APPLICATION OF FUZZY LOGIC AND GIS IN THE RANKING OF LOCAL SELF-GOVERNMENT UNITS FROM THE ASPECT OF RELIEF SUITABILITY ON THE EXAMPLE OF JABLANICA AND PČINJA DISTRICTS, SERBIA

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ABSTRACT

The characteristics of relief are among the most important natural conditions, and the possibility of spatial utilization depends largely on them. The technique and density of construction, the development of infrastructure in a certain area, the possibility of carrying out certain activities, the dominance of one economic sector over another, depend on hypsometry, slope, aspect, vertical dissection and curvature of terrain. Therefore, it is important to thoroughly analyze these characteristics when planning spatial development, both at the state level and at the local community level. This paper analyzes the characteristics of the relief and then ranks the 13 local self-government units in the Jablanica and Pčinja districts in the Southern Serbia, according to those characteristics. The ranking took into account both quantitative criteria, such as the average height of the terrain, the average slope of the terrain, the percentage of the terrain surface with a slope of less than 5°, as well as more than 25°, the percentage of the terrain without curvature, etc., and qualitative criteria, such as the suitability of the relief forms, the relationship between relief and transport infrastructure, etc. Using GIS, the values of quantitative criteria were obtained for each unit of local self-government, and the qualitative criteria were evaluated by triangular fuzzy number. Then, using the Fuzzy Analytical Hierarchical Process (AHP), the weighting coefficients of each criterion were determined, and finally, using the Fuzzy MULTIMOORA method, the ranking of local self-government units was performed based on established criteria. The results obtained show the possibilities of local economic development in accordance with the characteristics of the relief with the possibility of efficient investments in certain units of local self-government, while, on the other hand, they show which units should be given more attention so that they do not lag behind in development..

Keywords: Hypsometry, Slope, Geographic Information System, Fuzzy AHP, Fuzzy MULTIMOORA

INTRODUCTION

Knowledge of natural conditions aims at a proper and rational approach in utilization of the natural potential of a certain territory, without significant disruptions to its natural balance. A complex analysis of the natural conditions of a certain area can determine its optimal usage [1]. One of the most important natural condition is the relief, and its characteristics, such as hypsometry, slope, aspect, vertical dissection and curvature of

terrain, largely condition the possibility of using the space, conducting certain activities, and even determining which economic branch will be dominant. If the relief conditions are favourable, then they will provide great opportunities for engaging in certain activities and for the economic prosperity, while in the opposite case, they represent a limiting factor for the development of a certain territory. Therefore, it is important to thoroughly analyze the characteristics of relief when planning spatial development, both at the state level and at the local community level.

This research aims to rank the local self-government units, which belong to the Jablanica and Pčinja districts, Southern Serbia, from the aspect of relief suitability. Most of these units cannot boast of a level of economic development, which should be given much more attention in the future. In order for the ranking to be possible, a detailed analysis of the existing characteristics of the relief is required. Using Geographic Information Systems, the necessary data on relief characteristics was obtained, and by applying fuzzy logic the ranking of local self-government units was performed based on established criteria.

STUDY AREA

Study area consists of 13 local self-government units in the Jablanica and Pčinja districts, located in the Southern Serbia, bordering the Republic of North Macedonia and the Republic of Bulgaria. Out of 13 local self-government units, 2 have the status of cities, the city of Leskovac in Jablanica district and the city of Vranje in Pčinja district, while other 11 units are municipalities. Total research area is 6290 km^2, of which 2770 km^2 belongs to the Jablanica district, and 3520 km^2 to the Pčinja district. According 2011 and 2002 census data, research area had a population of about 432 thousand, each district about 216 thousand people. Average population density for research area is 69 inhabitants per square kilometre (Jablanica district 78, Pčinja district 61). This is one of the least developed parts of Serbia, with very unfavourable demographic situation. The municipality of Crna Trava is least populated local self-government unit in Serbia, also with the lowest population density.

