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Development of a Method and Algorithm for Assessing Visual Properties of Territories (Case of Yangantau Geopark)

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Abstract:

The study provides a comprehensive approach to evaluating the visual attractiveness of landscapes in the context of a case study from the UNESCO Global Geopark Yangantau. Combining landscape, aesthetic, and ecological evaluation methods, the research develops a GIS-based multi-criteria approach to analyze panoramas. The approach involves the development of functional and information models, the extraction of geospatial data (relief, vegetation, water), and their combination with ArcGIS Pro and Python. Weighted sum model approximates the ultimate visual attractiveness index, enabling planning and sustainable tourism development. The multi-criteria approach enables landscape planning and sustainable tourism development in protected areas through informed decision-making. This study introduces a new method of GIS technology application accompanied by a well-organized multi-criteria evaluation algorithm to calculate vantage point attractiveness. The use of IDEF0 and IDEF1X modeling frameworks enhances automation and visualization of information, providing realist instruments in sustainable tourism development and strategic landscape planning.

Keywords: *GIS, Visual Analysis, Geopark, Multi-Criteria Evaluation, Landscape Planning, SRTM, NDVI.*

تطوير طريقة وخوارزمية لتقييم الخصائص البصرية للأراضي (حالة منتزه يانغانتاو الجيولوجي)

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ملخص:

تُقدّم هذه الدراسة نهجًا شاملاً لتقييم الجاذبية البصرية للمناظر الطبيعية في سياق دراسة حالة من حديقة يانغانتاو الجيولوجية العالمية التابعة لليونسكو. تجمع الدراسة بين أساليب تقييم المناظر الطبيعية والجمالية والبيئية، وتُطوّر نهجًا متعدد المعايير قائمًا على نظم المعلومات الجغرافية لتحليل الصور البانورامية. يتضمن هذا النهج تطوير نماذج وظيفية ومعلوماتية، واستخراج البيانات الجغرافية المكانية (التضاريس، والغطاء النباتي، والمياه)، ودمجها مع ArcGIS Pro و Python. يُقارب نموذج المجموع المرجح مؤشر الجاذبية البصرية النهائي، مما يُمكّن من التخطيط والتنمية السياحية المستدامة. يُمكّن النهج متعدد المعايير تخطيط المناظر الطبيعية والتنمية السياحية المستدامة في المناطق المحمية من خلال اتخاذ قرارات مستنيرة. تُقدم هذه الدراسة أسلوبًا جديدًا لتطبيق تكنولوجيا نظم المعلومات الجغرافية، مصحوبًا بخوارزمية تقييم متعددة المعايير منظمة جيدًا لحساب جاذبية نقطة المراقبة. يُعزز استخدام أطر النمذجة IDEF0 وIDEF1X أتمتة المعلومات وتصورها، مما يوفر أدوات واقعية في التنمية السياحية المستدامة والتخطيط الاستراتيجي للمناظر الطبيعية.

الكلمات المفتاحية: *نظم المعلومات الجغرافية؛ التحليل البصري؛ الحديقة الجيولوجية؛ التقييم متعدد المعايير؛ تخطيط المناظر الطبيعية؛ مهمة تضاريس رادار المكوك؛ مؤشر الغطاء النباتي الوطني.*

1. Introduction

UNESCO Geoparks promote the sustainable development of regions, particularly through geotourism. For a geopark to operate optimally, it must be understandable and accessible for both tourists and residents, so it is necessary to have an easily navigable and informative website (Wahab et al., 2015), with good print materials—maps, brochures, and an appealing visual identity—to introduce people to the area better (Herrera-Franco et al., 2021; Wahab et al., 2015).

According to UNESCO, an international geopark is an area with outstanding geological heritage of international significance. Such places allow people to better understand important global and local environmental issues and promote sustainable development. Diversity of natural landscapes and cultural and historic elements form a great foundation for tourism infrastructure construction and promotion of the region (Echtner & Ritchie, 1991).

