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A GIS-BASED ANALYSIS FOR ECOTOURISM SUITABILITY IN A GEOLOGICAL COMPLEX AREA OF CARPATHIANS

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ABSTRACT: The purpose of this study is to contribute to the sustainable development of ecotourism through spatial analysis. The aim of the study was to identify suitable locations for various types of ecotourism activities and infrastructure development. This was achieved using multiple criteria analysis and spatial thinking as the foundation for decision-making. The principles of sustainable development were applied and translated into specific criteria and factors for a study location in the Carpathians. The presence or absence of criteria was transformed into GIS data as logical layers, which were later combined to produce the final results. The outcome offers several scenarios for the effective utilization of the ecotourism potential in the protected area of the geological complex. Spatial analysis identified locations suitable for eight types of ecotourism activities, represented in ecotourism suitability maps. The combined suitability map for ecotourism activities and infrastructure covers an area of 113 km^2 in the study area, the geological complex of Racos (Romania) and can be used by authorities for their various spatial development plans. Given that the results are feasible, we believe that this methodology can be adapted to other locations by adjusting the parameter values for various factors.

Key-words: *Spatial planning, Multiple criteria analysis, GIS, Ecotourism, Geosite, Racos, Romania*

1. INTRODUCTION

In the past years the whole tourism market and ecotourism as well has suffered due to the COVID-19 pandemic. Most of recent studies are concentrated of the negative effects of the situation created in different locations around the world (Vidal, M.D. et al., 2021; Chang, C-N. et al., 2022; Persada, S.F. et al., 2023). However, in some point of view new opportunities appeared especially for ecotourism as people started to prefer more remote and preferably natural, less crowded places. This study is a response to the current changing process trying to reveal new opportunities for the study area. Ecotourism is one of the most intensively developing form of tourism. Researches related to this form of tourism appeared first time, in the late 1980s, but after two decades, in 2002 the United Nations declared it the International Year of Ecotourism, gaining ever more importance as one of the crucial objectives being long term sustainable development (Whitelaw et al., 2014).

This kind of long-term thinking in tourism planning is absolutely essential and it can be said that the study is a sort of a response to the current situation in the study area, where the number of tourists has started to increase in the past years based on the evaluation of local authorities and local touristic information office. Hereinafter this study will strengthen the concept that the analysis of ecotourism possibilities can scientifically contribute to the development of ecotourism (Băltărețu, 2011; Dombay et al., 2008), which as a result confirms what can be done and what is worth doing in the region based on spatial modelling. Spatial analysis is crucial in the assessment of tourism potential because it enables a more comprehensive understanding of the relationships between different variables that influence the potential for tourism development. These variables can include physical and natural resources, accessibility, infrastructure, cultural heritage, and social and economic factors. By analyzing these variables in a spatial context, it becomes possible to identify areas of high tourism potential and quantify their importance (Ruda, 2016; Ruda and Pokladníková, 2016).

Additionally, spatial analysis provides a powerful tool for evaluating the potential impact of tourism activities on specific areas, such as protected natural areas or cultural heritage sites

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(Kusumayudha, 2021). This enables decision-makers to make informed decisions about the allocation of resources and development of infrastructure, ensuring that tourism development is sustainable and responsible. Spatial analysis also enables the integration of data from multiple sources and can be used to create visual representations of data, making it easier to understand complex relationships and patterns. Multi-criteria analysis present in our research is a largely used tool for finding suitable locations. It has been applied in various fields, such as urban green spaces planning (Gelan, 2021), industrial site selection (Rikalovic et al., 2014), landfill site selection (Abujayyab et al., 2017), public school site selection (Prasetyo, 2018). Tourism and, specifically, ecotourism activities and development can be planned based on multi-criteria evaluation in GIS. However, the term "multi-criteria analysis" integrated in GIS and combined with spatial analysis doesn't denote a single specific methodology. It is often coupled with fuzzy logic (Omardezh et al., 2022; Ronizi et al., 2020) or the analytical hierarchy process (Ahmadi et al., 2015; Mansour et al., 2020).

