# APPLICATION OF GIS IN THE SELECTION OF SUITABLE LOCATIONS FOR THE CONSTRUCTION OF AN OBSERVATORY AT THE EXAMPLE OF THE MUNICIPALITY OF ŽAGUBICA

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**Abstract:** The municipality of Žagubica is the subject of research for suitable locations for the construction of a viewpoint. The area of the municipality of Žagubica is located in Eastern Serbia, it belongs to the Braničevo district. The goal of this work is to show the most suitable locations for the construction of a viewpoint from which selected geo-localities can be seen, which will additionally attract tourists. The GIS method and the AHP method were used in the analysis of the selected locations. The criteria used to obtain the results are: terrain slope, altitude-hypsometry, land use and distance from roads. By choosing the evaluated criteria and using the AHP method, we can conclude that about 30 % of the territory can be suitable for the construction of a viewpoint, of which 5.48 % of the territory is very suitable. Four locations were chosen as the most attractive in the scope of the territory that belongs to suitable areas for construction.

**Keywords:** GIS; analytic hierarchy process (AHP); suitable locations; observatory; viewpoints; Žagubica, Serbia

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# INTRODUCTION

The municipality of Žagubica is the subject of research for suitable locations for the construction of a view point. The area of the municipality of Žagubica is located in Eastern Serbia, it belongs to the Braničevo district. It is bordered by the mountain ranges of the Homolje mountains, to the north (940m above sea level), the Crni Vrh massif (1043m above sea level), to the south-east by Beljanica, to the south (1339m above sea level), and to the west by the lowland Donja Mlava. It is separated by the Gornjačke mountains (825 m above sea level). In the center between the mountain ranges are the basins of Zagubica and Krepoljina-Krupaja (JUGINUS, 2010).

Administratively, the municipality of Žagubica borders the municipalities: Kučevo in the north, Majdanpek in the northeast, Bor in the east and southeast, the municipality of Despotovac in the south and the municipality of Petrovac in the northwest. It extends over an area of 765 km2, where 14,823 inhabitants live in 18 settlements. The municipality includes parts of 19 cadastral municipalities: Žagubica (settlement of Žagubica), Laznica Selo (settlement of Selište), Medveđica (settlement of Medveđica), Izvarica (settlement of Izvarica), Gornjak (no settlement), Milatovac, Breznica (settlement of Breznica), Ribare (settlement of Ribare), Vukovac (settlement of Vukovac) , Bliznak (Bliznak settlement), Mali Kamen (no settlement), Jošanica (Jošanica settlement), Krupaja (Krupaja settlement), Milanovac (Milanovac settlement), Sige (Sige settlement), Krepoljin (Krepoljin settlement), Laznica Selište (Laznica and Lipe), Suvi Do (Suvi Do settlement), Osanica (Osanica settlement) (JUGINUS, 2010).

The goal of this work is to show the most suitable locations for the construction of a viewpoint from which selected geo-localities can be seen, which will additionally attract tourists. The criteria chosen for evaluation will be described in more detailed in the following work.

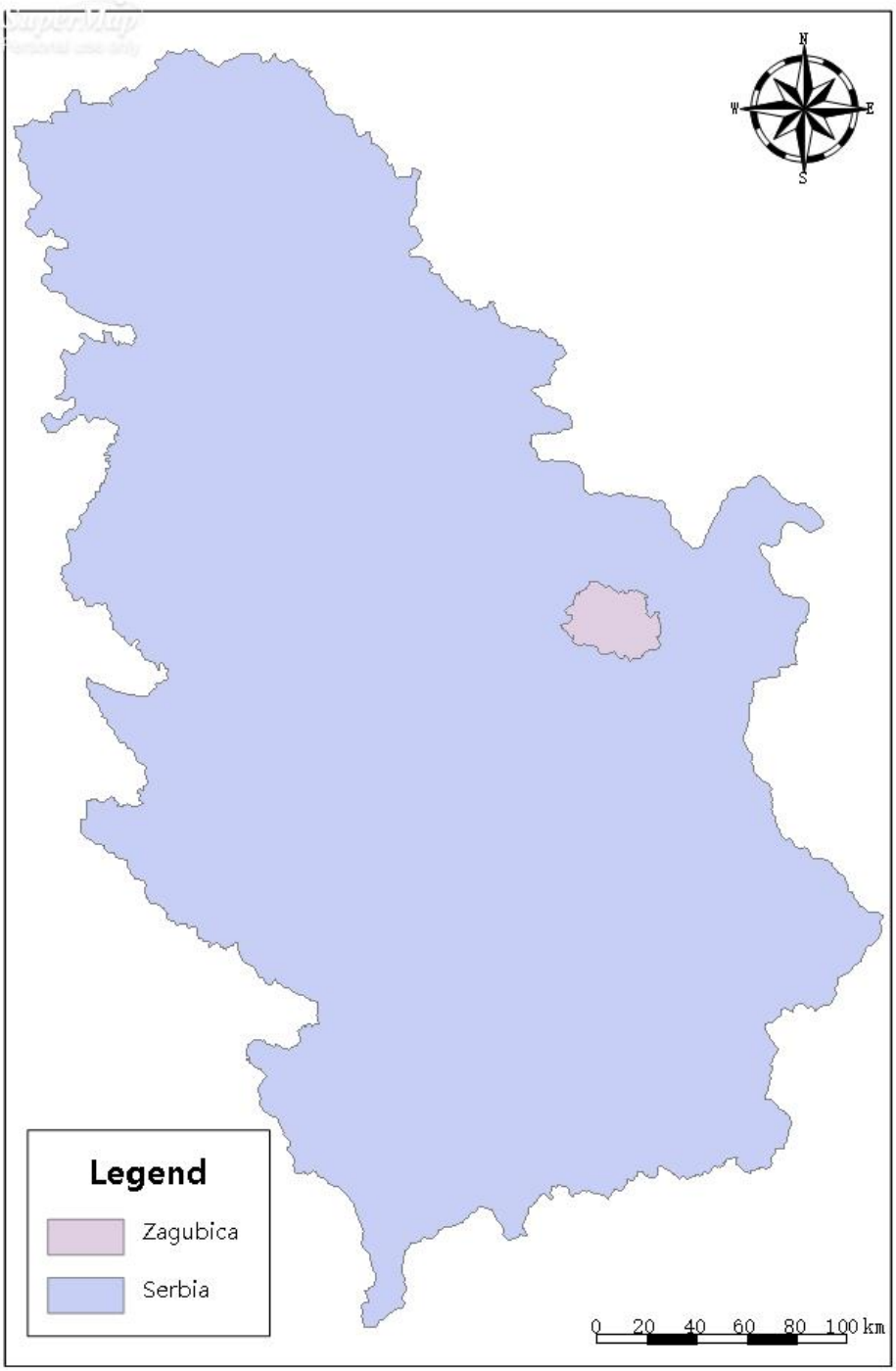
The GIS method and the AHP method were used in the analysis of the selected locations. The criteria used to obtain the results are: terrain slope, altitude-hypsometry, land use and distance from roads.