Geoparks are not only beautiful natural locations; they are actually ecotourism centers where nature, geology, and culture merge in harmony. The "Yangantau" Geopark in Bashkortostan is a living example of such harmony. It is there that one can see distinctive geological formations, visit rich flora and fauna, and learn about the unique cultural heritage of the area. However, one of the major issues of today is the relative lack of interest in the visual perception of observation platforms. This hinders the full realization of the tourist potential of the area and dissuades it from visits (Teodoronsky, 2021).

The goal of our study is to fully assess the visual appeal of locations selected for observation platforms in the Yangantau Geopark, particularly in the area of the Mechetlino geological section. We utilize modern geospatial data technologies (GIS) and multi-criteria analysis (Klimanova & Kolbovsky, 2015), taking into account relief, vegetation cover, and water reservoirs' state (Hernández & Hidalgo, 2005). Landscape expressiveness parameter zoning of the area helps us define key factors to support the development of environmentally oriented tourist trails combining protection and development (Kistemann et al., 2002).

Our research is focused on specific areas of the Yangantau Geopark designed for the development of observation platforms.

The subject is the technique which helps make decisions based on information about the look of these areas, to make the tourist routes as attractive and enjoyable as possible for the visitors.

2. Study Area

The Yangantau Geopark, located in the Republic of Bashkortostan, Russia, is an excellent example of a geopark that combines geological heritage with cultural and recreational value. Yangantau, as a UNESCO Global Geopark, safeguards a diverse landscape with remarkable geological features, rich biodiversity, and archaeological sites (UNESCO, 2023). It houses one of the most significant features, the Mechetlino geological section, a protected natural monument revealing a 30-meter-thick stratigraphic section from approximately 280 million years ago in the Permian era. The site is of exceptional scientific value for stratigraphic and geological research.

Its location close to the Yangantau health resort, which is a strategic position, enhances the accessibility and appeal of the geopark as a tourism and health center. The geopark offers different types of ecotourism activities such as hiking, horseback riding, and cycling, all incorporated with interpretive trails and information boards. The territory is also culturally significant, reflecting the heritage and traditions of the Bashkir people.

Yangantau Geopark also participates in active sustainable development and serves as a pilot territory for introducing ESG (Environmental, Social, and Governance) model implementation into landscape management (Trišić et al., 2023). It is provided with infrastructure supporting scientific research, environmental education, and community-based tourism, and for this reason is an ideal location for piloting geospatial tools and techniques for enhancing landscape visual assessment and planning (Pomering, A. 2013).

The undulating nature of the park, with high viewpoints and low vegetated slopes and bodies of water, renders it an ideal natural laboratory for experimenting with visual attractiveness using GIS-based methods. As it happens, Yangantau Geopark is endowed with the richness as well as complexity necessary to experiment with and apply high-level geospatial analysis software, e.g., the WSM tool developed in this study.

The code for this tool is available at: https://github.com/FatimaAlsharifKS/WSM-Tool

3. Theoretical Framework and Literature Review

Visual landscape beauty is a key factor in geopark sustainable development (Ode et al., 2008). Not only is it a decision-making criterion for the tourism potential but also for preserving natural and cultural heritage (Zhu et al., 2021), developing environmental education, and fostering local identity (Yu et al., 2019). Previous research indicates three main ways of assessing visual elements: landscape, aesthetic, and ecological.

The landscape design is centered on objective geographic characteristics such as relief, vegetation, and hydrological factors, which are inclined to apply GIS methods in visibility analysis, terrain classification, and landform mapping. It provides measurable ground for infrastructure construction and zoning but ignores subjective human perception (Trišić et al., 2023).

The aesthetic approach is interested in human experience and gains its knowledge from professionals' opinions, individuals' views based on polls, and photo preference studies. This investigates how people psychologically and emotionally respond to different surroundings, evaluating factors such as contrast, distinctiveness, and harmony. While informative, it is still subjective and may vary according to cultural and personal history.

