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Article

# Promoting geotourism through digital accessibility: A study of Portuguese geoparks's websites

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**Abstract:** Natural Protected Areas (NPAs) are critical for biodiversity conservation and ecological balance. These areas are not only refuges for wildlife but also pivotal in promoting sustainable tourism. Geoparks, a unique subset of NPAs, emphasize geological heritage, offering distinctive educational and recreational opportunities. This article explores the significance of Geoparks in Portugal for geotourism and assesses the accessible digital communication strategies of Portuguese Geoparks, emphasizing the analysis of pedagogical concerns. The study highlights the importance of online engagement in enhancing visitor experiences and promoting sustainable tourism practices.

**Keywords:** natural protected areas; geoparks; geotourism; sustainable tourism; digital communication; virtual accessibility

## 1. Introduction

Natural Protected Areas (NPAs) are integral to environmental conservation and significantly support biodiversity. They serve as habitats for various species and are vital for maintaining ecological functions. NPAs are designated regions aimed at preserving natural habitats and biodiversity. They include national parks, nature reserves, wildlife sanctuaries, and marine protected areas. These protected zones are essential for the conservation of endangered species and ecosystems. NPAs also play a key role in supporting scientific research, providing natural laboratories for studying ecological processes and species behaviour (Balmford et al., 2015; Eagles, 2014).

Beyond their environmental importance, NPAs are crucial for nature tourism, providing avenues for recreation, education, and environmental appreciation. Nature tourism within NPAs is a significant economic driver because it encompasses a range of activities such as hiking, birdwatching, wildlife safaris, and eco-tours. These activities generate revenue through entrance fees, guided tours, accommodations, and other tourism-related services (Eagles, 2014). Moreover, nature tourism promotes environmental awareness among visitors, fostering a conservation mindset and encouraging sustainable practices. Tourism in NPAs also supports local economies by creating jobs and stimulating local businesses. Community involvement in tourism activities ensures that the economic benefits are shared with local populations, enhancing their livelihoods and fostering a sense of ownership and responsibility toward conservation efforts (Balmford et al., 2015; Nyulas et al., 2024). However, managing NPAs for tourism requires balancing visitor demand with conservation

objectives to mitigate potential adverse impacts, such as habitat degradation, pollution, and wildlife disturbances. Striking this balance is essential for ensuring the long-term preservation of these areas, with shared responsibility between policymakers, tourism managers, and visitors (Honey, 2008; Hummel et al., 2017). Within the broader category of NPAs, Geoparks stand out due to their unique focus on conserving geological heritage while integrating educational, environmental, and economic development goals (Henriques and Brilha, 2017). As special-designated sites recognized by UNESCO, Geoparks emphasize geo-education and community engagement, using geotourism to foster sustainable local development and highlight the region's geological significance (Henriques and Brilha, 2017; UNESCO, 2020). As of 2024, there are over 213 UNESCO Global Geoparks in 48 countries, including six in Portugal, reflecting the growing global recognition of Geoparks as key assets for sustainable tourism and local engagement (Kudlas et al., 2024; Nyulas et al., 2024). To fulfil their conservation and educational missions, Geoparks increasingly rely on digital platforms to engage visitors and promote sustainable tourism. These online tools allow Geoparks to showcase their geological and ecological value to a broad audience, supporting responsible tourism and accessibility goals.

This study, therefore, focuses on how Portuguese Geoparks' websites are organized, to support and enhance visitor education and inclusivity, in line with current accessibility standards.

Digital communication tools are becoming increasingly vital as Geoparks seek to connect with a global audience, especially since the COVID-19 pandemic accelerated the adoption of virtual experiences and digital accessibility across many sectors, including tourism (Perakakis et al., 2016). Given the accessibility requirements outlined in Directive (EU) 2016/2102 and the European Standard EN 17161:2019, we assess how these websites align with the Web Content Accessibility Guidelines 2.0 (WCAG 2.0) of the World Wide Web Consortium (W3C), aiming to make educational and promotional content accessible to a diverse audience, including those with disabilities.

Considering the unique characteristics of Geoparks and their role in environmental conservation and tourism, this study explores how digital engagement through websites can foster both visitor education and sustainable tourism practices. The Portuguese Geoparks included in this study are Oeste, Açores, Naturtejo, Arouca, Terras de Cavaleiros, and the Estrela Geopark, which are the Portuguese Geoparks included in the UNESCO Global Geoparks Network. By assessing the digital accessibility and communication strategies of these Geoparks, this study seeks to contribute to the growing body of research on sustainable tourism and digital engagement accessibility in regarding natural heritage sites

