ASSESSMENT OF EDUCATIONAL POTENTIAL OF GEODIVERSITY ON EXAMPLE OF CERKNICA POLJE, SLOVENIA

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Abstract

The concept of geodiversity has been present for more than 20 years. The majority of methods for valuing geodiversity is applied for evaluation of geoconservation or geotouristic potential. There is a deficiency of methods that could be used for evaluation of geodiversity and its educational potential. The aim of the paper is to propose a new method for valuing geodiversity for determining the educational potential of an area. The method can be utilized for teaching purposes at the stage when educators plan to organise excursions or fieldworks.

Keywords: geodiversity, nature protection, education, excursion, Cerknica polje

I INTRODUCTION

Geodiversity evaluation is a range of methods where values of specific areas are assessed in terms of importance and diversity of abiotic nature elements (Panizza, Piacente, 1993; Pereira, Pereira, Caetano Alves, 2007; Reynard et al., 2007; Zouros, 2007; Reynard, 2009; Erhartič, 2012). The methods are mostly used to identify potential natural values or other needs of nature conservation, and for identification of areas appropriate for geotouristic objectives (Panizza, Piacente, 1993; Pereira, Pereira, Caetano Alves, 2007; Reynard, Coratza, 2007; Zouros, 2007; Erhartič, 2012; Gray, 2013). Authors stress that it is important to value also geodiversity for educational purposes (Gray, 2013), but scientific articles published until now do not focus on the topics.

The main goal of the article is to develop and assess a method for valuing geodiversity for educational purposes. Full evaluation method will take place in two phases. The first phase will identify areas with a higher geodiversity index. Those areas are, due to higher landscape diversity, more suitable for educational purposes. The second phase

will include identifying the added value of selected areas that were recognised as having a greater degree of geodiversity. Added value will be defined by elements, which are important in the process of organizing an excursion or fieldwork. We tested the method at Cerknica Polje, Slovenia. The area is, due to its accessibility and enormous variety of karst phenomena, already a well-established destination for organized excursions.

To achieve the purpose of the study we set the following goals: (1) identification and calculation of geodiversity index in the research area, (2) assessment of additional values in the areas that have a higher geodiversity index, and (3) evaluation of educational potential of those areas.

2 GEODIVERSITY AND EDUCATION

Different authors (Wilson, Doyle, 1994; Bennett, Doyle, 1997; Doyle, Bennett, 1998) recognize several types of values of physical environment. They acknowledge that geodiversity has a variety of values, such as intrinsic value, cultural value, aesthetic value, economic value, and research and educational value (Gray, 2013). According to Gray (2013), one of the most important is the educational value of geodiversity. This is because the physical environment is enabling us to study natural processes, Earth history, and to monitor the environment.

In the Slovenian educational system, every school has to ensure at least one geographical excursion per year (Učni načrt, 2011). One of the aims of the excursions is to teach about natural and cultural landscape; therefore, a teacher has to use different fieldwork techniques in order to expand student's knowledge and understanding of the physical and social processes. When preparing the excursion, an important task for a geography teacher is to select an appropriate site, with variety of landforms and processes. For that reason, evaluation of geodiversity for educational purposes is an important tool for identifying appropriate areas for organizing excursions.

3 THE STUDY AREA: CERKNICA POLJE

One of the most recognized and most studied karst phenomena in Slovenia is Cerknica Polje. It is positioned in the Ljubljana River basin in-between Loško Polje and Rakovško-Unško Polje. Towards the northeast it is bound by the Slivnica Mountain, towards the south and southwest by the Javorniki Mountains. The whole area of the polje is quite diverse from the geologic perspective. Western, southern, and eastern slopes of the polje are built of Jurassic and Cretaceous limestone combined by narrow stripes of Jurassic and Triassic dolostone. The floor of the polje is covered by Quaternary deposits, with the exception of four residual hills. The most dominant geologic structure along which the polje was formed is the Idrija Fault, which is dissecting the polje in NW-SE direction (Pleničar, 1963).

