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EFFICIENCY ANALYSIS OF AGRICULTURE IN SERBIA BASED ON THE CODAS METHOD

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ABSTRACT

The issue of analyzing the efficiency of agriculture on the basis of multi-criteria decision-making methods is very current, complex and significant. Based on that, this paper investigates the efficiency factors of agriculture enterprises in Serbia using the CODAS method. The AHP method is used to calculate the weight coefficients of the criteria. The AHP method is used to calculate the weight coefficients of the criteria. The goal and purpose of that is to process the given problems through the complex theoretical, methodological and empirical prisms in the function of improving the efficiency of agriculture in Serbia in the future by taking appropriate measures. The theoretical and practical significance of the research of the treated problem in this paper is reflected in the fact that the application of the CODAS method provides a more realistic situation in relation to the ratio analysis in order to improve the efficiency of agriculture in Serbia in the future by taking adequate measures. There are no similar studies in the literature for other countries, which makes international comparison difficult.

Research using this method and including the period from 2013 to 2020 has showed that agriculture in Serbia were the most efficient in 2018. Then we have: 2020, 2019, 2017, 2016, 2015, 2014 and 2013.

Recently, under the positive influence of numerous macro and micro factors, the efficiency of agriculture in Serbia has significantly improved. The effects of Covid-19 on the performance of agriculture in Serbia have, among other things, been mitigated to some extent with increased electronic sales of agriculture products.

Keywords: *efficiency, factors, Serbian agriculture, CODAS method*

INTRODUCTION

In recent times, in all economic sectors, which include agriculture as well, various methods of multi-criteria decision-making are increasingly used in order to evaluate efficiency as realistically as possible and in the function of improvement [1], [2]. [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43]. One of them is the CODAS method. With this in mind, the subject of research in this paper is the analysis of efficiency factors of agriculture in Serbia based on the CODAS method. The goal and purpose of this is to assess as realistically as possible the efficiency of agriculture in Serbia in the function of improvement in the future by taking appropriate measures. Recently, as is well known, there has been plenty of literature devoted to the analysis of the efficiency of companies from different economic sectors based on the CODAS method. Unlike the application of AHP, TOPSIS, DEMATEL, WASPAS and other methods, there are very few papers dedicated to the analysis of the efficiency of agriculture based on the CODAS method. In the relevant literature, there is, as far as we know, no comprehensive work dedicated to the analysis of the efficiency of agriculture in Serbia on the basis of the CODAS method [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28]. In this paper, based on the reputation of contemporary foreign literature, for the first time the efficiency of agriculture in Serbia is analyzed using the CODAS method. Among other things, this reflects the scientific and professional contribution of this paper to the literature in Serbia in the field of agriculture.

The review of very rich foreign literature in this paper serves as a theoretical, methodological and empirical basis for a proper analysis of the efficiency of agriculture in Serbia based on the CODAS method. This has certainly been done in the function of improving their efficiency in the future by more efficient control of critical factors and stricter control of the implementation of adequate measures. The significance of the research of the treated problem in this paper is reflected in the fact that the application of the CODAS method provides an understanding of the more realistic situation in relation to the ratio analysis in order to improve the efficiency of agriculture in Serbia in the future by taking adequate measures.

The primary research hypothesis in this paper is that continuous monitoring of the efficiency of agriculture is a prerequisite for improvement in the future: in our case in Serbia. This facilitates and indicates what adequate measures should be taken to achieve the target efficiency of agriculture in Serbia.

In the methodological sense of the word, the application of the CODAS method plays a significant role in this. The AHP (Analytical Hierarchical Process) method [34], as well as statistical analysis were used in the paper in addition to the CODAS method. The AHP method is used to calculate the weight coefficients of the criteria. There are no similar studies in the literature for other countries, which makes international comparison difficult.

Necessary empirical data for the research of the problem discussed in this paper were collected from the Business Registers Agency of the Republic of Serbia and they have been “produced” in accordance with relevant international standards and in terms of international comparability there are no restrictions.

MATERIALS AND METHODS

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The **CODAS** (Combinative Distance-Based Assessment) method is a newer method of Multi-Attribute Decision Making (MCDM) developed based on the Euclidean and Hamming distance measures, in order to choose the best alternative from the available options. The basic principle of the CODAS method is that the best alternative should have the greatest distance from the negative ideal solution [35]. In the case when the Euclidean distances of two alternatives have the same value, then Hamming distances are compared in order to choose the best alternative [8].

