

# DIGITAL PATHWAYS FOR THE SUSTAINABLE PROMOTION OF BRIDE'S VEIL WATERFALL, CLUJ COUNTY

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**ABSTRACT.** *Digital Pathways for the Sustainable Promotion of Bride's Veil Waterfall, Cluj County.* This study developed an evidence-based digital tourism product for Bride's Veil Waterfall (Vălul Miresei/Răchițele), located in the Apuseni Natural Park, Romania, by integrating geographic information systems, virtual reality, 360° photography, multimedia documentation, onsite query form and immersive storytelling. The research combined a netnographic analysis of 3,890 Google Maps reviews published between 2013 and 2026, including 3,720 photographs and 142 videos, with thematic content analysis, on-site field survey, drone imagery, terrestrial photography, and the development of an interactive ArcGIS StoryMap. The results highlight the waterfall's strong scenic, hydrological, geomorphological, recreational, and cultural appeal, including its 30-metre cascade, distinctive veil-like water flow, surrounding limestone landscape, forest environment, hiking opportunities, seasonal ice formations, and associated local legend. At the same time, the analysis identified several challenges, including insufficient parking lots during high season, road and signage deficiencies, seasonal accessibility problems, the absence of public toilets and waste bins, littering, illegal vehicle access, overcrowding, and insufficient multilingual information. The resulting StoryMap addresses these issues by providing interactive maps, route-planning information, seasonal comparisons, hiking-trail data, safety recommendations, environmental guidelines, 360° panoramas, videos, and ambient audio. The study demonstrates that the integration of GIS, virtual reality, and immersive storytelling can enhance the accessibility, interpretation, promotion, and sustainable management of natural heritage sites, while future research should assess users' experiences, accessibility, immersion, and the platform's influence on visitor behavior.

**Keywords:** waterfall, virtual reality, storytelling, Apuseni Mountains, virtual tourism

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## 1. INTRODUCTION

Virtual reality (VR) plays an important role in tourism by providing an immersive digital simulation that can reproduce destinations and travel-related experiences in ways that are both engaging and accessible, allowing users to explore, interact, and feel present in a synthetic environment that may be fully immersive or semi-immersive (Bergua et al., 2025; Milgram & Kishino, 1994; Kieanwatana & Vongvit, 2024). In tourism contexts, this role is strengthened when visual interface quality, audio, vividness, authenticity, and user control are carefully designed, because these elements enhance immersion, enjoyment, and the sense of a lifelike experience, which can in turn support interest in travel and ecotourism intentions (Sharma et al., 2025; Le et al., 2026).

VR offers several key advantages in tourism, especially for natural, cultural, and ecotourism destinations. It supports sustainability by reducing the need for physical travel, which can lower carbon emissions and environmental pollution, while also helping protect fragile sites and promote conservation awareness (Le et al., 2026; Miswar et al., 2026; Bergua et al., 2025; Miłosz et al., 2025; Sharma et al., 2025; Sugiharto et al., 2025). It also strengthens destination promotion by increasing tourists' interest, improving destination image and branding, and encouraging travel intention, with positive effects on local economic development and community support (Miswar et al., 2026; Bergua et al., 2025; Sugiharto et al., 2025; Kieanwatana & Vongvit, 2024; Sousa et al., 2024).

In addition, VR helps tourists plan and customize their trips more effectively, provides better access for people with physical, financial, or geographical limitations, and offers educational value by conveying environmental, cultural, and scientific information in an immersive format (Miłosz et al., 2025; Chan et al., 2025; Sugiharto et al., 2025; Miswar et al., 2026).

VR-based 360-degree virtual tours can enhance public interest in natural attractions by simulating on-site exploration and highlighting the site's scenic and experiential qualities. For Curug Cimanintin and Campurasa Waterfall, this technology presents not only the visual beauty of the waterfall but also practical information about access routes, facilities, and ecotourism points of interest, thereby strengthening the destination's promotional value (Sugiharto et al., 2025). Waterfalls are among the oldest and most popular natural tourist attractions, having drawn visitors since ancient times (Hudson, 2006). Their appeal stems from the combination of the aesthetics of falling water, the sound of the torrent, and the surrounding ecosystem, which transforms them into major attractions (Canpolat, 2022). Beyond the aesthetic pleasure and the sense of "rejuvenation" experienced by visitors, famous waterfalls have become true tourist icons, and the landscapes created by water in the topography motivate people to explore them firsthand (Canpolat, 2022; Hudson, 2006). In the specialized literature, waterfalls are analyzed as geomorphological features-landforms of scientific,

historical, cultural, aesthetic, and socio-economic value-and understanding their role in local tourism and their tourism potential is considered essential for establishing and sustaining investments in tourism (Canpolat, 2022).

In Romania, waterfalls are a distinctive feature of the mountainous karst landscape, and the Apuseni Natural Park (ANP) provides an ideal setting for this type of ecosystem. The park is one of the largest continuous protected areas in Romania, comprising one natural park, three Natura 2000 sites, and fifty-five protected areas of national interest. Overlapping the Apuseni Mountains unit, it has moderate altitudes (maximum 1,848 m at Bihor Peak) and accessible slopes. The hydrographic network is particularly rich: the main watercourses originate in the central area, and the karst hydrogeology generates swallow holes (ponors) and intermittent springs (*izbucs*), giving water a leading role in the landscape (Moş & Brînzan, 2024). Its tourism impact at the county and regional levels is reflected in: (a) accessibility, favored by the moderate relief of the Apuseni Mountains and the proximity to the main road arteries; (b) integration into the tourist circuits of the ANP, which operates as a unified system of protected areas; (c) inclusion in a natural park, which confers protection and landscape management status (Moş & Brînzan, 2024). In 2009, the ANP received the title of European Destination of Excellence, because tourism is "the youngest sector of the local economy," capable of ensuring a steady infusion of financial resources into communities, especially when local companies provide services (Moş & Brînzan, 2024). The level of digitalization associated with promoting waterfalls as tourist attractions is low, and initiatives to create virtual tours associated with natural phenomena at the national level are underdeveloped. Thus, there are few examples of waterfalls that are promoted with virtual tours: Lolaia Waterfall (Retezat Mountains), Şopot and Cornet Waterfall (Poiana Ruscă Mountains) and the waterfall on the Gârbea estate (near Chiojdu, in Buzăului Mountains), where can be found limited 360° panoramic images.

Several arguments support the necessity of a VR tour for waterfalls: a) accessibility for people with physical disabilities, financial constraints, or time limitations (Calisto & Sarkar, 2023); b) virtual experiences can function as marketing tools and preparation for physical visits, without necessarily replacing them (Kokkhangplu, 2024); c) sustainability by reducing physical overcrowding and the carbon footprint (Calisto & Sarkar, 2023); d). VR covers planning and management, marketing, entertainment, education, accessibility, and heritage conservation (Calisto & Sarkar, 2023).

The aim of this article was to create a digital tourism product associated with the Bride's Veil Waterfall, from Cluj County, using emerging technologies (GIS, VR) and communication techniques (storytelling) to enhance its accessibility and promotion.

## **2. CONCEPTUAL FRAMEWORK**

### **2.1. Virtual reality in tourism: technological frameworks and sustainability implications**

VR is seen in tourism as a double-edged instrument: it can encourage people to visit real destinations, enrich later on-site experiences, and support learning and planning, but it can also discourage interest if the experience is technically weak or historically inaccurate (Alonso-García et al., 2025; Miłosz et al., 2025; Sharma et al., 2025).

VR applications in tourism display significant variation in terms of interactivity, immersion, and technological complexity, ranging from basic passive visualizations to advanced, participatory environments. At the simplest level, virtual tours consist of static 360° panoramic representations that allow users to observe a destination without influencing it. More advanced implementations progressively incorporate interactive features such as adjustable viewing angles, zoom, gyroscope integration, and selectable information nodes, while the most complex systems enable user-generated content, transforming virtual tours into participatory platforms that contribute to the enrichment of local tourism data. A systematic review of 360° virtual tour studies confirms that current practice emphasizes interactive and immersive design as a tool for digital tourism promotion (Sugiharto et al., 2025).

From a content perspective, VR tours can be developed either from recorded real-world imagery or through digitally reconstructed environments. Natural sites are typically represented using original 360° footage, processed through workflows involving stitching, stabilization, color correction, audio enhancement, and narrative integration (Miswar et al., 2026). In contrast, built heritage and architectural spaces are often recreated through 3D modelling based on detailed scans, as illustrated by the virtual reconstruction of the Pahlavon Mahmud mausoleum (Miłosz et al., 2025). This distinction has important implications for perceived authenticity, user engagement, and the diversity of destinations that can be represented.