## 2. Natural protected areas (NPAs) in Portugal

Portugal is known for its rich biodiversity and varied ecosystems, encompassing coastal, forested, and mountainous regions. To protect these areas, the country has established a network of NPAs, including a National Park, multiple several Natural Parks, Reserves, and UNESCO Geoparks. Geoparks, however, differ in their mission by focusing on geodiversity—a combination of unique geological formations, fossils,

and rock structures and actively promoting geoheritage as a part of sustainable tourism (Marta-Pedroso et al., 2018; UNESCO, 2020). While NPAs support a broad range of biodiversity, Geoparks emphasize geological awareness, community involvement, and geotourism, making them integral to nature tourism with a distinctive educational appeal. More specifically, according to the Portuguese Institute for Nature Conservation and Forests (ICNF, 2024), Portugal's network of NPAs includes one National Park, fourteen Natural Parks, eleven Natural Reserves, fourteen Protected Landscapes, seven Natural Monuments, and four Private Protected Areas. These protected areas help preserve biodiversity and serve as a platform for promoting sustainable tourism, which balances conservation with the economic and social needs of local communities (Marta-Pedroso et al., 2018). As noted in recent literature, sustainable tourism in NPAs requires carefully managed visitor flows, efforts to reduce the ecological footprint, and strategies for enhancing visitors' environmental awareness and behaviour (Hummel et al., 2017; Kudlas et al., 2024; Nyulas et al., 2024).

Thus, NPAs play a vital role in preserving Portugal's unique flora and fauna. They protect habitats of national and international importance, including those of endangered species like the Iberian lynx (*Lynx pardinus*) and the Spanish imperial eagle (*Aquila adalberti*) (Decree-Law 11/2023). Beyond biodiversity conservation, NPAs contribute to ecosystem services such as water regulation, soil protection, and carbon sequestration, which are essential for environmental sustainability and human well-being (Hummel et al., 2017; Marta-Pedroso et al., 2018).

The Institute for Nature Conservation and Forests (ICNF) is the authority responsible for managing NPAs in Portugal and for implementing management strategies which involve developing and implementing action plans that focus on habitat restoration, species monitoring, and the regulation of human activities within protected zones (https://www.icnf.pt/conservacao/rnapareasprotegidas). Collaborative efforts with local communities, non-governmental organisations, and academic institutions enhance the effectiveness of these conservation measures.

Consequently, sustainable tourism in NPAs, and more specifically geotourism, has gained significant attention over the past few decades to balance environmental conservation with economic development. The growing awareness of the environmental impacts of tourism has prompted stakeholders to promote practices that ensure the long-term sustainability of natural resources (Butler, 1999). Nevertheless, promoting sustainable tourism in natural areas faces several challenges, namely environmental degradation through the increased tourist activities that can lead to habitat destruction, pollution, and depletion of natural resources (Liu, 2003); community displacement and loss of traditional cultures (Honey, 2008); and economic leakage, since profits from tourism often do not remain in the local economy but are repatriated by foreign investors (Matos et al., 2022; Weaver, 2001).

## 2.1. Geoparks and geotourism

Geoparks are distinctive within NPAs for their focus on geodiversity and the geological processes that shape natural landscapes. The Portuguese Geoparks highlight significant geological formations, such as volcanic landscapes and fossil

records, alongside natural and cultural attractions. These sites aim to foster sustainable tourism through geoeducation and community involvement, providing visitors with insights into the geological heritage of the region (Henriques and Brilha, 2017; UNESCO, 2020). Recent studies indicate that the integration of geodiversity and biodiversity conservation in Geoparks enhances their role as tourism destinations and educational hubs, strengthening both local identities and environmental stewardship (Nyulas et al., 2024).

Recognised by UNESCO, Geoparks play a multifaceted role in conservation and tourism, serving as outdoor museums, educating visitors about Earth's history and geological processes.

By interpreting geological heritage, Geoparks contribute to understanding natural phenomena and the importance of preserving geodiversity (UNESCO, 2020). This educational aspect differentiates Geoparks from other NPAs, adding a layer of scientific and cultural enrichment to the visitor experience. Therefore, in addition to geological conservation, Geoparks promote sustainable development through geotourism. Geotourism, a specialized form of nature tourism, focuses on geological and geomorphological features. It serves as an educational tool, raising awareness of geological heritage and promoting the conservation of geodiversity within the context of nature tourism (Migo´n and Pijet-Migo´n, 2024). Portuguese Geoparks have become significant geotourism destinations, attracting both international tourists and local visitors interested in exploring unique geological landscapes, offering valuable opportunities for sustainable tourism that aligns with the goals of environmental conservation and public education (Al Mohaya and Elassal, 2023; Dowling, 2014; Henriques and Brilha, 2017). The distinctiveness of Geoparks in promoting geotourism lies also in their integration of local communities, as well as their provision of educational content, which fosters a deeper understanding of earth sciences among visitors. Research has shown that these initiatives can lead to greater local engagement and support for conservation efforts, as communities gain both economic benefits and a stronger sense of identity (Kudlas et al., 2024; Nyulas et al., 2024). Through their emphasis on geotourism, Geoparks enhance the visibility of geological heritage, contribute to regional development, and provide an inclusive, educational experience for all visitors.