There is a remarkable diversity of Cerknica Polje in hydrologic and geomorphologic terms. Just beneath the southern and eastern slopes is a range of karst springs, from which a number of streams emerge to the surface. The most important streams that surface in those areas of the polje are Stržen, Šteberščica, and Žerovniščica. In the areas of their

Figure 1: The middle section of Cerknica Polje with a low level intermittent lake around the Rešeto swallow hole (photo: Uroš Stepišnik).

springs, steephead valleys are located. The southern section of the polje, which is named Zadnji Kraj, is hosting a group of estavelles that have interchanging functions as springs or as ponors. From the northern side, which is composed mainly of dolostone, a surface stream of the Cerkniščica River is flowing to the polje. Within the central part of the polje is a number of swallow holes, where floodwaters and streams from the polje submerge. The biggest swallow holes are Rešeto and Vodonos, which are located south of Dolenje Jezero. Below the western slopes, a non-distinct blind valley is located. A number of small-scale ponors are situated within the blind valley. The biggest ponors are entrances to the Velika Karlovica Cave and Mala Karlovica Cave. Following the hydrologic classification of poljes (Gams, 1978), we can define the Cerknica Polje as overflow polje, due to inflow of karst streams, and as a border polje, due to surface inflows to the polje from the north.

4 MATERIALS AND METHODS

4.1 Identifying areas of high geodiversity index

Geodiversity evaluation for Cerknica Polje was conducted using various GIS tools, predominantly quantitative surface analysis. The main reason was to eliminate subjective assessments as much as possible, since they are very common in evaluating geodiversity (Erhartič, 2012). The basic purpose of our calculations was to get the results independent of the geodiversity evaluator to the greatest degree possible. The calculation of geodiversity index, suggested by Serrano and Ruiz-Flaño (2007), was performed as follows.

Figure 2: General map of the research area.

The study area of 45.97 km² contains the entire Cerknica Polje, together with periodic Cerknica Lake and some of its very close surroundings. The main digital data source was raster digital elevation model (1x1 m resolution), created from LiDAR vector ground points. We used orthorectified aerial photos and topographic maps (scales 1:5,000, 1:25,000, and 1:50,000) for identification of abiotic surface features as geodiversity elements. Identified surface features were later corrected and updated by field mapping. The process gave us all together 137 geodiversity elements: karst springs (19), estavelles (3), swallow holes (5), ponors (10), hums (4), streams (82), blind valley (1), collapse dolines (8), alluvial fan (1), steephead valleys (3), and Cerknica Polje together with the intermittent lake. According to the spatial extent of features, some of them were identified as points (springs, ponors, etc.), some as lines (streams), and some as polygons (valleys, fan, etc.). All features were further automatically transformed (buffering of streams, springs,

Figure 3: Geodiversity elements of the research area with LiDAR digital elevation model.

estavelles, etc.) or manually digitized (swallow holes, ponors, etc.) into polygons with a total area of 35 km².

The next step was the calculation of the parameters that are anticipated in the equation (Equation 1) as suggested by Serrano and Ruiz-Flaño (2009):

(Equation 1)

$$Gd = \frac{Eg \cdot R}{Ln S}$$

Where Gd = geodiversity index; Eg = number of different geodiversity elements in the unit; R = roughness coefficient of the unit; S = area of the unit (km²); Ln = naperian logarithm.

The parameter E_g is obtained by counting the different geodiversity elements. The coefficient of roughness (R) is an attempt to include the variety of orientation and gradient of slopes. The result is a semi-quantitative scale that permits the formation of five values of geodiversity, from very low to very high for each homogeneous unit (Serrano and Ruiz-Flaño, 2007). The highest values of geodiversity index can be marked as geodiversity hotspots that can contribute the most to the educational purposes of the area.

For the roughness coefficient (R) we calculated a *terrain ruggedness index (TRI)* (Błaszczynski 1997; Riley et al., 1999). *TRI* is a measurement expressing the amount of elevation difference between adjacent cells of a digital elevation grid (Riley et al., 1999; Conrad, 2010; Evans, 2015). Next, using focal statistics and context GIS analysis, we determined the number of different geodiversity elements covering and overlapping every

Figure 4: Terrain roughness index (upper left), number of geosites (upper right), geosite variability (lower left), and raster index of geodiversity (lower right).

cell of the 1x1 m raster. From the calculated Eg and R , and standardized by the area of the unit, a continuous raster layer of geodiversity index (Gd) was calculated.