Ecotourism planning in general may consider various aspects of the natural surroundings, infrastructural facilities, accessibility and also vulnerability of the site. Depending on the specific objectives of a study it may emphasize or omit some aspects. Although there are studies which lacks on the spatial aspect of planning (Shang, 2020), most of them use spatial data for which factors and constrains are defined to detect those locations which satisfactorily facilitate the desired conditions (Fung and Wong, 2007; Sánchez-Prieto et al., 2021; Indriyani et al., 2020).

1.1. Study site

The study region is represented by the Racoș Geological Complex as a central point of attraction with various points of interest around it. Is positioned in the Carpathians between longitude 25°37'25.54"E and 25°47'23.41"E having the latitude coordinates between 45°99'86.17"N and 46°06'26.52"N with an altitude range from 450 m to 815 m. The study area contains the geological complex- protected natural area, a geological area of national importance of 95.2 ha (2006) and is integrated into the Natura2000 Homoroadelor Hills since 2007 (**Fig. 1**).

Fig. 1. Localization and arial view of the study region.
Source: Google Earth.

From a scientific point of view the Geological Complex of Racoș a complex area, millions of years old, presenting itself as an open book for Geology and a real "paradise" for geologists. This unique natural formation (Cioacă, 2002) is located in the Perșani Mountains, in the county of Brașov, Romania, in the commune of Racoș and represents a particularly picturesque and natural wild area (Albotă and Fesci, 1980) as presented in **figure 2**.

Fig. 2. Natural potential of the study area
Source: romtur.ro.

1.2. Objectives of the study

The primary objective of this study is to contribute effectively to the foundation of a new concept of ecotourism planning for the study area, a concept based on spatial thinking (Haidu and Haidu, 1998), which will underpin approaches to a more conscious decision-making process. Develop a GIS assessment approach that considers both the current response of the study area and the resulting solutions as part of a long-term development plan of the site which.

To achieve the desired result the following objectives have been set:

i. establishing, creating, editing and managing geospatial master data in the GIS with various datasets holding the necessary criteria;

ii. identification the possible locations for ecotourism objectives studied as a result of different spatial analyses;

iii. integrating the obtained ecotourism possibilities into a general map.

2. DATA AND METHODS

The methodology applied to this study is suitability assessment, based upon employing multiple criteria. This GIS data-based analysis can model the suitable locations for the development of ecotourism activities and infrastructure.

2.1. Data

The GIS data was created for the purpose of elaborating a complex set of layers in a spatial database (Islam et al., 2019). A variety of spatial data from different sources was collected to be applied by the assessment methodology. This includes base data: elevation model, hydrography, various routes and vegetation, and also derived data such as slope, exposition and visibility.

Primary, and the most essential basic GIS data is the digital elevation model, abbreviated as DEM (CDMEA, 2016). It plays an important role for the elaboration of the study. As existing DEM data has a very rough resolution for this local analysis, we decided to create an own model. The primary data sources for DEM modelling were the contour lines, resulted by digitizing them from a basic map of scale 1:5000.

The DEM was obtained by interpolating the vector data using the TIN model (Triangulated Irregulated Network) in QGIS (Cutts and Gasser, 2018). After the first results the need to correct/update appeared because of the changes of relief caused by exploitation and by the fact that the acquired topographic map was made before mining started. For this reason, it was necessary to find appropriate solutions. To solve this problem several onsite elevation measurements were made which were integrated in the new DEM generation process, resulting a final DEM with a resolution of 1 meter.

The elaboration of various other above mentioned primary data occurs through the process of interrogation (using plugin QuickOSM) and vectorization using mainly the basic map. Further data as terrain slope, exposition, visibility resulted by the terrain analysis based on DEM data. Vegetation cover was achieved from GisLounge, having the global land cover in GeoTIFF format. It has been recently released by Impact Observatory (IO) and ESRI.

2.2. Assessment based on multiple criteria

The methodology assessment based on multiple criteria is based on the establishment of criteria in the first phase, which are brought to a comparable form, i.e. a reclassification and then put together by combining them (Mohd and Ujang, 2016).

Once the baseline data is acquired and prepared as appropriate it will be followed by the establishment of the criteria considered being an important step of the analysis (Fung and Wong, 2007). By defining more criteria based on ecotourism experts having GIS and field knowledge the analysis results may have a higher usability being a better model of the reality. Prior to this analysis, a paperwork was done where highlighting tourist prospecting method, the field method, SWOT as actual situation analysis tool, and tourist potential evaluation of the area.

