THE ROLE OF GEOPARKS IN SUSTAINABLE TOURISM DEVELOPMENT: A CASE STUDY APPROACH

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Abstract: This study aims to explore the role of geoheritage in sustainable tourism development by integrating geosites into tourism planning and analyzing their impact on local economies, environmental conservation, and community well-being, and visitor relaxation. The study also examines how the principles of a circular society, which emphasize resource regeneration and human well-being, can be applied to enhance the sustainability and appeal of geoheritage-based tourism. A mixed-methods approach was used, incorporating both qualitative and quantitative analyses. Case studies from Azores Geopark, Jeju Island Geopark, and Marble Arch Caves Geopark were selected to evaluate the socio-economic and environmental impacts of geoheritage-based tourism. The results indicate that geoheritage-based tourism significantly contributes to economic growth and environmental conservation, particularly when supported by strong community involvement and infrastructure development. Statistical analyses revealed positive correlations between visitor numbers and economic benefits, as well as between community engagement and conservation outcomes. Additionally, the promotion of relaxation at geosites was found to reinforce both environmental stewardship and visitor satisfaction, aligning with circular society principles by creating a regenerative tourism model. Geoheritage-based tourism promotes sustainable development by balancing economic, environmental, and social dimensions. The findings suggest that successful tourism management requires careful planning, infrastructure investment, and active community participation. This study did not include a comparative analysis of areas that are underutilized in terms of both geoheritage and geosites with tourism potential, primarily due to limited resources and time constraints. Incorporating such a comparison would offer valuable insights into the key conditions required for the successful development of geoheritage-based tourism. It is anticipated that future research will address these limitations by broadening the scope of case studies to include a more diverse range of geographical contexts. Moreover, future studies should seek to integrate qualitative approaches alongside quantitative approaches in order to better understand the wider social and cultural role and impacts of geoheritage-based tourism, which can thus be an important tourism product worldwide.

Keywords: geoheritage, geosites, sustainable tourism, environmental conservation, economic development, community involvement, tourism planning, geoparks, circular society

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INTRODUCTION

The tourism industry is the fastest-growing sector in the world's economy; besides bringing economic gains, it fosters cultural exchange and improvement. In recent decades, niche tourism, called geotourism, has also attracted attention toward natural landscapes, geological formations, and geoheritage sites. Geotourism not only enriches the tourism experience with special insights into the geological history of the Earth but also plays an important role in environmental education, conservation, and community development. Interest in geosites and geoheritage as part of tourism is on the increase; this underlines the need for their preservation into the future as natural assets. Within the framework of a circular society, tourism development emphasizes not only sustainable resource use but also the promotion of human well-being. A key aspect of such well-being is relaxation, which fosters a mindful connection between visitors and nature.

By integrating relaxation opportunities within sustainable tourism, destinations can enhance both environmental conservation and the quality of life for tourists, aligning with the principles of a circular society where resources and experiences are shared and regenerated. The paper aimed to explore how geoheritage might play its role in developing sustainable tourism by integrating geosites into tourism plans, according to how such planning affects the local economy,

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environmental conservation, and the well-being of communities. Assessment, through case studies from three particular geoparks, uses a mixed-method approach, including both qualitative and quantitative analyses in measuring the impacts of geoheritage-based tourism on the socio-economic and environmental status.

It is also defined as the inventory of geomorphological sites, landforms, and landscapes of scientific, aesthetic, or cultural importance. Geotourism is developed around such concepts, focusing on specific sites where the geoheritage is well represented. Common geosites include mountains, caves, waterfalls, and rock formations that provide a window to the Earth's history and present state. Besides giving a boost to the local economy, such geosites raise environmental conservation awareness. They are living museums where interaction with the natural environment may be informative in as many different geological processes as have been taking place for many millions of years.