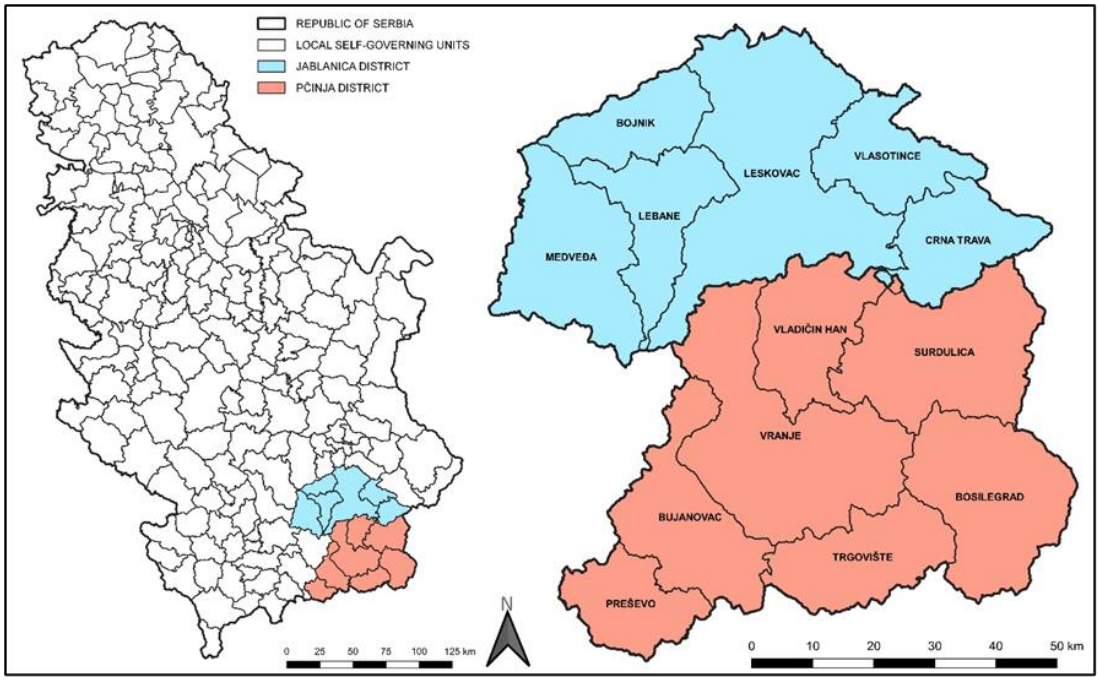

Figure 1. Local self-government units of the research area and their position in the Republic of Serbia

Table 1. Basic data of studied local self-government units

Local self-government units	Area [km^2]	Population	Population density [inh./ km^2]
Bojnik	263.9	11104	42.1
Crna Trava	312.0	1663	5.3
Lebane	336.8	22000	65.3
Leskovac	1025.0	144206	140.7
Medveđa	524.3	7438	14.2
Vlasotince	307.9	29893	97.1
Bosilegrad	571.2	8129	14.2
Bujanovac	460.9	43302	94.0
Preševo	264.7	34904	131.9
Surdulica	628.4	20319	32.3
Trgovište	370.6	5091	13.7
Vladičin Han	365.8	20871	57.0
Vranje	858.4	83524	97.3

Largest part of the research area belongs to the Black Sea drainage basin, with Južna Morava River as the main watercourse, while south-eastern part of research area belongs to the Aegean Sea basin, with Pčinja River and Dragovištica River as main watercourses. Južna Morava River valley has great agricultural and tourist potential, but also a very important traffic function. It is a natural route for the railway and highway Belgrade-Skopje-Thessalonica [2].

Average altitude of research area is 711 m (Jablanica district 588 m, Pčinja district 915 m). Lowest point of research area is exit of Južna Morava River riverbed out of the research area with an altitude of 191 m a.s.l., and the highest point is on Mt Besna Kobila with an altitude of 1923 m a.s.l. Average terrain slope of the research area is 12.5° (Jablanica district 10.8°, Pčinja district 13.8°).

RESEARCH METHODOLOGY

The ranking of the researched local self-government units from the aspect of relief suitability was performed using fuzzy logic with the help of Geographic Information Systems. The first step in the analysis is the selection of criteria on the basis of which the ranking is made. Criteria can be positive, where the priority will be higher as their value is higher, and negative, where the situation is opposite. The criteria that were taken into account for the purposes of this paper are: average altitude, average slope, transport accessibility, share of areas with slopes under 5°, share of areas with slopes over 25°, share of areas with altitude over 1000 m, suitability of the relief forms and processes, share of suitable areas around watershed, as well as share of areas with flat slopes between 5° and 25° (Table 2).

The criteria can be quantitative, whose values were obtained by analyzing geospatial data through GIS and expressed with appropriate units of measure, as well as quantitative, whose value are expressed by a triangular fuzzy number. In this case, a triangular fuzzy number was used, which represents the basic component of the fuzzy system [3]. Data on the average terrain height, average slope, share of areas with slopes under 5°, share of areas with slopes over 25°, share of areas with altitude over 1000 m, share of suitable areas around watershed, as well as share of areas with flat slopes between 5° and 25° were derived from 25x25 m cell size EU-DEM terrain model [4] using QGIS software. Values for the transport accessibility were assigned by reviewing the relationship between road infrastructure, especially state roads of first and second order, and relief forms, especially

river valleys. Values for the suitability of the relief forms and processes were assigned by analyzing qualitative and quantitative characteristic of relief forms from various topographical and geomorphological maps.

Table 2. Ranking criteria and their weighting coefficients

Number	Criterion	Unit	Positive/ negative	Weighting coefficient (W)
1	Average altitude	m	negative	0.1435
2	Average slope	deg	negative	0.1358
3	Transport accessibility	fuzzy number	positive	0.1283
4	Areas with slopes under 5°	%	positive	0.1243
5	Areas with slopes over 25°	%	negative	0.1167
6	Areas with altitude over 1000 m	%	negative	0.1076
7	Suitability of the relief forms and processes	fuzzy number	positive	0.0982
8	Suitable areas around watershed	%	positive	0.0853
9	Areas with flat slopes between 5° and 25°	%	positive	0.0603

Given that not all criteria are of equal importance, assigning of the weight coefficients to the criteria is necessary. It was performed through the fuzzy Analytical Hierarchy Process (AHP). Fuzzy AHP is a technique of incorporating the fuzziness of human thoughts into decision making [5]. In the fuzzy AHP model, a combination of AHP and fuzzy sets is used to assign weights to the corresponding factors [6]. The first stage of the fuzzy AHP method involves creating a fuzzy criteria comparison matrix. After that, it is necessary to calculate the value of the synthetic fuzzy extension for each element [7]. Further, the degree of possibility that the convex fuzzy number of a given criterion is greater than the convex number of other criteria is analyzed [8]. The weight vector is derived from the previous step, and through normalization, the vector is reduced to the form of a weight coefficient [9].