This form of tourism is designed to minimise environmental impacts, support local economies, and involve communities in managing and promoting geological heritage (Al Mohaya and Elassal, 2023). Geoparks often implement sustainable tourism practices such as eco-friendly accommodations, renewable energy use, and waste management systems, aligning with broader conservation goals.

In Portugal, there are six UNESCO Global Geoparks, highlighted in **Figure 1**.


**Figure 1.** Location of portuguese UNESCO world geoparks.
Source: https://geoparquealgarvensis.pt/unesco/rede-portuguesa-dos-geoparques-mundiais.

These Geoparks are Naturtejo, Estrela and Oeste in central Portugal, Arouca and Terras de Cavaleiros in northern Portugal and Geopark Açores, located on the Azores islands in the middle of the Atlantic Ocean. There are also two more candidates for classification of UNESCO Global Geoparks, one in Viana do Castelo and another in Algarve. The territories each covers have very different characteristics, having in common the concern for the conservation and protection of natural and cultural values and the promotion of sustainable development involving local communities.

The Naturtejo Geopark, the first to be classified, is home to seventeen geo monuments, including the Portas de Ródão on the Tagus River and the ichnofossils of Penha Garcia. Its territory encompasses the Tagus International Natural Park and allows the activity of birdwatchers with 154 species to observe. It also allows other leisure and sports activities, such as climbing, canoeing, mountain biking, and hiking, very popular among adventure enthusiasts.

Estrela Geopark is where the highest mountain in mainland Portugal is located. In this territory, the marks of the last glaciation stand out in several places, such as the Zêzere Glacier Valley or Lagoa Comprida. Marked trails allow visitors to access unique views, especially the lagoons and rocky landscapes. Also noteworthy is the variety of cultural heritage in the small villages, including castles, churches, temples and museums.

Geopark Oeste's geological heritage is internationally known for its unique preservation characteristics and discoveries in palaeontology, with more than 180 fossil sites and 12 species of dinosaurs found for the first time in the territory having been identified. In this region, there is also an incredible biodiversity of fauna and flora and 70 geosites, including coastal cliffs made up of layers over 200 million years

old. Several walking trails and vehicle routes allow visitors to discover historical sites where important battles were fought against the invasions of Napoleonic troops.

The Arouca Geopark has 41 geosites, including the Castanheira birthing stones or the giant Trilobites of Canelas. This mountainous territory, whose highest points are in the mountains of Freita and Montemuro, is crossed by rivers with excellent conditions for canyoning, canoeing or rafting, with the Paiva rapids being one of the most popular places for nautical activities. Other attractions are the Frecha da Misarela waterfall, an outstanding natural attraction, and the Paiva Walkways, which cross the geopark for 8 km. It was the second Portuguese geopark to be created in April 2009.

In the Geopark Terras de Cavaleiros, around 180 km of trails go along 42 geosites, where the Protected Landscape of Albufeira do Azibo stands out. The diverse activities include bird watching, mountain biking, canoeing, and kayaking. This region also addresses attention to promoting local gastronomy and cultural traditions, particularly the Caretos de Podence.

The Azores Geopark has 121 geosites spread across the nine islands and the surrounding marine area, reflecting the archipelago's vast volcanic geodiversity. Each of the islands has specific characteristics, having in common the overwhelming beauty of an intoxicating nature. Volcanoes, calderas, lagoons, lava fields, fumaroles, thermal waters, "fajãs"–a flat coastal land formed by landslides or lava flows, cliffs, caves and volcanic caves are part of the geological sites where Pico Mountain stands out.

## 3. Geoparks, geotourism and virtual accessibility

In the context of geotourism, analyzing Geoparks' websites is essential for understanding how these unique sites communicate their geological and ecological value to the public. Websites serve as primary platforms for conveying information about geological heritage, conservation initiatives, and sustainable tourism practices, effectively bridging the gap between Geoparks and potential visitors. A well-designed website not only provides practical details on visiting but also offers educational content that enhances visitors' appreciation of geological and cultural features, fulfilling the Geopark's mission of geo-education. Additionally, websites play a crucial role in promoting accessibility and inclusivity, allowing Geoparks to reach diverse audiences and engage those who may not be able to visit in person (Carrión-Mero et al., 2020). By assessing the content, structure, and accessibility of Geoparks' websites, we gain valuable insights into how digital communication supports the goals of geotourism, fostering responsible visitation and broader public understanding of geological heritage (Xanthakis et al., 2024). It also allows to reach a global audience, attracting tourists worldwide. By maintaining an informative and visually appealing website, Geoparks can showcase their unique attractions and highlight their significance (Xanthakis et al., 2024). Through the linkage of social media platforms such as Facebook, Instagram, and Twitter it is possible to amplify their reach, enabling them to connect with a diverse audience and promote their activities and events (Perakakis, 2016). Digital communication facilitates collaboration with international organisations, researchers, and other Geoparks. This connection enhances knowledge exchange and best practices, contributing to the global effort to preserve geological heritage and promote sustainable tourism ((Xanthakis et al., 2024).