After criteria have been established the research procedure conducted to operations to carried out the assessment methodology, which is GIS related.

The phases of the analysis process consist of four main steps:

1. *establishing of criteria and parameters*, conditions which must be fulfilled for an optimal functionality of ecotouristic objectives. Parameter’s setting for each criteria are site-specific.
2. *generation of the criteria maps/layers,* according to the type of criteria. The criteria are set for those spatial data that have been created and prepared previously. All these data are materialized in a different type of layers.
3. *reclassification of layers,* where every criteria layer follows a rule defined by parameters value, based on this each cell will receive a new value. It is a yes / no condition, represented by logical levels, where 0 - represents the fact that condition is not satisfied, and 1 - represents the fact that the condition is satisfied. By this the space is delimited in areas that are not suitable and in areas that are suitable for the analyzed activity, according to criteria.
4. *combination of reclassified layers*, application of a condition system between different logical raster layers. During these operations, mathematical or logical operations are performed between the corresponding cells of different layers that represent the same area at the same resolution (Imbroane, 2018). The result of the operation is reflected in a new raster layer.

On this basis, a land suitability analysis was carried out individually for each ecotouristic activity postulated by the interest groups in the area.

2.3. Defining criteria and parameters value

This step is a major step in the methodology, which requires as much knowledge of geoinformatics as of tourism. Suitability is estimated with the help of several criteria. These factors can be GIS data as well as non-GIS data. Different criteria are identified for specific ecotourism infrastructure / activities. Most of the exact values in criteria are based on field expertise and logical reasoning as follows.

Viewpoints, lookout points are elements for observing the natural environment in natural areas, such as the study area (relief, flora, fauna, etc.), and are basic elements of the ecotourism infrastructure. They are important destination points, generally an integral part of thematic or educational trails. According to the point of view, a total of seven types of criteria are established for modelling the ecotourism infrastructure (**Table 1 - A**), elevation, vegetation, slope, visibility, distance, and area. Parameters values were defined for each of the factors according to the specificity of infrastructure/ activity and site characteristics. Where the hight, *elevation* has been set to greater than 700 m, to be above the geological complex. It makes absolute sense for the *vegetation* criteria to have the parameter without trees and bushes, first for all having the viewpoint function to see around. Another criterion *visibility*, which means visibility from a point or points to a given area/area of interest. In other words, „what area can see from point x to each point from all directions" (Imbroane, 2018). In conclusion visibility has an area-specific parameter and is set according to the object want to see. *Terrain slope* and *area*, linked to the construction needs, were set to have a flat terrain and at least 64 m^2 surface. Accessibility, one of the most important tourism characteristics after attractivities, is expressed in *distance* from the roads, where 200 m is a fair distance, not far away, easily can be reached from the roads. Viewpoint distance from center of the area was established to 5km, ecotourism point of view to be accessed by foot. It can be affirmed that these criteria are valid anywhere in the world, and the parameters value depends on the study terrain conditions. Where for example the height is specific to the study area, first depends on the altitude range.

Table 1

Criteria and factors for assessing suitability for various ecotouristic facilities and activities

A. Factors for viewpoint

#	Criteria/factors	Value (parameters)
a	elevation	h > 700 m
b	vegetation	no trees and bushes
c	terrain slope	degree < 3^0
d	distance from castle	d <5 km
e	visibility	Geological Complex; Sükösd-Bethlen Castle
f	distance from roads	d < 200 m
g	area	A = 64 m^2

B. Factors for eco-village

#	Criteria/factors	Value (parameters)
a	terrain slope	degree < 17^0(30%)
b	built area	excluding built-up area
c	industrial zone	excluding industrial area + buffer zone with d = 200m
d	Geological Complex area	excluding the surface of the protected area
e	distance from the DJ131C road	d > 3 km
f	distance from paths/forest roads	d < 200 m
g	distance from the Racoș Gorge / Olt River	50 m < d < 750 m
h	southern part of the gorge	excluding the northern part of the gorge
i	area	A=3 ha (30.000 m^2)

C. Factors for kayaking on the Olt river

#	Criteria/factors	Value (parameters)
a	Racoș Gorge	gorge surface
b	„islands" on the surface of the river	excluding surface area of the islands
c	distance from the shore	2m