Table 3. Fuzzy criteria comparison matrix

Criterion	1	2	3	4	5	6	7	8	9
1	1; 1; 1	0.5; 1.5; 2.5	0.6; 1.6; 2.6	0.7; 1.7; 2.7	0.8; 1.8; 2.8	1; 2; 3	1.2; 2.2; 3.2	1.5; 2.5; 3.5	1.75; 2.75; 3.75
2	0.4; 0.67; 2	1; 1; 1	0.5; 1.5; 2.5	0.6; 1.6; 2.6	0.7; 1.7; 2.7	0.8; 1.8; 2.8	1; 2; 3	1.2; 2.2; 3.2	1.5; 2.5; 3.5
3	0.38; 0.63; 1.67	0.4; 0.67; 2	1; 1; 1	0.5; 1.5; 2.5	0.6; 1.6; 2.6	0.7; 1.7; 2.7	0.8; 1.8; 2.8	1; 2; 3	1.2; 2.2; 3.2
4	0.37; 0.59; 1.43	0.38; 0.63; 1.67	0.4; 0.67; 2	1; 1; 1	0.6; 1.6; 2.6	0.7; 1.7; 2.7	0.8; 1.8; 2.8	1; 2; 3	1.2; 2.2; 3.2
5	0.36; 0.56; 1.25	0.37; 0.59; 1.43	0.38; 0.63; 1.67	0.38; 0.63; 1.67	1; 1; 1	0.6; 1.6; 2.6	0.7; 1.7; 2.7	0.8; 1.8; 2.8	1.2; 2.2; 3.2
6	0.33; 0.5; 1	0.36; 0.56; 1.25	0.37; 0.59; 1.43	0.37; 0.59; 1.43	0.38; 0.63; 1.67	1; 1; 1	0.6; 1.6; 2.6	0.7; 1.7; 2.7	1; 2; 3
7	0.31; 0.45; 0.83	0.33; 0.5; 1	0.36; 0.56; 1.25	0.36; 0.56; 1.25	0.37; 0.59; 1.43	0.38; 0.63; 1.67	1; 1; 1	0.6; 1.6; 2.6	1; 2; 3
8	0.29; 0.4; 0.67	0.31; 0.45; 0.83	0.33; 0.5; 1	0.33; 0.5; 1	0.36; 0.56; 1.25	0.37; 0.59; 1.43	0.38; 0.63; 1.67	1; 1; 1	0.8; 1.8; 2.8
9	0.27; 0.36; 0.57	0.29; 0.4; 0.67	0.31; 0.45; 0.83	0.31; 0.45; 0.83	0.31; 0.45; 0.83	0.33; 0.5; 1	0.33; 0.5; 1	0.36; 0.56; 1.25	1; 1; 1

The final stage of the procedure is the calculation of the consistency of the comparison matrix. The comparison matrix, created using a triangular fuzzy number, requires a defuzzification process. Furthermore, it is necessary to calculate the degree of consistency (CR), which represents the ratio of the consistency index (CI) and the random index (RI), whose value depends on the number of compared criteria. The results of the comparison

are considered consistent if the condition CR < 0.10 is met [3,9]. In this case, the consistency coefficient is 0.058, which means that the consistency of the fuzzy matrix is satisfactory.

After determining the weighting coefficients of the criteria, the ranking of local self-government units was performed using the fuzzy MULTIMOORA method. MULTIMOORA includes three or more methods that control each other and rank alternatives depending on their performance values [10]. Multi-objective optimization based on ratio analysis plus the full multiplicative form – MULTIMOORA, is a technique for making decisions using multi-criteria analysis, based on the results of three methods: The Ratio System, Reference Point Approach and Full Multiplicative Form [11]. In this case, it is about the application of the fuzzy MULTIMOORA method, given that the weighting coefficients were assigned using the fuzzy AHP method, and the qualitative criteria for each local self-government unit were evaluated with a triangular fuzzy number.

The three mentioned methods that rank the local self-government units according to the selected criteria are applied to for each local self-government unit, and the final rank of the local self-government units is obtained based on the mean value of the rank of all three applied methods. Before applying the methods, it is necessary to normalize the values assigned to the local self-government units for each criterion, in order to make it possible to compare the values expressed in different measurement units and the values expressed by the triangular fuzzy number. First, the coefficient for normalization is calculated, which is equal to the square root of the average sum of squares of all values for a given criterion, and then each value of a given criterion is divided by the coefficient for normalization of that criterion [10].

