

# ZERO UNITARIZATION METHOD FOR DETERMINING LAND CONSOLIDATION PRIORITIES: A CASE STUDY OF THE MUNICIPALITY OF BELA CRKVA

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## ABSTRACT

Land consolidation represents one of the most important measures for increasing productivity, improving agrarian structure, and enhancing agricultural production. A key challenge in practice is the need for a comprehensive and objective determination of priorities, specifically the ranking of cadastral municipalities for implementing land consolidation projects. The main objective of this paper is to apply the Zero Unitarization Method (ZUM) to rank land consolidation projects within the Municipality of Bela Crkva, based on ten socio-economic and agrarian criteria. The input dataset includes cadastral municipalities with heterogeneous agricultural characteristics, while the zero unitarization method is employed to transform diverse stimulative and non-stimulative criteria into a unified evaluation scale. The results show that the cadastral municipality Dobričevo ranks as the highest priority, whereas Kajtasovo occupies the lowest position, with significant differences observed in the composite index values. The resulting ranking provides a foundation for planning future land consolidation projects, and the proposed methodological approach can be applied to other municipalities in Serbia.

## KEYWORDS:

land consolidation, zero unitarization method, multicriteria decision-making, agrarian structure, ZUM.

## 1 INTRODUCTION

Land consolidation, financed by public funds, is a key instrument of national and regional agricultural policy in the context of sustainable rural development, understood as areas of agricultural production and living space [1,2,3]. According to the latest estimates of the Statistical Office of the Republic of Serbia (RZS) for 2024, approximately 42,8% of the total population (or 2,82 million people) reside in rural areas [4], where they are directly or indirectly engaged in agricultural activities. From a comprehensive perspective, issues such as excessive parcel fragmentation, irregular plot shapes, the absence of irrigation systems, inadequate infrastructure—particularly with respect to access via field roads—along with other limiting factors, significantly affect the productivity of agricultural production. For the aforementioned reason, the state adopted strategic decisions on initiating and financing land consolidation projects. The implementation of these projects has been carried out through the Ministry of Agriculture of the Republic of Serbia, the Provincial Secretariat for Agriculture in the Autonomous Province of Vojvodina, and local self-governments. The identified needs clearly underscore the necessity of determining priority areas for the initiation of land consolidation interventions.

Problems in agriculture similar to those faced by Serbia are also present in other European countries. This is particularly evident in the nations of Central, Northeastern, and Southeastern Europe. Among these European regions, it is noteworthy that the Polish scientific school holds a leading position in research related to land consolidation. This prominence is reflected in its approaches, applications, suitability assessments, and procedures for determining the priorities of land consolidation projects. Frequently, the approach involves integrated MCDM–GIS models, which include analyses of parcel fragmentation, economic indicators, market values, and multicriteria evaluation of landholding structures, as demonstrated in studies [5,6,7,8,30].

The experiences gained in Poland highlight a distinct need to introduce a broad spectrum of transparent and straightforward criteria for the ranking and selection of land consolidation projects. Given that a larger number of criteria generally enhances the quality of the ranking process, it is essential to carefully select the most relevant criteria and implement them within an appropriate ranking methodology. Taking all of this into consideration—including limited financial resources and the large number of land consolidation requests submitted by local self-governments—the aforementioned approaches have been applied to support the ranking and selection of cadastral municipalities for land consolidation.

In Slovakia, priorities for initiating land consolidation are determined according to a project-complexity algorithm developed by Kuzevicova, Z.; Bobíková, D.; Kuzevic, S.; and Khouri, S. The practical application and national-level ranking of cadastral municipalities is led by Muchová, Z. and her team through the project APVV-19-0494 “Effective Land Consolidation” [27].

