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Application of mathematical models in the evaluation of agricultural lands

Svetoslav Iliychovsky*, *Teodora* Filipova, and *Petya* Yordanova

Tsenov Academy of Economics, 5250 Svishtov, Bulgaria

Abstract. The success of any business is associated with the creation of value for all stakeholders: owners, associates, staff, the environment, and society. In order to achieve this goal, it is necessary to meet ESG standards. This leads to a review of the strategy that companies follow but also to a change in the valuation of the entire business and individual assets. The present research focuses on the possibility of evaluating agricultural lands through the use of mathematical models based on indicators that characterize them (area, category, and distance from infrastructure). The estimated value of agricultural land is determined based on accumulated statistical data. Two models are attached. In the mathematical model with a matrix, an appraised plot is compared with four analogues based on a proposed algorithm, and an estimated value of the appraised property is derived. The Hierarchical Linkage Analysis method also compares the evaluated parcel with four similar ones and separates the stages in its application, starting with modeling the problem as a hierarchy, building the hierarchy, selecting factors affecting the value of agricultural land, selecting analogues of agricultural land, construction of multiple matrices based on the comparison of individual parameters, and using hierarchical synthesis to weigh the obtained results and determine the market value of the assessed plot.

1 Introduction

Nowadays, in order to meet national and international standards, the management of companies is required to comply with increasingly serious commitments regarding sustainability, eco-compatibility, and climate change [1,2,3,4]. This fact causes the need to redefine the goals. Along with protecting the interests of the owners, the management of companies should take into account the ecological and social impact of the activity on the environment [5]. To meet these requirements, companies must publish integrated financial and ESG (environmental, social and corporate governance) reports. In this context, in order for a business to be successful, it must create value for all stakeholders – owners, staff, environment, society as a whole [6]. The main target of every entrepreneur should be the coverage and fulfillment of ESG standards [7]. An example of a successful investment is the climate risk hedging strategy developed by Andersson [8].

* Corresponding author: s.iliychovski@uni-svishtov.bg

As a consequence of the application of these standards, the new behaviour of companies would also lead to a change in the valuation of the entire activity and of specific assets [9].

The development of the agricultural land market in Bulgaria implies an increase in the role of expert evaluations of this object of assessment, because otherwise it becomes difficult to realize successful transactions, especially in the absence (limitation) of information about the value of agricultural land. Deriving a reliable estimate is a necessary condition for running an efficient business [10]. When evaluating agricultural land, the Bulgarian and international valuation standards recommend the use of three approaches/methods for evaluation – cost approach, income approach and comparative approach [11].

2 Literature review

Land within the meaning of Art. 21, para. 1 of the Constitution of the Republic of Bulgaria is a chief national asset, that enjoys the particular protection on the part of the State and society. Some authors define it as a "primary factor of production", which includes all natural conditions for carrying out a production process. According to other authors, it is "a natural activity and at the same time an economic category". The Constitution states that arable land is used only for agricultural purposes. In this context, agricultural land, according to Art. 2 of the Law on Ownership and Use of Agricultural Land, is defined as that intended for agricultural production. In this sense is also the definition of the Law on the Protection of Agricultural Land, namely: as national asset, it is used only for agricultural purposes.

The valuation of agricultural land (agricultural land and permanent crops) is an important area of theory and practical research in the field of business valuation. The theoretical foundations of the problem were laid already in the 18th century by the representatives of classical economic theory – A. Smith, D. Ricardo. A significant number of diverse approaches, methods, models and techniques are used in the global theory and practice of agricultural land valuation. This is confirmed by the opinions of the various authors and publications in this field, as well as by the adopted standards for business valuation by the international associations of evaluators in Europe and America. All of them arise and develop on the basis of three main methods: reporting (accounting); financial; marketing (market-based).

Regardless of the differences among the authors' classifications, the variety of methods and techniques can undoubtedly be reduced to three main evaluation approaches, with their inherent methods: cost approach, income approach and comparative approach. In summary, it can be argued that the considered approaches, with their accompanying methods, find a place in the process of determining the value of agricultural land. They are not mutually exclusive, but are rather complementary. As a rule, more than one method of one or more evaluation approaches is used in evaluations.

The cost approach is applicable to the valuation of permanent crops. The approach allows for a value to be determined, taking into account the costs of establishing and growing permanent crops, physical, moral and economic attrition.