Continuous raster surface defines geodiversity very accurately and is the most suitable for further analysis. However, according to the geodiversity index, our goal was to get encircled, clearly delineated units. Therefore, in the last step, we performed the following transformations of Gd continuous raster surface: smoothing of the abrupt changes, aggregation of similar values, and generalization with encirclement, where larger units had priority over smaller ones (Figure 4).

4.2 Assessment of educational potential of geodiversity

Assessment of the educational potential of geodiversity was determined on various criteria that are important for organizing excursions, as well as for their quality; the area of an excursion has to be accessible and safe for attendants, and it has to be educational (related to the curricula). Therefore, in the proposed method we apply the following seven criteria: accessibility, safety, geodiversity content coverage with curricula, cross-curricular integration, integration into wider area of an excursion, fieldwork techniques and teacher materials.

Accessibility (A) of the area is one of the essential criteria for organizing an excursion. The most significant criteria for organizing excursions is also *safety* (S). If the area is not safe, an excursion cannot be organized there. *Geodiversity content coverage with geography school curricula* (GCG) is a third criterion, which is connecting assets on the proposed excursion area with objectives of the curricula. Within our research, we employed geography subject curricula of the Slovenian educational system (Učni načrt, 2011). *Cross-curricular integration* (CCI) is fundamental in modern education. Significant enhancement of educational value is a combination of geography lessons with another school subject. A geoscience education is, according to the Slovenian school system (Učni načrt, 2011), incorporated into geography classes. Therefore, we evaluated the possibility of integration of geography and another school subject curricula within an excursion area. *Integration into wider area of excursion* (IE) offers wider content of an excursion and is crucial for its quality. For some students, excursions might be the only way to see different landscapes outside their hometown or region; it is therefore vital that an excursion is planned in a wider context. Applying different *fieldwork techniques* (FT) within an excursion is a valuable advantage that improves its educational value. Fieldwork techniques that can be used on the field are: measuring soil characteristics (pH, colour, measuring, drawing and examining soil profile etc.), measuring water characteristics (T, flow speed, gradient, pH, colour etc.), measuring geological characteristics (the content of the carbonates in the rocks, types of rocks etc.), measuring relief characteristics (gradient, elevation etc.). *Teaching materials* (TM) are an important segment for planning an excursion. It is very useful for an educator that teaching materials (teaching manuals, worksheets, educational boards on the field, etc.) are accessible. Educators are regularly not trained experts in geosciences, and they are normally not familiar with a target area; therefore, teaching materials are of uttermost importance for successful organization of an excursion.

Each stated criteria is evaluated from 0 to 1 (0 is minimum; 1 is maximum) (Tab. 1). Final educational potential of a high-geodiversity site is asserted as *educational potential* (EP) value, which is a sum of the seven criteria:

$$EP = A + S + GCG + CCI + IE + FT + TM$$

Low educational potential values indicate that the area is not appropriate for excursions. On the other hand, high educational potential values suggest that the area is appropriate for organizing a high quality excursion (Tab. 2).

Table 1: Values for educational potential of the area for organizing an excursion.

Value	Defining educational potential of the area
0	The area is extremely inappropriate.
1	The area is inappropriate.
2	The area is conditionally suitable.
3	The area is less suitable.
4	The area is suitable.
5	The area is more suitable.
6	The area is very suitable.
7	The area is extremely suitable.

Table 2: Evaluation chart of various criteria for educational potential of high geodiversity areas.

	CRITERIA
A	AREA ACCESSIBILITY
0	Not accessible.
0.25	Difficult to access and only on foot.
0.50	Easily accessible, but only on foot.
0.75	Easily accessible, also by car.
1	Easily accessible, also by bus.
S	SAFETY
0	The entire area is unsafe.
0.25	Caution is needed. Unsafe part is not secured by fences or warning signs.
0.5	Need for additional caution. Unsafe part is partially secured by fences.
0.75	The area is generally safe, but caution is required in some parts.
1	The entire area is safe.