By analyzing the relevant scientific literature [28,29], it can be observed that over the past fifteen years the most frequently applied multicriteria decision-making (MCDM) methods include AHP [9], TOPSIS [10], VIKOR [11], SAW [12], among others. It is worth noting that, for robust, transparent, and straightforward solutions capable of providing a

comprehensive analysis involving a large number of criteria, normalization-based methods offer particularly strong performance. Within this group, the Zero Unitarization Method (ZUM) stands out due to its demonstrated efficiency, as presented in studies [13,14,15]. This method is especially practical in situations where the weights of individual criteria cannot be reliably determined, that is, when the objective is to establish an overall and fully objective ranking of land consolidation projects.

Previous research conducted in Serbia on the ranking of land consolidation projects has employed a wide range of multicriteria decision-making (MCDM) methods, in line with global trends. Among these, several approaches can be highlighted: the Simple Additive Weighting (SAW) method used in [16], the COPRAS method in [17], the VIKOR method in [4], the Analytic Hierarchy Process (AHP) applied in [18], the TOPSIS method in [19,20], as well as various hybrid combinations of the aforementioned MCDM methods presented in studies [18,21].

Based on the presented facts regarding the comprehensive application of MCDM methods for ranking land consolidation projects in the Republic of Serbia, it is surprising that the Zero Unitarization Method (ZUM), despite its transparency, mathematical simplicity, and wide application in other domains of multi-criteria analysis, has not yet been applied to address the problem of ranking land consolidation projects in Serbia.

Therefore, this study aims to fill the identified gap in the domestic scientific literature by introducing the Zero Unitarization Method as a novel, objective, and straightforward approach for determining the ranking of land consolidation projects. The proposed approach is characterized by a high degree of transparency, low sensitivity to subjective assessments of criterion weights, and practical ease of implementation.

The primary objective of this research is to develop an objective, quantitative, and methodologically consistent framework for ranking cadastral municipalities according to their suitability for land consolidation, using the Zero Unitarization Method (ZUM). Specifically, the goals are to:

1. Define a set of relevant criteria based on international practice and the specific characteristics of Serbia;
2. Perform data normalization and rank municipalities using the ZUM method;
3. Conduct graphical and spatial analysis of the results.

This research contributes to the advancement of the methodology for selecting land consolidation projects and, through the ranking process, enhances transparency in decision-making in the field of land consolidation.

## 2 THEORETICAL FRAMEWORK

The methodological procedure presented in this study constitutes the theoretical framework of this work. It is composed of three key subsections. The first subsection presents the land consolidation process as an instrument of rural development; the second

subsection discusses multi-criteria decision-making in land consolidation; and the third subsection introduces the Zero Unitarization Method (ZUM).

## 2.1 LAND CONSOLIDATION AS AN INSTRUMENT OF RURAL DEVELOPMENT

Land consolidation integrates agrarian, social, and infrastructural aspects of rural development [22]. The objectives of land consolidation include:

1. **Reduction of fragmentation and consolidation of parcels:** Land ownership fragmentation (a high number of parcels per owner and a large number of co-owners per parcel) is one of the main structural shortcomings of agriculture in most countries of Central and Southeastern Europe. Through new geometric arrangements and land exchanges, land consolidation reduces the average number of parcels per agricultural entity. This facilitates the economical use of large machinery and significantly reduces the time and costs associated with accessing the parcels [23].
2. **Creation of favourable conditions for agricultural modernization:** Consolidated parcels are spacious and regularly shaped, often rectangular or trapezoidal. Such parcels form a basic prerequisite for the widespread adoption of modern precision agriculture technologies, including GPS-guided machinery, wide-coverage auxiliary machines for sowing and crop protection, as well as the implementation of technologically demanding crop rotations and cropping systems. Properly shaped parcels simultaneously reduce fuel, seed, fertilizer, and pesticide consumption per unit area.
3. **Improvement of access roads and irrigation systems:** Land consolidation involves constructing new networks of field roads, as well as shared drainage and irrigation systems through the development of amelioration channels, creating conditions for the efficient application of modern irrigation systems on large areas.
4. **More rational management of natural resources:** Through mandatory common elements (protective belts, grass strips, retention structures, and afforestation), land consolidation reduces soil erosion (on average by 40–80% according to the USLE model), increases water retention in the landscape, and contributes to the preservation of biodiversity. At the same time, non-agricultural areas (erosion-prone hills, wetlands) are excluded from intensive cultivation and allocated to environmentally friendly functions, thus fulfilling the principles of sustainable and multifunctional rural development [24,25].

