GIS-BASED SPATIAL EVALUATION OF RECREATIONAL POTENTIAL IN THE LANDSCAPE UNDER ENVIRONMENTAL AND SOCIO-ECONOMIC CONSTRAINTS

Radovan Pondelík, Martin Zápotocký
ESPRIT, spol. s r.o., Pletiarska 2, 969 01 Banská Štiavnica, Slovak Republic

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Abstract
The sustainable development of recreational activities in natural landscapes requires an integrated understanding of both environmental potential and limiting factors. This study presents a GIS-based spatial evaluation of recreational potential, incorporating environmental and socio-economic constraints that affect its practical applicability. Four categories were assessed: winter recreation (snow-based sports), summer outdoor recreation outside built-up areas, cottage and second-home recreation, and educational and exploratory tourism. The evaluation was based on GIS-supported spatial analysis and multi-criteria modelling using selected landscape attributes, including topography, land cover and accessibility. The resulting spatially differentiated values were subsequently analysed in relation to limiting factors, particularly those related to landscape structure, nature and resource protection, and environmental stressors. By integrating calculated potentials with identified constraints, the study defines the realistic recreational potential of the landscape and provides a spatial framework for evidence-based and sustainable recreation planning.

Key words: recreation suitability; spatial modelling; outdoor recreation; nature conservation; land-use planning

Introduction

The evaluation of landscape potential represents a fundamental component of sustainable spatial planning and environmental management. Recreational use of the landscape is strongly dependent on both natural conditions and human-induced constraints, which together determine the actual usability of the territory. The concept of natural capital provides a suitable framework for such evaluations, as it integrates ecosystem functions and services into decision-making processes (Daily et al., 1997). In the Slovak context, this concept has been systematically developed in the Atlas of Natural Capital of Slovakia (Izakovičová et al., 2025), which provides a comprehensive methodological framework for the assessment of landscape potentials and ecosystem services. Advances in geographic information systems (GIS) and spatial data availability have significantly improved the capacity to assess landscape potential in a spatially explicit manner. Despite these advances, many assessments still rely predominantly on theoretical or physical suitability, often neglecting the influence of socio-economic constraints. This leads to systematic overestimation of actual landscape usability. Therefore, there is a need for approaches that integrate both natural determinants and limiting factors into a unified evaluation framework.

The aim of this study is to evaluate selected types of recreational potential using GIS-based multi-criteria analysis and to quantify the impact of environmental and socio-economic constraints on their realistic applicability

Material and methods

The methodological approach applied in this study is based on procedures we developed within the Atlas of Natural Capital of Slovakia (Izakovičová et al., 2025), with partial adaptations to the specific requirements of recreational potential assessment.

Conceptual framework

The evaluation is based on the concept of landscape potential as a function of environmental suitability and limiting factors. The term potential explicitly expresses that the evaluation focuses on potential, not actual conditions of landscape use. Such an approach reflects the concept of natural potential as defined by Drdoš (2006), where the initial calculation is performed without considering limiting factors arising from human activities.

Four categories of recreational potential were assessed:

- R1 – winter recreation (snow-based sports)
- R2 – summer recreation (outdoor activities outside built-up areas)
- R3 – cottage and second-home recreation
- R4 – educational and exploratory tourism

Each category reflects different requirements and sensitivities to environmental conditions.

Input data and determinants
The assessment integrates multiple groups of spatial determinants:
- Abiotic factors – relief, altitude, slope, climate conditions
- Landscape structure – land cover, ecological stability, fragmentation
- Biotic factors – vegetation structure and ecological value
- Accessibility indicators – transport infrastructure and spatial availability

All input data were processed in GIS environment and transformed into raster layers with a spatial resolution of 10 × 10 m.

Multi-criteria evaluation
The evaluation was carried out using a weighted multi-criteria decision approach, following the principles of landscape-ecological planning and functional evaluation of geoecosystems (Ružička & Miklós, 1982; Miklós & Špinerová, 2019; Izakovičová et al., 2025). Each determinant was assigned:
- a functional value (f_{xi}) expressing suitability,
- a weight coefficient (v_{xi}) representing its importance.