When applying the Fuzzy Reference Point Approach (FRPA) method, for each criterion, the minimum value of all local self-government units is subtracted from the values obtained by dividing by the coefficient for normalization, if it is negative criteria, while for positive criteria, it is subtracted from the maximum value of all local self-government units' value for a given local self-government unit. The values obtained in this way are multiplied with the weight criteria obtained by applying the fuzzy AHP method and then their comparison is made, so that only the highest value of all criteria for a given local self-government unit is taken into account for the ranking. The first in rank will be the local self-government unit with the smallest value, while the last one will be the one with the highest value [10].

When applying the Fuzzy Ratio System (FRS) method, for positive criterion, the quotients of the values assigned to a specific local self-government unit for that criterion and the normalization coefficient added, and then quotients of all negative criterions and their normalization coefficients are subtracted from them. The local self-government unit with the highest value of the results is the first in rank. When applying the Fuzzy Full Multiplicative Form (FFMF) method, the values of the positive criteria for each local self-government unit are multiplied, which are then divided by the values of the negative criteria. The first in rank is the local self-government unit with the highest value of the result, just as in case of the application of the Fuzzy Ratio System method [10].

RESULTS AND DISCUSSIONS

Terrain hypsometry is one of the most important natural conditions. Hypsometric characteristics of the relief represent the basis of all further research and give a more comprehensive idea of the analyzed terrain. On the basis of the hypsometry, we come to

knowledge whether it is a plain, hilly-mountainous or mountainous terrain, and depending on the altitude of the terrain, the possibilities of its planning and proper use also arise [2,12]. With the increase in altitude, the change of other natural conditions such as air temperature, precipitation amount, snow cover, type of vegetation etc. occurs. Also, the possibility to engage in many activities decreases, the composition of the air changes, and the number of agricultural crops that can be grown is reduced.

The average altitude of the terrain represents an indispensable data in calculating the intensity of erosive processes, sediment retention etc. [2,12]. Therefore, the average altitude of the terrain is the criterion with the highest weighting coefficient, in relation to the other criteria, and its value is 0.14 (Table 2). The municipality of Bojnik, with average altitude of 412 m a.s.l., is the local self-government unit with lowest average altitude among others in research area, which gives it least disadvantages considering terrain utilization from this point of view. The municipality of Bojnik is followed by the city of Leskovac, with average altitude of 450 m a.s.l., and the municipality of Lebane, where average terrain altitude is 475 m (Table 4). Local self-government unit with the highest average altitude is the municipality of Bosilegrad with average altitude of 1228 m a.s.l., followed by the municipality of Crna Trava (1162 m) and Surdulica (1141 m).