Given the importance of effective communication and accessibility in fostering geotourism, analysing Geoparks' websites becomes essential for understanding how they serve these goals. By examining the design, content, and accessibility features of Geoparks' digital platforms, we can assess how well they engage visitors, enhance educational experiences, and support diverse accessibility needs. This analysis also helps identify ways in which Geoparks can improve their online presence to provide a more inclusive and engaging experience. In doing so, Geoparks not only promote sustainable tourism practices but also reinforce their commitment to accessible geo-education and conservation, ensuring that these valuable resources are available to all potential visitors.

### 3.1. Enhancing visitor engagement through digital communication

Engaging with visitors through digital platforms enhances their experience and fosters a deeper connection with the Geoparks. Interactive elements such as virtual tours and multimedia galleries provide an immersive experience, making the websites more engaging and informative. Social media interactions, such as sharing photos, stories, and reviews, create a sense of community and encourage visitors to share their experiences. Moreover, digital communication allows Geoparks to provide real-time updates on events, weather conditions, and other relevant information. This context ensures that visitors are well-informed and can make the most of their visit. Engaging with visitors online also provides an opportunity to gather feedback and improve the services and attractions the Geoparks offer (Xanthakis et al., 2024). Even more important is that the digital communication carried out through the websites is accessible; that is, it complies with the requirements of WCAG 2.0 (W3C, 2023).

Virtual Accessibility, a user-centric approach, refers to the design and development of digital platforms (websites, apps, documents, multimedia) in ways that make them usable for everyone, including individuals with disabilities. It encompasses tools, techniques, and standards that enhance access to digital content for people with visual, auditory, motor, and cognitive impairments. Some core elements of virtual accessibility are screen reader compatibility (essential for users with visual impairments) (Thatcher et al., 2006) and keyboard navigation – designers must ensure that all interactive elements can be accessed via keyboard shortcuts without requiring a mouse (Henry, 2007); alternative text for images allows users who cannot see pictures to understand their content through accessible text descriptions (W3C, 2023); colour contrast and readability, which ensures sufficient contrast between text and background helps users with visual impairments, including those with colour blindness or low vision, to read content easily (Caldwell et al., 2008); closed captions and transcripts, that is, multimedia content should include captions for users who are deaf or hard of hearing - text transcripts can also provide an alternative way to access the content in audio or video files (Ellis and Kent, 2015); responsive design helps ensure that content remains accessible on both desktop and mobile devices (Marcotte, 2011); accessible forms and inputs with clear labels and simple instructions, ensuring that assistive technology can accurately interpret the inputs and outputs (Clark, 2002); avoiding flashing content that can cause seizures in individuals with photosensitive epilepsy (Waddell, 1998); and cognitive and language accessibility with simple and

straightforward language, consistent layouts, and intuitive navigation make content more accessible to understand for users with cognitive or learning disabilities (Seale, 2006).

By adhering to these principles of virtual accessibility, designers and developers play a crucial role in ensuring that digital platforms, and more specifically websites, are inclusive and usable by people with disabilities. Frameworks like the Web Content Accessibility Guidelines (WCAG) provide standards for accessible design, which can be applied to various digital environments. These efforts are not just ethical but also align with legal requirements in many countries, ensuring broader digital inclusivity and upholding the rights of all users (Silva and Borges, 2020).

### 3.2. Geopark's "green" digital communication

Digital communication plays a crucial role in promoting sustainable tourism practices. By providing information on efforts, sustainable accommodations, and responsible travel guidelines, Geoparks can educate visitors and encourage environmentally friendly behaviour (Henriques and Brilha, 2017). Highlighting community-based tourism initiatives and local products supports local economies and promotes sustainability. Additionally, digital platforms can raise awareness about environmental issues and the importance of preserving geological heritage. By sharing stories, photos, and videos of conservation efforts and the impact of tourism, Geoparks can inspire visitors to become advocates for conservation and sustainability tourism (Perakakis et al., 2016). Geoparks, therefore, encourage sustainable tourism, promoting interactions between visitors and local communities. This minimises the environmental impact and strengthens the local economy by supporting small businesses and valuing local products (Newsome and Dowling, 2018). Many websites offer tips and guidance on how tourists can support sustainability, such as reducing their carbon footprint during their visit, preferring environmentally friendly modes of transportation, and participating in volunteer activities.