The technological ecosystem supporting VR tourism encompasses tools for recording, processing, delivering, and consuming immersive content. Data acquisition commonly relies on 360° cameras such as Samsung Gear 360 or Insta360 X2, typically mounted on tripods for stability (Bergua et al., 2025; Clemente et al., 2025; Miswar et al., 2026). Post-processing is conducted using specialized software (e.g., 3DVista, Insta360 Studio), often supported by standard computing infrastructure for rendering and editing. Additionally, web-based technologies such as Three.js and Mapbox GL JS facilitate the development of interactive 3D environments and enable cross-platform accessibility via browsers on both mobile devices and VR headsets (Sharma et al., 2025).

Content delivery is increasingly web-oriented, with VR experiences hosted on tourism websites, dedicated platforms, or repositories such as Sketchfab, which support the integration of 3D models and interactive environments in HTML format (Sugiharto et al., 2025; Chan et al., 2025; Bergua et al., 2025). This approach enhances accessibility and supports the integration of VR directly into destination marketing strategies (Sousa et al., 2024).

On the user side, the level of immersion is determined by the type of device employed. Basic experiences can be accessed via smartphones, laptops, or desktop screens, whereas higher levels of immersion require dedicated VR headsets such as Oculus Quest 2, HTC Vive Pro 2, or Meta Quest Pro, often supported by OpenXR standards to ensure interoperability (Clemente et al., 2025; Miswar et al., 2026; Miłosz et al., 2025). Immersion can be further enhanced through controlled physical environments, such as rotatable chairs or dedicated VR spaces.

Beyond visual immersion, recent research highlights the growing importance of multisensory integration in VR tourism. Experimental systems incorporate haptic feedback (e.g., force, temperature, touch), as well as olfactory and gustatory stimuli, contributing to enhanced presence, improved destination image, and stronger cognitive and memory effects (Chan et al., 2025; Kieanwatana & Vongvit, 2024). However, the high cost and limited scalability of such technologies remain significant barriers. Consequently, the development of more accessible multisensory solutions, alongside complementary devices such as haptic gloves and full-body wearables, is identified as a key direction for future research, particularly in relation to increasing user engagement and enabling shared, socially interactive virtual experiences (Sousa et al., 2024).

International public policies increasingly provide a supportive framework for the use of immersive technologies in tourism. The European Strategy on Web 4.0 and Virtual Worlds, for example, positions Extended Reality (XR) as a key instrument for digital transformation, linking it to citizen empowerment, digital skills, industrial development, public services, and open standards, while also emphasizing its relevance for cultural and educational fields. This institutional recognition gives immersive applications such as virtual museums, virtual galleries, and other XR-based cultural experiences strategic legitimacy beyond their experimental status. In this sense, tourism-related immersive projects are no longer seen merely as technological innovations, but as initiatives supported by supranational policy priorities that encourage adoption, interoperability, and respect for digital rights (European Commission, 2023).

## **2. Encouraging pro-environmental behavior through virtual tourism**

Virtual tourism has emerged as an important instrument for encouraging pro-environmental behavior, not only by reducing the need for physical travel, but also by shaping users' awareness, attitudes, and intentions toward nature

conservation. Through immersive digital experiences, VR can foster a stronger appreciation of fragile ecosystems and protected areas, allowing users to explore them without causing physical degradation. This is particularly relevant for sensitive natural and cultural sites, where virtual experiences may help build environmental sensitivity and encourage more responsible behavior during later physical visits (Miłosz et al., 2025; Stappung et al., 2023). At the same time, the low-carbon nature of digital tourism makes it attractive for environmentally conscious travelers, especially among younger generations whose travel choices increasingly reflect concern for ecological impact (Choi et al., 2022; Mavrin et al., 2024).

The pro-environmental potential of virtual tourism is closely linked to presence, immersion, and emotional engagement. By creating a convincing sense of “being there,” VR can evoke emotional responses that strengthen users’ connection to the destination and increase their willingness to protect it (Shih, 2025; Stappung et al., 2023). This effect is reinforced when virtual experiences combine visual realism with contextual information about ecosystems, heritage values, or conservation challenges, helping users understand why a site requires protection. In this sense, virtual tourism functions as a learning environment in which tourists can develop ecological awareness before, during, or instead of an actual visit (Mavrin et al., 2024; Miłosz et al., 2025).

Another important contribution of virtual tourism lies in destination management. By offering compelling virtual alternatives, it can help redirect visitor interest away from overcrowded or environmentally vulnerable sites, thereby reducing pressure on places that are already suffering from intense tourism impacts (Miłosz et al., 2025). In addition, augmented reality can complement these efforts by overlaying interpretive information directly onto the environment, such as data on erosion, species presence, or restricted access zones, thereby guiding visitors toward less invasive forms of engagement (Ikeda et al., 2025). Together, these technologies support a more reflective and environmentally responsible form of tourism consumption.

A key condition for achieving these effects is authenticity. When virtual reconstructions preserve the sense of place and communicate the real value of a destination, they are more likely to inspire respect, curiosity, and protective attitudes among users (Mavrin et al., 2024; Miłosz et al., 2025). Research on the Virtual Travel Experience construct suggests that both affective dimensions, such as enjoyment, and cognitive dimensions, such as spatial understanding, contribute to the formation of a responsible image of the site (Choi et al., 2022). In this way, virtual tourism can operate as a digital pre-visit experience that builds knowledge and concern and may later translate into more careful on-site behavior and stronger conservation-oriented intentions.

Empirical studies support this interpretation. Research on ecotourism and heritage contexts shows that virtual experiences can increase interest in real

destinations while also raising awareness of their fragility and value (Le et al., 2026; Bergua et al., 2025). In the case of the Maule360 platform, users not only expressed strong intentions to visit after virtual experience, but also accessed the content primarily on smartphones, indicating that mobile-friendly design can broaden environmental outreach and democratize access to conservation-related information (Stappung et al., 2023). Similarly, studies of Gen Z users show high acceptance of VR tours as tools compatible with sustainable tourism, suggesting that immersive technologies may be especially effective among digitally literate audiences with strong environmental concerns (Miłosz et al., 2025).

Despite these promising results, several limitations remain. Current VR systems still struggle to replicate the full sensory richness of real environments, and their effects depend heavily on technical quality, realism, and ease of use (Chan et al., 2025; Miłosz et al., 2025). Poorly designed experiences may reduce engagement or fail to communicate the value of the destination effectively. Cybersickness, limited multisensory feedback, and concerns that prior virtual exposure may reduce the sense of novelty during a later physical visit also constrain adoption (Chan et al., 2025; Sousa et al., 2024). For this reason, virtual tourism should be understood not as a replacement for physical travel, but as a complementary tool that can support education, awareness, and more sustainable visitor behavior when carefully designed and responsibly implemented.

### **2.3. Immersive storytelling in virtual tourism**

Immersive storytelling in virtual tourism refers to the use of interactive digital narratives that combine visual, auditory, and participatory elements to create a stronger sense of presence and engagement. The effectiveness of immersive storytelling depends on the combination of technological immersion and psychological immersion. The first is grounded in the system itself and supports spatial presence, while the second is user-centered and produces telepresence, or the feeling of being inside the virtual environment. These dimensions are mutually reinforcing and are built through several interdependent components, including scenography, sound design, real-time rendering, virtual actors, and branching narrative structures (Pop et al., 2025). Sound design plays a particularly important role, as ambient audio, contextually aligned music, spatial sound, and professional narration amplify presence, guide attention, and sustain emotional engagement (Pop et al., 2025; Corrêa de Almeida et al., 2023; Le et al., 2026; Sugiharto et al., 2025; Clemente et al., 2025). From a consumer behavior perspective, well-crafted narratives and multisensory cues enhance flow experience and experiential quality, which in turn increase satisfaction and behavioral intentions; among these dimensions, immersion, participation, and surprise are especially important drivers of user value (Shih, 2025).

A notable recent development is the integration of generative artificial intelligence, which makes it possible to create personalized and adaptive

storytelling experiences on a scale. Ferracani et al. (2024) illustrate this through a mobile heritage tourism application that uses GPT-4 to generate narratives in which the tourist becomes the protagonist, moving through urban points of interest via AI-generated choices and imagery. At the same time, immersive storytelling is increasingly delivered through a variety of platforms, from advanced VR development environments to accessible web-based tools. ESRI Story Maps combine geographic information with text, images, video, and interactive maps, while platforms such as HeritageMaps and Sketchfab integrate spatial representation with interpretive content in ways that are educational, emotional and geographically grounded (Prayoga & Jumadi, 2026; Bergua et al., 2025). Destination-specific websites also provide an effective distribution channel for these experiences, extending their accessibility to wider audiences (Sugiharto et al., 2025).