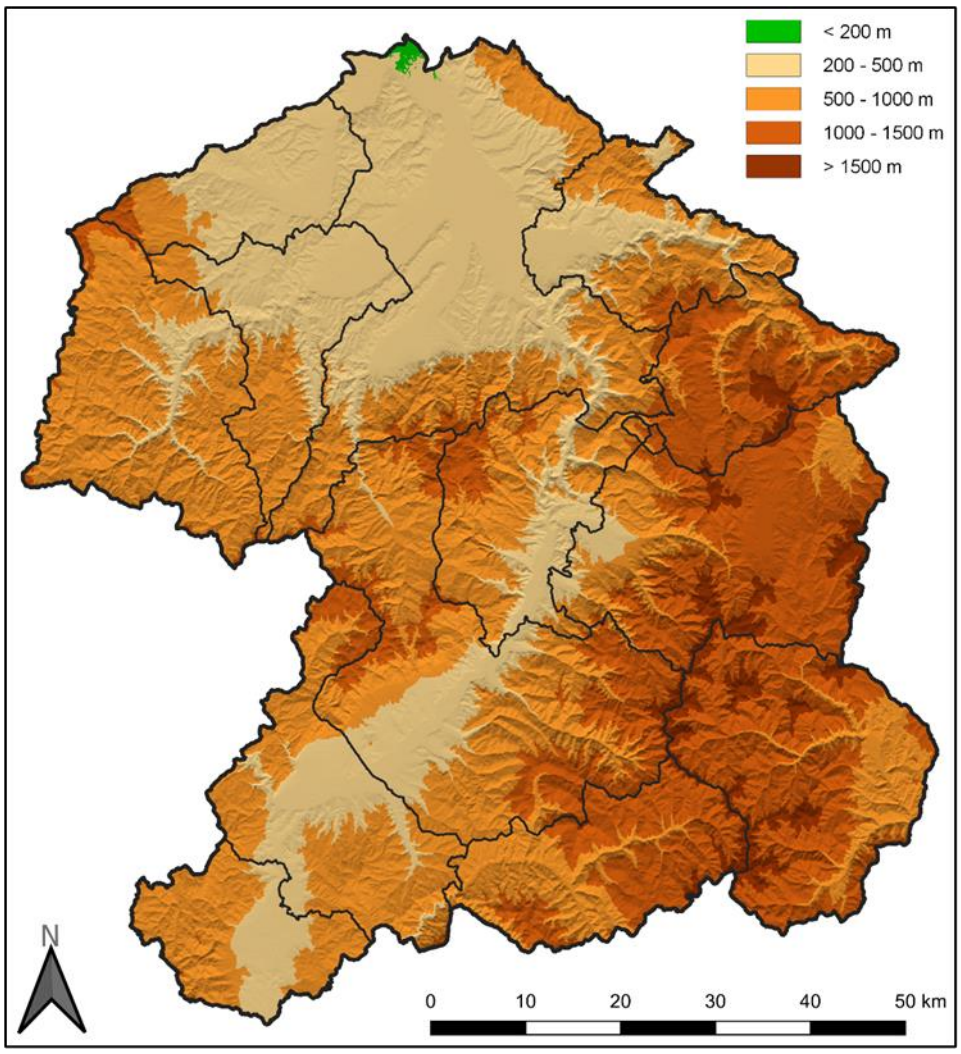

Figure 2. Hypsometry map of the research area

Table 4. Evaluated criteria for each local self-government unit

Local self-governing units	Average altitude (-)			Average slope (-)			Transport accessibility (+)		
Bojnik	412	412	412	5.3	5.3	5.3	4	5	6
Crna Trava	1162	1162	1162	16.8	16.8	16.8	1	2	3
Lebane	475	475	475	8.7	8.7	8.7	3	4	5
Leskovac	450	450	450	8.8	8.8	8.8	4	5	6
Medveđa	692	692	692	13.8	13.8	13.8	2	3	4
Vlasotince	569	569	569	13.0	13.0	13.0	2	3	4
Bosilegrad	1228	1228	1228	17.6	17.6	17.6	2	3	4
Bujanovac	628	628	628	9.1	9.1	9.1	3	4	5
Preševo	632	632	632	8.5	8.5	8.5	3	4	5
Surdulica	1141	1141	1141	14.1	14.1	14.1	2	3	4
Trgovište	1069	1069	1069	16.4	16.4	16.4	1	2	3
Vladičin Han	690	690	690	14.0	14.0	14.0	3	4	5
Vranje	812	812	812	13.9	13.9	13.9	3	4	5
Local self-governing units	Areas with slopes under 5° (+)			Areas with slopes over 25° (-)			Areas with altitude over 1000 m (-)		
Bojnik	55.9	55.9	55.9	0.3	0.3	0.3	4.3	4.3	4.3
Crna Trava	4.3	4.3	4.3	14.3	14.3	14.3	75.7	75.7	75.7
Lebane	33.6	33.6	33.6	1.5	1.5	1.5	0.5	0.5	0.5
Leskovac	40.2	40.2	40.2	4.1	4.1	4.1	3.0	3.0	3.0
Medveđa	7.2	7.2	7.2	5.3	5.3	5.3	4.2	4.2	4.2
Vlasotince	17.7	17.7	17.7	7.4	7.4	7.4	6.5	6.5	6.5
Bosilegrad	4.1	4.1	4.1	15.4	15.4	15.4	78.5	78.5	78.5
Bujanovac	27.1	27.1	27.1	1.7	1.7	1.7	7.8	7.8	7.8
Preševo	37.3	37.3	37.3	1.6	1.6	1.6	0.7	0.7	0.7
Surdulica	12.1	12.1	12.1	9.6	9.6	9.6	71.6	71.6	71.6
Trgovište	4.0	4.0	4.0	9.9	9.9	9.9	60.3	60.3	60.3
Vladičin Han	12.0	12.0	12.0	9.1	9.1	9.1	13.1	13.1	13.1
Vranje	16.4	16.4	16.4	9.6	9.6	9.6	27.5	27.5	27.5
Local self-governing units	Suitability of the relief forms and processes (+)			Suitable areas around watershed (+)			Areas with flat slopes between 5° and 25° (+)		
Bojnik	3	4	5	10.8	10.8	10.8	1.8	1.8	1.8
Crna Trava	2	3	4	11.6	11.6	11.6	0.9	0.9	0.9
Lebane	2	3	4	8.0	8.0	8.0	1.0	1.0	1.0
Leskovac	2	3	4	5.5	5.5	5.5	1.1	1.1	1.1
Medveđa	2	3	4	6.3	6.3	6.3	0.6	0.6	0.6
Vlasotince	2	3	4	5.8	5.8	5.8	0.9	0.9	0.9
Bosilegrad	2	3	4	7.9	7.9	7.9	0.8	0.8	0.8
Bujanovac	2	3	4	6.3	6.3	6.3	1.1	1.1	1.1
Preševo	2	3	4	7.6	7.6	7.6	0.9	0.9	0.9
Surdulica	3	4	5	7.8	7.8	7.8	1.1	1.1	1.1
Trgovište	1	2	3	5.6	5.6	5.6	0.7	0.7	0.7
Vladičin Han	1	2	3	7.1	7.1	7.1	0.7	0.7	0.7
Vranje	2	3	4	5.8	5.8	5.8	0.8	0.8	0.8

Since altitude of 1000 m represents conditional border for intensive agricultural activity in Serbia [12], and that there is a rapid decrease in suitability for conducting various activities, one of the criteria that was used for this research is share of areas with altitude over 1000 m a.s.l in total areas of each local self-government unit. This criterion is the sixth most important with a weight coefficient value of 0.11 (Table 2). Largest share of areas with altitude over 1000 m are found in the municipality of Bosilegrad, with 78.5% of total municipality area. Second largest share of such areas is found in the municipality

of Crna Trava, with 75.7% of total area, and third is the municipality of Surdulica with 71.6% of total area (Table 4). Local self-government unit with the lowest share of areas with altitude over 1000 m is the municipality of Lebane, with only 0.5% of total area, followed by the municipality of Preševo (0.7%), and the city of Leskovac (3%).