## 4. Materials and methods

The methodology was based on analyzing all six Portuguese Geoparks's websites. It was carried out qualitative and quantitative studies of the six websites, always from the user's perspective, emphasizing the pedagogical communication of their content. It was created observation grids for compliance with virtual accessibility requirements, and after collecting the URLs, we carried out quantitative and qualitative analyses of the information published on the respective websites. The integration of both qualitative and quantitative findings offers a holistic view of the digital engagement strategies employed by Portuguese Geoparks. This methodological approach not only highlights current strengths and weaknesses but also provides insights for optimizing digital platforms to better serve diverse audiences and foster sustainable tourism practices (Nyulas et al., 2024).

Regarding the quantitative analysis, the degree of compliance with the recommendations of WCAG 2.0, currently implemented by AMA (Agency for Administrative Modernization, I. P.), was checked, and we used the Access Monitor Plus automatic validator, version 2.1. This software is an automatic web accessibility

practices validator (WCAG 2.1), which verifies the application of accessibility guidelines in HTML content on a scale of 1.0 to 10.0. The three types of results are stratified by three priority levels (‘A’, ‘AA’ and ‘AAA’).

For a website to be considered accessible, text alternatives must be provided for any non-text content. This situation allows adaptation to the needs of each user, such as printing in enlarged characters, Braille, the possibility of reading aloud, symbols and more straightforward language. All content must be adaptable, discernible and accessible via the keyboard. It is also essential that there is a help option, and multimedia elements must provide identified content and texts with subtitles or audio descriptions (https://www.w3.org/Translations/WCAG20-pt-PT/) duly.

We checked for level A, AA, and AAA errors regarding acceptable and unacceptable and warnings to be checked manually. Digital accessibility errors are classified into different levels of compliance according to the WCAG (Web Content Accessibility Guidelines), organized into three levels that reflect the degree of compliance with accessibility principles and vary according to the severity and difficulty of implementation of corrections. Level A is the most basic and includes the minimum accessibility requirements that must be met for content to be considered accessible. Level AA is regarded as the standard for many accessibility laws in many countries worldwide, ensuring that content is accessible to a broader range of users. Level AAA is the highest and requires full compliance with accessibility standards. It is more difficult to achieve and is not mandatory for all websites, but it is the one that offers the most significant degree of accessibility.

Errors that need to be checked manually generally involve more subjective aspects, such as content clarity or usability, so it is essential to combine automatic testing with manual audits carried out by accessibility experts (W3C, 2023).

The tests on the first user interface pages in Access Monitor Plus were compiled between the 8th and 10th of September 2024. This data is essential as the websites are constantly being updated, so the validity of the analysis is relatively short.

The elements chosen for the qualitative analysis of the virtual accessibility of the six websites were those listed below: the accessibility symbol, the existence of search functionality, the educational services page, online activities related to educational services, sustainability concerns, and tourist programs. This option is related to the fact that the elements are usually selected for qualitative analysis based on existing literature (Silva and Borges, 2020; Silva et al., 2022). However, the selected elements for qualitative analysis were adapted according to the theme of the research. In this investigation, it was highlighted the importance of analyzing the educational services page, online activities related to educational services, sustainability concerns, and tourist programs. The selection of other elements is related to accessibility issues. If a website has the accessibility symbol, it implies that it has managed to overcome all the basic elements of virtual accessibility. Moreover, the existence of search functionality is a basic element that allows for the quick retrieval of any information.

### 4.1. Digital adaptation and virtual accessibility

The compliance of the websites analyzed with the different levels, although variable (**Table 1**; **Figure 2**), presents medium and weak values, with none reaching the desired value of 10.

**Table 1.** Characterization of some elements of the websites analyzed.

| Geopark | Website | Index Access Monitor Plus | Accessibility Symbol | Search functionality | Educational Services Page | Online activities | Sustainability concerns | Tourist programs |
|---|---|---|---|---|---|---|---|---|
| Naturtejo | https://www.naturtejo.com/ | 6.1 | No | Yes | Yes | Yes | Yes | Yes |
| Estrela | https://www.geoparkestrela.pt | 7.3 | No | Yes | Yes | Yes | Yes | Yes |
| Oeste | https://www.geoparqueoeste.com | 7.6 | Yes | Yes | Yes | Yes | Yes | Yes |
| Arouca | http://aroucageopark.pt | 6.7 | No | Yes | Yes | Yes | Yes | Yes |
| Terras de Cavaleiros | https://geoparkterrasdecavaleiros.pt/p/pt/ | 5.6 | No | No | Yes | Yes | Yes | Yes |
| Açores | https://www.azoresgeopark.com/ | 3.4 | No | Yes | Yes | No | Yes | Yes |

Source: authors.