In museum and heritage contexts, immersive storytelling helps reinterpret cultural spaces as environments in active dialogue with their public, supporting both discovery and interpretation. However, analysis of Romanian museum virtual tours shows that most still achieve only moderate to low levels of immersion, mainly because sound design, virtual actors, and branching narrative techniques are often absent (Pop et al., 2025). This gap between the theoretical potential of immersive storytelling and its practical implementation confirms the need for richer narrative structures and more integrated multisensory design in future virtual tourism applications (Sousa et al., 2024).

### **3. METHODOLOGY**

#### **3.1. Study area**

To assess a virtual tour associated with a waterfall, the Bride's Veil Waterfall from Cluj County was selected, located in the northern area of the Apuseni Natural Park. From a morphodynamic point of view, the stream presents a succession of three water-drop steps with a total height of approximately 35 m, developing towards the base into a characteristic flared shape with remarkable scenic value. The hydrological dynamics of the waterfall are closely linked to the pluvio-nival regime, its maximum visual potential being reached in spring, during the snowmelt period, or during intervals with excess precipitation.

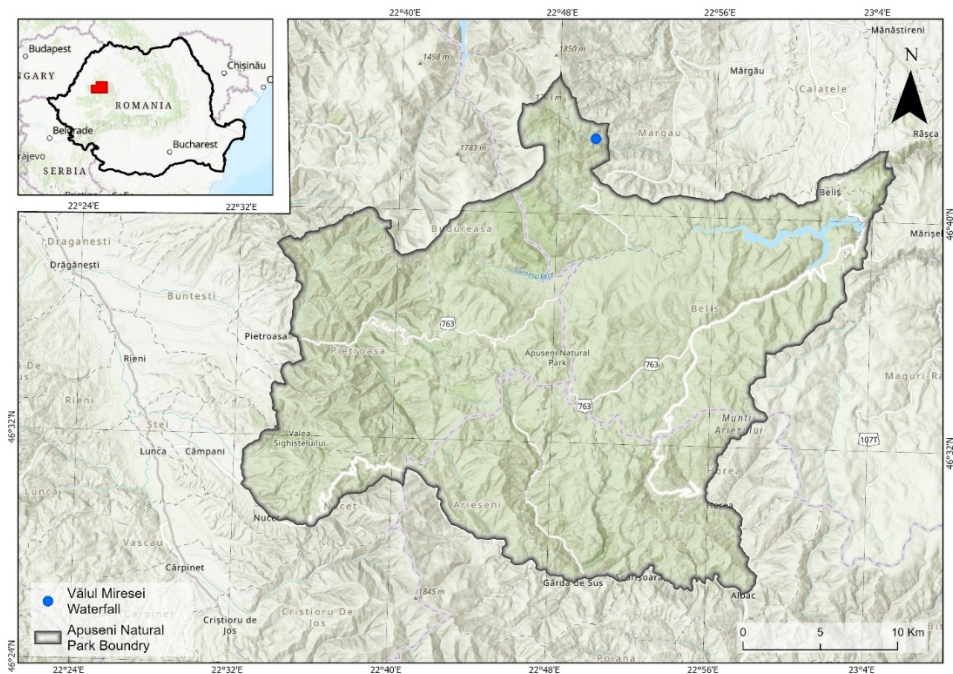


*Figure 1. Location of the study area in a territorial context*

### 3.2. Data collection

Netnographic analysis is a qualitative research method adapted from ethnography that focuses on examining the behaviors, interactions, and cultural dynamics of online communities and digital environments (Heinonen and Medberg, 2018). The primary data source for this study is Google Maps, chosen for its role as a leading global platform for user-generated content and its ability to provide "naturally occurring e-WOM" in a service context (Heinonen & Medberg, 2018). This study captures organic user-generated content to map the customer journey and identify key digital touchpoints within the service environment. The dataset consists of 3,890 reviews associated with the destination ("The Bride's Veil Waterfall"). This volume of data provides a robust longitudinal perspective, covering a 14-year period (2013-June 2026) (Table 1, 2). Consistent with netnographic best practices, the data collection includes non-textual elements (3,720 photos), responding to the call for research that moves beyond simple text analysis to gain a complete picture of value creation (Heinonen & Medberg, 2018). While 62% of the reviews are ratings without text, the high volume of 5-star ratings (87.9%) and the surge in reviews starting from 2019 indicate a significant growth in destination popularity and digital engagement.

**Table 1. Number of reviews associated with Bride's Veil Waterfall within 2013-2026**

| Year         | Reviews (no.) | Rating type (no.) |           |           |            |             | Review depth (no.) |                          |
|--------------|---------------|-------------------|-----------|-----------|------------|-------------|--------------------|--------------------------|
|              |               | 1*                | 2*        | 3*        | 4*         | 5*          | With text          | Without text/Rating only |
| 2013         | 1             | 0                 | 0         | 0         | 1          | 0           | 1                  | 0                        |
| 2014         | 2             | 0                 | 0         | 0         | 0          | 2           | 1                  | 1                        |
| 2015         | 3             | 0                 | 0         | 0         | 0          | 3           | 3                  | 0                        |
| 2016         | 9             | 0                 | 0         | 0         | 2          | 7           | 3                  | 6                        |
| 2017         | 70            | 0                 | 0         | 1         | 12         | 57          | 41                 | 29                       |
| 2018         | 116           | 0                 | 0         | 3         | 20         | 93          | 63                 | 53                       |
| 2019         | 915           | 11                | 5         | 17        | 104        | 778         | 327                | 588                      |
| 2020         | 598           | 1                 | 1         | 6         | 55         | 535         | 223                | 375                      |
| 2021         | 526           | 1                 | 0         | 17        | 43         | 456         | 202                | 324                      |
| 2022         | 481           | 2                 | 0         | 6         | 39         | 434         | 333                | 148                      |
| 2023         | 310           | 0                 | 1         | 4         | 32         | 273         | 189                | 121                      |
| 2024         | 376           | 1                 | 2         | 9         | 31         | 333         | 126                | 250                      |
| 2025         | 432           | 3                 | 3         | 9         | 26         | 391         | 141                | 291                      |
| 2026         | 51            | 0                 | 1         | 0         | 1          | 49          | 22                 | 29                       |
| <b>Total</b> | <b>3,890</b>  | <b>19</b>         | <b>13</b> | <b>72</b> | <b>366</b> | <b>3420</b> | <b>1466</b>        | <b>2424</b>              |

*Data source: Google Maps*

**Table 2. Number of reviews associated with Bride's Veil Waterfall within 2013-2026, according to multimedia content and temporal context.**

| Year         | Reviews (no.) | Multimedia content (no.) |            | Temporal context (no.) |            |               |               |
|--------------|---------------|--------------------------|------------|------------------------|------------|---------------|---------------|
|              |               | Photos                   | Videos     | Weekday                | Weekend    | Legal Holiday | Not Mentioned |
| 2013         | 1             | 0                        | 0          | 0                      | 0          | 0             | 1             |
| 2014         | 2             | 0                        | 0          | 0                      | 0          | 0             | 2             |
| 2015         | 3             | 0                        | 0          | 0                      | 0          | 0             | 3             |
| 2016         | 9             | 0                        | 0          | 0                      | 0          | 0             | 9             |
| 2017         | 70            | 29                       | 0          | 0                      | 0          | 0             | 70            |
| 2018         | 116           | 62                       | 0          | 0                      | 0          | 0             | 116           |
| 2019         | 915           | 683                      | 0          | 0                      | 0          | 0             | 915           |
| 2020         | 598           | 418                      | 0          | 0                      | 0          | 0             | 598           |
| 2021         | 526           | 541                      | 0          | 0                      | 0          | 0             | 526           |
| 2022         | 481           | 483                      | 2          | 2                      | 7          | 0             | 472           |
| 2023         | 310           | 439                      | 13         | 59                     | 81         | 16            | 154           |
| 2024         | 376           | 544                      | 54         | 81                     | 118        | 10            | 167           |
| 2025         | 432           | 460                      | 50         | 111                    | 140        | 17            | 164           |
| 2026         | 51            | 58                       | 23         | 10                     | 21         | 4             | 16            |
| <b>Total</b> | <b>3,890</b>  | <b>3720</b>              | <b>142</b> | <b>263</b>             | <b>367</b> | <b>47</b>     | <b>3213</b>   |

*Data source: Google Maps*

To acquire high-resolution spatial and visual data necessary for a detailed site analysis, comprehensive field documentation was conducted on 18 May 2026, at Brides Veil Waterfall. The primary objective of this stage was to collect multi-source data (both arial and terrestrial) for the spatial evaluation, structural mapping and visual modeling of the waterfall's surrounding landscape. For aerial data collection, an advanced DJI Mavic 3E Enterprise Remotely Piloted Aircraft System (RPAS) equipped with a Real-Time Kinematic (RTK) module was deployed. During these flight missions, 42 high-resolution aerial photographs and 11 videos were captured from various altitudes and viewpoints, enabling detailed mapping of the geomorphological structures and vegetation layer around the waterfall. Simultaneously, the arial survey was complemented at ground level by a Sony a7II full-frame mirrorless camera that was utilized to capture 16 photographs. These ground-based images focused on high-detail tactical features, rock face textures, and specific points of interest that could not be optimally captured from an aerial perspective.