## 2.2 MULTI-CRITERIA DECISION-MAKING IN LAND CONSOLIDATION

MCDM methods have long been used for ranking land consolidation projects [26]. In this context, the ranking is based on the simultaneous consideration of agricultural, economic, demographic, and ownership-related criteria. Various indicators are normalized and aggregated into a single composite index, thereby providing a transparent and comparable basis for decision-making. This approach enables rational planning of land consolidation and the effective allocation of public funds to areas with the highest expected benefits.

### 2.3 ZERO UNITARIZATION METHOD (ZUM)

The Zero Unitarization Method (ZUM) is a composite indexing technique based on linear data normalization, in which the values of all criteria are transformed into the interval [0,1] [13].

For stimulatory criteria:

$$Z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

For disincentive criteria:

$$Z_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

The data formula normalizes the disincentive criterion on the interval (0,1) so that a smaller starting value gives a larger normalized result.

Composite index:

$$S_i = \frac{1}{m} \sum_{j=1}^m Z_{ij} \quad (3)$$

where  $m$  is the number of criteria.

The composite index  $S_i$  represents the average of all normalized criteria and is used for the ranking of cadastral municipalities. The closer  $S_i$  is to 1, the higher the priority for consolidation, and the closer to 0, the lower the priority

## 3 MATERIALS AND METHODS

### 3.1 STUDY AREA

The study was conducted in the territory of the Municipality of Bela Crkva (South Banat, Autonomous Province of Vojvodina, Republic of Serbia), which covers an area of 339 km<sup>2</sup> and comprises twenty cadastral municipalities. Of these, fifteen were included in the study, while five cadastral municipalities were excluded due to their small size. The research focused on the following cadastral municipalities: Banatska Palanka 1, Banatska Subotica, Bela Crkva, Vračev Gaj 1, Vračev Gaj 2, Grebenac, Dobričevo, Dupljaja, Jasenovo, Kajtasovo, Kaluđerovo 1, Kruščica, Kusić 1 and 2, Kusić 3, and Crvena Crkva.

This territorial unit was selected due to its very specific characteristics. It exhibits a high degree of parcel fragmentation, has a favourable geographical location (near the 45<sup>th</sup> parallel), proximity to rivers, and relatively well-developed drainage and irrigation channels. Additionally, the area has an outdated state survey over 140 years old and a strong initiative from agricultural producers to implement land consolidation. All of these factors enabled the quantitative collection of all necessary input data for the cadastral municipalities included in the study.

### 3.2 INPUT CRITERIA

For the purposes of this study and analysis, all relevant data were collected for ten selected criteria. Although this number may appear limited compared to Polish research in this field, the criteria describe ownership, territorial, economic, demographic, and other essential characteristics of each cadastral municipality (Table 1). Official data were obtained from the Republic Geodetic Authority (Real Estate Cadastre Office, Bela Crkva), the Statistical Office of the Republic of Serbia, local tax administration, the Register of Agricultural Holdings of the Ministry of Agriculture, Forestry and Water Management, as well as from land consolidation programs, based on the reported costs and effects of land consolidation conducted between 2010 and 2024.