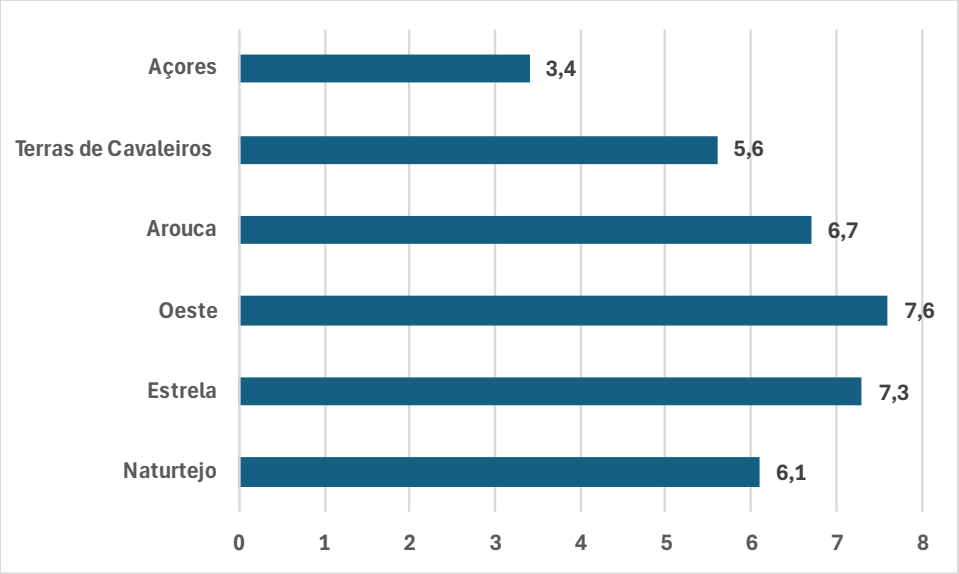


**Figure 2.** Access monitor plus indexes for the websites analyzed.

Source: authors.

It was started the qualitative analysis with the websites that present the best performance in terms of virtual accessibility. The Geopark of the Oeste is the one that performs the best. **Table 1** clearly shows that all qualitative elements analyzed are present on the Oeste Geopark website. The assessment highlights the educational services webpage as the strongest feature, offering a variety of online and in-person activities for six distinct groups: daycare, preschool, first through third cycles, high school, higher education, and seniors (https://www.geoparqueoeste.com/menu/662/geopark-oeste). This attention to providing information tailored to different age groups is commendable and represents a significant asset. The accessibility symbol only exists on the Geopark do Oeste website, as none meet the virtual accessibility requirements.

The search functionality exists in all the Geoparks' websites, except on the Terras de Cavaleiros Geopark website.

Educational services pages occur on all websites, even though the content's informative quality and diversity differ for each site. In the case of the Azores Geopark, the poorest of all, there are only a few documents to download.

Online activities related to educational services are also very diverse and naturally adapted to the realities of each geographic area, with learning activities about environmental conservation as the primary concern, generally carried out through partnerships with schools, which participate in trips, field activities or field activities focused on the environment and geodiversity—many websites present teaching materials and suggested activities that teachers can use before and after visiting the geopark.

Unfortunately, none allow interactivity or virtual visits, which would be very interesting. Some activities can be carried out remotely, while others can be done in person.

Concerns about sustainability, such as providing programs aimed at tourists, are present on all websites. Geopark managers seek to make tourists aware of the importance of responsible tourism practices while promoting enriching and environmentally conscious experiences. The focus on education, preservation and involvement of local communities strengthens the role of geoparks as promoters of sustainable development and conservation of natural heritage. The Naturtejo Geopark website promotes itineraries that combine history, geology and biodiversity, encouraging responsible tourism and contact with nature. The Arouca Geopark is known for offering sustainable trails, such as the famous "Passadiços do Paiva" route, which is why the website highlights efforts to maintain the region's sustainability, encouraging visitors to respect protected areas and adhere to low-cost tourist practices. impact. In the case of the Azores Geopark, which covers several islands in the Azores archipelago, geological and cultural tourism programs are offered that value both the natural heritage and the local community, with information on geotourism activities, environmental education and sustainable tourism events.

It is also interesting to offer information on almost all websites about regional gastronomy to strengthen the connection between tourists and local communities, promoting sustainable materials and products.

Regarding the available languages, we found that some websites have translations into multiple languages. However, internet features allow automatic translation, so we no longer consider this item relevant.

The quantitative analysis from the study of websites through Access Monitor Plus version 2.1 was chosen to analyze only the quantifiable results of level A, AA, and AAA errors (**Figure 3**), relating to acceptable, unacceptable, and warnings to be checked manually (**Table 2**).