In the face of climate change and environmental degradation challenges of the 21st century, among others that border on socio-economic inequalities, serious attention needs to be directed towards the question of sustainable tourism development. As sustainable tourism increasingly requires integrated governance and innovation-driven policies, insights from related sectors can be instructive. For instance, Afadzinu et al. (2024) highlight how audit institutions can play a catalytic role in policy innovation, particularly within Ghana's industrial sector, offering lessons that could extend to tourism and natural resource management contexts. Tourism based on geoheritage might have huge potential in encouraging responsible tourism respectful of natural resources and bringing economic advantages at the local level. Geosites would play a dual role: an important tourist attraction as well as a means for taking conservation work forward. However, the prosperity of geoheritage-based tourism must be carried out in a carefully planned, managed manner and with community input. Without such elements, tourism can result in ecological degradation and compromise the very resources on which tourism would focus. This paper aims to discuss the potential and role of geoheritage in the processes of sustainable tourism development, especially in relation to the integration of geosites into tourism planning. Supported by a literature review and several worldwide case study analyses, this paper will go on to discuss the level at which geoheritage-based tourism is able to contribute to economic development, environmental conservation, and community well-being. The subsequent sections will then highlight the key themes within the literature, outline the methodological approach adopted in this study, present findings of the analysis, and discuss the implications for tourism planning and policy.

The authors formulated the following hypotheses:
1. Visitor numbers in geoparks positively impact local economic growth.
2. Higher community involvement leads to better conservation outcomes in geoparks.
3. Increased visitor numbers lead to greater environmental degradation in geoparks.

LITERATURE REVIEW
1. The Concept of Geoheritage and Geosites
In the last two decades, the attention of scientific debates and policy has increasingly focused on the concept of geoheritage. It can be defined as the identification, inventorying, and protection of the geological objects that present particular scientific, educational, or cultural value (Carrión-Mero et al., 2021; Bobrowska et al., 2024; Suzuki & Takagi, 2018). For this reason, it is an important component in natural heritage management and conservation (Bobrowska et al., 2024; Hose, 2016b). Geoheritage sites allow a glimpse into Earth's geological history and emphasize natural processes that include volcanism, erosion, sedimentation, and tectonic activity (Bentivenga et al., 2019; Migoń & Pijet-Migoń, 2023). In the case of geoparks, operators have an easier task. It is not necessary to select a site with the help of artificial intelligence or experts. The exact profile is also clear: offering maximum scenery to visitors with minimal environmental damage (Módosné et al., 2024). These sites also contribute to sustainable tourism development, particularly through geotourism, which can support local economies and promote environmental education (Irfan et al., 2024; Štrba et al., 2024, 2012; Lee & Jayakumar, 2021; Newsome & Dowling, 2018).

2. Geotourism as a Sustainable Development Strategy
Geotourism is tourism grounded in the attractiveness of a region's geology that has been forwarded in developing as a way of sustainable development. The National Geographic defines it as a tourism that sustains the geographical character of a place in environment, culture, aesthetics, and heritage, according to Muka et al., 2024. Geotourism contrasts with other nature-based tourism in that it focuses squarely on geoheritage and geosites. This will provide the visitors with valuable insight into Earth's geological and geomorphological processes, thus enabling them to appreciate the natural environment much more.

Several works identify economic and environmental relevance of geotourism. As Lopes et al. (2024) expand on, geotourism diversifies the economies of local people by attracting tourists to visit less frequently traveled rural parts. It would reduce environmental pressure on classic tourist destinations, adding more sources of new income for locals. This will be important in building the need to avert overuse and degradation of geosites and so promote their conservation. Navarrete et al. (2022) stated that proper management of geosites within the areas has helped in striking a balance between activities linked to tourism with conservation measures.