# GEOGRAPHICAL LOCATION AND BASIC CHARACTERISTICS OF THE MUNICIPALITY

The municipality of Žagubica is located in the eastern part of Serbia between 21°31' 30" and 21° 58' 30" east longitude and 44° 05' and 44° 21' 30" north longitude. Due to its morphological isolation in a mountainous environment, without sufficient high-quality traffic connections with the surrounding area, it has a relatively favorable geographical position. It extends over an area of 760 km2, where less than 15,000 inhabitants live in 18 settlements.

The territory of the municipality of Žagubica extends to the southeastern part of the Braničevo district and includes the southern slopes of the Homoljske mountains, the northern slopes of Beljanica and Crni Vrh, as well as the Žagubica basin with the Mlava River and the Krepoljinsko - Krupajska basin with the Krupajska River. State roads of the second order lead through the territory of the municipality to Petrovac, Bor and Despotovac, and the zones along these roads are the most populated. As the most striking features of the relief of this part of Serbia, the mountain ranges of Beljanica, Crni Vrh and Homoljske mountains, Žagubička and Krepoljinsko - Krupajska valley dominate, and in the hydrography of the municipality, the Mlava and Krupajska rivers stand out with their tributaries, which often have picturesque valleys, numerous waterfalls and hot springs. The Tisnica river, the largest right tributary of the Mlava, flows through Žagubica, and in the Krepoljina zone, its largest left tributary in this area, the Krupajska river, flows into the Mlava. All settlements are mostly located next to the main roads, along the Mlava and Krupajska rivers. The municipality of Žagubica borders the municipalities: Kučevo in the north, Majdanpek in the northeast, Bor in the east and southeast, the municipality of Despotovac in the south and the municipality of Petrovac in the northwest (JUGINUS, 2010).

Favorable climatic conditions and favorable altitude, wealth of forests, waters, etc. enables the development of animal husbandry, agriculture, forestry and fishing. The municipality is also a potential tourist attraction. The most populated areas are around the rivers (all settlements are concentrated around the Mlava River and its tributaries). The central part of the municipality in the Žagubička basin and Krepoljinsko - Krupajska basin / valley is favorable for settlement (conditions for cattle breeding, fruit growing). Higher mountain zones are less favorable for settlements (areas on the Beljanica mountains, Homoljski mountains), due to the geological structure of the terrain, pronounced erosion, lower quality pedological substrate and harsher climatic conditions, as well as poor traffic connections in those parts of the municipality (JUGINUS, 2010).




*Map no.1 Location of the municipality of Žagubica on the territory of the Republic of Serbia*

# WORK METHODOLOGY

## GIS METHOD

GIS is a special purpose database, in which the generally accepted spatial coordinate system is used as the basic cohesive factor. It is a system for creating and managing spatial data with associated attributes. Definitions of organization-based GIS: GIS represents an institutional entity, reflecting an organizational structure that integrates technology with databases, expertise and ongoing financial support over time (Kukrika, 2000).

The basic components of GIS are:

• Input of data from existing surveys and other sources;

• Saving, searching and referencing data;

• Data processing, transformations, analysis and modeling of spatial data, including spatial statistics;

• Presentation of spatial data in the form of geographic maps, reports and plans.

GIS contains various tools that are used to prepare data for further processing. The application of GIS within the analysis of terrain predisposition for the selection of the most suitable locations for the construction of viewpoints is reflected in the consideration of significant factors that influence their creation, such as, for example terrain slope, terrain elevation, land use and distance from roads.

The available data used for the analysis of the area of the municipality of Žagubica are: DEM (Digital Elevation Model) with a resolution of 100x100m, CORINE Land Cover (CLC) database from 2018, as well as Openstreetmap.org - a website from which the data on roadways were downloaded.

## AHP METHOD

The AHP method was chosen for the purposes of determining the suitability of the area for the construction of a viewpoint in the territory of the municipality of Žagubica. The Analytical Hierarchy Process (AHP) is a method to support the decision-making process, which is based on the formation of a hierarchy of problems and an original procedure for evaluating elements by levels of the hierarchy until the weights of all elements (alternatives) at the lowest level are determined in the final synthesis in relation to the element at the highest level. The essence of this method consists in comparing pairs of elements in the matrix A, where the number of rows and columns in the matrix is defined by the number of elements that need to be quantified in accordance with the set goal. Numerical evaluations of the comparison of pairs of elements at a given level of the hierarchy are entered into the comparison matrix, which is reciprocal, that is, the elements from the upper triangle are symmetrically reciprocal to the elements from the lower triangle, while the elements on the main diagonal are equal to 1 (table no. 1).

Within the SuperMap software, which was used during the work, it is possible to use the Raster Calculator option, through which a combined raster is obtained that includes the weighting coefficients

shown in table 3. In this work, the slope of the terrain was chosen as the most important factor, then the elevation, while land use and distance from roads have equal importance (table no. 1).