An interactive web-based platform was developed using ArcGIS Online via the ArcGIS StoryMaps application to synthesize and showcase the collected cartographic and multimedia data. The core purpose of this digital tool was to promote the Bride's Veil Waterfall within a dynamic, virtual ecosystem, providing the public with an immersive, educational, and highly interactive experience. The individual 360-degree panoramic imagery was fully processed and integrated utilizing ArcGIS Pro before deployment to the web interface. From a structural and functional standpoint, our Story Map (<https://arcg.is/0znfua4>) integrates interactive cartography and immersive 360 visualization of the waterfall, with seasonal differences.

To verify the public awareness regarding the actual state of touristic valorization of Bride's Veil waterfall, a field survey was applied during the last weekend of August 2026, on the site of the fall. The query was divided into four distinctive sections, to approach and retrieve a synthetic perspective on visiting people and their opinion regarding present infrastructure and facilities around the fall, Virtual Reality tour and 360° previous experiences and possible improvement solutions that might increase the number of tourists within the area. The analysis of the answers received from the applied questionnaire is presented in sub-chapter 4.2.

### **3.3. Data analysis**

For the data processing and interpretation phase, this study deployed a hybrid methodological approach centered on thematic content analysis. This method serves as an established scientific framework to systematically transform unstructured, user-generated text from online environments into structured, conceptually defined categories (Lai & To, 2015; Neuendorf, 2018; Rutherford et al., 2022). While traditional content analysis operates predominantly within

quantitative or deductive boundaries, the integration of qualitative thematic analysis allows researchers to capture latent meanings, contextual nuances, and the authentic experiential dimensions embedded within visitor narratives (Andreotta et al., 2019; Neuendorf, 2018).

The empirical material for this research consisted of the text corpora from written reviews posted by visitors on Google Maps. To process this qualitative digital data while minimizing interpretive bias, the analysis followed rigorous grounded theory procedures, ensuring that codes and conceptual nodes emerged organically from the ground up (Branley & Covey, 2017; Lai & To, 2015). Through this systemic textual screening, several highly relevant and recurrent themes (no = 5) and sub-themes (no = 35) directly associated with the waterfall ecosystem (e.g., environmental features, infrastructure, and emotional responses) were successfully isolated. Following a manual qualitative extraction of these text-based themes, a descriptive quantitative validation was performed by calculating the exact frequencies of the codes across all sub-themes. This dual-layered qualitative-quantitative matrix allowed the study to map out satisfaction profiles and identify areas of friction, providing a balanced, data-driven overview of visitor perceptions.

In this stage of data analysis, the focus shifted from managing raw geospatial data to synthesizing a cohesive digital storytelling framework within ArcGIS Online. The primary objective was to design an immersive, educational, and visually compelling narrative. The narrative structure was engineered around a dynamic scroll telling architecture, ensuring that text descriptions, geographic transitions, and interactive widgets change synchronously to maintain contextual continuity. To maximize user engagement and facilitate autonomous spatial exploration, several advanced interactive elements were embedded directly into the ArcGIS Online environment:

- **Interactive Multi-City Routing Maps:** A dynamic web map was configured to display optimal travel routes, distances, and navigation paths from various nearby cities to Bride's Veil Waterfall. This enables potential tourists to assess accessibility based on their point of origin interactively.
- **Seasonal Landscape Slideshow/Swipe Tool:** To highlight the temporal dynamics of the Apuseni landscape, a comparative slideshow was integrated. This feature allows users to directly contrast the aesthetic differences of the waterfall and its surrounding environment between the summer and winter seasons, emphasizing its year-round tourism appeal.
- **Immersive 360-Degree Photography:** Panoramic 360-degree photos were embedded to grant users complete visual agency, allowing them to virtually look around the base of the waterfall and experience the scale of the landscape as if they were physically present.

- **Multimedia Integration (Video and Photo Galleries):** High-definition videos capturing the water flow and acoustic ambience were paired with curated photo galleries. These assets enrich the textual descriptions, transforming a traditional static map into a highly engaging sensory experience that stimulates sustainable tourism.

This methodological combination of structured geographic sequences and user-driven interactivity ensures that the Story Map functions not just as a promotional tool, but as an advanced spatial communication asset.

## **4. RESULTS**

### **4.1. The attractive features of the Bride's Veil Waterfall**

The Bride's Veil waterfall from Cluj County is one of the most iconic natural touristic sites within the Apuseni Mountain, which is associated with the water resource. The hydronime "Bride's Veil" (Vălul Miresei – in Romanian) is a common one use for naming waterfalls. Within Romania, there are another three waterfalls with this name or a very close similar one: first, on the western slope of Biharia peak (1597 m) within the Bihor mountains, a waterfall that is a part from a cluster of six falls situated in the upper hydrographic catchment of Crișul Negru River; second one called "Voalul miresei" is situated downstream of Stâna de Vale alpine resort on a short tributary of Valea Iadului River; third one, called the same "Voalul miresei" is on a right side tributary of Jieț River within a very narrow gorge sector that is define by another cluster of six falls. There is even a fourth one but does not include the "veil" in its name, which is called just Bridal Fall on a right-side tributary of Arieșul Mic River in the limits of Nemeși settlement, part of Vidra village in Alba County.

The most well-known waterfall from Cluj Conunty is situated on Valea Stanciului Creek, a left-side tributary of Valea Săcuieului River, upstream of Răchițele village, which sometime borrow its name to the waterfall in some reference sources. To access the fall, you got to start from Huedin, the smallest city in Cluj County and follow the county road DJ 108 towards Beliș village. From Răchițele village center you must take a right on the narrow road that goes upstream along Valea Stanciului for about 6 km. Along the road you will find several places for lodging or camping. The paved road is ending about 1 km before reaching waterfall and it is recommended that you park around this area and continue foot to the site. The fall is developed on to a knickpoint present on the longitudinal profile of Stanciului Creek. Based on its shape, the waterfall is associated with the fan-horsetail class (Beisel, 2006) with a multi-step sequence of three steps with following heights: 5, 8 and 22 meters. The water stays in contact with rock formation at a variable angle of at least 50-degree slope. The upper part lets the water flow into a narrow channel. After the first two small steps water transits its first plunge pool, around 2 meters deep followed by the

largest step toward the base that features a larger plunge pool. The last step is defined by a widening of flow into a fan-like shape which is like a classic bridal veil. The discharge is quite variable during the year, with larger volumes transited during spring season and lower ones in other seasons. In winter large ice formations surround the fall with steep icy walls and funnel-like tubes that create a dramatic waterscape. On the eastern slopes of Vlădeasa Mountains there are few other waterfalls that might get tourists' attention for visiting, which are less famous than the Bride's Veil fall. Thus, on the same creek, but upstream it can be found another fall: *Cascada de la Tău* and on a creek located north of this area, in the outskirts of Scind-Frăsinet village, the Răcad waterfall. Beyond the large base plunge-pool the riverbed is defined by a large variety in size of boulders and rocks barely rounded shape which comes mainly from local wall collapses, rather than from long-distance fluvial transport. Local petrography, according to the geological map of Romania is defined by a mixture of dacites and Jurassic age limestones.



**Figure 2. The Bride's Veil Waterfall and nearby facilities**  
*Photo: Cristurean Ainhua (2026)*

Site accessibility has been significantly optimized through modernization of local transport infrastructure, specifically a partially paved forest road from the village of Răchițele, facilitating consistent visitor flow via a gentle pedestrian approach of approximately 1.3 kilometers. However, adaptability for individuals with locomotor disabilities remains structurally constrained by the rugged natural

terrain (Peregrin prin Lume, 2015). Certified mountain trail signage (indicated by the red dot marker), along with local infrastructure such as wooden footbridges and protective guardrails, manages territorial connectivity originating and visitor safety (Cluj Tourism, 2026). Tourism promotion uses a dual approach, combining traditional physical media, such as maps and brochures, and the use of the landscape as a cinematic backdrop.

Seasonality trip extension and winter appeal are driven by the partial freezing of the vertical rock face, transforming the waterfall into a reference site for the technical mountaineering community by hosting ice-climbing competitions and gatherings (Romania Journal).