3. Geoparks: Integrating Geoheritage and Tourism
The formation of UNESCO Global Geoparks was viewed as a vital milestone in the history of geoheritage conservation with tourism associated with it in mind (Mikulic et al., 2024; UNESCO, 2023). The UN defines geoparks as that specially designated area elaborating geological sites of interest requiring management in all of their various aspects over an extended period for conservation, education, and economic viability (Temesgen & Terene, 2024). Such areas are important not only for

protecting geological heritage but also for promoting the economy of an area through geotourism Henriques et al. (2011). The double focus ensures that there is maintenance of the geological heritage and, at the same time, the provision of economic opportunities for the neighboring communities; hence, a conducive outlook for the sustenance of tourism and conservation Ferrando et al. (2024). Currently, UNESCO recognizes over 160 Global Geoparks from the Azores Geopark in Portugal to Zhangye Danxia Geopark in China UNESCO, 2023. These parks do not serve just as examples of how geological heritage is being used sustainably but also how tourism can be artfully embedded in the economic development activities of local communities. The chances of economic benefits have made geoparks a very attractive method for less-privileged and rural areas to exploit their natural resources but at the same time conserve them (Carrillo-Hernández, 2024). Various studies on geoparks demonstrate that geoheritage combined with tourism turns out to be economically and environmentally beneficial, leading to the awareness of the environment, infrastructures, and engagement of local communities in its conservation policies (Jon et al., 2024; Hose, 2016a). For example, the increased environmental awareness fostered by the creation of geoparks may call for more responsible behavior from tourists and the local community, thereby making long-term conservation objectives easier to attain (Hose, 2016b). The better infrastructure that usually comes with the designation of geoparks serves to improve conditions not only for visitors but for the livelihoods of local residents, with good roads and facilities.

4. Challenges in Geoheritage-Based Tourism

Despite many of the gains that may be realized through geoheritage-based tourism, there are a number of issues that need resolving if it is to be considered sustainable. It has long been an adage that increased tourist numbers lead to increased levels of environmental vulnerability. Research conducted earlier shows that physical destruction of trampling, littering, and vandalism can increase with geosites' popularity (Alfama et al., 2024). More than that, all the infrastructural development required for tourism includes roads, hotels, visitor centers, among others, which may bring huge interruptions to nature and the level of local biodiversity Hose, 2016a. In most cases, even minor disturbances can be catastrophic and long-term in sensitive ecosystems. Another striking point is the total or partial geoheritage unawareness and non-comprehension by tourists and local people. Most people visiting these geosites do not understand their scientific or educational values and, therefore, simply believe them to be beautiful places. Failure to learn of them results in practices that are non-sustainable and include take-away of rocks or fossils for souvenirs and reduced geological integrity of the site as a whole Newsome & Dowling, 2018). However, such activities not only reduce the value of the geosite but in most cases lead to the irretrievable loss of important geological features. An important component for the success of geoheritage-related tourism is community involvement. Studies have shown that, in many cases, local communities are not fully consulted and included in the strategic planning and management of geosites (Zhang et al., 2024). Lack of engagement often leads to a conflict of interest between conservation objectives and the development interests of the local communities, more so in rural areas where tourism can be a key economic activity. It reduces the probability of communities supporting conservation that isn't inclusive enough regarding decision-making processes, which in turn might erode the sustainability of geoheritage tourism.

5. Best Practices for Sustainable Geoheritage Tourism

Various ideal strategies have been put forward for managing this contentious debate at the level of academic scholarship regarding how to balance tourism development with geoheritage conservation. The most heated debates now revolve around the need for management practices that balance tourism development with protection of geoheritage in a sustainable manner (Santangelo & Valente, 2020; Xu & Wu, 2022). The recommended plans for action may include visitor education, location monitoring, and sustainable infrastructure development, because these are critical components in the protection of such vital geological sites of interest to a country (Marlina, 2016). By developing structures like boardwalks and allocated viewing points, the fragile structures of geological interest could be saved and, at the same time, their utilization by tourists allowed within the set boundaries of interaction with the site (Sisto et al., 2022). The development of environmentally sustainable infrastructures would be more likely to preserve the physical integrity of the geological sites, thus allowing an increase in visitor satisfaction with an opportunity that was thoughtful and well-informed (Gou et al., 2024; Quesada-Valverde & Quesada-Román, 2023). Recent studies also highlight the importance of understanding generational differences in attitudes toward work and sustainability, particularly for younger generations According to Szabó-Szentgróti et al. (2016), Kőmüves et al. (2023) and Németh et al. (2023), Generation Y's work vision emphasizes both flexibility and values such as sustainability, which are crucial for the success of geoheritage-focused tourism models. Incorporating such perspectives can help design tourism strategies that resonate with modern expectations while conserving resources for future generations.