The ecological approach assesses visual quality alongside environmental sustainability. It considers biodiversity metrics, ecosystem health indicators, and landscape integrity to retain the scenic value and ecological functionality of nature (Yu et al., 2019).

Literature shows that an integrated approach that brings these three orientations together provides a more complete image of landscape value. In geoparks, integration is used to enable the development of tourism infrastructure and preserve geodiversity and local tradition.

Some have been given as being determinants of landscape beauty: unique geologic structures, species diversity, accessibility, grandstand views, and restricted visual pollution (Ode et al., 2008; Lozbeneva, E. A. 2022). Empirical methods such as GIS-based spatial analysis and weighted indices (e.g., aesthetic index, visual interest index) have been widely applied in assessing these factors. Advanced techniques like view shed analysis, visual impact assessment, and 3D modeling also enhance accuracy in management and planning (Trišić et al., 2023).

In addition, techniques such as the Weighted Sum Model (WSM) allow multi-criteria decision-making through the aggregation of weighted values from several visual indicators such as topography, vegetation, availability of water, and openness of vistas. Conjoined with field observation and photographic data, these models allow for long-lasting and reproducible evaluations that inform sustainable tourism development planning.

In summary, the literature highlights the importance of integrating visual, ecological, and cultural elements in landscape evaluation. That premise is what this research is founded on with the introduction of a GIS-based approach supplemented by automated processes for searching and optimizing the visual attractiveness of observation points in geoparks, with particular focus given to Yangantau Geopark.

4. Methodology

4.1 Data Collection and Processing

The analysis is based on geospatial data processed within a GIS environment. The primary data sources include: a Digital Elevation Model (DEM) from the SRTM mission with a spatial resolution of 30 meters to represent terrain; Sentinel-2 satellite imagery for deriving the Normalized Difference Vegetation Index (NDVI) to assess vegetation density; raster and vector data of hydrographic features to identify water bodies; and point-based datasets for constructing visibility zones. All spatial data were preprocessed in ArcGIS Pro, including reprojection to the WGS 1984 Zone 40N coordinate system and clipping to the boundaries of the study area.

4.2 Visual Criteria and Scoring

In this study, four primary criteria were established to evaluate the visual attractiveness of the landscape: topography, vegetation, water presence, and visibility. All of the factors were grouped and graded on a score of 0 to 2 based on their visual significance. For topography, a Digital Elevation Model (DEM) was used to identify elevation zones, which were then reclassified into three categories: mountainous zones were visually ranked high and scored 2; hilly zones were moderately ranked as 1; and flat zones were visually ranked low and scored 0. Vegetation analysis included the calculation of the Normalized Difference Vegetation Index (NDVI) from Sentinel-2 images to assess the cover density green. NDVI values were binned into classes and scored corresponding to those classes, with more concentrated vegetation scoring higher on a scale from 0–1. The presence of water bodies was evaluated based on their spatial extent, with significant water features receiving a score of 1 and the absence of water resulting in a score of 0. Lastly, visibility analysis involved generating viewsheds from observation points. Visibility zones were categorized as medium range (up to 2 km) or long range (greater than 2 km), with open, unobstructed views assigned a score of 1 and visually blocked areas receiving a score of 0. These criteria formed the basis for a weighted multi-criteria evaluation of landscape visual attractiveness.