The slope of the terrain, along with hypsometry, is one of its most important characteristics. The ability to engage in certain activities, as well as their efficiency, largely depends on the slope of the terrain. The slope affects temperature fluctuations and other climatic elements, due to the different incidence angle of the sun's rays in combination with the aspect. Steeper slopes reduce the possibility of applying agrotechnical measures in agriculture, an increased slope significantly increases the fuel consumption of agricultural vehicles and reduces work productivity, while reducing the yield of most agricultural crops. A higher slope angle of the terrain reduces the suitability for the construction of settlements and infrastructure and significantly increases construction costs. On the other hand, terrains with a greater slope are favourable for engaging in certain types of tourism and recreation [12]. The slope of the relief is one of the basic factors that defines the intensity of soil erosion process. This is conditioned by the fact that as the slope of the terrain increases, so does the kinetic energy of the water flowing down the slope. Therefore, the same amount of water on a horizontal and an inclined surface has different energy and can erode a much larger amount of material [2,12].

The average terrain slope gives a picture of what the overall utilization of the terrain is possible in relation to suitability of the terrain. Therefore, in this work, it is the second most important criterion with a weight coefficient value of almost 0.14 (Table 2). The municipality of Bojnik, with average slope 5.3° is the local self-government unit with lowest average slope, while second and third ranked are the municipality of Preševo, with average slope of 8.5° and the municipality of Lebane, with 8.7° (Table 4). Local self-government unit with steepest average slope is the municipality of Bosilegrad where average slope is 17.6°, followed by the municipality of Crna Trava (16.8°) and Trgovište (16.4°).

Beside average slope, it is important to determine what is the share of areas with the slope under 5°, as well as over 25°. Terrains with slopes under 5° are suitable for most of the activities, while their productivity is at maximum. Possibility for construction of the objects and infrastructure is highest and also highest productivity and yield in agriculture is present. It should not be forgotten that risk of the slope processes on such terrains is lowest. The limitations of such terrains arise from other characteristics, such as the relationship with underground water and flood zones, geological characteristics, etc. The weight coefficient value of this criterion is 0.12 (Table 2). In the research area, highest share of areas with the slopes under 5° are found in the municipality of Bojnik, with 55.9% of total municipality area. Second ranked is the city of Leskovac with 40.2% of total area, and third is the municipality of Preševo with 37.2% of total area (Table 4). Local self-government unit with the lowest share of areas with terrain slope under 5° is the municipality of Trgovište, with 4% of total area, followed by the municipality of Bosilegrad (4.1%), and the municipality of Crna Trava (4.3%).

Terrains with slopes over 25° have quite opposite characteristics comparing to above-mentioned. Number of activities that can be conducted on such terrains is much smaller and productivity of the most activities that are conducted on such terrain is very reduced. Risk of slope processes and natural disasters that arise from such processes (torrential floods, landslides, rockfalls, avalanches) is high, if other conditions are met. Such areas

have a higher energy of mass movement and they affect the velocity of water flow and the development of erosion processes [13,14]. The weight coefficient value of this criterion is almost 0.12 (Table 2). Largest share of areas with terrain slope over 25° are found in the municipality of Bosilegrad, with 15.4% of total municipality area. Second largest share of such areas is found in the municipality of Crna Trava, with 14.3% of total area, and third is the municipality of Trgovište with 9.9% of total area (Table 4). Local self-government unit with the lowest share of areas with terrain slope over 25° is the municipality of Bojnik, with only 0.3% of total area, followed by the municipality of Lebane (1.5%), and the municipality of Preševo (1.6%).