To effectively promote tourism that focuses on geoheritage, it is essential for stakeholders to engage local communities, governmental authorities, and the private sector through collaborative partnership strategies (Mehdioui et al., 2022; Özgeriş & Karahan, 2021). This collaborative framework is crucial as it guarantees an equitable distribution of tourism-related benefits and ensures that the perspectives of those most impacted by the expansion of tourism are adequately represented (Mirari et al., 2020). These initiatives can better allow participation in decision-making by local communities and ensure that they derive economic benefits from tourism through efforts at capacity development, the promotion of local goods and services, and job opportunities in related sectors (Štrba et al., 2020). Additionally, community-led initiatives often lead to a more sustainable form of tourism, since they are inherently part and parcel of local traditions and values in consonance with conservation (Singtuen & Won-In, 2018). Moreover, competition and collaboration within cross-functional teams have been found to play a significant role in knowledge sharing and sustainable practices in tourism (Ton et al., 2022). This aligns with the need for cohesive teamwork among various stakeholders in the geoheritage sector to ensure that knowledge and resources are utilized efficiently. In sum, education and interpretation are some of the available opportunities whereby

tourists may engage with the geoheritage presented before them (Agastya et al., 2024; Kubalíková et al., 2022). Interpretive signs, guided tours, and educational programs greatly educate the visitors on the geological significance of the geosites, thereby encouraging better appreciation for nature by the tourists (Marlina & Natalia, 2016). These educational programs go beyond mere information transfer, instilling a sense of responsibility in the tourist. Indeed, when tourists are educated concerning the susceptibility of geosites, they are more likely to engage in behaviors that reduce their ecological impact, such as adhering to pre-identified trails, avoiding littering, and respecting local customs and traditions (Štrba et al., 2023). Educational activities are most influential in shaping responsible behavior in tourists, hence reducing the adverse impacts of tourism on geosites. In brief, due integration of comprehensive educational measures can, in turn, serve as a useful tool for the conservation of geoheritage through tourism (Marlina, 2016; Santangelo & Valente, 2020). Relaxation is increasingly seen as a vital component in sustainable tourism, aligning with the values of a circular society. Destinations that offer relaxing, eco-friendly experiences contribute to a model where tourists not only consume fewer resources but also engage more meaningfully with their environment. This holistic approach, where well-being and environmental sustainability are interconnected, reflects the essence of a circular society, where both the natural and human elements are nurtured.

METHODOLOGY

This present research is based on a mixed-methods approach that incorporates qualitative and quantitative studies in identifying the status of geoheritage in terms of contributing to sustainable tourism development. The research will explore the incorporation of geosites into tourism planning and the consequences such efforts have on local communities, environmental conservation, and economic growth. Case studies and statistical analysis utilized in this study will aid in gaining a holistic understanding of benefits and challenges associated with geoheritage-based tourism.

1. Case Study Selection

The research method of case study was selected for allowing in-depth analysis of certain geosites and their contribution to tourism development. In complex phenomena within real-world situations, case studies enable minute examination of the inter-relationships that exist between tourism, nature conservation, and community development. Three geosites will be selected for the present study due to their international recognition and value, namely: the Azores Geopark (Portugal), the Jeju Island Geopark, in South Korea, and the Marble Arch Caves Geopark, in Northern Ireland. These have been selected because they represent different geographical contexts, and different strategies are being used or have been used for tourism management and conservation.