	CRITERIA
GCG	GEODIVERSITY CONTENT (GDC) COVERAGE WITH GEOGRAPHY SCHOOL CURRICULA (GSC)
0	GDC of the area is not covered with objectives from GSC.
0.25	GDC of the area is covered with at least 3 objectives from GSC.
0.5	GDC of the area is covered with 4–6 objectives from GSC.
0.75	GDC of the area is covered with 7–10 objectives from GSC.
1	GDC of the area is covered with at least 11 objectives from GSC.
CCI	CROSS-CURRICULAR INTEGRATION WITH ADDITIONAL SCHOOL SUBJECT (SS)
0	GDC of the area can be linked only to Geography.
0.25	GDC of the area can be linked to Geography and 1 additional SS.
0.5	GDC of the area can be linked to Geography and 2 additional SS.
0.75	GDC of the area can be linked to Geography and 3 additional SS.
1	GDC of the area can be linked to Geography and at least 4 additional SS.
IE	INTEGRATION INTO WIDER AREA OF EXCURSION (distance to other interesting points of excursion)
0	The area is very distant to other points on the way.
0.25	The area is quite distant, but it could be linked to at least 1 other point on the way.
0.5	The area is quite distant, but it could be linked with at least 2 other points on the way.
0.75	The area is quite near, but it could be linked with at least 3 other points on the way.
1	The area can be easily linked with at least 4 or more points on the way.
FT	FIELDWORK TECHNIQUES FOR RESEARCHING GEODIVERSITY OF THE AREA
0	We cannot conduct any school fieldwork techniques.
0.25	We can conduct 1 school fieldwork technique.
0.5	We can conduct 2 school fieldwork techniques.
0.75	We can conduct 3 school fieldwork techniques.
1	We can conduct at least 4 school fieldwork techniques.
TM	TEACHING MATERIALS (TM) FOR THE AREA
0	There aren't any already prepared TM.
0.25	There is 1 already prepared TM, but for a broader area.
0.5	There are at least 2 already prepared TM, but for broader area.
0.75	There is 1 area specific TM already prepared.
1	There are at least 2 area specific TM already prepared.

On the basis of the adapted method of the geodiversity index calculation (Serrano, Ruiz-Flaño, 2007; Serrano, Ruiz-Flaño, 2009), we recognized the state of geodiversity in Cerknica Polje. In the research area of Cerknica Polje, there are 11 different geodiversity elements that had been recognized, and 137 in total. Most of them (87.6%) are directly connected to the karstic system of the periodic appearance of Lake Cerknica (streams, springs, etc.), and they also cover the largest part of the research area (75.4%). Hydrologic elements overlap with each other and also by other geodiversity elements. In this research, geodiversity elements were not given values of importance, attractiveness, or

uniqueness in order to retain the objectivity of the method and to avoid the subjective influence of the evaluator or local community.

The maximum sum of different geodiversity elements on the same spot is 4. The second element that defines the results is surface roughness (ruggedness), which represents the diversity of surface elements (geomorphic, hydrologic, pedologic, etc.) and is very low (Nunn, Puga, 2012). They are arranged on the interval from 0 to 10.66, with clear left asymmetry (Table 3). The result is not surprising, since the majority of the polje (78.14 %) has slope inclinations less than 5°. The range of altitudes is also very low, extending from 545.8 to 670.69 m a.s.l.

Finally, the geodiversity index, standardized with the relatively large research area, extends from zero in all of the outskirts of the research area to a maximum of 721.0. The *Gd* index was classified in five classes from very low to very high (Tab. 3).

Table 3: Areas (relative and absolute) of the homogenous geodiversity index units within Cerknica Polje.

Gd	Area [km²]	%
1, very low	3.73	8.12
2, low	31.61	68.74
3, medium	8.69	18.90
4, high	1.34	2.91
5, very high	0.61	1.33
Σ	45.97	100.00

Large homogenous areas of very high geodiversity index accompanied by areas of high geodiversity index appear within three places on Cerknica Polje. The first area is located on the southern side of the polje. It occupies the steephead valley, where two major springs Cemun and Obrh are located. From these springs, Stržen River is emerging on the surface. The second area is located in the middle section of the polje. It is limited to the area of Zadnji Kraj, where a variety of hydrologic as well as geomorphologic features interact. The third area is positioned on the northwestern side, where a variety of ponors, collapse dolines, and other geodiversity elements merge. This area is an enlarged blind valley, referred to as Jamski Zaliv.