**Table no.** 1. Matrix

| Criterias | Slope | Elevation | Land use | Distance from roads |
|---|---|---|---|---|
| **Slope** | 1 | 2 | 3 | 3 |
| **Elevation** | 0.5 | 1 | 2 | 3 |
| **Land use** | 0.33 | 0.5 | 1 | 1 |
| **Distance from roads** | 0.33 | 0.5 | 1 | 1 |

The weighting coefficients are obtained in the following way, by the mathematical operation of squaring the matrix (table no. 1) a new matrix is obtained (table no. 2), then the rows are summed, and then the columns are summed. When we divide the sum of the rows for each of the criteria by the total sum of the summarized columns ($\sum$ 87.89), we get the weight coefficients (table no. 3), that is, the importance for each of the mentioned criteria.

**Table no. 2.** New matrix

| Criterias | Squared matrix | | | | SUM of the rows |
|---|---|---|---|---|---|
| **Slope** | 3.98 | 7 | 13 | 15 | 38.98 |
| **Elevation** | 2.65 | 4.5 | 8.5 | 9.5 | 25.15 |
| **Land use** | 1.24 | 2.16 | 3.99 | 4.49 | 11.88 |
| **Distance from roads** | 1.24 | 2.16 | 3.99 | 4.49 | 11.88 |
| **SUM of the columns** | 9.11 | 15.82 | 29.48 | 33.48 | 87.89 |

**Table no. 3.** Weight coefficients

| Criterias | Coefficients |
|---|---|
| **Slope** | 0.44 |
| **Elevation** | 0.29 |
| **Land use** | 0.14 |
| **Distance from roads** | 0.14 |

The efficiency of the AHP method is expressed by the formula:

$$CR = CI/RI$$

where CR represents consistency ratio, CI represents coefficient of subjective error and RI represents random index. The random index is expressed in Saaty's scale for the total number of coefficients (Saaty, 1990).

**Table no. 4.** Saaty's scale

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0,58 | 0,9 | 1,12 | 1,24 | 1,32 | 1,41 | 1,45 | 1,49 |

CR must be below 0.1 to be consistent.

The consistency index is obtained by multiplying the weight coefficients with the values from the initial matrix. Then we sum up the rows, then we divide the sum of the rows by the weight coefficient. From the last obtained column, we select λ max.

The formula for the coefficient of subjective error is:

$$CI = (\lambda max\ -\ n)/(n-1)$$

where n represents the number of criteria, and λ max. represents the largest number in the column.

λ max= 4.14 ;

CI = (4.14-4) / (4-1) => CI= 0.05 ;

RI= 0.9

We insert the obtained result into the efficiency formula of the AHP method, where we obtained the following results:

$$CR = CI/RI$$

CR = (0.05/0.9) = 0.052

# CRITERIA OF THE AHP METHOD

## The slope of the terrain

Slope is the most important topographical parameter, given that the surface of the terrain is completely formed by slopes and the angles of the slope control the gravitational forces that drive all geomorphological processes. The slope of the terrain, among other things, depends on the speed of runoff of surface water, the saturation of the soil with moisture and the intensity of geomorphological processes.

The slope angle of the terrain is of great importance in determining the predisposition of a certain area for the development of various processes in the natural environment, and it is especially important for the implementation of human activities. The slope of the terrain can be expressed in percentages and parts per thousand (Jezdić, 2020).

For the sake of easier analysis and consideration of potential opportunities for the development of a geographical area, a general classification of the terrain was made depending on the slope.

• up to 1˚ flat terrain

• 1-3˚ very slightly sloping terrain

• 3-5˚ slightly sloping terrain

• 5-8˚ quite sloping terrain

• 8-12˚ inclined terrain

• 12-16˚ very sloping terrain

• 16-20˚ moderately steep terrain

• 20-30˚ medium steep terrain

• 30-40˚ very steep terrain

**Table no. 5.** Valorization of the slope of the terrain

| Slope | Grade |
|---|---|
| **<5°** | 5 |
| **5-10°** | 4 |
| **10-20°** | 3 |
| **20-30°** | 2 |
| **30-40°** | 1 |
| **>40°** | 0 |

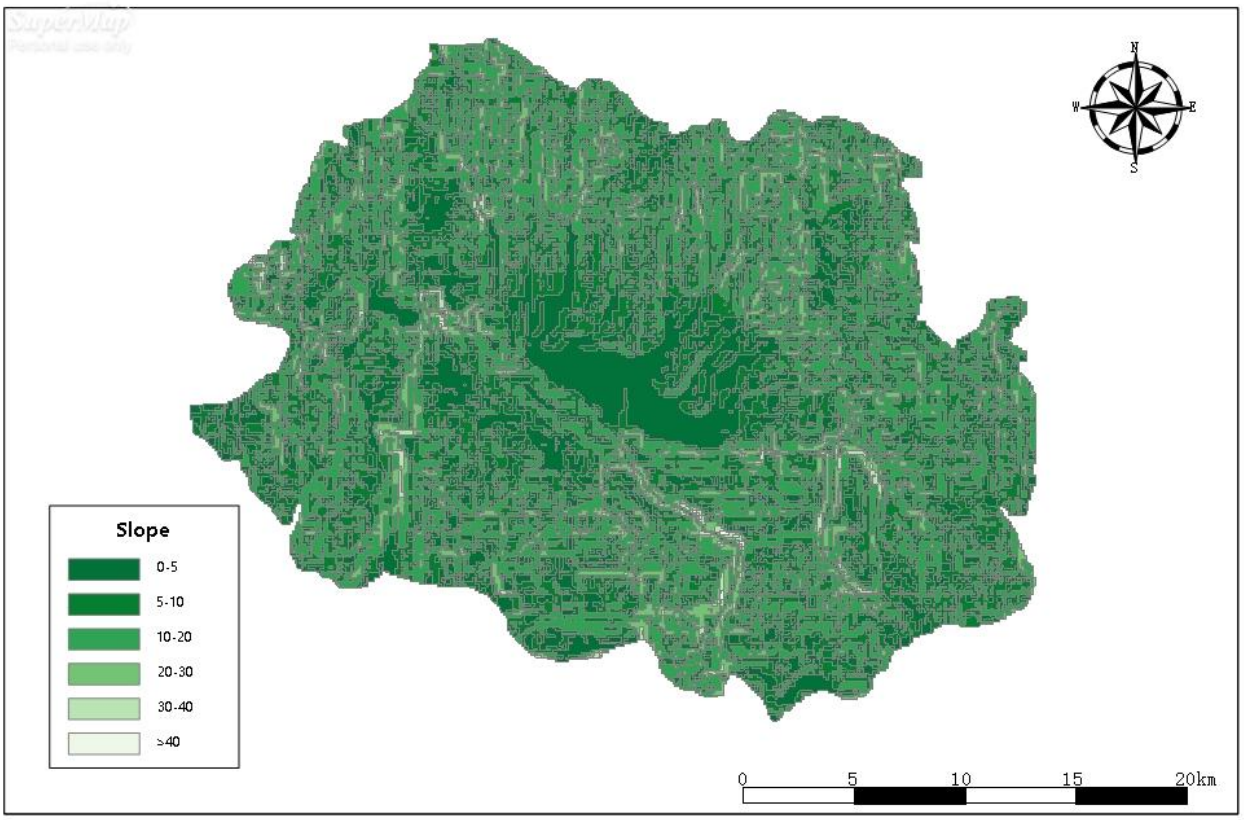
The highest grade (5) is given to terrain slopes that are less than 5°. Terrain slopes from 5° to 10° are graded 4. These two classes are the most important to us when building a view point. Everything that is over 40° is graded 0. Those terrains are eliminated.