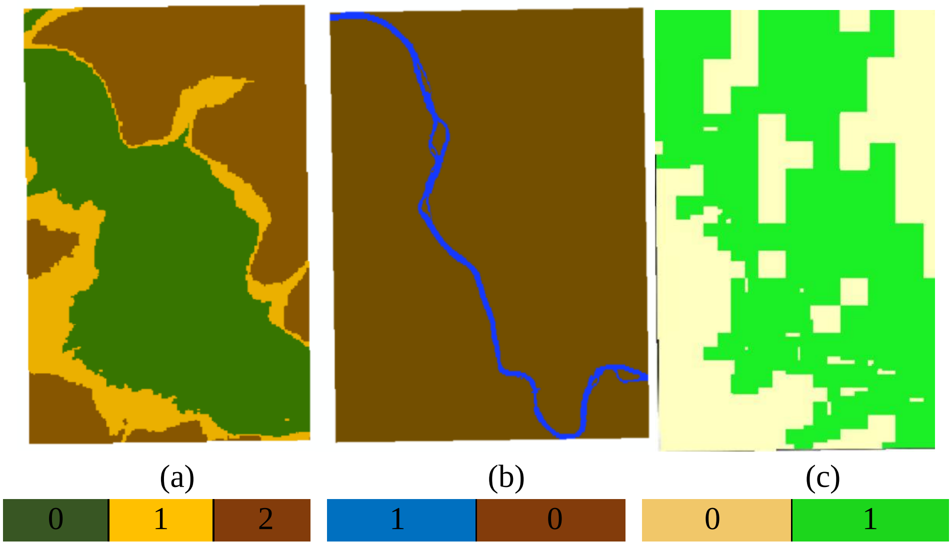
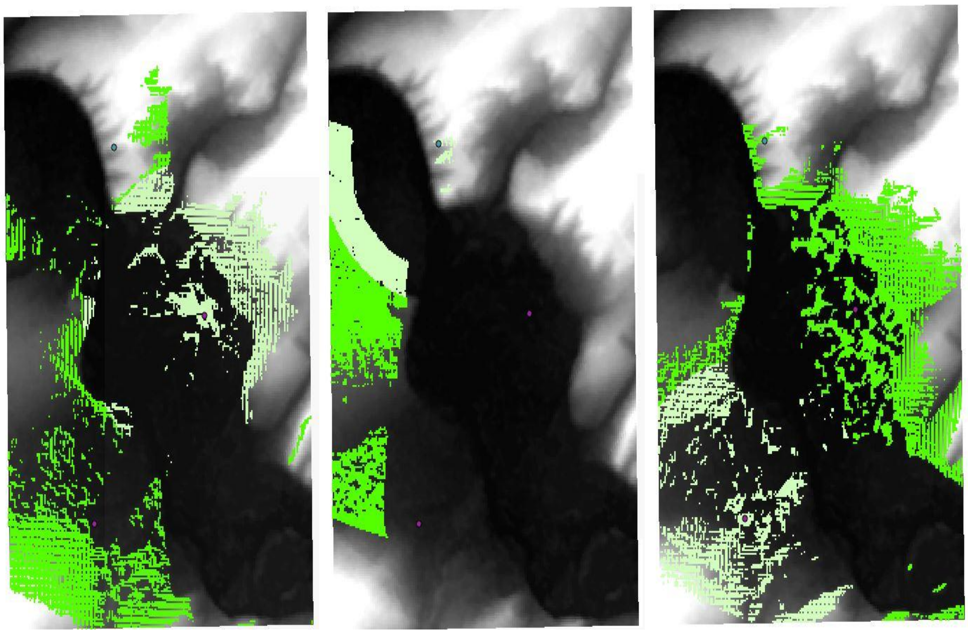


Figure 1: (a) Terrain Classification Map, (b) Water Feature Classification Map, (c) Vegetation Classification Map
Source: Author's own work



(a) (b) (c)

Figure 2: (a) The visibility from the first observation point, (b) The visibility from the second observation point, (c) The visibility from the third observation point.