Table 1. List of Criteria

Type	Criterion Description	Code
F1	Share of arable land in the total agricultural land area	Stimulatory
F2	Average parcel size	Destimulatory
F3	Number of parcels per property deed	Stimulatory
F4	Average holding size	Stimulatory
F5	Percentage of producers with holdings larger than 5 ha	Stimulatory
F6	Share of state-owned land	Stimulatory
F7	Active agricultural population	Stimulatory
F8	Project implementation cost per hectare	Destimulatory
F9	Payback period	Destimulatory
F10	Profitability coefficient (5-year period)	Stimulatory

Table 2. Overview of Input Indicators

Criterion	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Unit	%	ha/parc	parc/LN	ha/LN	%	%	%	e/ha	god	N. br.
Objective	Stim.	Dest.	Stimul.	Stim.	Stim.	Stim.	Stim.	Dest.	Dest.	Stim.
Cadastral Municipalities										
Ban.Palanka 1	25,54	0,49	10,12	4,93	10,99	53,53	74,45	142,0	9,6	0,52
Ban. Subotica	75,82	0,56	6,09	3,39	16,42	21,98	75,23	159,1	3,6	1,38
Bela Crkva	74,39	1,30	3,22	4,19	2,44	29,66	5,65	133,5	3,1	1,61
Vračev Gaj 1	60,71	0,43	5,47	2,35	9,71	25,18	51,36	160,5	4,6	1,09
Vračev Gaj 2	77,03	0,60	3,18	1,91	5,41	38,16	51,36	228,9	5,1	0,97
Grebenac	57,25	0,46	5,44	2,53	10,97	23,23	89,35	162,3	4,9	1,02
Dobričevo	84,04	0,92	7,02	6,48	16,35	48,00	89,17	132,1	2,7	1,84
Dupljaja	53,70	0,41	7,21	2,94	13,89	24,08	81,17	171,6	5,5	0,90
Jasenovo	79,43	0,43	5,51	2,39	10,88	15,69	36,75	133,3	2,9	1,72
Kajtasovo	11,76	0,80	4,44	3,57	2,88	75,24	89,14	211,4	31,1	0,16
Kaludjero 1	68,56	0,47	13,86	6,24	24,52	23,89	80,56	173,1	4,4	1,14
Kruscica	87,27	0,36	9,43	3,43	13,48	9,54	55,34	133,4	2,6	1,89
Kusic 1 i 2	76,39	0,32	6,17	2,01	8,71	16,05	45,02	139,9	3,2	1,54
Kusic 3	64,79	0,42	17,17	7,28	5,13	59,86	45,02	204,9	5,5	0,91
Crvena Crkva	78,94	0,50	5,61	2,78	8,23	19,22	28,45	141,1	3,1	1,62

### 3.3 METHODOLOGICAL PROCEDURE

The methodological framework applied in this study relies on the sequential and integrated application of statistical analysis, followed by multi-criteria evaluation, and finally the Zero Unitarization Method (ZUM) to achieve a comprehensive and objective ranking of land consolidation areas in Bela Crkva. The applied procedure consists of five mutually integrated phases.

#### 3.3.1 Determination of Minimum and Maximum Values for ZUM Normalization

For each of the ten criteria, the following were determined:

- minimum values (min),
- maximum values (max),

Based on these values, the criteria are classified into:

1. **Stimulatory criteria** (higher values are more desirable),
2. **Destimulatory criteria** (lower values are more desirable).

This classification enables the proper application of the ZUM method, as it allows the transformation of heterogeneous data into a unified, dimensionless scale ranging from [0,1].

#### 3.3.2 ZUM Normalization

Stimulatory criteria are calculated using the formula:

$$Z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (4)$$

Destimulatory criteria are calculated using the formula:

$$Z_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (5)$$

#### 3.3.3 Calculation of the Composite Index for Ranking Land Consolidation Projects

The composite index ( $S_i$ ) represents an aggregate indicator of the priority ranking of land consolidation projects and is defined as a linear aggregation of normalized criteria. It is expressed by the formula:

$$S_i = \frac{1}{m} \sum_{j=1}^m Z_{ij} \quad (6)$$

In this study, the basic variant is presented, where all criteria are assigned equal weight. This contributes to the transparency and simplicity of the proposed method, while avoiding subjective assignment of importance to individual criteria. Depending on the need, the model can be extended by introducing specific weights; however, in our research, the unweighted approach is maintained.