***Table 3. Calendar, labels, organizers and participants for ice-climbing events at Bride's Veil waterfall between 2004-2017***

| <b>Year / dates</b>                   | <b>Label (edition)</b>                                       | <b>Organisers and partners</b>                                                       | <b>No.</b> |
|---------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------------------------------|------------|
| 2004, 30-31 <sup>st</sup><br>January  | Cupa Răchițele, ed. I; National Ice Climbing Championship    | ANP, Salvamont and Local Council Mărgău,                                             | 20         |
| 2005, 28-30 <sup>th</sup><br>January  | Cupa Răchițele, ed. II; National Ice Climbing Championship   | ANP, Salvamont and Local Council Mărgău,                                             | 30         |
| 2006, 03-05 <sup>th</sup><br>March    | Cupa Răchițele, ed. III; National Ice Climbing Championship  | ANP, Salvamont and Local Council Mărgău,                                             | 38         |
| 2007, 02-04 <sup>th</sup><br>February | Cupa Răchițele, ed. IV; National Ice Climbing Championship   | ANP, Salvamont and Local Council Mărgău, Asociația Outdoor Apuseni                   | 35         |
| 2008, 01-03 <sup>rd</sup><br>February | Cupa Răchițele, ed. V; National Ice Climbing Championship    | ANP, Salvamont and Local Council Mărgău FRAE                                         | 45         |
| 2009, 06-08 <sup>th</sup><br>February | Cupa Răchițele, ed. VI; National Ice Climbing Championship   | ANP, Salvamont and Local Council Mărgău,                                             | 40         |
| 2010, 30-31 <sup>st</sup><br>January  | Cupa Răchițele, ed. VII; National Ice Climbing Championship  | Outdoor Apuseni, ANP, Salvamont and Local Council Mărgău, Cluj County Council, FRAE, | 40         |
| 2011, 29-30 <sup>th</sup><br>January  | Cupa Răchițele, ed. VIII; National Ice Climbing Championship | Outdoor Apuseni, Salvamont Vlădeasa; Cluj County Council, Mărgău Local Council, FRAE | 50         |
| 2012, 03-05 <sup>th</sup><br>February | Cupa Răchițele, ed. IX; National Championship                | Salvamont Vlădeasa, Cluj County Council, Mărgău Local Council, FRAE, ANP             | 40         |
| 2013, 01-03 <sup>rd</sup><br>February | Cupa Răchițele, ed. X; National Championship                 | Salvamont Vlădeasa, Cluj County Council, Mărgău Local Council, FRAE, ANP             | 45         |
| 2014, 08-09 <sup>th</sup><br>February | Cupa Răchițele, ed. XI; "ice climbing"                       | Salvamont Vlădeasa, ANP, Mărgău local Council                                        | 35         |
| 2015, 13-15 <sup>th</sup><br>February | Festivalul Pereților de Gheață                               | Salvamont Vlădeasa, Salvamont and Local Council Mărgău, ANP                          | 100        |
| 2016, 05-07 <sup>th</sup><br>February | Festivalul Pereților de Gheață                               | Salvamont Vlădeasa, Mărgău Local Council, ANP, Romanian Alpine Club                  | 100        |
| 2017, 04-05 <sup>th</sup><br>February | Festivalul Pereților de Gheață                               | Salvamont Vlădeasa Cluj; Mărgău local Council, ANP                                   | 50         |

Thus, on the left side of the fall, during cold winters, a natural ice wall, developed on a vertical cliff, has been the host for more than a decade between 2004 and 2017 for a free-climbing ice festival contest. The event has known two major phases: the first one (2004-2014) as the *championship phase* -” Cupa Răchițele” as a local and then national ice climbing contest; the second one was the *festival phase* with a rebranding as Ice-Walls Festivals -” Festivalul Pereților de Gheață” which was dedicated to all nature lovers and inviting everyone to experience ice-climbing sport. Table 3 presents some data regarding the calendar’s events, organizers and partners and official participants numbers.

Ultimately, the site’s tourist appeal is augmented by cultural storytelling techniques rooted in intangible local heritage; collective memory preserves the tragic myth of a bride who fell from the cliffs on her wedding day, whereby the tears of the wedding guests and the veil caught on the rocks supposedly formed the cascade, adding a mystical and romantic dimension to the overall visitor experience (Beyond Dracula, 2022; Cluj Tourism, 2026).



Figure 3. Posters from ice-climbing events organized at Bride’s Veil waterfall.

#### 4.2. Visitors' perceptions associated with Bride's Veil Waterfall

The thematic interpretation of user content associated with Bride's Veil Waterfall in table 4 provides a deep, qualitative look into how tourists experience the destination. By evaluating the text-based reviews, several clear behavioral, infrastructure, and perceptual patterns emerge across the five predefined analytical dimensions.

**Table 4. The main perceptions of tourists at Bride's Veil Waterfall, Cluj County**

| Theme/Sub-theme                              | Reviews (no.) |          |          | Observations                                                                                                                |
|----------------------------------------------|---------------|----------|----------|-----------------------------------------------------------------------------------------------------------------------------|
|                                              | Total         | Positive | Negative |                                                                                                                             |
| ACCESSIBILITY                                |               |          |          |                                                                                                                             |
| Parking                                      | 37            | 20       | 17       | Positive: organized parking, 10 lei/day.<br>Negative: insufficient spaces, lack of organized parking at the forest entrance |
| General accessibility (road + walking trail) | 90            | 75       | 15       | Positive: paved road, easy access, 15 min on foot.<br>Negative: difficult in winter, road damaged at certain points         |
| Connectivity (phone signal)                  | 4             | 2        | 2        | Mentioned either as a disadvantage or positively (disconnecting from technology - "No signal, enjoy the scenery!")          |
| Apuseni Natural Park                         | 18            | 18       | 0        | Mentioned positively as part of Apuseni Natural Park; ecological and territorial brand attraction                           |
| Narrow road                                  | 22            | 0        | 2        | Access-waterfall Road, single lane; difficulties when meeting oncoming vehicles                                             |
| Road condition (quality / works)             | 20            | 8        | 12       | Positive: recently paved/rehabilitated road.<br>Negative: potholes, last 5 km disastrous, ongoing roadworks                 |
| SUSTAINABILITY                               |               |          |          |                                                                                                                             |
| Nature (forest, river, rocks, vegetation)    | 75            | 70       | 5        | Negative: trees falling near the waterfall, storms bringing down fir trees; rocky face freezes in winter                    |
| Clean air                                    | 35            | 35       | 0        | Frequently appears as a standalone review: "clean air" - recognized relaxation and wellness value                           |
| Quietness                                    | 25            | 22       | 3        | Negative: weekend crowds destroy the quiet; weekday visits recommended                                                      |
| Hiking / walking                             | 55            | 55       | 0        | Easy hike, suitable for children, elderly, families; trail along the stream                                                 |
| Photography                                  | 18            | 18       | 0        | "Best photo experience", "amazing for photography lovers", rainbow visible in the spray on sunny days                       |
| Ice climbing                                 | 6             | 6        | 0        | Niche activity: rocky face freezes in hard winters; mentioned as a sporting objective                                       |
| Scenery                                      | 60            | 60       | 0        | "Superb / dreamlike / wondrous scenery" - extremely frequent; Stanciu stream gorge, limestone rocks                         |
| Viewpoint / panorama                         | 12            | 12       | 0        | Lespezi Peak (1 hour from the waterfall) and Pietrele Albe - repeatedly recommended as trail extensions                     |
| Litter / Waste                               | 25            | 3        | 22       | Positive: clean areas, respectful visitors.<br>Negative: rubbish on the trail, tissues, bottles, beer cans                  |
| Public toilet (absence)                      | 8             | 0        | 8        | "No toilets anywhere", "public toilets are missing", people use the forest as a toilet                                      |
| Bins (absence)                               | 7             | 0        | 7        | "Not even a single bin provided", "bins should be installed" - completely absent along the trail                            |