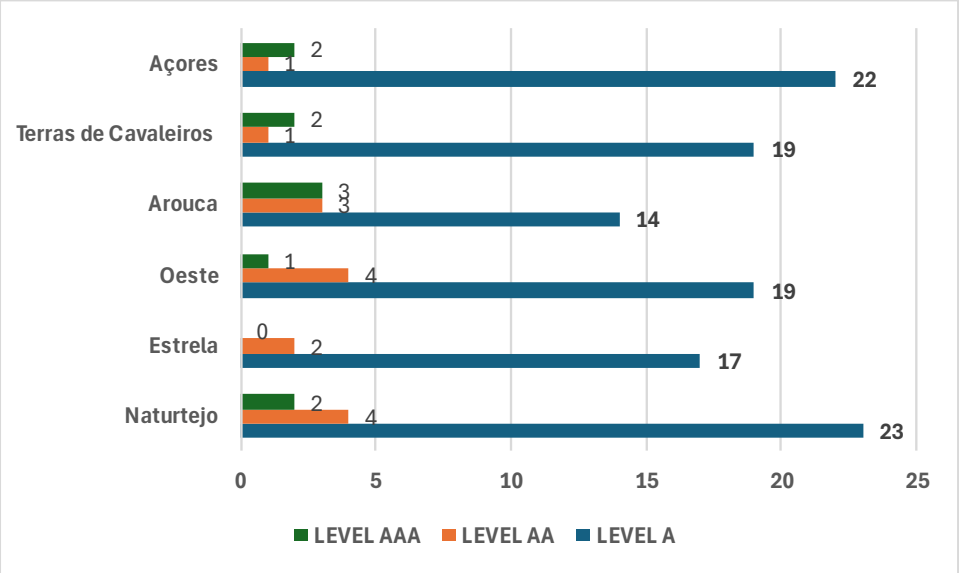


**Figure 3.** Error totals of the "A", "AA", and "AAA" level tests.
Source: authors.

The target audience comprises ordinary people, teachers, and different types of educators, students, and families who access educational services on websites to access various information. In this way, they intend to obtain diverse information to occupy, pedagogically, their free time or seek information that serves as a basis and/or support for different programmatic contents at the various levels of education. However, the results reveal poor accessibility for anyone with or without difficulty. The conclusions are very similar to those obtained with the analysis of the educational services of several Portuguese museums (Silva et al. 2022).

**Table 2.** Results of the "A", "AA", and "AAA" level tests were found.

| | **Access Monitor Index** | **LEVEL A** | | | | **LEVEL AA** | | | | **LEVEL AAA** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Acceptable** | **To see manually** | **Non acceptable** | **Total** | **Acceptable** | **To see manually** | **Non acceptable** | **Total** | **Acceptable** | **To see manually** | **Non acceptable** | **Total** |
| Naturtejo | 6.1 | 14 | 3 | 6 | 23 | 2 | 0 | 2 | 4 | 0 | 2 | 0 | 2 |
| Estrela | 7.3 | 9 | 3 | 4 | 17 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Oeste | 7.6 | 13 | 2 | 4 | 19 | 3 | 0 | 1 | 4 | 0 | 1 | 0 | 1 |
| Arouca | 6.7 | 8 | 0 | 6 | 14 | 2 | 0 | 1 | 3 | 0 | 3 | 0 | 3 |
| Terras de Cavaleiros | 5.6 | 6 | 1 | 12 | 19 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 2 |
| Açores | 3.4 | 6 | 3 | 13 | 22 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 2 |

Source: authors.

The quantifiable results of level A, AA and AAA errors, relating to acceptable, unacceptable and warnings to be checked manually, present high values in some cases, especially in the results of level A errors, also standing out unacceptable errors, as can be seen in **Figure 3**, are the highest on websites with less accessibility, such as those of Geoparques from Terras de Cavaleiros and the Azores.

In this quantitative analysis of errors by level, we noted the existence of high values and, as such, revealed the problems that most websites present regarding compliance with what is intended to be accessible to everyone. Thus, we can note that the quantitative data corroborates the qualitative data.

## 5. Discussion and conclusions

In today's digital era, effective online communication is essential for promoting Geoparks and engaging with potential visitors. The websites of Portuguese Geoparks are crucial tools for disseminating information, highlighting attractions, and providing practical details for tourists. An analysis of the websites of Portuguese Geoparks reveals several key features that enhance visitor engagement and promote sustainable tourism.