Geo-data on terrain slope values were generated based on a digital terrain model with a spatial precision of 100m.

In the territory of the municipality of Žagubica, the slope of the terrain ranges from 0 to 45.49°. A large part of the territory of the municipality is covered by slopes of up to 10˚ with a share of 56.38% in the total area of the municipality. Those slopes represent very convenient and convenient parts of the territory. The smallest area is occupied by terrain slopes >40° with a share of only 0.05%.

**Table no. 6.** Terrain slope, area and share in the municipality

| Slope [°] | Area [km²] | Share in the total area [%] | Grade |
|---|---|---|---|
| <5° | 169.63 | 22.01 | 5- very convenient |
| 5-10° | 264.88 | 34.37 | 4-suitable |
| 10-20° | 277.5 | 36.00 | 3-partly suitable |
| 20-30° | 52.51 | 6.81 | 2-inconvenient |
| 30-40° | 5.88 | 0.76 | 1-very inconvenient |
| >40° | 0.36 | 0.05 | 0-eliminated |




*Map no.2 Slope of the terrain in the territory of the municipality of Žagubica*

## Elevation

The height above sea level (absolute height or altitude) is the height of a point on Earth in relation to the reference surface, according to which all elevations on land and underwater depths are determined. It is defined as the distance in meters vertically, from the mean level of the ocean surface to a point on the Earth's surface (Jezdić, 2020).

Depending on the altitude of the terrain, the possibilities of its planning and proper use also arise. The division of relief according to altitude zones was made into three categories, lowlands 0-200 m above sea level, mountainous area 200-500 m above sea level (low hills 200-300 meters above sea level and high hills 300-500m above sea level) and mountainous areas above 500 m above sea level ( Dragićević, Filipović, 2016).

Altitude is a very important parameter when choosing a location for a viewpoint because of the area that can be seen and contribute to a more beautiful view and enjoyment of the landscape. As the absolute height increases, the temperature decreases (about 0.65 °C for every 100 meters), the pressure decreases, and the air is thinner. During the classification, it was taken into account that the temperature and the feeling of comfort decrease during a long stay at high altitudes, as well as they can cause health problems for some people. That is why we defined the class where the altitude is higher than 1000 m as very unsuitable (Jezdić, 2020).

The lowest elevation is at 176 m, while the highest is at 1329 m. The highest grade is given to terrains from 400-600 m above sea level, then from 176-400 m, and the lowest grade from 1000 m to 1200 m. Altitudes above 1200 m are eliminated.

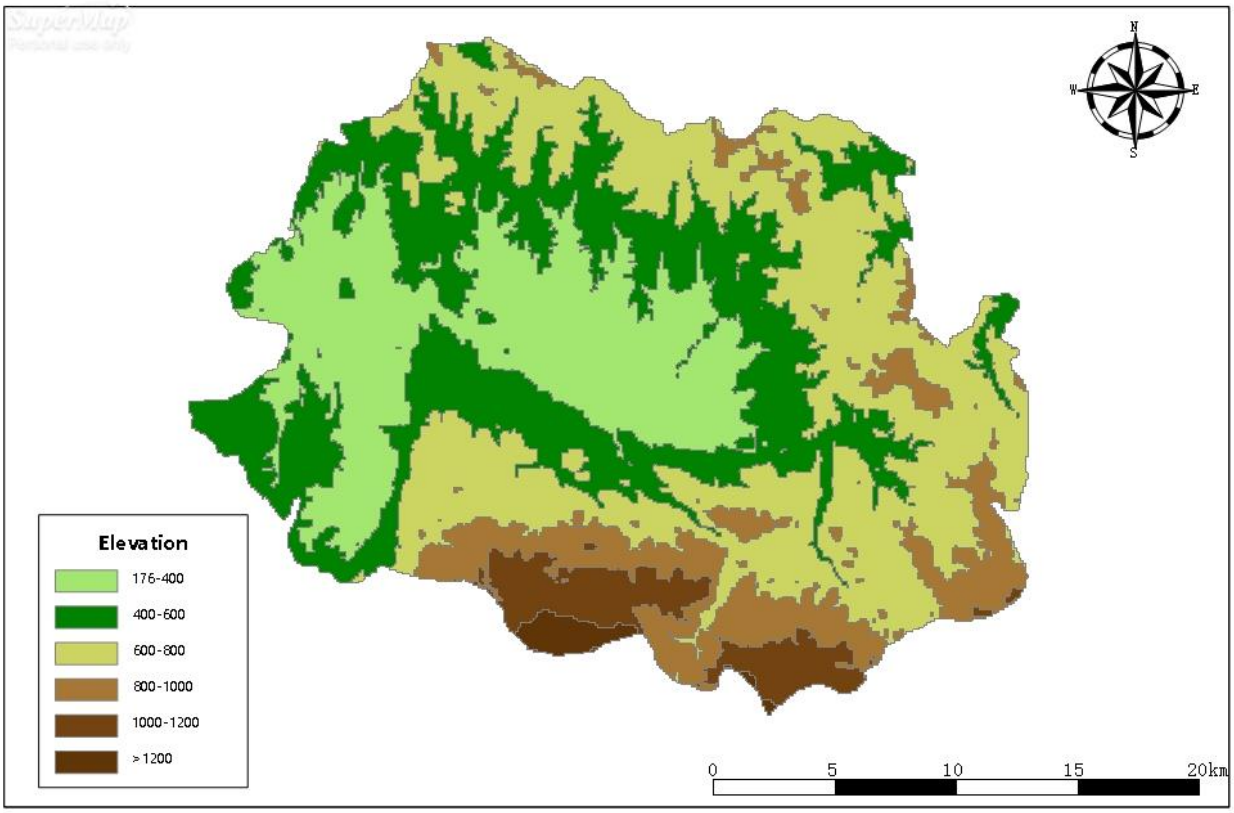
**Table no. 7.** Valorization of altitude