The stages of the CODAS method process are as follows [1], [29], [8], [28], [35]:

Step 1. Defining the decision matrix.

Decision makers evaluate alternatives according to each attribute (criterion).

$$[x_{ij}]_{n\,x\,m} = \begin{bmatrix} \tilde{x}_{11}\tilde{x}_{12} & \cdots & \tilde{x}_{1m} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{n1}\tilde{x}_{n2} & \cdots & \tilde{x}_{nm} \end{bmatrix} \quad (1)$$

where x_{ij} shows the rating of the value of the *i*-th $i \in \{1,2,\dots,n\}$ alternative in relation to the *j*-th attribute $j \in \{1,2,\dots,m\}$.

Step 2. Calculate the normalized decision matrix.

The decision matrix is linearly normalized using the following equation:

$$\tilde{n}_{ij} = \begin{cases} \tilde{x}_{ij}/max_i\tilde{x}_{ij} & if\ j \in N_b \\ min_i\tilde{x}_{ij}/\tilde{x}_{ij} & if\ j \in N_c \end{cases} \quad (2)$$

N_b represents sets of useful, i.e., revenue (higher value is desirable), and N_c non-useful (cost) attributes (lower value is preferred).

Step 3. Calculate the weight-normalized decision matrix.

The weight-normalized decision matrix is determined using the following equation:

$$s_{ij} = w_j \tilde{n}_{ij} \quad (3)$$

where $w_j \in [0,1]$ represents the weighting factor assigned by the decision maker for the different attributes and $\sum_{j=1}^{m} w_j = 1$.

Step 4. Identify negative ideal solutions.

Negative ideal solutions (*NI*) are obtained by applying the following equation:

$$NI = [n_{tj}]_{1\,x\,m} \quad (4)$$
$$n_{tj} = min\, s_{ij}$$

Step 5. Calculate the Euclidean (*ED*) and Hamming (*HD*) distances of alternatives from the negative ideal solution.

The Euclidean and Hamming distances of alternatives from the negative ideal solution are calculated using the following equations:

$$ED_i = \sqrt{\sum_{j=1}^{m} (s_{ij} - n_{tj})^2} \quad (5)$$
$$HD_i = \sum_{j=1}^{m} |s_{ij} - n_{tj}| \quad (6)$$

Step 6. Construct a relative estimation matrix.

The relative estimation matrix (Ra) is obtained using the following formula:

$$Ra = [p_{il}]_{n\,x\,n}$$
$$p_{il} = (ED_i - ED_l) + (\delta(ED_i - ED_l))x((HD_i - HD_l))$$

where $l \in \{1,2,\dots,n\}$ and δ are threshold function used as follows:

$$\delta(x) = \begin{cases} 1\ if\ |x| \geq \rho \\ 0\ if\ |x| < \rho \end{cases} \quad (7)$$

The value of the threshold parameter is between 0.01 and 0.05. It can also be determined by the decision maker [8]. If the difference between the Euclidean distances of the two alternatives is less than the defined threshold value, then they are compared according to the Hamming distance.

Step 7. Assign a grade (*AS*) to each alternative.

The *AS* value of each alternative is calculated as follows:

$$AS_i = \sum_{l=1}^{n} p_{il} \quad (8)$$

According to the higher grade, the most suitable alternative is chosen.

Step 8. Ranking the alternatives according to the *AS* value.

Alternatives are ranked according to the value of *AS* in descending order. The alternative with the highest *AS* value is the best option among the alternatives.

Considering that in this paper the weight coefficients of criterion in the application of the CODAS method are determined using the AHP method, we will briefly look at its theoretical and methodological characteristics.

The **Analytical Hierarchy Process** (AHP) method consists of the following steps [34]:

Step 1: Forming a matrix of comparison pairs

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (9)$$

Step 2: Normalizing the matrix of comparison pairs

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, i, j = 1, \dots, n \quad (10)$$

Step 3: Determining the relative importance, i.e., weight vector

$$w_i = \frac{\sum_{i=1}^{n} a_{ij}^{*}}{n}, i, j = 1, \dots, n \quad (11)$$

Consistency index – CI (consistency index) is a measure of deviation *n* from λ_{max} and can be represented by the following formula:

$$CI = \frac{\lambda_{max} - n}{n} \quad (12)$$

If CI <0.1, the estimated values of the coefficients a_{ij} are consistent, and the deviation of λ_{max} from *n* is negligible. This means, in other words, that the AHP method accepts an inconsistency of less than 10%. Using the consistency index, the consistency ratio CR = CI / RI can be calculated, where RI is a random index.