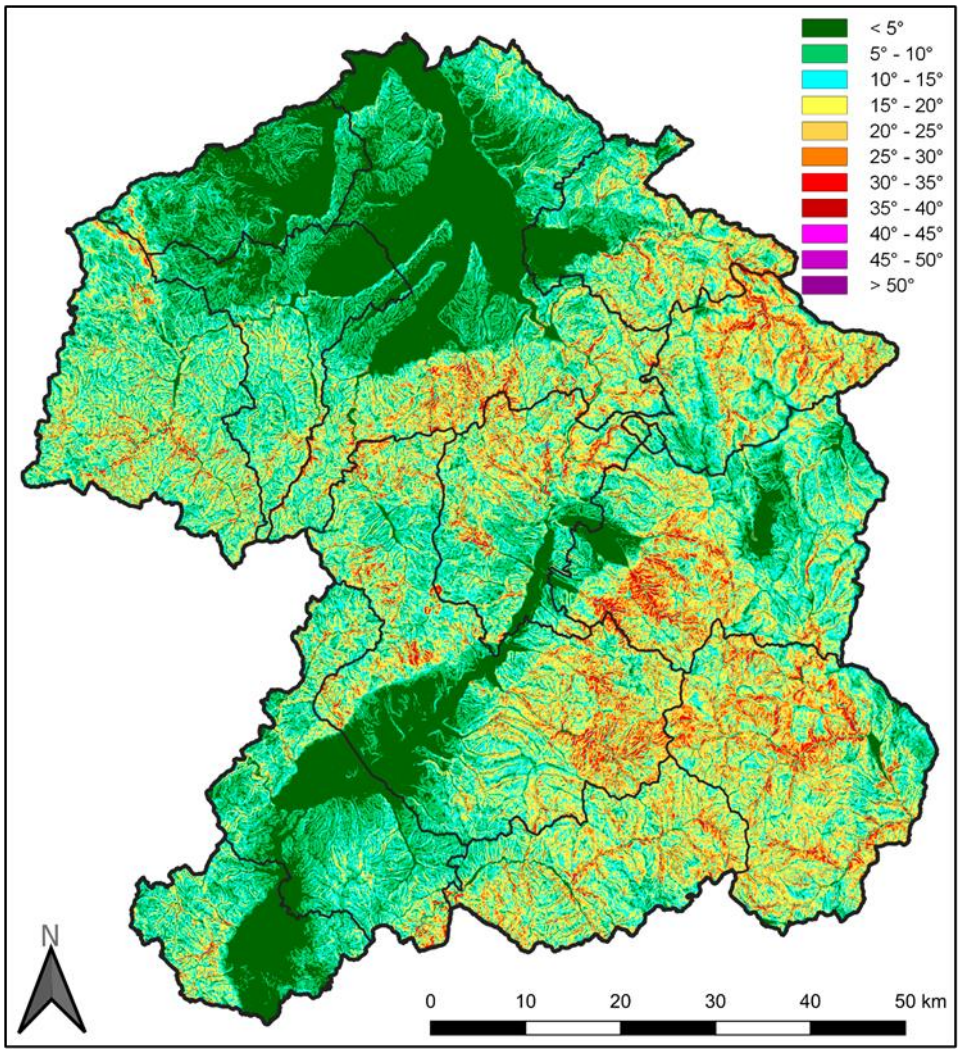

Figure 3. Terrain slope map of the research area

Besides surfaces in wider river valleys, which are considered as one of the most suitable, in determining the overall suitability of the relief, it is necessary to take into account suitable areas around the top of watershed of all river basins in research area. Such areas, if terrain slope is low, could be favorable for various activities, and limitation of their use, first of all comes from their accessibility. Such areas were determined first by calculating relative slope position in QGIS software, using EU-DEM as basic input data, and then taking into account only areas where value of relative slope position is higher than 0.975. The weight coefficient value of this criterion is lower than 0.09 (Table 2). Largest share

of suitable areas around the top of watershed is present in the municipality of Crna Trava, with 11.6% of total municipality area. Second largest share of such areas is found in the municipality of Bojnik, with 10.8% of total area, and third is the municipality of Lebane with 8% of total area (Table 4). Local self-government unit with the lowest share of suitable areas around the top of watershed is the city of Leskovac, with 5.5% of total area, followed by the municipality of Trgovište (5.6%), while third place is shared by the municipality of Vlasotince and the city of Vranje (5.8%).

Terrain curvature is the amount of terrain deviation along a certain line from a straight line [15]. It is the second derivative of the topographic surface and represents the degree of change of the first derivative, such as slope and exposure, in a certain direction [16]. Most often, profile (vertical) curvature and planform (tangential, horizontal) curvature are calculated, which determine whether the terrain is flat, convex or concave, in the direction of greatest slope or isohypse. Combining profile and planform curvature cases gives 9 different classes of terrain curvature, where vertically flat and horizontally flat slopes are most suitable for conducting in various activities. For purposes of these research such slopes, with angle between 5° and 25° were taken into account. Terrains with slope angles below 5° and above 25° were already analyzed in this paper regardless their curvature, since on such terrains they do not modify suitability in larger amount. Taking into account that targeted areas cover very small share of total areas of slope angles between 5° and 25°, weight coefficient of this criterion is lowest, with the value of 0.06 (Table 2). Largest share of such areas in research area is in the municipality of Bojnik (1.8%), and lowest is in the municipality of Medveđa (0.6%).

Transport accessibility is important from the point of terrain utilization and future development. Wide river valleys give possibilities to develop traffic infrastructure and to easily connect parts inside one local self-government unit, areas in different units. On the other hand, narrow valleys and high dissection relief forms significantly lower connection possibilities. This is the third most important criteria, with a weight coefficient value of 0.13 (Table 2). The highest value for this criterion is assigned to the city of Leskovac and the municipality of Bojnik, where river valleys of Južna Morava River and its tributaries are widely open, allowing good connectivity in a large part of those units, while the lowest value is given to the municipalities of Crna Trava and Trgovište (Table 4), where narrow valleys and lack of flat terrain represent a problem for building new and improving existing traffic infrastructure.