| Elevation (m) | Grade |
|---|---|
| 176-400 | 4 |
| 400-600 | 5 |
| 600-800 | 3 |
| 800-1000 | 2 |
| 1000-1200 | 1 |
| 1200-1500 | 0 |

As the most suitable altitude, an altitude of 400 to 600 m was taken, which is represented on an area of 217.58 km² (share of 28.41 %), then from 176 m to 400 m with a share of 21.69 %. In table no.8 are represented the classes and areas of each class, and on map no.3 a spatial representation of the classification of altitudes in the territory of the researched area.

**Table no. 8.** Altitude zones, area and share in the municipality

| Elevation zones [m] | Area[km²] | Share in the total area [%] | Grade |
|---|---|---|---|
| 176-400 | 166.15 | 21.69 | 5- very convenient |
| 400-600 | 217.58 | 28.41 | 4-suitable |
| 600-800 | 253.15 | 33.05 | 3-partly suitable |
| 800-1000 | 85.23 | 11.13 | 2-inconvenient |
| 1000-1200 | 36.72 | 4.79 | 1-very inconvenient |
| 1200-1500 | 7.16 | 0.93 | 0-eliminated |




*Map no.3 Altitude of the municipality of Žagubica*

## Land use method

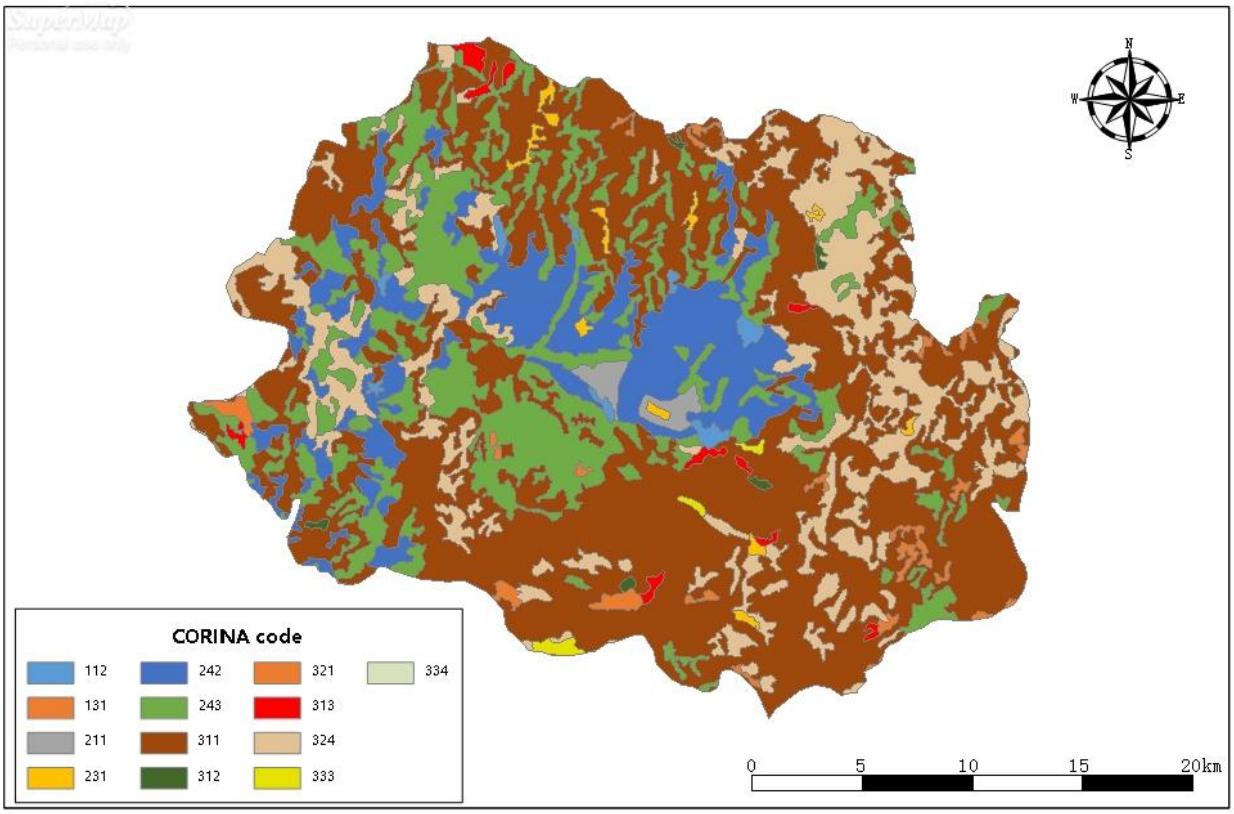
CORINE Land Cover was designed in the 1980s to standardize data collection across Europe and support environmental policy. The data provided by CORINE Land Cover shows the biophysical characteristics of the Earth's surface. The images collected by satellite represent the basic source of data in the further analysis of the purpose and use of space (Kukrika, 2000).