5.1 Steephead valley of Stržen

The steephead valley of Stržen is located in the southernmost section of the polje. The steephead valley is hosting a series of karst springs and surface streams. In the hinterland of the springs, one collapse doline is located.

The whole area is easily accessible via numerous pathways; the accessibility (A) value is therefore 0.5. The location is completely safe also for younger schoolchildren;

Figure 6: The stream Stržen with its steephead valley in the rear (photo: Uroš Stepišnik).

safety (S) of the area was therefore valued at 1. Geodiversity content coverage with curricula (GCG) was evaluated at 1, since the content can be covered with at least 11 objectives from curricula (Učni načrt, 2011).

Geography topics can be combined with biology and chemistry topics within the area of the steephead. As a result, cross-curricular integration (CCI) was assessed at 0.5. The eastern part of the Cerknica Polje is rich in geomorphologic and hydrologic features, as well as in cultural heritage. Therefore, integration into the wider area of excursion (IE) was valued at 0.75. Fieldwork techniques (FT) value was assessed at 1 since at least four different fieldwork techniques can be accomplished within the area (e.g. soil profiling, examining soil properties, investigating water properties, surveying bedrock by utilizing geological map, analyzing the landscape, etc.). Teaching materials about the area are scarce. Nevertheless, there are articles concerning the steephead valley and one information board about the local geodiversity is located in the area. Hence, a teaching material (TM) value was valued at 0.75.

Table 4: Educational potential of the high geodiversity index areas within Cerknica Polje.

	Steephead valley of Stržen	Zadnji Kraj	Jamski Zaliv
Accessibility (A)	0.5	0.25	0.25
Safety (S)	1	0.25	0.75
Geodiversity content coverage (GCG)	1	1	1
Cross-curricular integration (CCI)	0.5	0.5	1
Integration into wider area (IE)	0.75	0.5	0.75
Fieldwork techniques (FT)	1	1	1
Teaching materials (TM)	0.75	0	0.75
Educational potential (EP)	5.5	3.5	5.5

The sum of all criteria, or educational potential (EP) of the site, is 5.5. The value indicates that the area of the steephead valley is more to very suitable for organizing an excursion.

5.2 Zadnji Kraj

Zadnji Kraj is located in the southwest margin of the polje, just below the steep slopes of the Javorniki Mountains. The area resembles a bay that is separated from the central part of the polje by an elongated peninsula. Within the area, there are series of hydrologic features, including springs, swallow holes, and estavelles.

The whole area is easily accessible by road. However, geodiversity elements within the area, which would be a point of interest of excursions, are hardly accessible. There are no paths leading to them, a dense vegetation overgrows the majority of the area, and, additionally, the intermittent lake occasionally inundates the whole section of the polje. Therefore, accessibility (A) criteria was valued at 0.25. Safety (S) criteria was evaluated at 0.25. Because of the aforementioned reasons, the areas around swallow holes and estavelles are not secured by protective fences or warning signs. This can represent a threat, especially for younger schoolchildren. Geodiversity content coverage with geography school curricula (GCG) was assessed at 1, since it can be used to cover at least 11 objectives from the curricula (Učni načrt, 2011).

Geodiversity content of the area can be combined with two other subjects: biology and chemistry. Therefore, cross-curricular integration (CCI) was evaluated at 0.5. Within an excursion to Zadnji Kraj, at least two other subjects on the way can be linked. Even though the area is rather remote, we assessed the integration into the wider area of the excursion (IE) at 0.5. Fieldwork techniques (FT) were evaluated at 1, as the area is appropriate for conducting at least four different fieldwork techniques (e.g. soil profiling, examining soil properties, surveying carbonate content of the bedrock, surveying bedrock by utilizing a geological map, analyzing the landscape, etc.). Teaching materials (TM) were evaluated at 0, as there is no available teaching material for the area. Based on the

calculation, the Educational potential (EP) value is 3.5, which means that Zadnji Kraj is less suitable to suitable for organizing a school excursion.

5.3 Jamski Zaliv

The area of Jamski Zaliv is located in the westernmost part of the polje. It is an enlarged blind valley with a series of ponors and a group of collapse dolines in the adjacent hinterland.

Figure 7: Entrance to the cave Velika Karlovica in the area of Zadnji Kraj (photo: Blaž Repe).