The possibility of space utilization will depend on the relief forms, their dimensions and other characteristics, therefore relief forms were evaluated for the purpose of this paper. Also, geomorphological processes and their intensity were also taken into account, especially erosion intensity and landslide process, since they can directly and indirectly present a limitation to terrain utilization and development. The weight coefficient value for this criterion is 0.1 (Table 2). Highest values for the suitability of relief forms and processes was given to the municipalities of Bojnik and Surdulica, and the lowest to the municipalities of Trgovište and Vladičin Han (Table 4).

By evaluating all the criteria for the investigated local self-government units, as well as by applying the fuzzy MULTIMOORA method, their ranking was performed from the aspect of the relief suitability. According to the Fuzzy Reference Point Approach (FRPA) method, the municipality of Bojnik is most suitable from the aspect of relief, followed by the city of Leskovac and the municipality of Preševo, while the municipalities of Trgovište, Bosilegrad and Crna Trava, are marked as units with the lowest suitability (Table 5).

According to the Fuzzy Ratio System (FRS) method, the municipality of Bojnik also has the highest suitability. The city of Leskovac is again ranked as second, while the municipality of Lebane is at third place. The last in relief suitability according to this method is the municipality of Bosilegrad (Table 5).
According to the Fuzzy Full Multiplicative Form (FFMF) method, as in the previous two cases, ranked as first is also the municipality of Bojnik. The municipality of Lebane is ranked as second, and the municipality of Preševo is third. The last in relief suitability according to FFMF method is the municipality of Trgovište (Table 5).

Table 5. Ranked local self-government units from the aspect of relief suitability

Local self-governing units	FRPA	FRS	FFMF	FINAL RANK
Bojnik	1	1	1	1
Crna Trava	11	12	11	11
Lebane	4	3	2	3
Leskovac	2	2	4	2
Medveđa	10	7	7	7
Vlasotince	6	6	6	6
Bosilegrad	12	13	12	12
Bujanovac	5	5	5	5
Preševo	3	4	3	4
Surdulica	8	10	10	10
Trgovište	13	11	13	12
Vladičin Han	9	8	8	8
Vranje	7	9	9	8

According to the final ranking, which takes into account the results of all three applied techniques within the fuzzy MULTIMOORA method, the highest suitability of the relief has the municipality of Bojnik, which is the first ranked according to all three applied techniques (Table 5). This municipality is best in most of categories, it has lowest average altitude of the terrain, lowest average slope, highest transport accessibility and suitability of the relief forms and processes, highest share of areas with slope below 5°, lowest above 25°, and highest share of flat terrains with slopes between 5° and 25°. Sadly, the municipality of Bojnik is not as near developed as it should be, according to the relief suitability, even within the surveyed districts. Hopefully future development plans and investments could take into account this kind of research, which could significantly improve the situation.
The city of Leskovac is second by final ranking, and before 1990s it was using this potential notably, standing out as an economic leader in this part of Serbia. Unfortunately, the suitability of the relief could not affect the socioeconomic processes that negatively affected the state of this local community in past decades. Third in final ranking is the municipality of Lebane, which is also not as near developed as it could be, according to its relief suitability. Last in final rank are the municipalities of Trgovište and Bosilegrad (Table 5), where relief proved to be one of the limiting factors of development, and taking into account their demographic situation, there is a little chance that the situation will improve significantly in the near future. This also applies to the municipality of Crna Trava, which is ranked just before last two municipalities.
When viewed from the district's point of view, Jablanica district has better situation than Pčinja district. First three ranked local self-government units are all from the Jablanica district, and only the municipality of Crna Trava has very low rank. When looking Pčinja district, first in rank is the municipality of Preševo, second is the municipality of

Bujanovac, and third place is divided by the city of Vranje and the municipality of Vladičin Han. All of those local self-government units should find a way to use relief suitability much better in the future.

CONCLUSIONS

Although socioeconomic factors are the main factors when it comes to development, but also the decline of a certain territory, natural conditions should also be taken into account when planning and improving the development of local communities and local self-government units. Relief, as one of the basic natural conditions, should certainly be considered as an important development factor, but also as a limiting factor. The goal of this paper was to rank local self-government units of Jablanica and Pčinja district from the aspect of relief suitability. Based on the selected criteria, it was determined that the greatest relief suitability in the research area has the municipality of Bojnik, which cannot be considered as developed community. It is followed by the city of Leskovac, and municipality of Lebane, all from the Jablanica district. In the Pčinja first in rank by the relief suitability is the municipality of Preševo. All mentioned local self-government units should try to utilize this suitability much more in the future, and to improve their economic situation. The worst ranked are the municipalities of Trgovište, Bosilegrad and Crna Trava, where relief conditions together with demographic situation present serious limiting factor of development, with a little hope of greater improvement in near future.
This research considered general suitability of the relief. Next researches could address relief suitability from the point of view of certain economy branch or activity, such as agriculture, energy sector, in order to improve situation and economic development, not only in research area, but such research can be used in other parts of Serbia and the Balkan Peninsula.

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