D. Factors for scientific camp

#	Criteria/factors	Value (parameters)
a	terrain slope	degree < 5^0
b	Geological Complex area	excluding the surface
c	built area	excluding built-up area

d	industrial zone	excluding industrial area + buffer zone with d = 200m
e	distance from Geological Complex	d < 500 m
f	Natura2000	Natura2000 protected area
g	distance from roads	d < 200 m
h	area	A =1.5 ha (15000 m^2)

E. Factors for thematic hikes

	#	Criteria/factors	Value
Common criteria	a	terrain slope	degree<35°
	b	distance from the roads	d < 300 m
	c	Olt River and Smarald Lake	excluding the surface of the river and lake area
I.Geodiversity	**G**	distance from geodiversity attractions: **G_1; G_2**	d < 300 m
		distance from attractions: **G_3; G_4; G_5; G_6; G_7**	d < 500 m
		distance from attraction **G_8**	d < 300 m
		distance from attraction **G_9**	1<d < 200 m
II. Biodiversity	**B**	distance from biodiversity attractions: **B_1; B_2: B_3**	d < 300 m
		distance from attraction **B_4** (polygon)	d < 500 m
III. Cultural-historical	**CI**	distance from cultural-historical attractions: **CI_1; CI_2; CI_3; CI_4; C_5; CI_6; CI_7; CI_8; CI_9**	d < 500 m
		distance from attractions: **CI_{10}**	d < 200 m

F. Factors for pontoon

#	Criteria/factors	Value (parameters)
a	above the lake surface	A= lake polygon
b	distance from paths + pontoon length 10m	D < 30m , D= d_1+ d_2 d_1 = 20 m; d_2 = 10 m
c	aspect	S- E
d	area	A=25m^2

However, the distance being the most used factor in the model, distance from roads, distance from tourism objectives. Accessibility is a key parameter in tourism, and it is expressed in terms of distance from roads, tourism objectives / attractions and others.

To implement an ecotourism activity or infrastructure the following factors were determined in the study depending on the activity and requirements which are listed in the tables below (**Table 1**).

3. RESULTS AND DISCUSSION

With the establishment of the spatial database and applying the analysis methodology in QGIS with proper spatial operations (Wegmann et al., 2020), now sites suitable for ecotourism activities and infrastructure can be identified. Six objectives were selected namely, 1. viewpoint; 2. eco-village; 3. pontoon the lake; 4. scientific camp; 5. thematic hikes; 6. kayaking on the river Olt, which were all outlined in the analysis. A similar assessment is created for each activity, which means that the main steps are similar, the basic idea remains the same, but the factors will change, and so will the analysis tools, too. The suitability analysis process for ecotourism objectives consists of following these three steps of the above presented methodology.

3.1. Reclassifying and combining the criteria layers

Every criterion is represented by one raster layer as a result of the reclassification process. All reclassified raster layers are shown in the **figure 3** for an objective viewpoint, where the white patches represent - areas suitable for a viewpoint and the black ones - areas not suitable for a viewpoint due to the defined parameters.