#### 3.3.4 Ranking of Land Consolidation Projects

Land consolidation projects are ranked according to the descending values of the composite index. Higher values of  $K_i$  indicate a higher priority for implementing consolidation. The resulting ranking list represents the final and key outcome of this research, providing the opportunity to compare different cadastral municipalities in a fair, objective, and reproducible manner.

### 3.3.5 Visualization of Results – Presentation of Statistical Graphics

To facilitate a more comprehensive interpretation of the obtained results, the following visualizations are presented:

- Boxplot diagrams for all ten criteria,
- Radar charts to display the profiles of individual projects.

The graphical representations included in the study complement the research findings through commentary and contribute to establishing a standardized framework for presenting results in future rankings of land consolidation projects.

## 4 RESULTS

The results of the study, obtained using the Zero Unitarization Method (ZUM) on a set of ten predefined criteria for fifteen cadastral municipalities within the Municipality of Bela Crkva, are presented in this chapter. A synthetic indicator for ranking land consolidation projects was derived, serving as the basis for the objective ranking of consolidation projects and the justification for implementing land consolidation (Si). All calculations were performed using the EXCEL software package, and the results are presented step by step in Tables 3, 4, and 5 to ensure full transparency.

Table 3. Statistical table showing the minimum and maximum values of the criteria

Criterion	Min	Max
F1	11,76	87,27
F2	0,32	1,30
F3	3,18	17,17
F4	1,91	7,28
F5	2,44	24,52
F6	9,54	75,24
F7	5,65	89,35
F8	132,10	228,90
F9	2,60	31,10
F10	0,16	1,89

Table 4. Normalized values of criteria (F1–F10) for all cadastral municipalities

Cadas. Munic.	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Ban. Palanka 1	0,182	0,173	0,496	0,562	0,387	0,670	0,822	0,898	0,754	0,208
Ban. Subotica	0,848	0,245	0,208	0,276	0,633	0,189	0,831	0,721	0,965	0,705
Bela Crkva	0,829	1,000	0,003	0,425	0,000	0,306	0,000	0,986	0,982	0,838
Vračev Gaj 1	0,648	0,112	0,164	0,082	0,329	0,238	0,546	0,707	0,930	0,538
Vračev Gaj 2	0,864	0,286	0,000	0,000	0,135	0,436	0,546	0,000	0,912	0,468
Grebenac	0,602	0,143	0,162	0,115	0,386	0,208	1,000	0,688	0,919	0,497

Dobričevo	0,957	0,612	0,274	0,851	0,63	0,585	0,998	1,000	0,996	0,971
Dupljaja	0,555	0,092	0,288	0,192	0,519	0,221	0,902	0,592	0,898	0,428
Jasenovo	0,896	0,112	0,167	0,089	0,382	0,094	0,372	0,988	0,989	0,902
Kajtasovo	0,000	0,49	0,09	0,309	0,02	1,000	0,997	0,181	0,000	0,000
Kaludjero 1	0,752	0,153	0,763	0,806	1,000	0,218	0,895	0,576	0,937	0,566
Kruscica	1,000	0,041	0,447	0,283	0,500	0,000	0,594	0,987	1,000	1,000
Kusic 1 i 2	0,856	0,000	0,214	0,019	0,284	0,099	0,470	0,919	0,979	0,798
Kusic 3	0,702	0,102	1,000	1,000	0,122	0,766	0,470	0,248	0,898	0,434
Crvena Crkva	0,89	0,184	0,174	0,162	0,262	0,147	0,272	0,907	0,982	0,844

Table 5. Ranking of Cadastral Municipalities (ZUM)

Cadastral Municipalities	Si	Rank
Dobričevo	0,7876	1
Kaludjero 1	0,6668	2
Kruscica	0,5851	3
Kusic 3	0,5742	4
Ban. Subotica	0,5622	5
Bela Crkva	0,5369	6
Ban. Palanka 1	0,5153	7
Jasenovo	0,4991	8
Crvena Crkva	0,4824	9
Grebenac	0,4721	10
Dupljaja	0,4687	11
Kusic 1 i 2	0,4638	12
Vračev Gaj 1	0,4294	13
Vračev Gaj 2	0,3647	14
Kajtasovo	0,3087	15