Inner radius visibility.
Outer radius visibility.
Source: Author's own work

4.3 Weighted Sum Model

Each of the criteria was assigned a weight coefficient expressing its relative importance to the entire visual attractiveness of the landscape. The weights were placed as: W1 for topography due to its impact on accessibility and visibility; W2 for vegetation due to its ecological and visual significance; W3 for water bodies due to their scenic and recreation value; and W4 for obstructions or visibility depending on how open the view is. The weights could be tailored based on specific analytical or planning objectives. For the estimation of the final visual attractiveness index (S), weighted sum method was used, using the following formula:

$$S = (W1 \times (B1 / B1max)) + (W2 \times (B2 / B2max)) + (W3 \times (B3 / B3max)) + (W4 \times (B4 / B4max)) \quad (1)$$

In the equation (1): where Wi is the weight of each criterion, Bi is the score of the criterion using field or remote-sensing data, and Bimax the highest score for that criterion.

In the equation (2): Weighted Sum for Multi-Criteria Evaluation. In the equation (3): B is the score and Bimax the highest possible score per criterion.

$$S = \sum (Wi \times Bi) \ (2)$$

$$B = Bi/Bimax \ (3)$$

The model is conducive to a normalized and scalable index where all factors make their contribution relative to the ultimate determination of the visual quality. The flexibility of the model enables its application on disparate landscapes and decision-making conditions.

5. Development of the “WSM tool”

The primary purpose of the WSM tool (Weighted Spatial Modeling tool) is to implement a Weighted Sum Model for the overall assessment of visual attractiveness or spatial suitability of lands according to a multi-criteria decision. Developed in Python in Visual Studio Code and made ArcGIS Pro compatible using the ArcPy library (Esri. 2022; Lontai-Szilágyi et al., S. 2019), the tool automates complex spatial analyses such as visibility modelling, buffering, and terrain analysis. It accommodates various types of spatial data, such as classified vector layers, NDVI raster’s, and digital elevation models, and provides a flexible setup that enables users to specify input layers, buffer radii, weights, and NDVI thresholds. Of particular importance is the tool's intuitive graphical interface that increases the ease of use and accessibility for applied GIS analysis. Moreover, the tool includes the function—"Calculate Criteria Percentages"—to analyse the coverage of each criterion by computing the proportion of non-zero values between raster layers. This enables users to evaluate the spatial representativeness and completeness of input data. By incorporating geospatial reasoning and landscape context into its development, the WSM tool provides a functional, effective, and interactive tool for landscape planning practitioners, environmental monitoring, and territorial analysis. The code for this tool is available at: https://github.com/FatimaAlsharifKS/WSM-Tool