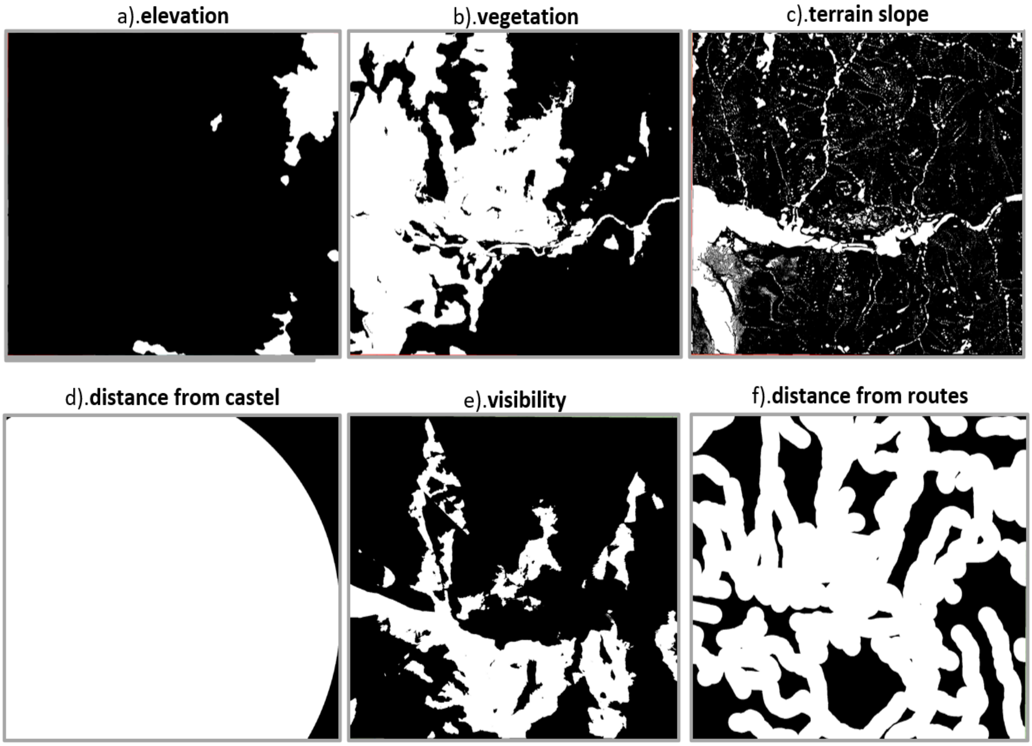

Fig. 3. Reclassified layers of criteria for objective viewpoints.

By combining the resulted logical layers, we are interested in locations that fulfil all the factors for a specific objective. The results for the suitability viewpoint are presented below (**Fig. 4**), where the six reclassified raster layers were combined, and after that filtered by the last condition area.

By applying the multi-criteria evolution methodology, the objectives of the eight types of recreation and ecotourism infrastructure were analyzed and as result possible locations were identified. For each ecotourism objective there is a separate representation illustrated on a single raster layer, this can be transformed into a vector layer for visualization. These images represent suitable locations for viewpoint; eco-village; pontoon the lake; scientific camp; thematic hikes (geological, biological and cultural-historic); kayaking on the river Olt and all these aspects are presented one by one in a map. An important outcome is represented by the results obtained along the way for each type of activity, shown in the **figures 5-11**. The same colors used to mark the selected criteria in these figures are present in the synthetic map representation.

Criterion *area* can be applied only as an additional operation at the end, after spatial analysis of reclassified layers was done. The *surface* is the extra intervening part when suitable areas are identified. For example, to build a viewpoint you need a compact area, small areas with only one or a few pixels should be treated as unsuitable cells. Therefore, the final phase of the evaluation is the identification or with other words the filtering of the results obtained in terms of area, defined by the last criterion g). area.