The normative approach finds its main application in determining fees for land transactions, taxation, compensation to owners, etc. Its application is based on: Ordinance on the procedure for determining prices of agricultural land, Local Taxes and Fees Act (appendix 2) for tax assessment of agricultural land.

The income approach is applicable from the point of view of the investment motives and intentions of the potential investor, the expected benefits, benefits of investing funds in agricultural land. It allows to determine the value of the object by transforming the expected future income from its ownership into its current value, i.e., the income is obtained as a result of its functioning. At the same time, the volume, quality, and duration of receiving income play a major role in choosing the object of investment intentions.

Particular attention should be paid to the possible reliable determination of future flows. The accuracy of the forecast is influenced by many factors, some of which are related to the macro environment.

The income evaluation approach consists in determining the value of the object based on the income which it is capable of providing in the future to its owner.

The comparative approach is based on market information containing data from actual transactions or offers for the sale of agricultural land with characteristics similar to the evaluated property. The transactions or offers analysed should be in the area of the object being evaluated and should have been carried out and/or offered at a time close to the date of the evaluation. The following methods are used: method of market comparisons (analogues), method of market multiples, method of accessibility.

3 Method of the research

In the current paper, firstly, the application of a mathematical model with the construction of a matrix is considered, and secondly – the use of the Hierarchical Relations Method when deriving the market value of agricultural land. They are applicable to the comparative approach, since for the purposes of the calculations, characteristics of the analogues and the evaluated object are compared.

The determination of the market value – the most likely selling price of a relevant asset – is determined by the stochastic nature of the market itself. It, as an economic system, functions under the influence of many factors. They, in turn, can be considered as variable quantities that form a resulting indicator – market value [9].

The price of agricultural land is influenced by the effect of a significant number of factors, which makes it difficult to derive an accurate assessment of the impact of each of them. At the same time, there is a lack of consensus in the literature regarding the ranking of factors by degree of influence on the price of agricultural land. The factors affecting the value of agricultural land can be summarised as follows: income that can be received from the land; social and demographic factors; economic situation in the country and the region; natural conditions and environment; legal regulation and effective system of taxation; quality characteristics of the land; location of the land; development of land information system.

In addition to the above, many other factors influence the value of agricultural land. For the purposes of this study, we use the following predictors: area, category, rent and land location.

Secondly, we consider the method of hierarchical relationship analysis in ranking the factors affecting the value of agricultural land and inferring its value. One of the frequently used expert-oriented methods is the so-called analytic hierarchy process [12-14]. It was developed in [15], but it was made known by Saati and Kearns [16] who define it as a method of hierarchy analysis and discover a field of its use in solving theoretical and practical tasks in various fields (education, health, economics, evaluation of investment projects, selection of management staff).Vaidya and Kumar [17] present about 150 applications of the method. Louviere and Henley [18] in their research focus on accommodation rentals from students. Separate highlights, fragments for the application of the method of hierarchical relations can be observed, for example, in the optimal location of warehouses for new agricultural products [19], choosing a store location [20], select an optimal source of financing innovation [21], choice of retail location [22], for forecasting real estate prices in combination with GIS [23].

Other authors [24] interviewed 5 investors and 305 clients using the following main criteria: location, design, building design, financial or economic characteristics. In the present paper, the possibility of applying the model to the evaluation of agricultural lands is demonstrated [25- 27]. For this purpose, the criteria - "area", "category", "location" and "rent per hectare" were selected. The following stages for the application of the Hierarchical Linkage Analysis Method in the evaluation of agricultural land can be distinguished: modelling the problem as a hierarchy; building the hierarchy (goals, criteria, alternatives); selecting the factors affecting the value of agricultural land; the choice of analogues – agricultural land in the example four; creating multiple matrices based on correlation of individual parameters; checking the coherence index; using hierarchical synthesis to weigh the obtained results; determining the market value of the evaluated object. The pairwise comparisons are carried out through summarisation and expert opinion of the evaluator. The process allows documentation and repeatability. There are two aims of such research: *First,* to perform a relatively objective ordering of the elements from each hierarchical level on the scale in dependence on the elements from the higher hierarchical level. *Second*, to establish whether and to what extent there is consistency in individual evaluations, as well as among the opinions of experts on research issue. When comparing pairs, evaluators may use a 9-point scale, such that for each pair of criteria being compared, "1" means that they are equally important, and "9" means that one criterion is more important than the other.