## 5 DISCUSSION

In this study, the Zero Unitarization Method was applied to rank the cadastral municipalities within the territorial boundaries of the Municipality of Bela Crkva. The resulting ranking list, combined with the analysis of graphical representations, highlighted pronounced structural, spatial, and ownership differences among the cadastral municipalities, which significantly influence the formation of the composite index Si. This chapter provides a detailed interpretation of the index distribution, along with a comprehensive discussion of the visual representations, which complement the numerical results and offer a clear and integrated understanding of the entire ranking process.

### 5.1 ANALYSIS OF THE COMPOSITE INDEX SI DISTRIBUTION

The distribution of the composite index Si demonstrates pronounced heterogeneity among the cadastral municipalities, with values ranging from 0,187 (Kajtasovo) to 0,787 (Dobričevo). This indicates significant differences in agrarian, demographic, and economic conditions. The boxplot diagram and ranking lists confirm a slight right-skewness in the

distribution. Most municipalities cluster within the mid-range of the index (0,40–0,60), suggesting a moderate level of need for land consolidation in the majority of localities.

Kajtasovo represents the only significant outlier in the low-priority zone ( $S_i < 0,30$ ), with its very low index primarily resulting from unfavorable economic parameters, such as extremely high implementation costs, a long investment payback period, and a lack of agricultural land. Most municipalities fall into the medium-priority class, where a combination of favorable agrarian indicators and limiting economic factors results in balanced Sivalues.

The highest priorities are attributed to Dobričevo, Kruščica, Jasenovo, Bela Crkva, and Crvena Crkva, which are characterized by favorable production, structural, and economic indicators. These municipalities offer the best conditions for the rapid and efficient implementation of land consolidation measures, positioning them as the most rational and cost-effective candidates for investment in the forthcoming planning period.

## 5.2 BOXPLOT DIAGRAMS

The presented boxplot diagrams for the ten criteria (F1–F10) across fifteen cadastral municipalities (Figure 1) reveal pronounced differences in distribution, variability, and the presence of extreme values. This visual analysis allows for the identification of structural inconsistencies between municipalities, which is crucial for subsequent multicriteria analysis and ranking.

At first glance, the diagrams clearly show the distinctiveness of the criteria, with some indicators playing a key role in differentiation, while others appear nearly uniform. Overall, the criterion structure is highly diverse, indicating that all fifteen cadastral municipalities differ substantially in economic, agrarian, and even demographic aspects.

Finally, it should be noted that certain criteria (F1, F6, F7) demonstrate very high analytical significance, whereas others, such as F2, F8, and F9, contribute more modestly to the ranking of land consolidation projects.