|                                                           |             |             |            |                                                                                                                                       |
|-----------------------------------------------------------|-------------|-------------|------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Visitor behavior                                          | 15          | 1           | 14         | Climbing dangerous rocks, writing on rocks, fires, lack of ecological awareness.<br>Positive rare: "locals are respectful"            |
| Tree felling                                              | 5           | 0           | 5          | "Shame they cut the trees near the waterfall", "nature is beautiful, shame about the deforestation"                                   |
| <b>ATTRACTIVENESS</b>                                     |             |             |            |                                                                                                                                       |
| Beautiful / gorgeous / wow / must see / spectacular, etc. | 400         | 390         | 10         | Most frequent category.<br>Negative: disappointment at low flow or during dry periods                                                 |
| Existing resource                                         | 450         | 440         | 10         | Virtually all reviews.<br>Negative: low flow, felled trees obstructed the view                                                        |
| Water flow / debit                                        | 12          | 7           | 5          | Positive: spectacular after rain. Negative: "just a trickle" (dry August), "we were disappointed"                                     |
| Seasonality / Best time to visit                          | 18          | 15          | 3          | Recommendations: spring / after rain, early morning, weekdays; winter - unique experience                                             |
| Legend /Story (Vălul Miresei)                             | 10          | 10          | 0          | Legend of the bride who fell from the rocks, veil caught on the rocks - mentioned with enthusiasm by visitors                         |
| <b>TOURISM PROMOTION</b>                                  |             |             |            |                                                                                                                                       |
| Map (orientation panel)                                   | 5           | 3           | 2          | "The map next to the waterfall shows the trails";<br>Some criticize the lack of clear maps in the area                                |
| Trail                                                     | 25          | 22          | 3          | Information on marked trails, distances, walking times; trails to Lespezi and Pietrele Albe                                           |
| Google Maps signage                                       | 5           | 1           | 4          | Wrong address on Maps, signs destroyed by roadworks; "impossible to find the way without GPS"                                         |
| Road signage                                              | 12          | 2           | 10         | "Poorly promoted through signage", lack of warning signs, no signs in Hungarian                                                       |
| Tourist services (kiosk, stalls, food)                    | 25          | 20          | 5          | Positive: pastries, lángos, tea, ice cream at the parking area. Negative: cash only, no products near the waterfall                   |
| Informational materials                                   | 6           | 2           | 4          | "A few panels with the legend, conduct rules wouldn't go amiss"; lack of information in minority languages                            |
| <b>TOURIST DESTINATION</b>                                |             |             |            |                                                                                                                                       |
| Congestion (illegal car access)                           | 28          | 0           | 28         | Luxury cars, BMWs, ATVs up to the waterfall, ignoring road signs; calls for barriers / fines / surveillance cameras                   |
| Tourist flow (general crowding)                           | 22          | 0           | 22         | "Crowded on weekends and holidays", "packed like sardines"; recommendation to visit on weekdays or early morning                      |
| Tourist infrastructure                                    | 15          | 10          | 5          | Positive: wooden bridge, shelter, selfie pontoon.<br>Negative: broken/dangerous bridge, lack of benches on the trail                  |
| Safety                                                    | 6           | 0           | 6          | Young photographer deceased (mentioned in 2 reviews), slip hazard, bridge with missing planks, fallen trees (site temporarily closed) |
| Destination experiences (atmosphere, energy)              | 15          | 15          | 0          | "Radiates positive energy", "you recharge your energy", "magical place" - subjective experiential dimension                           |
| <b>TOTAL</b>                                              | <b>1591</b> | <b>1342</b> | <b>249</b> | //                                                                                                                                    |

Data source: Google Maps

## 1. Accessibility

The final approach to the waterfall is widely recognized as a highly therapeutic, gentle walk that is exceptionally well-suited for families with small children or elderly visitors, with tourists noting that it is an "*Easy walk. For kids*

*of every age*" (N11, 2026) or describing it as *"one very beautiful experience both for us and for the little one"* (N281, 2025). However, the infrastructure leading to this point presents structural friction. The 10 lei/day organized parking lot is perceived positively as cheap and functional. However, it often faces physical limitations during peak tourist flows, as visitors note that *"when it is crowded there are no parking spaces"* (N12, 2026) or that they faced *"adventures due to the lack of parking spaces"* (N1075, 2023). The road layout from Răchițele village is offering highly polarizing feedback. While recent paving and rehabilitation projects are heavily praised because *"from Răchițele the road is paved, which is a plus compared to previous years"* (N344, 2025), the narrow single-lane morphology causes significant navigation stress when vehicles encounter oncoming traffic, leaving visitors to complain that *"the road is paved but too narrow in some places, sections where two cars do not fit very well from opposite directions"* (N394, 2025).

Seasonal dynamics further introduce extreme accessibility challenges. Winter landscapes turn parts of the unpaved trail into hazardous sheets of ice, making access difficult or impassable without specialized gear, as reviewers mention that *"given that we went in the cold period, we caught super slippery ice on the road on several sections and it was more difficult"* (N19, 2026). Interestingly, network connectivity reveals a split perception: the complete lack of mobile phone signal is either flagged as a logistical downside or celebrated as a valuable opportunity for technological detachment and environmental immersion, with users stating, *"no signal on the phone in the area, so enjoy the scenery!"* (N1013, 2023).

## **2. Sustainability**

Environmental quality is the destination's most distinct value proposition. The sensory combination of crisp air, the soothing roar of the water, and the natural scents of the forest functions as a highly restorative escape from urban fatigue, where users find *"only little birds, the murmur of the water, you cannot wish for more"* (N11, 2026), experiencing a state where *"all the tension from city life melted away"* (N182, 2025) and *"the forest smelled absolutely intoxicating"* (N220, 2025). This pristine imagery, however, is increasingly threatened by human negligence and administrative voids. The complete absence of public trash bins and waste management along the trail is a major source of public frustration, as summarized in reviews noting that *"the only downside is that there is no trash bin although there is a shelter set up right next to it"* (N842, 2024).

Visitors frequently report litter, plastic bottles, and discarded tissues in the surrounding woods, directly linking this pollution to a broader deficit in environmental awareness, stating that *"some people leave bottles, beer cans etc... ugly aspect"* (N1334, 2022). Similarly, the complete lack of public toilets forces visitors to use the forest edge, which severely degrades the aesthetic and hygienic

status of the natural park, with tourists noting that *"since there is no public toilet, people do their business next to the road, so the amount of trash is disappointing"* (N1334, 2022). Landscape aesthetics are also sensitive to physical disturbances. At the same time, natural windthrows from storms are understood; visible tree-felling activities close to the waterfall are actively criticized for altering the wild, ancient charm of the ecosystem, with tourists observing that *"unfortunately the wind knocked down the pine forest next to the waterfall, the place was cleaned, but it looks a bit deserted"* (N630, 2024).

### **3. Attractiveness**

The waterfall holds immense visual and symbolic authority, often described as a striking *"nature's work of art"* (N1844, 2021) or simply *"God's creation"* (N1649, 2022). The geological features -such as the massive limestone walls and the deep oval basin at the base - maximize the water's dispersal, perfectly justifying its romantic name, as it *"looks like a flowing bride's veil"* (N148, 2025) or because *"at the base of the upper step there is a deep oval basin... which scatters the water in the form of a veil"* (N347, 2025). The historical and cultural narrative of the fallen bride adds a unique emotional layer to the visit, with tourists often recounting the local legend with genuine enthusiasm and emphasizing the *"beautiful story and a fascinating place!"* (N28, 2026). Despite its high rating profile, the experience remains highly dependent on seasonal hydrological fluctuations. Visits during rainy springs or post-storm periods record maximum satisfaction due to the *"rainy weather this year which favored the waterfall with a fantastic flow"* (N804, 2024). Conversely, visiting during dry summer periods (particularly August) often results in public disappointment, as the grand cascade shrinks to a simple, weak stream, with users dryly noting: *"August 2024, only a trickle of water"* (N388, 2025).

### **4. Tourism promotion**

The spatial integration of Bride's Veil with the broader trail network of the Apuseni Natural Park is partially functional but lacks systematic backing. Educational infrastructure, like the map panel next to the waterfall, is noted as helpful for extending day hikes toward Lespezi Peak or Pietrele Albe, with reviewers suggesting that *"the route is very easy... it can be continued for Lespezi Peak"* (N47, 2026). However, signage deficiencies remain a recurring complaint. Digital navigation apps like Google Maps occasionally route users onto closed, dangerous forestry tracks, creating unnecessary confusion, with tourists warning: *"do not make the mistake to go to Arieșeni on the road indicated by Google Maps... unless you want to test your car for an off-road contest!"* (N1008, 2023). Physical signage is also lacking on alternative access routes, as users point out that *"between Remeți and Stâna de Vale... you have to be careful to discover it because for now there is no indicator"* (N584, 2024). Furthermore, international and

regional minority inclusion is largely ignored; foreign and Hungarian-speaking tourists explicitly point out the total absence of translated informational materials and multilingual roadside indicators on the interpretive boards, stating that there is *"not a single word in Hungarian on the informative panels"* (N3436, 2019) or detailing the historic naming discrepancies (N301, 2025). On the commercial side, food services at the base (selling local pastries, *lángos*, and snacks) are highly popular and add to the destination's hospitality vibe, with users recommending comment *"highly recommend the snacks from the stands!"* (N205, 2025).