The resulting potential was calculated as:
$\varphi_i = \Sigma (f_{xi} \cdot v_{xi})$
The values were classified into six categories ranging from “excluded” to “excellent potential”.

Levels of potential
Three hierarchical levels of potential were defined:
1. Theoretical potential – assumes no constraints
2. Technical potential – excludes unsuitable areas
3. Realistic potential – incorporates partial limitations

Socio-economic constraints were expressed through reduction coefficients: no limitation (1.0), partial limitation (0.5) and exclusion (0.0). Constraints were derived from protected areas and legislative restrictions, protection zones of natural resources (water, soil), built-up areas and infrastructure, environmental stressors (pollution, degradation) and natural hazards (landslides, avalanches).

Results
The evaluation of recreational potential revealed substantial differences between theoretical, technical and realistic potential levels across all categories (R1–R4). These differences reflect the cumulative impact of environmental and socio-economic constraints on the actual usability of the landscape.
A detailed quantitative overview of the results is presented in Table 1.

Tab. 1: Comparison of theoretical, technical and realistic recreational potential

Category	Potential level	Sum of values	Mean value (1–6)	% of theoretical	Loss (%)
R1 (winter recreation)	Theoretical	1719248369	3.51	100	–
	Technical	1620690060	3.52	94.27	5.73
	Realistic	919858277	2.00	53.50	46.50
R2 (summer recreation)	Theoretical	1638697935	3.35	100	–
	Technical	1557096730	3.41	95.02	4.98
	Realistic	1071217759	2.35	65.37	34.63
R3 (cottage and second-home recreation)	Theoretical	1741252926	3.55	100	–
	Technical	1604694160	3.61	92.16	7.84
	Realistic	977617992	2.20	56.14	43.86
R4 (educational and exploratory tourism)	Theoretical	1516782039	3.10	100	–
	Technical	1296766477	2.96	85.49	14.51
	Realistic	1101700010	2.51	72.63	27.36

The transition from theoretical to technical potential results in relatively moderate reductions across all categories. The proportion of technical potential ranges from 85.49 % to 95.02 % of the theoretical potential. The lowest reduction was observed in R2 (summer recreation), where technical potential reaches 95.02 % of the theoretical value, corresponding to a loss of 4.98 %. In contrast, the highest

reduction occurs in R4 (educational and exploratory tourism), where technical potential represents 85.49 % of the theoretical value, corresponding to a loss of 14.51%. Categories R1 and R3 show intermediate values, with technical potential reaching 94.27 % and 92.16 % of the theoretical potential, respectively. A substantially greater reduction is observed when moving from technical to realistic potential, which reflects the influence of partially limited areas. In this case, realistic potential reaches between 53.50 % and 72.63 % of the theoretical potential. The lowest proportion is observed in R1 (winter recreation), where realistic potential represents 53.50 % of the theoretical value, corresponding to a total loss of 46.50 %. Similarly, R3 (cottage and second-home recreation) shows a considerable reduction, with realistic potential reaching 56.14 % of the theoretical value (loss of 43.86 %). Moderate reductions are observed in R2 (summer recreation), where realistic potential reaches 65.37 % of the theoretical value, corresponding to a loss of 34.63 %. The least affected category is R4 (educational and exploratory tourism), where realistic potential remains at 72.63 % of the theoretical value, corresponding to a loss of 27.36 %. In addition to these differences, changes in mean values indicate shifts in the overall quality of remaining areas after the exclusion of unsuitable locations. In categories R1, R2 and R3, the mean value slightly increases when moving from theoretical to technical potential, suggesting that the removal of unsuitable areas leads to a relative improvement in average suitability. In contrast, category R4 shows a decrease in mean value (from 3.10 to 2.96), indicating that excluded areas may also include locations with relatively higher suitability.
Overall, the results indicate that while the exclusion of unsuitable areas has a moderate impact on the total potential, the inclusion of partially limited areas significantly reduces the realistically usable landscape potential across all categories.