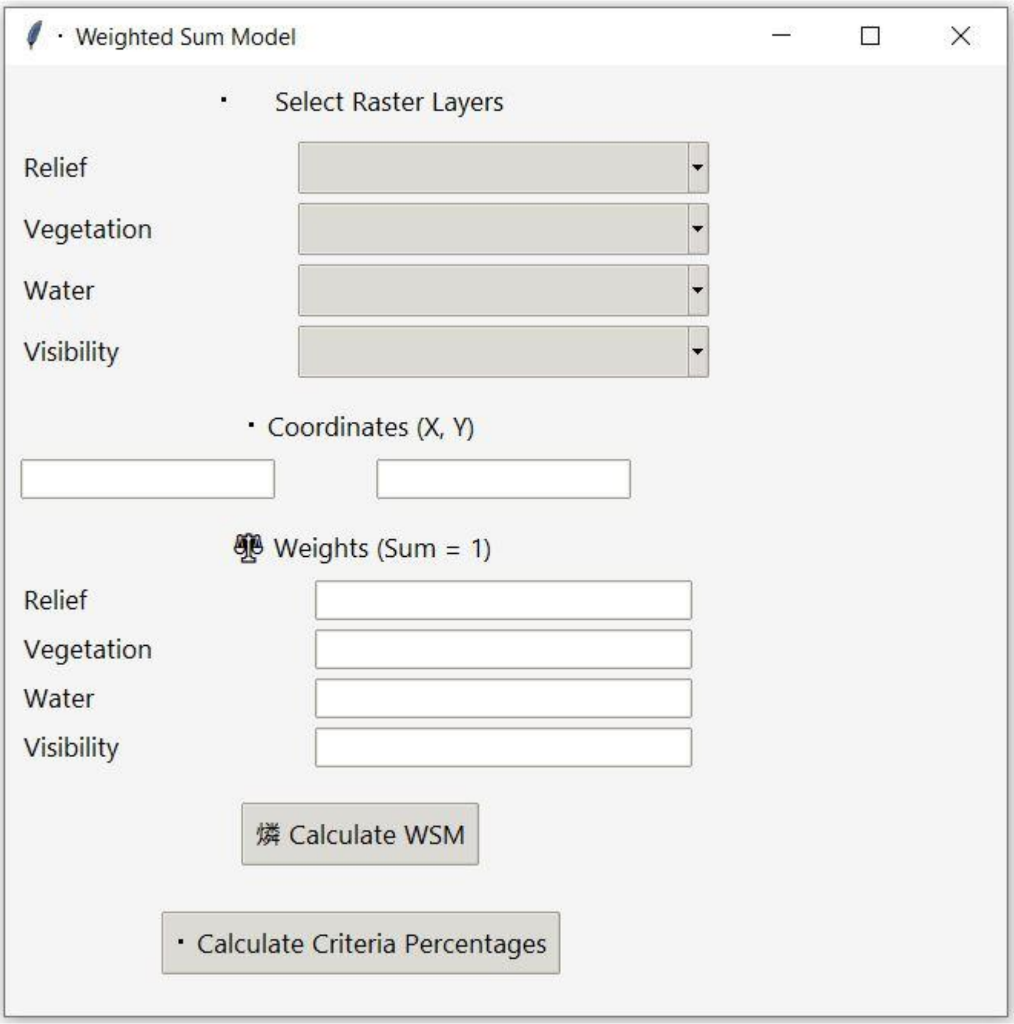


Figure 2: WSM Tool Interface
Source: Author's own work

6. Results and Discussion

The conclusions of the current research confirm the effectiveness of the proposed approach to studying the visual attractiveness of territories using Geographic Information Systems (GIS). GIS-analysis attested that the “Mechetlino” region of the Yangantau Geopark is highly visually attractive because it possesses high relief, dense forest cover, and broad panoramic views. The sophisticated methodology, integrating physical-geographical, ecological, and perceptional aspects, facilitates top-level landscape analysis and logical planning of tourist facilities. WSM tool was used to perform automated mapping and zoning of scenic view spots, measuring visual quality across complex landscapes. Its flexibility, through weighted adjustment of the evaluation criteria, makes it a valuable decision-support system for environmental planning and sustainable tourism development. The spatial data and visual assessment obtained with this method can be incorporated into strategic planning models of ecologically balanced and aesthetically rich tourist routes. In addition, the use of GIS allows standardization of analysis techniques, enhances the objectivity of decision-making processes, and provides an opportunity to repeat this method in other geoparks and nature reserves.

7. Conclusion

This study contributes to the geospatial landscape evaluation discipline by providing a reproducible and adaptable method for the assessment of the visual beauty of landscapes in geoparks according to Geographic Information Systems (GIS). The developed approach integrates physical, ecological, and subjective aspects of landscape vision to enable scientifically informed planning for sustainable geotourism development. By combining GIS data, multi-criteria decision-making, and visual perception modeling, the methodology enables systematic evaluation of territorial appeal and enhances the quality level of tourist routes and the eco-features of the area. The obtained data can be incorporated into spatial planning models for creating more attractive and ecologically friendly infrastructure. Moreover, GIS technology simplifies standardizing the spatial data and integrating it into broader regional development plans. Future research can explore integrating feedback from users in real-time and scaling the model to other protected natural areas.