Soil is an important element of the natural environment and an important natural resource. The vegetation cover, in addition to the slope of the terrain, is one of the most important factors in the analysis and determination of suitable locations for viewpoints. In the purpose of space, i.e. land use in the area of the

municipality of Žagubica, deciduous forests are represented in the largest percentage with 50.73 % of the total area, followed by agricultural areas with natural vegetation 17.84 %, woody-shrub vegetation with 14.64 %, complex agricultural plots 12.04 %. All other listed root classes, except pasture (1.45 %), are represented by less than 1 %.

**Table no. 9.** Valorization of land use

| CORINA code | Land use | Area [km²] | Share in the total area [%] | Grade |
|---|---|---|---|---|
| 112 | Larger settlements | 4.77 | 0.62 | 1 |
| 131 | Exploitation of mineral raw materials | 0.26 | 0.03 | 1 |
| 211 | Non-irrigated agricultural areas | 5.86 | 0.76 | 5 |
| 231 | Meadows | 4.95 | 0.65 | 4 |
| 242 | A complex of agricultural plots | 92.32 | 12.04 | 5 |
| 243 | field areas with a significant proportion of natural vegetation | 136.82 | 17.84 | 4 |
| 311 | Deciduous forests | 388.92 | 50.73 | 1 |
| 312 | Coniferous forests | 1.67 | 0.22 | 1 |
| 313 | Mixed forests | 5.58 | 0.73 | 1 |
| 321 | Pastures | 11.14 | 1.45 | 2 |
| 324 | Woody-shrubby vegetation | 112.26 | 14.64 | 3 |
| 333 | The area is sparsely vegetated | 2.14 | 0.28 | 5 |




*Map no.4 Ways of land use in the municipality of Žagubica*

## Distance from roads

The road network is partially developed in the municipality of Žagubica. The main traffic corridor is state road of II order no. 105: Požarevac - Petrovac - Žagubica - Bor. From Žagubica, there is also state road of II order no. 104 (Žagubica - Laznica - Jasikovo - Majdanpek), which is of significantly worse quality. The same statement applies to state road no. 216 (Krepoljin - Despotovac). All villages in the territory of the municipality are connected by the municipal network of roads, but the network itself is in a very bad condition because it is poorly maintained. Of the uncategorized roads, the road Žagubica - Buk - Beljanica should be singled out. The municipality is not connected by a railway network and there is no developed air traffic (JUGINUS, 2010).

The distance from the roads is an important criterion for transport and the construction of the viewpoint itself. It is expected that the viewpoints will be more visited if they are easily accessible by roads. The further the location is from the main roads, the lower the rating of this criterion.

**Table no. 10.** Valorization of the distance from the traffic infrastructure

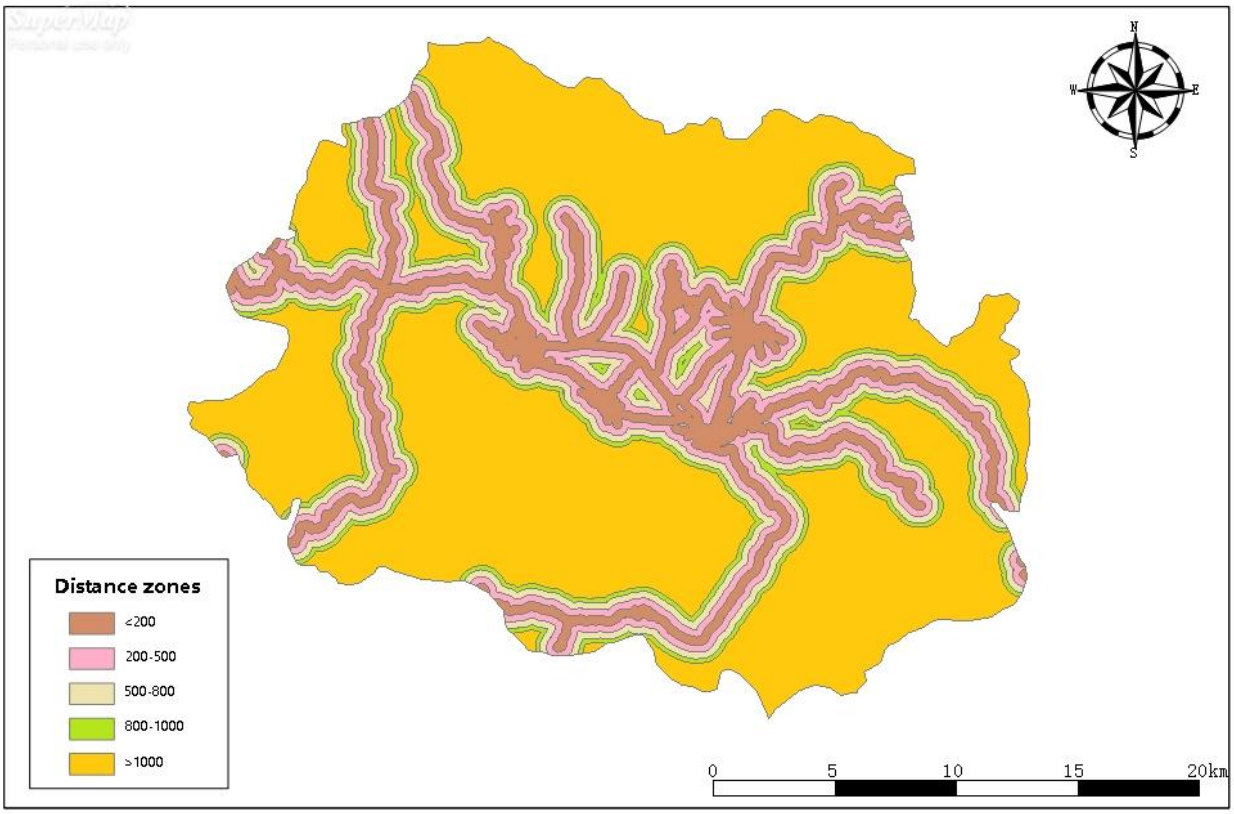
| Distance from the road (m) | Grade |
|---|---|
| <200 | 5 |
| 200-500 | 4 |
| 500-800 | 3 |
| 800-1000 | 2 |
| >1000 | 1 |