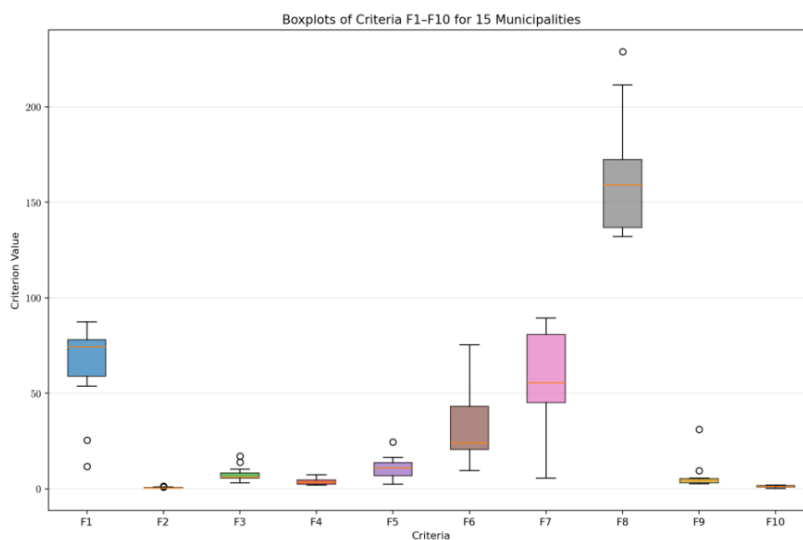


Figure 1. Boxplot diagrams for all ten criteria

### 5.3 HEATMAP REPRESENTATION OF THE COMPOSITE ZUM INDEX (S<sub>i</sub>)

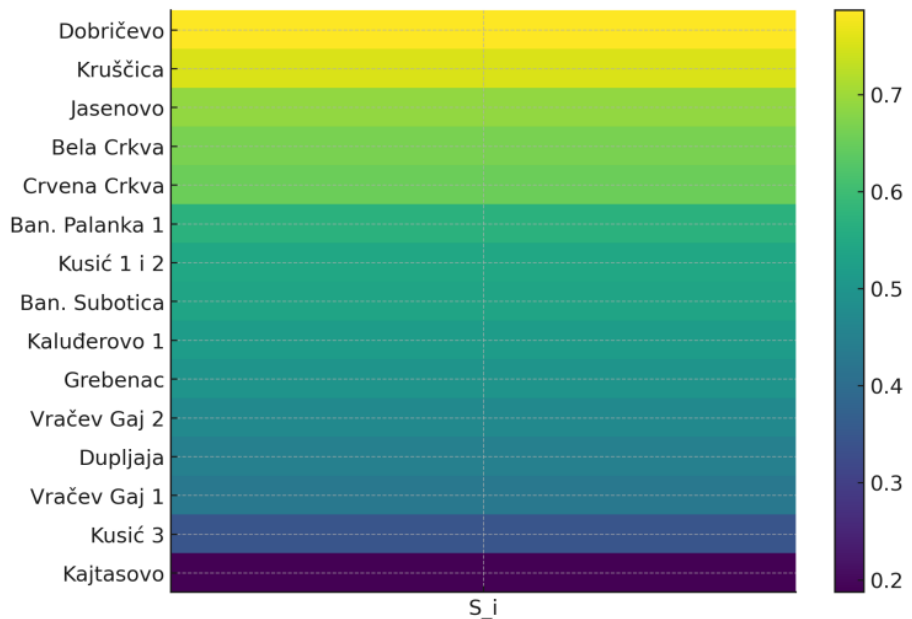


Figure 2. Heatmap of the composite ZUM index (S<sub>i</sub>) for all cadastral municipalities

The heatmap of the ZUM index clearly distinguishes cadastral municipalities according to their land consolidation priority. The composite ZUM heatmap highlights municipalities such as Dobričevo, Kruščica, Jasenovo, and Bela Crkva as the most favorable, whereas Kajtasovo, Kusić 3, and Vračev Gaj 1 are depicted as the lowest-ranked municipalities. The composite ZUM heatmap employs a gradient from lighter to darker shades, representing a stable priority scale. This gradient also reflects clear differences in agricultural, demographic, and economic conditions across the study area.

The heatmap visualization provides a clear overview of the differences among cadastral municipalities across all criteria, highlighting F1 and F7 as the primary factors, while emphasizing the dominant influence of the destimulatory criteria F8 and F9 on the extreme values of the composite index. It also confirms that municipalities with a higher share of state-owned land (F6) generally achieve more favorable rankings. This representation indicates that the combination of landholding structure and economic efficiency has the greatest impact on the need for land consolidation.

The ranking diagram clearly identifies a group of municipalities with the highest composite ZUM index, among which Dobričevo, Kaluđerovo, and Kruščica stand out as priority areas for land consolidation. The middle section of the ranking list comprises a relatively homogeneous group of cadastral municipalities with moderate index values, indicating a stable but not decisive developmental potential. At the bottom of the list are Vračev Gaj 2 and Kajtasovo, whose low values reflect limited agrarian, demographic, or economic conditions for a high-priority implementation of land consolidation measures.