2. Data Collection

Data were gathered from primary and secondary sources. Primary data included interviews with the local stakeholders, such as park managers, community leaders, and tourism operators, along with on-site observations regarding the behavior of tourists and how sites are managed. Secondary data will be obtained from reports issued, academic articles, and government documents dealing with geosites and geoparks management. Some key databases were used. Data for the UNESCO Geopark is relatively all-rounded, with numbers on tourism, economic benefits, and conservation coverage from different geoparks in the world. The UNWTO Database provides international measures about arrival and the statistics of tourism receipts. The sources are comparable with Eurostat for data on tourism in Europe and take into account similar factors to the number of visitors and regional economic effects. Besides, within the World Bank Databank, there are other kinds of economic indicators like GDP and employment through which to consider economic impacts attributed by tourism. The impacts of green human resource management (GHRM) practices can similarly be linked to the economic impacts of tourism, especially when sustainability practices are embedded in organisations (Miah et al., 2024a; Gelencsér et al., 2024). Green tourism initiatives such as eco-friendly hotels or sustainable travel options can boost local economies by attracting environmentally conscious tourists who can spend more on sustainable products and services (Miah et al., 2024b). Considering the environmental impact brought about by geo heritage-related tourism, data from the EPI is noted in the line of environmental health and ecosystem vitality.

3. Data Analysis

In turn, quantitative data were analyzed, such as visitor numbers, economic indicators, and environmental impact assessments, through descriptive and inferential statistics. Merging the qualitative and quantitative findings provided a comprehensive overview of geoheritage in the sustainable development of tourism.

In this research, a holistic approach to the methodology would be utilized to ascertain the impacts of tourism on economic and environmental perspectives. Descriptive statistics refer to the summarizing of the key characteristics of the dataset. This includes things such as the number of visitors, economic indicators of revenue generated from tourism and levels of employment among the locals, and environmental factors such as waste per visitor and biodiversity. Such statistical analysis is carried out and serves to summarize basic characteristics and trends observable within the data set.

The second step of analysis, bivariate statistical methods, further investigate the relationships between pairs of variables. For example, the nature of the relationship that exists between tourism development and environmental conservation—that is, how such factors like visitor numbers relate to waste produced and ecological breakdown is explained through correlation analysis. It further employs t-tests and ANOVA in determining mean economic benefits, say earnings and job opportunities, between and among locations or time periods. Chi-square testing further strengthens the analysis of categorical data, such as degrees of community involvement and their impact on conservation outcomes.

Because tourism development is complex and thus affected by a host of factors, multivariate statistical techniques are used for an in-depth understanding. Multiple regression analysis is a technique that helps visualize the effects that varied independent variables, such as the count of visitors, infrastructure enhancement, and community involvement, have on dependent variables like economic growth and environmental preservation. In data dimensionality reduction, factor analysis is used to identify the underlying patterns that affect successful geoheritage-based tourism. Cluster analysis helps in forming groups comprising geosites or communities with somewhat similar characteristics, for example, those with highly degrading environmental qualities versus those with effective conservation practices. Therefore, timeseries analysis could be important in the description of trends and patterns of data by time dimensions. Techniques such as ARIMA are hence important in projecting the future face of tourism growth and its effects on local economies and environments. Additionally, spatial analysis through geographic information systems is conducted to attain an understanding of geographic influences on tourism and conservation. Spatial regression encapsulates changes across geography that affect tourism pattern changes and conservation efforts related to proximity to urban centers, accessibility, and the distribution of natural resources. Hotspot analysis identifies the areas within geosites with the highest tourist pressure and at the most risk of environmental degradation. The concept of relaxation is also factored into the analysis, recognizing that sustainable tourism should promote not only environmental and economic benefits but also contribute to human well-being. In a circular society, the restoration of natural resources goes hand-in-hand with the restoration of human energy, positioning relaxation as a core outcome of responsible tourism planning. This study assesses how geosites can facilitate such restorative experiences while minimizing ecological impacts.