## **5. Tourist destination**

The site faces an escalating management crisis regarding spatial control and behavioural monitoring. The most aggressive complaints target illegal motorized access. Despite clear regulatory signage banning vehicles past the parking lot, undisciplined drivers frequently force luxury cars, SUVs, and loud ATVs directly up to the base of the waterfall to take photos, entirely ruining the quietness, generating dust, and posing safety threats to pedestrians, with visitors complaining about *"people who go with cars until near the waterfall, even if they are warned through panels"* (N454, 2025) and stating that *"some with BMWs even climb right into the lip of the waterfall... maybe with some cameras and heavy fines they could stop this!"* (N3346, 2019). Weekend overcrowding creates a stressful environment that diminishes the overall quality of the experience, prompting frequent recommendations to *"come before 10 in the morning for the tranquility"* (N879, 2023) or to avoid it because it is *"extremely crowded at the end of the week"* (N1533, 2022). While built infrastructure upgrades - like the modern wooden bridge, protective shelter, and selfie pontoon - are praised for bringing visitors safely closer to the water spray (N535, 2024), safety issues remain a major concern. Tourists explicitly ask for better rules and monitoring because *"some people climb on the rock right next to the waterfall where there is a danger of slipping"* (N759, 2024), while others state that *"a few panels with the legend of the waterfall, conduct rules and cleanliness would not hurt, including someone who could warn them regarding safety rules"* (N698, 2024).

The applied questionnaire was completed on paper by 26 visitors, which agreed to share their opinions and thoughts about this subject. As mentioned before, the structure was divided into four sections: visitor's profile data, the quality of present infrastructure and nearby facilities, virtual reality with 360-degree media experience and overall ratings and improvement recommendations. Based on the age of the respondents, the results show that most respondents were within 26-60 years interval (more than 60 %), while the younger tourists were distributed equal at two intervals: under 18 and within 18 to 25 years, each one around 20 % share. Regarding the origin of the visitors, 58% came from Cluj County (mainly from Cluj-Napoca, but also from some close villages). Other counties with a share of 42% were representing tourists from Bihor, Sălaj, Timiș,

Satu Mare, Bistrița, Alba, Arad, Sibiu and Brăila. Most of them travelled with their family (73% of the respondents), with friends (15 %) and a mix of family and friends (12%). An interesting fact is that nobody has come alone or in an organized group. Most respondents have experienced this location for at least one in the past (69%) while for around one third of the total visitors this was their first visit.

On the second part of the questionnaire, associated with visitors' perspective on the actual infrastructure and available facilities, the answers were mainly positives: the road and trail to waterfall was very easy in most of the tourists' perceptions. The same opinion was derived from the signage rating, a question that was evaluating the quality and clarity of signage and large panel of tourist information along the trail and at the site location. The cleanliness of the trail and within the waterfall area was also a quality indicator of visitors' perception, which had met high value. The parking facilities nearby were another subject within the query form. Most of the answers received were happy with actual conditions (61%), even though from the parking lot to the fall you must go on foot for about 1.3 km. For analyzing future improvements, a semi-open question for possible solutions to increase the site infrastructure was also applied. The answers were suggesting that drinking water points, recycling bins, and available toilets onsite are the most recommended ideas.

The virtual reality and 360-degree media experience were another subject addressed to the visitors. More than 80% have not used this technology in the past but are convinced that VR can increase attractivity for this site in the future (11 - "yes" answers, 13 - "don't know" answers and only 2 -" no" answers). In association with last question another one based on the using of VR technique was applied, focused on what content might be integrated for visual experience. Most of them, 19 out of 26 received answers, would like to see an aerial/drone view of the waterfall, or an interactive map of hiking trails within the proximity of the site (13 answers).

### **4.3. Bride's Veil Waterfall Story Map**

To facilitate advanced geospatial dissemination and enhance the digital representation of natural heritage, an interactive Story Map was developed using the ArcGIS Online ecosystem. This web-mapping application bridges the gap between traditional cartography and modern multimedia, offering users an immersive geo-visualization experience. By structuring geographical, cultural, and environmental data into cohesive chronological and spatial sequences, the application serves as a comprehensive tool for sustainable tourism management and virtual geographic environments.

The application initiates with a rigorous geographical introduction to the Bride's Veil Waterfall (Răchițele), contextualizing its geomorphological significance within the Apuseni Mountains. To establish multi-scale spatial

awareness, the narrative integrates a web map hosted via ArcGIS Online. It provides micro-level localization by identifying the waterfall's precise geographic coordinates and immediate topographical features, and macro-scale delineation by outlining the site's boundaries within the protected area of the Apuseni Natural Park and illustrating its connectivity to Romania's national geographic network. Users can dynamically interact with these cartographic interfaces through pan and zoom functionalities, facilitating an intuitive understanding of the regional topography and accessibility.

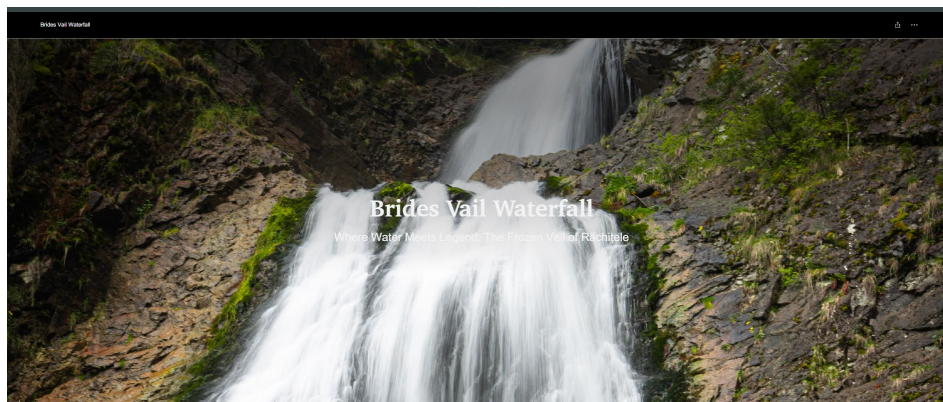


***Figure 4. StoryMap associated with Bride's Veil Waterfall***

To enrich the spatial data with cultural context, the subsequent section pairs high-resolution photography with local folklore. Detailed visual assets capture the complex morphology of the 30-meter water drop, highlighting its structural elements. Alongside this visual documentation, the cultural narrative of the Bride's Veil legend is integrated. This dual approach ensures that the digital twin of the site preserves both its physical-geographical attributes and its intangible cultural heritage.

A core interactive feature of the application is the temporal comparative analysis titled "A Tale of Two Seasons." Using a geospatial swipe widget, this section allows users to execute a side-by-side visual evaluation of the landscape's seasonal dynamics. By sliding a central partition, users can observe the hydrological contrast between the high-discharge summer flow and the completely frozen vertical ice walls characteristic of winter. The accompanying academic narrative analyses seasonal shifts in touristic utility, detailing permissible recreational activities ranging from summer hiking and landscape photography to specialized winter ice climbing.

The Story Map further extends its spatial scope by mapping the local network of hiking trails intersecting at the waterfall hub. Technical attributes,

including difficulty levels, standardized trail markers, and estimated hiking times, are provided for surrounding routes such as those leading to Lespezi and The White Rocks trail.

Concurrently, regional accessibility is addressed through an interactive routing map that connects the tourist attraction to major urban centers in Western and Northwestern Romania, specifically Cluj-Napoca, Huedin, Oradea, Alba Iulia, and Târgu Mureș. This analytical layout provides prospective visitors with empirical travel times, infrastructure conditions, and clear recommendations on seasonal equipment and safety apparel, serving as a safety and planning tool.

Addressing the imperatives of sustainable territorial development, a dedicated section focuses on environmental ethics and visitor regulations within the Apuseni Natural Park. This segment outlines the official code of conduct, emphasizing waste management protocols, noise mitigation, and restricted camping zones. Field photographs are strategically embedded to visually reinforce the existing sustainable tourism infrastructure and the sensitivity of protected habitats, encouraging responsible ecological behavior among virtual and physical visitors alike.

The concluding phase of the Story Map demonstrates the implementation of virtual reality and advanced multimedia within digital earth frameworks. This section incorporates a 360-degree interactive panorama captured at the base of the waterfall. This VR-ready asset simulates physical presence and spatial immersion. To complement the static and panoramic imagery, a high-definition video component captures the acoustic and kinetic properties of the water discharge. This synthesis of omnidirectional vision, video, and ambient audio provides a multi-sensory validation of virtual reality as a viable methodology for modern digital tourism and landscape preservation.