RESULTS AND DISCUSSIONS

In order to fully understand the real situation, we will analyze the dynamics of the efficiency of agriculture in Serbia using the CODAS method. We will use the following as criteria: C1 – number of employees C2 – assets, C3 – capital, C4 – operating income and C5 – net profit. They measure efficiency and financial performance well. The weighting coefficients of the criteria determined by the AHP method are as follows: C1 – 0.3345, C2 – 0.1989, C3 – 0.1033, C4 – 0.1713 and C5 – 0.1920. Alternatives were observed in the year: A1 – 2013, A2 – 2014, A3 – 2015, A4 – 2016, A5 – 2017, A6 – 2018, A7 – 2019 and A8 – 2020. (Calculation was performed using the software program CODASSoftware-Excel.) Table 1 shows the initial data for measuring the dynamics of the efficiency of agriculture in Serbia using the CODAS method for the period 2013 – 2020.

Table 1. Initial data for measuring the dynamics of the efficiency of agriculture in Serbia, 2013-2020

	Number of employees	**Assets**	**Capital**	**Operating income**	**Net profit**
2013	36015	570352	305601	315477	21418
2014	33256	641869	353052	316220	17515
2015	33498	688188	382718	321608	16960
2016	32244	781508	480683	352715	20392
2017	32023	815393	508124	330809	20936
2018	32330	846778	523357	349616	32466
2019	31247	874451	544362	350328	19932
2020	30541	888940	563131	369368	21134
Statistics					
Mean	32644.2500	763434.8750	457628.5000	338267.6250	21344.1250
Median	32287.0000	798450.5000	494403.5000	340212.5000	20664.0000
Std. Deviation	1668.44476	116967.53410	96891.10740	19960.25615	4791.29671
Minimum	30541.00	570352.00	305601.00	315477.00	16960.00
Maximum	36015.00	888940.00	563131.00	369368.00	32466.00
NPar Tests					
Friedman Test					
Mean Rank	1.88	5.00	3.88	3.13	1.13
Test Statistics[a]					
N	8				
Chi-Square	30.600				
df	4				
Asymp. Sig.	.000				
a. Friedman Test					

Note: Absolute amounts are expressed in millions of dinars. The number of employees is expressed in whole numbers. The statistics were calculated using the SPSS software program
Source: Business Registers Agency of the Republic of Serbia

There is a significant statistical difference between the observed efficiency indicators, so that the null hypothesis is rejected (Asymp. Sig. .000< .05). In 2020, compared to 2019, the net profit was higher than the average (Median 20664.0000), which means that the efficiency of agriculture in Serbia increased slightly. The obtained results of the empirical research of the dynamics of the efficiency of agriculture in Serbia using the CODAS method are shown in the tables below (Tables 10, 11, 12, 13, 14 and 15).

Table 2. Initial matrix

Initial Matrix					
weights of criteria	0.3345	0.1989	0.1033	0.1713	0.192
kind of criteria	-1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**
A1	36015	570352	305601	315477	21418
A2	33256	641869	353052	316220	17515
A3	33498	688188	382718	321608	16960
A4	32244	781508	480683	352715	20392
A5	32023	815393	508124	330809	20936
A6	32330	846778	523357	349616	32466
A7	31247	874451	544362	350328	19932
A8	30541	888940	563131	369368	21134
MAX	36015	888940	563131	369368	32466
MIN	30541	570352	305601	315477	16960

Note: Author's calculations

Table 3. Normalized Matrix

Normalized Matrix					
weights of criteria	0.3345	0.1989	0.1033	0.1713	0.192
kind of criteria	-1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**
A1	0.8480	0.6416	0.5427	0.8541	0.6597
A2	0.9184	0.7221	0.6269	0.8561	0.5395
A3	0.9117	0.7742	0.6796	0.8707	0.5224
A4	0.9472	0.8791	0.8536	0.9549	0.6281
A5	0.9537	0.9173	0.9023	0.8956	0.6449
A6	0.9447	0.9526	0.9294	0.9465	1.0000
A7	0.9774	0.9837	0.9667	0.9485	0.6139
A8	1.0000	1.0000	1.0000	1.0000	0.6510