The pairwise comparisons are carried out through summarisation and expert opinion of the evaluator. The process allows documentation and repeatability. The analytical hierarchy method gives the opportunity to order the priority of the criteria for evaluating the variant. For this, evaluator performs correlation, consistency among different parameters, factors, activities and the result is presented in a matrix.

4 Results

To demonstrate the possibility of applying a mathematical model with a matrix in the evaluation of agricultural land, we use the information in Table 1.

Table 1. Data on sold agricultural land in Svishtov Municipality.

	Price	**Area (decares)**	**Category**	**Rent per decare**	**Location to (in km)**
Analogue 1	21578	14.8	3	85	road with permanent pavement -2 populated place – 5 municipal centre - 10
Analogue 2	2900	2,3	5	60	road with permanent pavement -7 populated place – 12 municipal centre - 21
Analogue 3	18200	13.5	3	80	road with permanent pavement -4 populated place – 7 municipal centre - 17
Analogue 4	8000	5,9	4	75	road with permanent pavement -3,5 populated place – 7 municipal centre - 11
Evaluated agricultural land		11	3	105	road with permanent pavement -2,5 populated place – 7 municipal centre - 13

The algorithm for determining the market value of agricultural land using a mathematical model with the construction of matrices is as follows: selection of factors influencing the value of the property (in the example – area, category, rent per decare and disposition of agricultural land (location)); selection of analogues – in the present example four; assigning factor scores (for example: it is assumed that if the area of the evaluated plot and the analogues is over 10 decares, then a score of 3 is given, if it is between 5 and 10 decares, the score is 2 and if it is up to 5 decares – 1. In the same way, point scores are determined for "location". The evaluator can make a general adjustment (to take into account the location to a road with a permanent pavement, to populated place and to a municipal centre). Regarding the "category" factor, 3 is set for I, II and III, from IV to VI - 2, and above the sixth category - 1. Regarding the rent, as follows: from 60 to 75 BGN/decare – 1; in the range of 76-100 BGN/decare – 2 and over 100 BGN/decare – 3; comparison of the ranked factors of the analogues with the evaluated object; building a matrix based on the received data; calculating inverse matrix; deriving the market value of agricultural land – multiplying the inverse matrix with the vector (built from the price per square meter) (Table 2).

Table 2. Parameters of analogues and evaluated object.

Agricultural land	**Analogue 1**		**Analogue 2**		**Analogue 3**		**Analogue 4**		**Evaluated property**
	1458 BGN per decare		1265 BGN per decare		1458 BGN per decare		1355 BGN per decare		-
Area	14.8	3	2.3	1	14.8	3	5.9	2	11
Category	3	3	5	2	3	3	4	2	3
Location	Average mean	3	Average mean	1	Average mean	2	Average mean	2	Average mean 3
Rent per decare	85	2	60	1	85	2	75	2	105

From the comparison of the studied factors, we get the following matrix:

$$\begin{pmatrix} 0 & 0 & 0 & 1 \\ 2 & 1 & 2 & 2 \\ 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$

The inverse matrix is:

$$\begin{pmatrix} 0 & 1 & -1 & -1 \\ 0 & -1 & 0 & 2 \\ -1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

In order to derive the market value of the evaluated object, the thus calculated inverse matrix and vector must be multiplied.

$$\begin{bmatrix} 0 & 1 & -1 & -1 \\ 0 & -1 & 0 & 2 \\ -1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 1458 \\ 1265 \\ 1400 \\ 1355 \end{bmatrix}$$

The result obtained is BGN 1445/decare, i.e. for the assessed plot of 11 decares – BGN 15 895. The market value of a plot of 11 decares is BGN 15 900. An *extremely* important condition for applying the model is that the information used must be reliable and objective [9]. A positive side of the model is that when an algorithm is developed or adapted and the functions in Microsoft Excel are used, deriving the market value is done relatively easily and quickly. Secondly, the results of the calculations largely depend on the knowledge and experience of the evaluator.

The main disadvantage is that there is certain subjectivity – in the ranking and comparison of the factors by the evaluator.

In accordance with the specified requirements and according to the method concerned, a hierarchy of relations is built. On this basis and with a view to achieve the objective (deriving the indicative value), it is necessary to determine the degree of importance of the selected factors – area, category, location and rent per decare. It is necessary to complete the matrix and calculate the weighted average.

Table 3. Comparison of parameters “area”, “category”, “location” and “rent per decare”.