8. Recommendation

Based on the spatial data analysis and results obtained using the WSM tool, a set of recommendations was developed to enhance the visual appeal of the studied areas while promoting sustainable landscape development and preserving natural and cultural values. Key improvement strategies include: optimizing the placement of observation points in areas with the highest visual index scores, along with the installation of informational signage to enrich visitor experience; reducing visual pollution by masking or relocating industrial elements and using natural materials in infrastructure design; restoring vegetation in low-NDVI zones with native plant species and creating eco-trails that combine ecological education with scenic enjoyment; and implementing integrated water body management through monitoring, ecological enhancement, and thoughtful integration of water features into tourism routes. These measures aim not only to elevate the visual quality of the landscape but also to support long-term spatial planning that safeguards both environmental and cultural heritage.

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References

Echtner, G., & Ritchie, J. R. B. (1991). The meaning and measurement of destination image. *Journal of Tourism Research, 31*(3), 3–16.

Esri. (2022). *ArcGIS Pro documentation*. https://pro.arcgis.com

Hernández, J., & Hidalgo, M. C. (2005). Effect of urban vegetation on psychological restorativeness. *Psychological Reports*, *96*(3), 1025–1028.

Herrera-Franco, G., Montalván-Burbano, N., Carrión-Mero, P., Jaya-Montalvo, M., & Gurumendi-Noriega, M. (2021). Worldwide research on geoparks through bibliometric analysis. *Sustainability (Switzerland), 13*(3), 1–32.

Kistemann, T., Dangendorf, F., & Schweikart, J. (2002). New perspectives on the use of Geographical Information Systems (GIS) in environmental health sciences. *International journal of hygiene and environmental health*, *205*(3), 169-181.

Klimanova, O. A., & Kolbovsky, E. Y. (2015). On the issue of multi-scale cultural landscapes: Typology and mapping at different territorial levels. *Proceedings of the Russian Academy of Sciences. Geographical Series, 2015*(2), 28–38.

Lontai-Szilágyi, Z., Bertalan-Balázs, B., Zsiros, B., Vasvári, M., Kumar, S. S., Nilanchal, P., Martonné Erdős, K., & Szabó, S. (2019). A novel approach of mapping landscape aesthetic value and its validation with rural tourism data. *Hungarian Geographical Bulletin*, *68*(3), 283–301.

Lozbeneva, E. A. (2022). Methodological approaches to assessment of aesthetic properties of landscapes. *RUDN Journal of Ecology and Life Safety*, *30*(2), 116-126.

Ode, Å., Tveit, M., & Fry, G. (2008). Capturing landscape visual character using indicators: Touching base with landscape aesthetic theory. *Landscape Research*, *33*(1), 89–117.

Pomering, A. (2013). A review of:'The Tourist Gaze 3.0' John Urry & Jonas Larsen London, Sage Publications Ltd, 2011. 282 pp.,£ 75, ISBN 978-1-84920-376-0 (hc).

Teodoronsky, V. S. (2021). On methods of visual-landscape assessment of territories in the design of landscape architecture objects. *Forestry Bulletin, 25*(2), 57–63.

Trišić, I., Nechita, F., Milojković, D., & Štetić, S. (2023). Sustainable tourism in protected areas—Application of the prism of sustainability model. *Sustainability*, *15*(6), 5148.

UNESCO. (2023). *Yangantau Geopark*. https://en.unesco.org/global-geoparks/yangantau

Wahab, S., Cooper, C., & Tyler, M. P. (2015). *Tourism in the age of social media*. Routledge.

Yu, X. H., Wang, X., Ren, Y. G., & Liu, J. C. (2019). The landscape evaluation system of ecotourism villages in qinling mountains. *Applied Ecology and Environmental Research*, *17*(4), 8955–8968.

Zhu, L., Davis, L. S., & Carr, A. (2021). Visualising natural attractions within national parks: Preferences of tourists for photographs with different visual characteristics. *PloS one*, *16*(6), e0252661.