The table below shows the classes and areas of each class, and map no. 5 shows the spatial distance from roads in the territory of the researched area.

The most distant areas occupy the largest area, 57.30 % of the territory or 439.35 km². The areas that are the most favorable for the construction of a viewpoints, with a rating of 5, cover an area of 88.31 km², with a share of 11.52 % of the total area. Grade 4 has favorable distances that occupy a total of 101.07 km² or 13.18 % of the total territory.

**Table no. 11.** Distance to the transport infrastructure of the municipality of Žagubica

| Distance from the road (m) | Area [km²] | Share in the total area [%] | Grade] |
|---|---|---|---|
| <200 | 88.31 | 11.52 | 5- very convenient |
| 200-500 | 101.07 | 13.18 | 4-suitable |
| 500-800 | 86.68 | 11.31 | 3-partly suitable |
| 800-1000 | 51.30 | 6.69 | 2-inconvenient |
| >1000 | 439.35 | 57.30 | 1-very inconvenient |




*Map no.5 Distance zones of the transport infrastructure of the municipality of Žagubica*

# RESULTS OF THE APPLICATION OF THE AHP METHOD

Map no. 6 shows the final results using the coefficients obtained by applying the matrix from table no. 1.

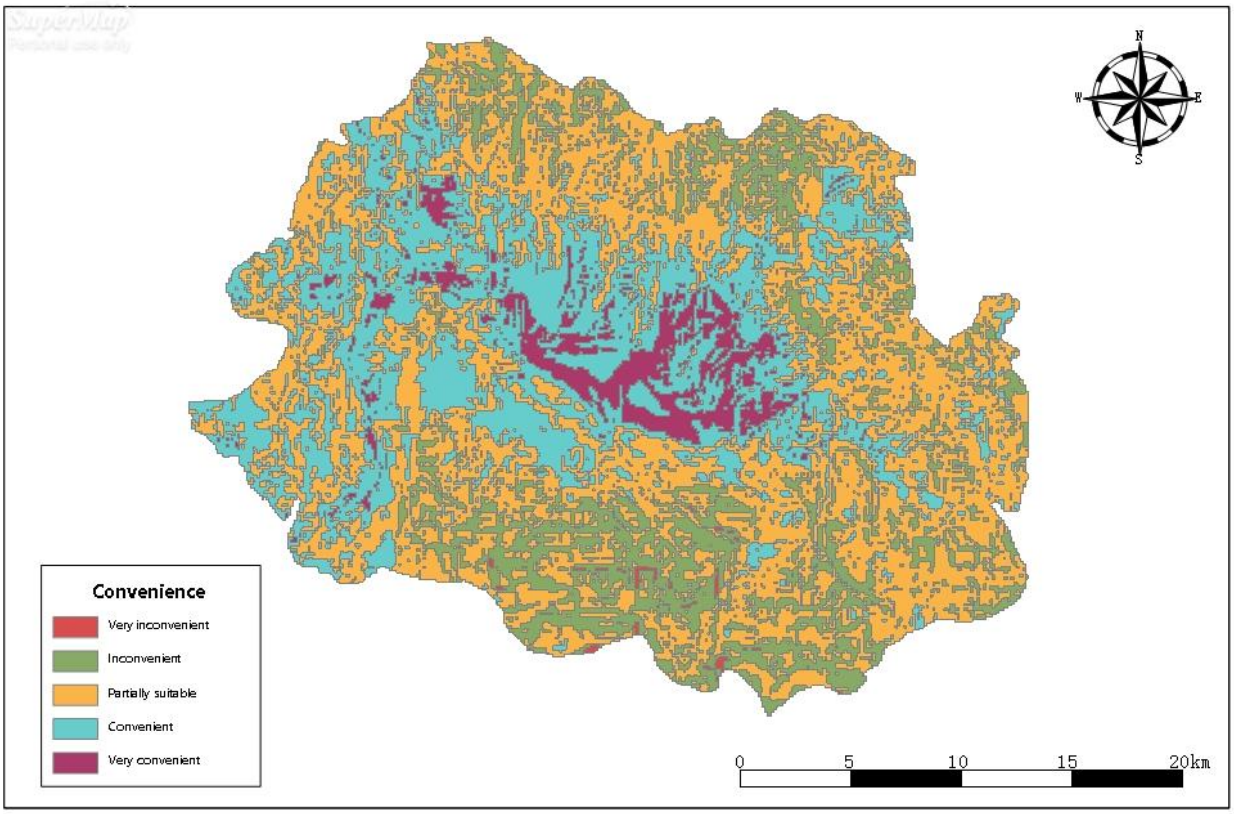
**Table no. 12.** Weight coefficients

| Criterias | Coefficients |
|---|---|
| **Slope** | 0.44 |
| **Elevation** | 0.29 |
| **Land use** | 0.14 |
| **Distance from the roads** | 0.14 |

We classified the obtained values into convenience classes for choosing the most favorable location for the construction of the observation deck (table no.13). Almost 30 % of the territory can be suitable for the construction of a viewpoint, and 5.48 % of the territory is very suitable. Unsuitable and very unsuitable territory occupies 18 %, i.e. 134.66 km². The results are shown on map no. 6.