Fig. 4 – Suitable areas for viewpoints marked with dark orange

Fig. 5 – Suitable areas for eco-village marked with mustard yellow

Fig.6 – Suitable areas for poonton marked with pink

Fig. 7 – Suitable areas for scientific camp marked with orange

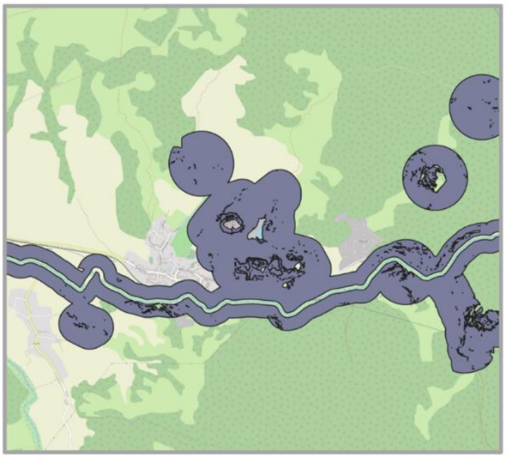

Fig. 8 – Suitable areas for geodiversity hiking marked with gray

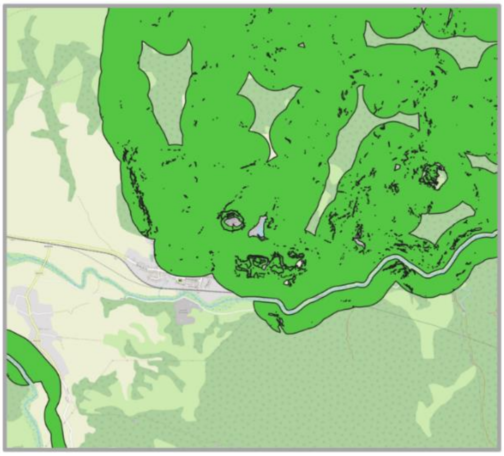

Fig. 9 – Suitable areas for biodiversity hiking marked with green

Fig. 10 – Suitable areas for cultural and historical hikes marked with purple

Fig. 11 – Suitable areas for kayaking on the river Olt marked with blue

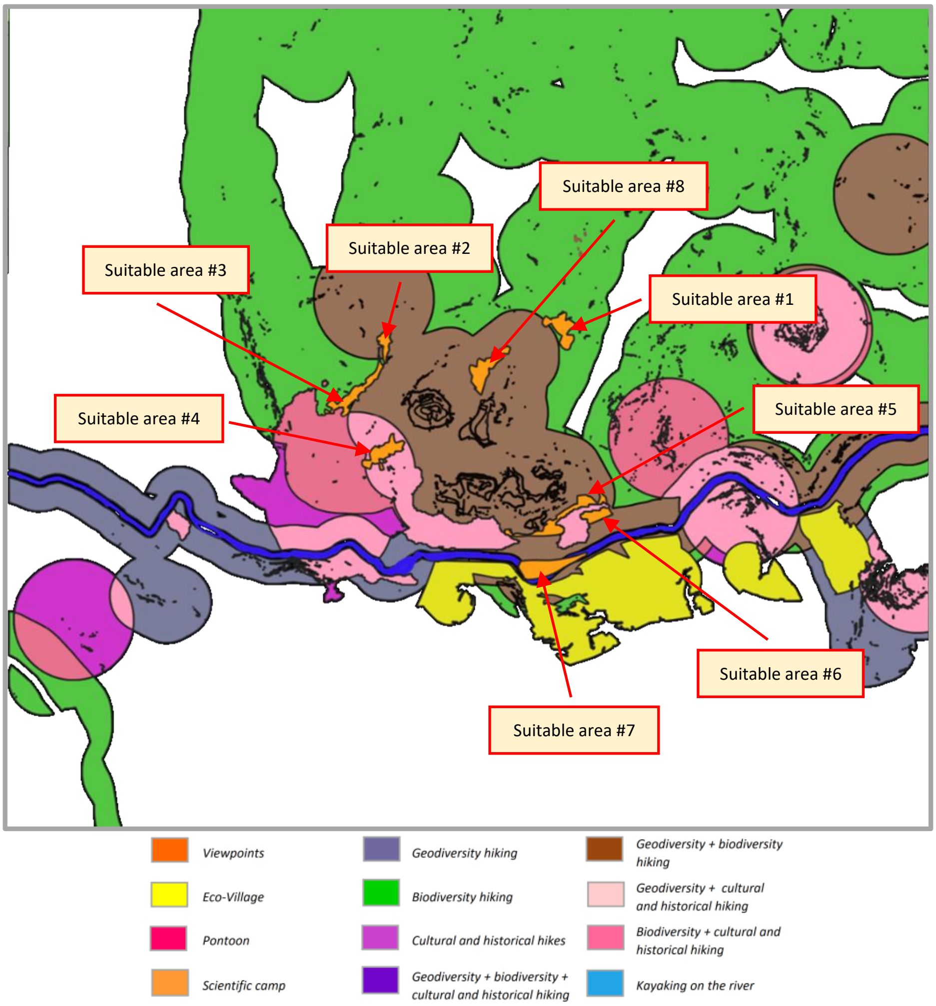

Fig. 12. Integrated map with the appropriate areas identified for recreational activities and ecotourism infrastructure with suitable areas for Scientific camp.

The **figures 4-11** show the distribution of sites suitable for ecotourism in the study area, which are located on specific areas for each ecotourism infrastructure, where as a result it was found from a few 3 to 10 sites, namely 3 destinations for viewpoint, 3 for pontoon, 5 for eco-village and 8 for scientific camp, and for hiking like 4 geodiversity; 4 biodiversity, 10 cultural and historical hiking, 1 kayak-canoeing on the river Olt with different sizes of area distributed over the study area.