## **5. DISCUSSIONS**

The accessibility pillar of the Story Map rests on well-established ground. The design of the platform as an equitable digital alternative for people with physical or sensory disabilities, medical conditions, age-related limitations, logistical constraints or reduced financial means is consistently supported by the literature, which documents that VR expands entertainment and travel possibilities for *"people with disabilities, mobility limitations, or economic hardship can participate in immersive experiences that would otherwise be out of reach"* (Alonso et al., 2025), proving especially useful for places with access restrictions or requiring special protection. At the same time, the consulted literature tempers this claim, noting that VR *"is only able to remove structural barriers to a certain extent, yet many PwDs (persons with disabilities) still suffer from inaccessible tourism services"*, that the industry still lacks accessibility standards, and that the majority of participants with mobility impairments oppose the idea of VR replacing physical travel (Saltık & Kamyabi, 2025). Our platform

is therefore positioned as a complement and a facilitator of access rather than a substitute, a framing that is itself validated by the evidence.

A second validated pillar concerns the mitigation of overtourism. The claim that a high-fidelity virtual experience can divert a portion of potential visitors and thereby reduce physical pressure on vulnerable trails is directly confirmed by findings that VR can help reduce tourist pressure on particularly sensitive sites, both environmentally and culturally, allowing users to visit national parks without being physically present and thus protecting these sites from degradation, littering and excessive tourism (Naramski & Stecuła, 2025), and that it can reduce physical tourism in vulnerable areas, positioning virtual reality as a sustainable alternative capable of minimizing human impact in fragile spaces.

The pre-visit planning function is equally well supported. The routing map, with empirical travel times from Cluj-Napoca, Huedin, Oradea, Alba Iulia and Târgu Mureş, together with the recommendations on seasonal equipment and safety apparel, corresponds to a function already validated in comparable frameworks designed to provide access to data on possible routes so that visitors can plan safe and informed visits and to enable structured planning of visitor access (Savini et al., 2025). Social acceptance of this function is high: 79.1% of surveyed users considered VR useful before a trip, for exploring, planning or previewing a destination, and 48.4% saw value in it after returning from a trip (Stecuła & Naramski, 2025).

On immersion, the combination of a 360-degree panorama captured at the base of the waterfall, high-definition video and ambient audio reflects the established finding that *"the perceived realism within the Metaverse greatly impacts users' behavioural intentions and increases their willingness to visit actual tourist locations"* (Linh et al., 2025). The multi-device, browser-based delivery of our Story Map also aligns with the optimisation logic reported for other web-based VR platforms, where models with lower levels of detail can be accessed easily across a wide range of mobile and desktop devices without requiring high hardware specifications, a design choice validated by the fact that mobile access dominates 360° virtual tour consumption (Stappung et al., 2023).

Finally, the platform's educational and awareness function also reflects a validated mechanism. Integrating the official code of conduct, waste management protocols and spatial boundaries within the Story Map is supported by evidence that VR allows for engaging and emotional presentations of issues related to environmental protection, local culture and sustainable development, and that the immersive nature of the content allows users to respond more emotionally, increasing the effectiveness of the educational message and fostering pro-ecological attitudes. Our result - that the digital platform compensates for the absence of systematic on-site monitoring and signage - is therefore an application

of a validated mechanism to a documented local deficit, rather than a novel theoretical claim.

Several **research directions** follow from this confrontation between our results and the existing literature. The most immediate is field testing of the platform, since the closest methodological parallel in the collection states explicitly that its platform has been implemented and validated from technical and functional perspectives, although it has not yet undergone field testing; the same limitation applies here, as measuring satisfaction, flow, ease of use and the actual diversion of visitors requires an evaluation stage this study does not yet include.

A final and more ambitious direction concerns the technological maturation of the platform itself and the broadening of its object. The Story Map developed in this study stands at an entry level of immersion, combining browser-accessible panoramas, high-definition video and ambient audio; it could be progressively upgraded toward higher-fidelity formats - stereoscopic 360° capture, headset-based navigation, spatial audio and, eventually, haptic and olfactory layers - since the literature associates perceived realism with users' behavioural intentions and with their willingness to visit the actual destination (Linh et al., 2025), while simultaneously warning that VR cannot fully replace a real tourism experience because it cannot reproduce the multi-sensory richness of physical travel (Saltık & Kamyabi, 2025). Closing this gap is therefore both a technical and a conceptual programme, and one that is particularly worth pursuing for landscapes whose sensory identity - the sound of falling water, humidity, temperature, the texture of stone and vegetation - is central to their appeal. Alongside this, the ambition of virtual tourism can be extended from anthropogenic heritage to natural heritage. Much of the documented VR activity has concentrated on built and cultural assets, such as monuments, museums and historical reconstructions, whereas natural landscapes - often the very sites most exposed to overtourism and degradation - remain comparatively less explored. The observation that virtual tourism is especially valuable for "*places with access restrictions or requiring special protection*" (Alonso et al., 2025), the emergence of nature virtual tourism and environmental protection as a research category in its own right (Naramski & Stecula, 2025), and existing work applying virtual reality to the management of a volcanic natural landscape (Bergua et al., 2025) all point in this direction. Extending Story Map-based virtual storytelling to waterfalls, karst gorges, peatlands and other fragile natural sites would thus represent a natural next step for the field, and one in which the present study could serve as a pilot protocol.

## 6. CONCLUSION

This study sets out to create a digital tourism product for the Bride's Veil Waterfall, using emerging technologies - GIS and virtual reality - together with

storytelling techniques, to enhance the site's accessibility and promotion. Judging against that aim, the objective has been attained. The result is an operational ArcGIS StoryMaps application that integrates interactive cartography with an immersive 360-degree visualisation of the waterfall, a multi-city routing map connecting the site to Cluj-Napoca, Huedin, Oradea, Alba Iulia and Târgu Mureş with empirical travel times and recommendations on seasonal equipment, the comparative "A Tale of Two Seasons" swipe widget contrasting the high-discharge summer flow with the frozen winter ice walls, a mapped network of intersecting hiking trails with difficulty levels, markers and estimated times, and a dedicated section on environmental ethics and visitor regulations. These elements are grounded in a substantial evidential base: 3,890 Google Maps reviews covering a 14-year period (2013-2026), 3,720 photographs and 142 videos, complemented by a field documentation campaign conducted on 18 May 2026 with 42 aerial photographs, 11 aerial videos and 16 ground-level photographs. The thematic analysis of that corpus, organized into 5 main themes and 35 sub-themes with a total of 1,591 coded mentions (1,342 positive and 249 negative), did not merely supply the content of the platform - it identified the precise deficits the platform was designed to address, which is why the product can be described as evidence-driven rather than merely descriptive. For on-site feedback a visitors' survey was conducted in the last weekend of August, offering direct responses to present challenges and future updates needed to increase general touristic experience.

The contribution of the study to the sustainability of the location operates on two levels. The first is diagnostic: by systematically coding user-generated content, the analysis documented an escalating management crisis, with 22 negative mentions of litter and waste, 7 mentions of the total absence of public bins, 8 mentions of missing toilets, 28 mentions of illegal motorized access and 22 mentions of general crowding. The second is corrective: the Story Map embeds the official code of conduct, waste management protocols, noise mitigation measures and restricted camping zones directly into the visitor's experience, acting as a proactive intervention precisely where physical infrastructure lacks systematic monitoring and signage. In doing so, the platform functions as an educational framework that fosters ecological awareness before the tourist arrives at the site, and as a mechanism capable of diverting a portion of potential visitors to a virtual format and thereby reducing physical foot traffic, soil erosion, waste accumulation and habitat disruption on the vulnerable trails. This dual function aligns with evidence that virtual reality can reduce tourist pressure on environmentally and culturally sensitive sites, allowing users to experience national parks without being physically present and so protecting them from degradation, littering and excessive tourism (Naramski & Stecuła, 2025), and with the broader finding that immersive experiences are particularly

valuable for places with access restrictions or requiring special protection (Alonso et al., 2025).

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### **CRedit authorship contribution statement.**

Ainhoa-Naomi Cristurean: Writing - original draft, Conceptualization, Methodology, Investigation, Formal analysis; Anna Bretschneider: Writing - original draft, Conceptualization, Visualization, Methodology, Investigation; Răzvan-Horațiu Băținaș: Writing - original draft, Methodology, Visualization, Validation, Supervision.

### **Declaration of generative AI use**

During the preparation of this manuscript, the authors used Claude (Anthropic, Opus 5) to assist with language editing, restructuring, and translation, and Jenni.AI for the literature review. These AI tools were utilized solely to accelerate the screening and preliminary synthesis of the referenced articles. The authors reviewed and revised all AI-assisted content and assumed full responsibility for the final version of the manuscript.

### **Appendix**

The raw survey used in the paper can be accessed through the following QR code:



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