The whole area is accessible by road, while separate elements of geodiversity must be accessed by forest trails. They are not well marked and are partially overgrown; therefore, the accessibility value (A) is 0.25. In general, the area is safe also for younger school-children with exceptions in some areas that can be easily avoided. As a result, safety (S) of the area was evaluated at 0.75. Within the area it is possible to cover at least 11 objectives from curricula; thus geodiversity content coverage with geography school curricula (GCG) was assessed at 1 (Učni načrt, 2011).

Cross-curricular integration (CCI) was evaluated at 1, since geodiversity content of the area can be linked to geography and to at least four other subjects: chemistry, biology, Slovenian language, and history. Even though the area is a bit remote, there is a possibility of including other areas into an excursion; therefore, integration into a wider area of the excursion (IE) was valued at 0.75. The last four school fieldwork techniques (FT) can

be applied in the area (e.g. soil profiling, examining soil properties, surveying carbonate content of the bedrock, surveying bedrock by utilizing geological map, analyzing the landscape, etc.); therefore, this criteria was assessed at 1. Teaching material (TM) was evaluated at 0.75, because of an information board and a variety of literature about the area. The final value of educational potential (EP) of the site is 5.5, which means that the area of Jamski Zaliv is more suitable to very suitable for organizing a school excursion.

6 CONCLUSIONS

The geodiversity definition, evaluation, and recognition is gaining significance within Earth Sciences (Gray, 2013; Melelli, 2014) due to geoconservation management, geotourism enhancement, and educational aspects. Established methods of geodiversity evaluation merged various criteria, which are usually divided into scientific values of geodiversity elements and their additional values (Pereira et al., 2007; Reynard, Coratza, 2007; Zouros, 2007; Gray, 2013). The scientific values aim to assess basic values of the elements in terms of rareness, representativeness, paleogeographical values, etc. (Reynard, 2009). The additional values differ according to the scope of geodiversity evaluation, emphasizing either conservation, touristic, or educational aspects. The majority of established methods of geodiversity evaluation is focused towards geoconservation and geotourism, while the educational aspect is often overlooked.

The new method for the evaluation of educational potential of high-geodiversity sites presented in this article uses two stages of assessment approach. Within the first stage, a geodiversity index within the area was identified. The areas with a high index are allegedly more suitable for educational purposes. Three areas of very high geodiversity index were identified on Cerknica Polje: steephead valley of the Stržen River, Zadnji Kraj, and Jamski Zaliv. Surprisingly, due to the objective methodology, currently the most popular site for excursions in the area of the polje around swallow holes Rešeto and Vodonos was not assessed as a high geodiversity site.

The second stage of assessment identified the added value of the high geodiversity areas. The added value is a combination of criteria that are crucial for organizing an effective and a high-quality excursion. The criteria define basic standards for organizing an excursion as accessibility and safety of the sites. On the other hand, they evaluate quality of the site according to curricula contents. The final assessment was expressed as educational potential of the site.

Application of assessing educational potential of the three selected sites revealed that Zadnji Kraj is the least suitable area for organizing an excursion. Quite low accessibility and safety values suggest that the area is not appropriate nor safe for excursions. Even though the area is appropriate for presenting contents defined by the curricula (Učni načrt, 2011), there are also no teaching materials available. Even though the area exhibits a very high geodiversity index, it is less suitable for an excursion.

The other two sites, the steephead valley of Stržen and Jamski Zaliv, exhibit the same educational potential, which was defined as more to very suitable for organizing excursion. Both places lack ease of access, since paths and forest trails are partially overgrown

and not well marked. Both of them are fairly safe and very suitable for presenting various topics and experiments associated with the geography curricula (Učni načrt, 2011). There are some teaching materials about both places, which presents an advantage for an educator when preparing an excursion. A little effort by the local community, in the form of improved accessibility, information boards, direction signs, and additional teaching materials, would significantly improve their education potential. As a result, both places would become important geoeducation sites of the polje.

The two-stage evaluation method of geodiversity educational potential turned out to be a valuable tool for organizing fieldwork and excursions. It can help educators to evaluate suitability and educational potential of each area, where they would like to organize fieldwork, which certainly contributes to a better quality of an excursion.

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