	Area	Category	Location	Rent per decare	Geometric mean	Weighted average
area	1	3	4	5	3.333333333	0.560773868
category	0.333	1	1.333	1.666	1.110833333	0.186877891
location	0.25	0.75	1	1.25	0.833333333	0.140193467
rent per decare	0.2	0.6	0.8	1	0.666666667	0.112154774
					5.944166667	1

The degree of preference thus assigned gives the weighted average of 0.5607 for “area”, 0.1868 for “category”, 0.1401 for “location” and 0.1121 for “*rent per decare*”.

At *the next stage*, the degree of influence of each of the factors on the value of agricultural land is determined. The matrix is filled in again and the weighted average values is calculated.

Table 4. Comparing the analogues according to the criteria "area".

Area	Analogue 1	Analogue 2	Analogue 3	Analogue 4	Geometric mean	Weighted average
Analogue 1	1	4	1	2	2.166666667	0.348993289
Analogue 2	0.25	1	1	0.5	0.791666667	0.127516779
Analogue 3	1	4	1	2	2.166666667	0.348993289
Analogue 4	0.5	2	0.5	1	1.083333333	0.174496644
					6.208333333	1

From the information thus obtained, we can assert that the area with the greatest weight is in analogues 1 and 3 – 0.3490, followed by analogues 2 and 4, respectively, at 0.1275 and 0.1744. Similarly, the degree of correspondence with the rest of the factors is determined.

Table 5. Comparing the analogues according to the criteria "category".

Category	Analogue 1	Analogue 2	Analogue 3	Analogue 4	Geometric mean	Weighted average
Analogue 1	1	3	1	2	1.833333333	0.338471953
Analogue 2	0.333	1	1	0.666	0.833166667	0.153820118
Analogue 3	1	3	1	2	1.833333333	0.338471953
Analogue 4	0.5	1.5	0.5	1	0.916666667	0.169235976
			5.4165	1		

In this particular case, preference is given to analogue 1 and analogue 3, the evaluation follows analogue 4 and it is lowest with analogue 2.

Table 6. Comparing the analogues according to the criteria "location".

Location	Analogue 1	Analogue 2	Analogue 3	Analogue 4	geometric mean	weighted average
Analogue 1	1	4	2	3	2.666666667	0.480033602
Analogue 2	0.25	1	0.5	0.75	0.666666667	0.120008401
Analogue 3	0.5	2	1	1.5	1.333333333	0.240016801
Analogue 4	0.333	1.333	0.666	1	0.8885	0.159941196
					5.55516667	1

In this case, preference is given to analogue 1 and analogue 3, followed by analogue 4 and analogue 2.

Table 7. Comparing the analogues according to the criterion "rent per decare".

Rent per decare	Analogue 1	Analogue 2	Analogue 3	Analogue 4	Geometric mean	Weighted average
Analogue 1	1	3	1	2	1.833333333	0.338471953
Analogue 2	0.333	1	1	0.666	0.833166667	0.153820118
Analogue 3	1	3	1	2	1.833333333	0.338471953
Analogue 4	0.5	1.5	0.5	1	0.916666667	0.169235976
					5.4165	1

On this criterion, the greatest weight is on analogue 1 and 3 – 0.3385; analogues 2 and 4 have a weight of 0.1538 and 0.1692, respectively.

Based on the calculation, when comparing the selected criteria on the analogues, the final weighted average values are derived.

Table 8. Final values for each of the factors used.

	Area	Category	Location	Rent per decare
Analogue 1	*0.348993289*	*0.338471953*	*0.480033602*	*0.338471953*
Analogue 2	*0.127516779*	*0.153820118*	*0.120008401*	*0.153820118*
Analogue 3	*0.348993289*	*0.338471953*	*0.240016801*	*0.338471953*
Analogue 4	*0.174496644*	*0.169235976*	*0.159941196*	*0.169235976*

Based on the use of hierarchical synthesis for weighting the obtained results, it is led to:

$$\begin{pmatrix} 0.3489 & 0.3384 & 0.48 & 0.3384 \\ 0.1275 & 0.1538 & 0.12 & 0.1538 \\ 0.3489 & 0.3384 & 0.24 & 0.3384 \\ 0.1744 & 0.1692 & 0.1599 & 0.1692 \end{pmatrix} \cdot \begin{pmatrix} 0.5607 \\ 0.1868 \\ 0.1401 \\ 0.1121 \end{pmatrix} = \begin{pmatrix} 0.36402 \\ 0.13427 \\ 0.33040 \\ 0.17076 \end{pmatrix}$$

The relative share of the involvement of the analogue in the value of the evaluated object is shown in Table 9.