**Table no. 13.** Classes of benefits

| Values | Area [km²] | Share in the total area [%] | Convenience |
|---|---|---|---|
| **0-1,5** | 2.04 | 0.27 | Very inconvenient |
| **1,5-2,5** | 132.62 | 17.31 | Inconvenient |
| **2,5-3,5** | 363.87 | 47.50 | Partially suitable |
| **3,5-4,5** | 225.45 | 29.43 | Convenient |
| **4,5-5** | 42.01 | 5.48 | Very convenient |

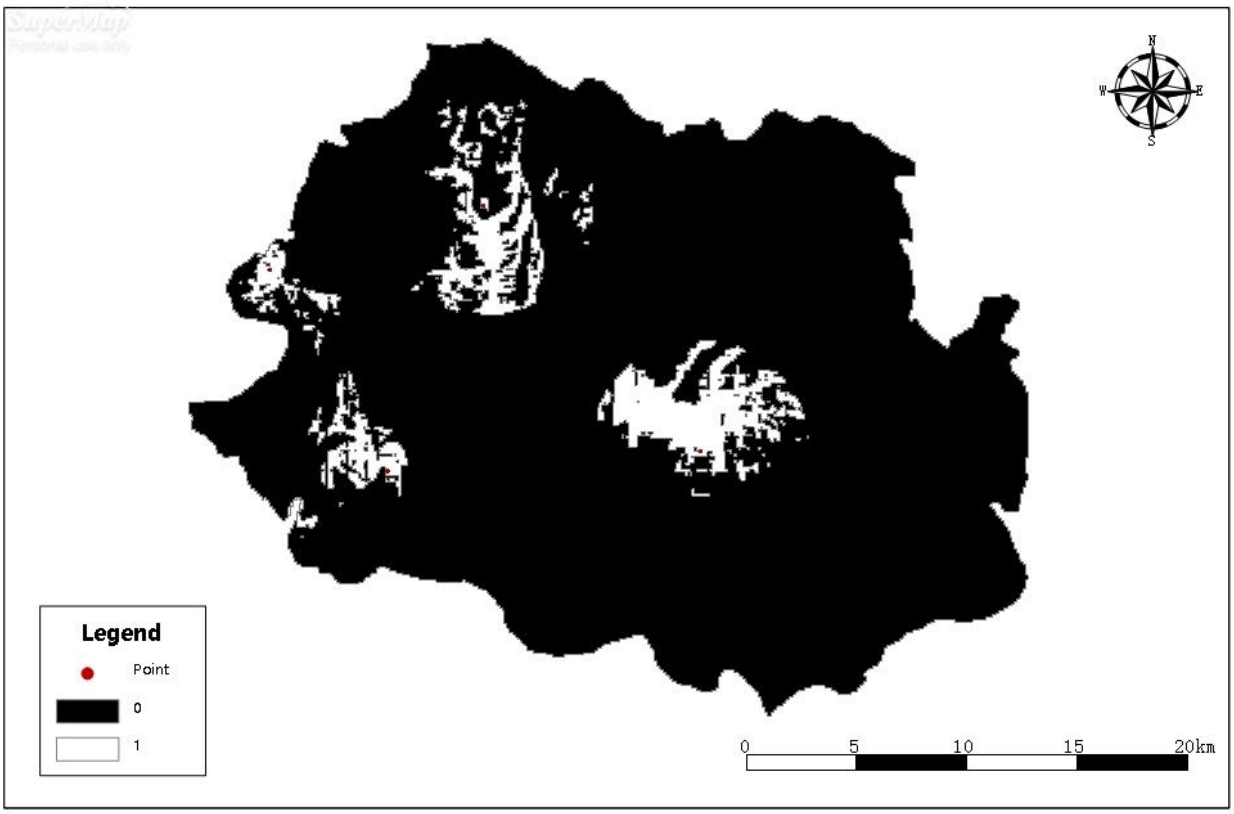



*Map no.6. Convenience classes for choosing the best location for building a lookout*

# VIEWPOINTS

By choosing the evaluated criteria and using the AHP method, we can conclude that about 30 % of the territory can be suitable for the construction of a viewpoint, of which 5.48 % of the territory is very suitable. After that, it was considered which natural values are within those areas. The territory of the municipality of Žagubica belongs to the protection zone of areas of exceptional natural values of special national importance. Strict nature reserves in the area of the municipality are: Busovata and Osanička river gorge, hydrological nature monuments are: spring of Mlava river, Krupajsko spring and Karški izvor - secret spring, geomorphological nature monument: Samar overgrowth. Cultural monuments should not be left out: the Trška church and the Gornjak monastery.

Four locations were chosen as the most attractive in the scope of the territory that belongs to suitable areas for construction. The first location represents the spring of Mlava river, the second location represents the Krupajsko spring, the third, the gorge of the Osanička river, and the fourth, the Gornjak monastery. In SuperMap, based on the Viewshed analysis option, we set the condition of a viewpoint height of 10 m and a range of 5 km. The total area covered from one vantage point is 54.01 km².




*Map no.7 Display of locations for the selected most attractive viewpoints*

# CONCLUSION

Based on the implemented methodology of the analytical hierarchical process, four criteria were analyzed for the suitability of the construction of viewpoints on the territory of the municipality of Žagubica. The AHP methodology used to select the importance of criteria is a subjective method. In this paper, four criteria were chosen in order of importance, namely: terrain slope, elevation, land use and distance from roads. After their selection, the matrices and their weighting coefficients are displayed.

Suitable areas for the construction of viewpoints cover almost 30 % of the territory, and 5.48 % of the territory is very suitable. Unsuitable and very unsuitable territory occupies 18 %, i.e. 134.66 km². After obtaining the most suitable areas, taking into account interesting morphological, hydrological and genetic features, with attractive landscape features, we chose the four most attractive locations within the obtained most suitable areas. From the attached results, we can see that the territory of the municipality of Žagubica has the potential for the construction of viewpoints.

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