Discussion

The results clearly demonstrate that assessments based solely on environmental suitability lead to systematic overestimation of landscape usability for recreational purposes. While the theoretical potential reflects the maximum possible suitability of the landscape, it does not account for spatial, environmental, and socio-economic constraints that significantly limit real-world applicability. The comparison between theoretical, technical and realistic potential highlights the importance of a multi-level evaluation approach. The relatively small reduction between theoretical and technical potential (approximately 5–15 %) indicates that completely unsuitable areas represent only a part of the landscape. However, the substantially larger decrease between technical and realistic potential (15–43 %) confirms that partially limited areas play a crucial role in determining actual usability. This finding suggests that the exclusion of unsuitable areas alone is not sufficient for realistic spatial assessment. The variability observed among individual categories (R1–R4) reflects their differing sensitivity to environmental conditions and constraints. Winter recreation (R1) and cottage and second-home recreation (R3) show the highest reduction of potential, indicating strong dependence on specific environmental conditions such as climate, terrain and landscape protection regimes. In contrast, educational and exploratory tourism (R4) retains the highest proportion of its theoretical potential, suggesting greater spatial flexibility and lower dependence on strict environmental requirements. From a spatial planning perspective, these results have important implications. The use of theoretical or even technical potential alone may lead to inappropriate allocation of recreational functions in the landscape. The incorporation of realistic potential allows for more accurate identification of areas suitable for development, while also supporting the protection of environmentally sensitive or constrained locations. The presented methodology, based on GIS-supported multi-criteria evaluation, provides a robust framework for integrating heterogeneous spatial data and translating them into decision-relevant outputs. Its application can support not only strategic spatial planning, but also environmental impact assessment, land-use planning, and the design of sustainable tourism development strategies. Furthermore, the approach enables the identification of areas where targeted interventions could increase usable potential, for example through infrastructure improvements or mitigation of limiting factors. At the same time, it highlights areas where development should be restricted due to environmental sensitivity or regulatory constraints.

Conclusion

The results demonstrate that the realistic recreational potential of the landscape is significantly lower than its theoretical potential due to the combined influence of environmental and socio-economic constraints. While technical potential remains relatively close to theoretical values, the inclusion of partially limited areas leads to a substantial reduction of usable potential across all evaluated categories. The degree of reduction varies among individual types of recreational activities. The most pronounced decrease was observed in winter recreation (R1) and cottage and second-home recreation (R3), whereas educational and exploratory tourism (R4) retained the highest proportion of

its theoretical potential. Summer recreation (R2) shows intermediate values, indicating a moderate sensitivity to limiting factors. These findings confirm that the evaluation of landscape suitability based solely on natural conditions leads to an overestimation of its actual usability. The integration of constraints provides a more realistic assessment and allows for a more accurate identification of areas suitable for recreational use. The presented GIS-based multi-criteria approach offers a practical tool for spatial planning and decision-making, enabling the evaluation of landscape potential in a way that reflects both environmental conditions and real-world limitations.

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Souhrn

Článek se zabývá GIS hodnocením rekreačního potenciálu krajiny se zohledněním environmentálních a socioekonomických omezení. Hodnoceny byly čtyři typy rekreace: zimní sporty, letní turistika, chalupářství a poznávací turismus.
Výsledky ukazují, že realistický potenciál dosahuje pouze 53–73 % teoretického potenciálu, což poukazuje na významný vliv omezení. Největší pokles byl zaznamenán u zimní rekreace a chalupářství, nejmenší u poznávacího turismu.
Metodika poskytuje vhodný nástroj pro podporu územního plánování a udržitelného rozvoje rekreace.

Contact:
Radovan Pondelík
E-mail: pondelik@esprit-bs.sk