Table 9. The relative share of the Analogues and the price of the sq. m. in euro of Analogue.

Parameters	Relative share	In percentage	Price per decare
Analogue 1	0.36452	36.45%	1400
Analogue 2	0.13427	13.43%	1265
Analogue 3	0.3304	33.04%	1458
Analogue 4	0.17076	17.08%	1355

If the obtained value is rounded up, then it turns out 1 400 BGN per decare. In this case, a plot of 11 dka., i.e. 15 400 BGN or the final estimate of the object, derived on the basis of the Hierarchical Linkage Analysis Method, is 15 400 BGN.

The results of applying the two models (model with matrix construction and method of hierarchical connections) are relatively close. In the first case, the market value of the assessed plot is BGN 15,900 or 8,130 euros, in the second model it is around BGN 15,400 or 7,874 euros, i.e. the difference is insignificant - BGN 500 or EUR 255. It is obtained from rounding on the one hand, on the other hand it may be due to the use of weighted averages in the method of hierarchical links. The appraiser can apply both models or whichever one he chooses is his discretion. The results obtained by them should be used to "support" the derived market value from the comparative approach.

5 Discussion

In recent years, the interest in applying mathematical models for the evaluation of various assets of companies has been continuously growing. For their successful use, it is necessary that the data be reliable, credible and objective. An advantage of the proposed mathematical model with a matrix for the evaluation of agricultural land is that, after developing its algorithm and using the functions, capabilities of Microsoft Excel, Linear Algebra Calculator [28, 29], the market value of agricultural land can be derived relatively quickly and easily. It should be noted that the correctness of the assessment largely depends on the experience and ability of the assessor/assessment team. This is a manifestation of a certain degree of subjectivism and a shortcoming of the model itself.

Saati and Kearns found an area for using the "method of hierarchical connections" in solving theoretical and practical problems in various fields [16]. Other authors [17] identify about 150 applications of the method. The possibilities of its application in residential property valuation are explored in the publications [25, 26,27]. In this article, it is applied in the evaluation of agricultural land. The selected criteria are the following: area, category, location, rent per acre. A method is a systematic procedure for presenting the elements of a given problem in a hierarchical manner. The main levels of the hierarchy may contain: the ultimate goal of the evaluation, approaches/methods of evaluation, criteria for achieving the goal, etc.

The main advantage of the method of analytical hierarchy is the possibility of comparison of criteria and the variability for pairwise solutions, which significantly facilitates the conclusion of the research. Within the framework of the method there are no general rules for the formation of the structure of the model for decision-making. It is a reflection of the real situation, such as different views on the same problems. Data from the discussed method are accumulated mainly through the comparison of parameters. Final results may be inconsistent, necessitating revision of the data to minimise potential conflicts.

This would take the evaluators a lot of time, but they would be more confident in their decision. Disadvantages of the method are that it is complex and time-consuming. There is also no means of verifying the reliability of the data. It is used to rank alternatives, but it does not have the internal resources to interpret them.

Regardless of the method of weighting the results, the evaluator must follow the steps of the proposed methodology: checking the data on which the evaluation is based; verification of the validity of the assumptions and limitations in carrying out the assessment; checking the correctness, accuracy of mathematical calculations; evaluation value synthesis.

6 Conclusions

The final value of the object is the magnitude of the value of the evaluated object, obtained as a justified summary of the results when using different approaches and methods of evaluation. Depending on the specific situation, the obtained values can be significantly different from each other. This requires their consistency by the evaluator. The methods proposed by various authors are primarily expert. The role of the chief expert is taken by the evaluators themselves, since they know where assumptions have been made in the evaluation, which information is insufficiently reliable and which factors have not been taken into account. Only a critical view on the results would help to derive a reliable final assessment. The presented possibility of applying a mathematical model with the construction of a matrix and the method of hierarchical relations in the evaluation of agricultural land is a current and prospective direction in the theory and practice of business evaluation. The development of similar models and evaluation methods would increase the reliability of the results and to a certain extent – reduce subjectivity when deriving the indicative value of the various evaluation objects. We must note that when deriving an indicative market value of objects, according to Bulgarian Standards for Assessment (BSS), a cost, income and comparative approach is applied. The models analysed in the present study can be applied to the market (comparative) approach, and with the results obtained from them – to "support" the derived market value.

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