## 5.4 DIAGRAM OF CADASTRAL MUNICIPALITY RANKING (ZUM)

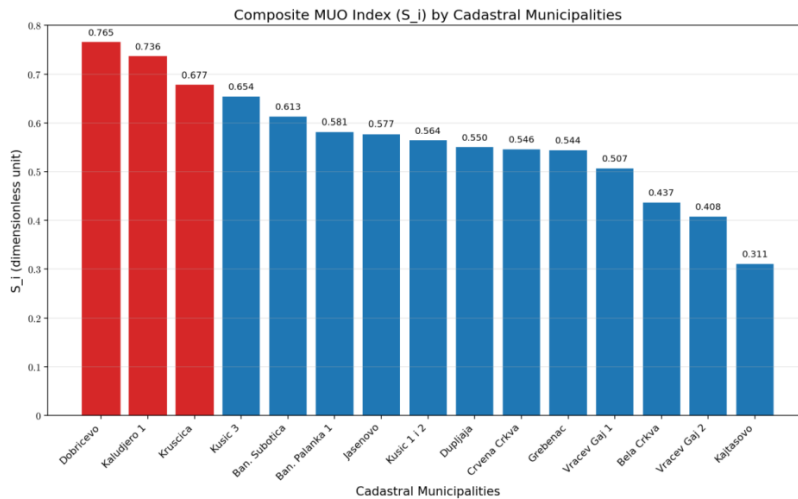


Figure 3. Ranking of Cadastral Municipalities (ZUM)

## 6 CONCLUSION

The conducted study aimed to determine land consolidation priorities in the Municipality of Bela Crkva using the Zero Unitarization Method (ZUM), based on ten relevant agrarian, demographic, and economic criteria. The ranking results indicate pronounced heterogeneity among the analysed cadastral municipalities in terms of the composite index  $S_i$ , highlighting significant structural differences in suitability and economic justification for land consolidation.

The application of the ZUM method enabled the preparation of a comprehensive ranking. The analysis identified the highest urgency for land consolidation in the cadastral municipalities of Dobričevo, Kruščica, Jasenovo, Bela Crkva, and Crvena Crkva, which are characterized by a combination of favourable agrarian parameters (high share of arable land, advantageous plot sizes, and active agricultural population) and stable economic indicators (lower costs per hectare, shorter payback periods, and higher profitability). These municipalities represent the most favourable environment for the efficient and economically viable implementation of consolidation programs.

Most municipalities fall within the mid-range of the index (0,45–0,60), indicating moderate, yet non-negligible, needs for land consolidation. This segment includes municipalities with mixed characteristics, where certain stimulatory parameters mitigate the negative effects of destimulatory factors. In contrast, Kajtasovo was identified as the lowest-ranked municipality, primarily due to extremely high consolidation costs and a long payback period, confirming that specific economic criteria can significantly influence final priority.

Graphical analysis (heatmap, radar diagram, and histogram) complemented the numerical results, confirming structural distribution patterns of the criteria and highlighting a clear group of high-priority municipalities. The histogram of  $Si$  values indicates a slight right skewness, suggesting that the highest priority is assigned to a minority of municipalities, while the majority of localities cluster around mid-range index values.

The results obtained confirm that the Zero Unitarization Method (ZUM) is a suitable and effective decision-support tool for land consolidation planning, particularly in cases involving a large number of heterogeneous criteria measured on different scales. The model is transparent, unambiguous, and straightforward to interpret, while the generated rankings provide a reliable basis for strategic planning of land consolidation aimed at increasing productivity, rationalizing landholdings, and improving land structure. To achieve optimal effects in determining consolidation priorities, it is necessary to significantly expand the set of applied criteria, so that the real legal, physical, economic, and ecological conditions of all cadastral municipalities are accurately reflected, leading to more relevant rankings and priority determinations for land consolidation projects using the ZUM.

Further research should focus on the introduction of weighting coefficients, assessment of ranking robustness (e.g., SMAA-2), integration of GIS indicators, and comparison of results with alternative MCDM methods to further enhance the precision and reliability of the decision-making process.

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