Note: Author's calculations

Table 4. Weighted Normalized Matrix

Weighted Normalized Matrix					
	C1	**C2**	**C3**	**C4**	**C5**
A1	0.2837	0.1276	0.0561	0.1463	0.1267
A2	0.3072	0.1436	0.0648	0.1467	0.1036
A3	0.3050	0.1540	0.0702	0.1492	0.1003
A4	0.3168	0.1749	0.0882	0.1636	0.1206
A5	0.3190	0.1824	0.0932	0.1534	0.1238
A6	0.3160	0.1895	0.0960	0.1621	0.1920
A7	0.3269	0.1957	0.0999	0.1625	0.1179
A8	0.3345	0.1989	0.1033	0.1713	0.1250
A-	0.2837	0.1276	0.0561	0.1463	0.1003

Note: Author's calculations

Table 5. The distance of the alternatives from the ideal negative solution

Alternatives	**Ei**	**Ti**	**threshold parameter**	
			τ	**0.02**
A1	0.0264	0.0264		
A2	0.0299	0.0519		
A3	0.0368	0.0647		
A4	0.0712	0.1501		
A5	0.0790	0.1580		
A6	0.1230	0.2417		
A7	0.0948	0.1889		
A8	0.1055	0.2190		

Note: Author's calculations

Table 6. Relative Assessment Matrix

Relative Assessment Matrix								
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	0.0000	-0.0036	-0.0105	-0.1686	-0.1842	-0.3119	-0.2310	-0.2718
A2	0.0036	0.0000	-0.0069	-0.1395	-0.1551	-0.2828	-0.2019	-0.2427
A3	0.0105	0.0069	0.0000	-0.1198	-0.1354	-0.2631	-0.1822	-0.2230
A4	0.1686	0.1395	0.1198	0.0000	-0.0078	-0.1433	-0.0623	-0.1032
A5	0.1842	0.1551	0.1354	0.0078	0.0000	-0.1277	-0.0158	-0.0876
A6	0.3119	0.2828	0.2631	0.1433	0.1277	0.0000	0.0810	0.0175
A7	0.2310	0.2019	0.1822	0.0623	0.0158	-0.0810	0.0000	-0.0107
A8	0.2718	0.2427	0.2230	0.1032	0.0876	-0.0175	0.0107	0.0000

Note: Author's calculations

Table 7. Ranking of the alternatives

	Alternatives	**Hi**	**Hi**	**Ranking**
2013	**A1**	-1.182	-1.182	8
2014	**A2**	-1.025	-1.025	7
2015	**A3**	-0.906	-0.906	6
2016	**A4**	0.111	0.111	5
2017	**A5**	0.251	0.251	4
2018	**A6**	1.227	1.227	1
2019	**A7**	0.602	0.602	3
2020	**A8**	0.922	0.922	2

Note: Author's calculations

Empirical research of the dynamics of the efficiency of agriculture in Serbia using the CODAS method showed that the best results were in 2018. Then follows: 2020, 2019, 2017, 2016, 2015, 2014 and 2013. There has been a certain improvement in the efficiency of agriculture in Serbia in recent years.

This was due to: The favorable economic climate, low bank interest rate, low inflation, stable exchange rate, increased employment, rising standard of living, subsidies and grants, increased awareness of the importance of insurance in agriculture against potential risks caused by climate change, increased production and sales of organic agriculture products, better regulation of the labor market and agriculture products market, development of electronic sales of agriculture products, branding of agriculture products, application of modern mechanization and agro-technical measures, and increasing digitalization of the entire business. The development of cooperatives certainly plays a significant role in this. The impact of Covid-19 on the performance of agriculture in Serbia has been mitigated in part by increased electronic sales of agriculture products.

The application of the CODAS method in relation to the ratio analysis provides more realistic results in terms of the efficiency of agriculture in Serbia. For these reasons, it is recommended.

As far as we know, there are no similar researches for other countries in the literature, so the international comparison is limited. For the purpose of international comparison, it is necessary to conduct similar research for other countries in the future.

CONCLUSIONS

Based on the obtained results of the empirical analysis of agriculture efficiency in Serbia using AHP and CODAS methods, we can conclude the following: According to the importance of the criteria, the number of employees is in the first place. Then follow: assets, net profit, operating income and capital.

Therefore, the efficiency of agriculture in Serbia can be significantly improved through better human resource management (training, reward system, part-time employment, social and health care). In this direction, it is also necessary to efficiently manage assets, profits, operating income and capital.

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