In order to get an overview of the eco-tourism possibilities of the study area, all these locations were combined in a map. The result of the suitability can be seen in just one picture (**Fig. 12**), which shows the eight global ecotourism activities of the studied region. This map is divided into areas having different colors (as shown in the legend), where the colored areas are suitable locations, and the black ones represent unsuitable locations for the chosen activities to analysis. The different colors highlight locations that are suitable for various recreational activities described in the legend.

Analyzing the all surface which are fit for some ecotourism activities/ infrastructure was found out that total is 25,46 % of 113 km^2 suitable for ecotourism recreation. Analyzing further the areas of the study region, the result is that there are locations that are suitable for a single ecotourism objective or even two or more types of objectives. The conclusion is that there are few overlapping areas as possible locations for ecotourism activities. Overlapping areas are locations with considerable values, because more than one eco-tourism activities can be carried out here.

The coverage of each possible location for eco-tourism activities / objectives can be calculated and the result shows an additional piece of information for ecotourism planning. For example, the science camp has got eight possible locations according to the analysis. These are located in different areas that are suitable for other ecotourism activities too, as you can see on the **table 2**. Where area number 4 is strategically located to an eco-tourism point of view, so it can be considered the most valuable area.

Table 2

Results for scientific camp sites - coverage with other areas

suitable scientific camp locations [#]	area [m^2]	biodiversity area [%]	geodiversity + biodiversity area [%]	biodiversity+ cultural-historic area [%]	geodiversity+ biodiversity+ cultural-historic area [%]
Suitable area 1	38629	95.50%	4.50%		–
Suitable area 2	16957	95,4 %	4,6 %		–
Suitable area 3	42019	80,6 %	16,2 %	3,2 %	–
Suitable area 4	39824	–	–	3,3 %	96,7 %
Suitable area 5	52311	–	100%	–	–
Suitable area 6	20151	–	100%	–	–
Suitable area 7	57363	–	100%	–	–
Suitable area 8	44042	–	100%	–	–

Using this methodology there are limitations that the map used is a decisive factor in modelling DEM. Where digitization is a long and time-consuming process. It is very important to establish from the beginning the qualitative level of the data structures (features) for the successful achievement of the objectives in the given project. At the same time, must be completed by field work, on-site measurement, requiring much study and detailed testing. Finally, of course the gains as result far outweigh the limitations. Such a vulnerable point there is the definition of criteria. However, these points did not affect the result of the study.

4. CONCLUSIONS

In this paper the ecotourism potential, suitable ecotourism sites of the Racoș Geological Complex and the surrounding area have been analyzed using a GIS-based methodology, concept based on spatial thinking. The principle of this study was the evaluation based on multiple criteria. Using different criteria levels and parameters value 8 types of ecotourism activity/infrastructure were analyzed to identify the suitable areas for ecotourism. The repartition of the suitability sites on the studied region was represented on a map for each ecotourism activity. Distribution of the well-identified results shown, specific location for each activity from 3 to 10 sites, namely 3 destinations for viewpoint, 3 for pontoon, 5 destinations for eco-village, 8 scientific camp and for hiking - like 4 geodiversity; 4 biodiversity -, 10 cultural and historical hiking, 1 kayak-canoeing on the river Olt with different sizes of area. The result of the integrated map represents the ecotourism suitability of the region, 25.46% of the 113 km^2 being suitable for ecotourism recreation, where the overlying area can be considered the most valuable area.

The applied methodology was able to model different scenarios, solutions for the chosen activities. Criteria plays a very important role, the factors are decisive in determining possible locations. Certainly, defining criteria can sometimes be a subjective approach but based on expert thinking is the appropriate way to achieve results. In conclusion the application of the GIS methodology used, database, adequate resolution, well-defined criteria, the through measurements and the other methods applied led this study to a success.

The objectives of this study are well-identified in the results, support for ecotourism planning, decision-making process, based on scientific criteria and value. The results can be integrated in local development plans an by this they can contribute to the development of ecotourism, showing where which type of activity can be carried out, what can be done and what is worth to be doing in the region.

Furthermore, as new possibilities, two directions can be followed: on the one hand, it can be a horizontal extension, which consists in examining other possible ecotourism activities, and on the other hand, this study can be a model for a new area where ecotourism planning is considered.

In the short term it may have applicability in shaping a better adaptation of planning in the natural environment, and in the long term it may have applicability in all forms of tourism and even in other areas such as the urban environment.

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