Some Portuguese Geopark websites provide detailed descriptions of geological sites, highlighting their significance and unique features. Informative content includes geological explanations, historical context, and descriptions of flora and fauna. This information helps visitors appreciate the scientific and cultural value of the Geoparks, fostering a deeper connection with the natural heritage. Additionally, the websites offer practical information such as opening hours, entrance fees, and safety guidelines. This information ensures that visitors are well-prepared for their visit and can plan their activities accordingly. Providing comprehensive and accurate information enhances the visitor experience and encourages responsible behavior.

Although Portugal, in 1999, was the first Member State of the European Union to adopt accessibility requirements for content and services made available by the Public Administrations on the Internet, the investigation revealed several weaknesses that affect the interest and motivations of visitors and other users about the offers of Geoparks and most protected territories in terms of nature. The computer analysis of the results of the websites allowed measurable data to be obtained, capable of enhancing the qualitative analysis regarding the strengths and weaknesses and the improvement needs that the analyzed websites require, from the perspective of any user and those that present, permanently or temporarily, limitations. The managers of the analyzed websites must make a considerable effort to make virtual accessibility a reality, both in terms of the enjoyment of the heritage they manage and in terms of the virtual accessibility of their websites, given that they do not comply with the basic principles of accessibility universal will negatively affect sustainability. We know that economic difficulties and the lack of professionals from different specialties continue to be difficult obstacles to overcome, but an effort must be made. Portuguese Geoparks websites would have much to gain from promoting interactive elements on websites, such as virtual tours, maps, and multimedia galleries, to enhance user experience and engagement. Virtual tours allow visitors to explore geological sites remotely, previewing the attractions and encouraging them to visit in person. Interactive maps highlight prominent sites and trails, helping visitors navigate the Geoparks and plan their itineraries. Multimedia galleries, including photos and videos, showcase the beauty and diversity of Geoparks, attracting potential visitors and providing visual insights into geological features. These interactive elements create an immersive online experience, making websites more engaging and informative.

Promoting sustainability is a core objective of Geoparks, which is reflected in their digital communication strategies. The websites provide information on conservation efforts, sustainable tourism practices, and preserving geological heritage. This messaging educates visitors about the need for responsible travel and encourages them to minimize their environmental impact. Additionally, the websites highlight eco-friendly accommodations, local products, and community-based tourism initiatives. It not only supports local economies but also promotes sustainable practices among visitors. By emphasizing sustainability, Geoparks can attract environmentally conscious tourists and foster a culture of conservation.

In this context, this study highlights the significant role of digital platforms in promoting sustainable tourism and geo-education within Portuguese Geoparks. The analysis of these Geoparks' websites revealed both strengths and areas for improvement in their digital communication and accessibility strategies. While these websites effectively serve as channels for providing geological and ecological information, educational resources, and visitor guidance, they also play an essential role in reaching a broader, diverse audience, including those with disabilities. Ensuring compliance with accessibility standards, such as WCAG 2.0, emerged as a critical factor in making these digital platforms more inclusive and engaging for all users.

Key findings suggest that incorporating interactive and multimedia elements—such as virtual tours, detailed geological descriptions, and immersive media galleries—not only enhances user engagement but also strengthens visitors' connection to the Geoparks' unique geological heritage. These digital features offer significant educational benefits, enabling remote visitors to experience and learn about Portugal's rich geological landscapes. To optimize engagement, Geoparks are recommended to further expand these interactive features and ensure that accessibility improvements are regularly audited to remain up to date with evolving standards and user needs.

Furthermore, linking these websites to social media platforms has proven effective in amplifying reach and creating a community around Geoparks. This approach fosters a sense of inclusivity and connection, encouraging visitors to actively participate in conservation and educational initiatives. Recommendations for enhancing these digital strategies include expanding social media content to include user-generated stories, conservation messages, and real-time updates on events and environmental conditions. By doing so, Geoparks can maintain strong visitor engagement, foster environmental awareness, and support local sustainable tourism goals.

In conclusion, this study underscores the need for continuous improvement in digital communication and accessibility strategies within Geoparks. By adopting these recommendations, Portuguese Geoparks can strengthen their role as accessible, educational hubs that promote sustainable geotourism, contribute to regional development, and foster global awareness of Portugal's geological heritage. These insights not only support local Geoparks but also offer valuable lessons for similar protected areas worldwide aiming to balance educational outreach with inclusive and sustainable tourism practices.

## 6. Study limitations

This study focuses on digital communication strategies and accessibility within Portuguese Geoparks. As a regional study, findings may not generalize to Geoparks in other countries, which may employ different digital engagement approaches.

The accessibility assessment relies on WCAG 2.0 compliance and automated tools, without direct input from users with disabilities; thus, user experience aspects were not directly evaluated. Future research could involve user feedback to provide deeper insights.

Additionally, digital content is dynamic; updates to websites and social media could affect accessibility features over time. Longitudinal studies could better capture these changes and their impact on accessibility and user engagement.

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