод Саати.