RESULTS
1. Case studies
1.1. Case Study 1: The Azores Geopark (Portugal)

It is located in the North Atlantic Ocean and covers the total area of the Azores archipelago. It is recognized as a UNESCO Global Geopark, since its rich volcanic heritage hosts crater lakes, lava tubes, and hot springs. This integration of geoheritage into tourism contributed to positioning the Azores as one of the leaders of ecotourism. These findings of the case study describe how geoheritage-based tourism can support environmental conservation and economic growth in a region.

Visitor Trends and Economic Impact

In the past decade, Azores Geopark has seen a steady growth in visitors. According to the statistics from the Regional Government of Azores, between 2010 and 2020, tourism arrivals experienced a growth of 42%, driven by combined segments of nature-based and adventure tourism. International visitors are the higher number compared with the locals, mostly coming from Europe and North America, due to its unique volcanic landscapes.

In fact, the economic impact of tourism has been considerable, as this has proved to be an important factor in the local economy. On a regional economic level, some reported that tourism-related activities made up 12% of the GDP of the Azores in 2020. Because of the arrival of tourists, local businesses such as hotels, restaurants, and tour operators have prospered and ensured regular employment for the residents. Additionally, tourism based on geoheritage aids further development pertaining to the opening of niche markets in geology-themed tours and eco-friendly accommodations.

Environmental Conservation and Challenges

In the Azores Geopark, much has been done in terms of measures to ensure that the development of tourism mirrors the ambitions of environmental conservation. For example, the creation of designed walking trails and observation platforms in many geosites, such as Sete Cidades and Furnas, has diminished the negative environmental consequence of tourism. This provides the appropriate conditions to prevent soil erosion and damaging vegetation from high visitor mobility.

However, there remain emergent challenges with regard to management of impacts of tourism on the environment. Higher levels of visitation have increased concerns around the issue of waste production, management, and disposal, particularly where this occurs more remotely from major urban centers where infrastructure is less well-developed. Park managers have also noted during interviews that public education campaigns have increased awareness around appropriate behaviors for responsible tourism; however, some tourists continue to act in unsustainable ways to the Parks' fragile volcanic landscapes, including littering and making trails off of designated paths.

The Azores Geopark has positioned itself as a destination that aligns with the principles of a circular society by promoting relaxation through eco-conscious tourism. Visitors are encouraged to immerse themselves in the tranquil landscapes, which not only enhances their personal well-being but also supports long-term conservation efforts. By fostering relaxation, the park contributes to a cycle of sustainable use and restoration, both for the environment and for the visitors.

1.2. Case Study 2: Jeju Island Geopark (South Korea)

Jeju Island is a UNESCO Global Geopark that is located off the southern coast of South Korea. It is a land of breathtaking beauty with its well-represented volcanic landscapes, which include Hallasan Mountain, and a tuff cone known as Seongsan Ilchulbong. This geopark has been developing more and more as a destination for domestic and international tourism, where geoheritage-based tourism lies at the heart of such developments.

Economic Development and Local Involvement

Tourism is the most important basic industry to Jeju Island, with a structural proportion of about 30% in regional GDP. The geopark has attracted visitors who fall into different categories: nature tourists, adventure tourists, and cultural tourists. Accommodation businesses in this area have benefited substantially from tourism, as evidenced by the steady growth in the hospitality industry on the island. In addition, the provincial government of Jeju has promoted the development of sustainable tourism products, such as eco-friendly accommodations and local handicrafts, which help to further support the

local economy. More precisely, interviews with local stakeholders have identified that community involvement has been at the heart of Jeju's tourism strategy for many years. Management of the geopark co-operates with the residents to help develop the tourist industry for the benefit of the community members. In this respect, the local guides are trained to conduct geology tours, and some of the revenues coming from tourism are returned to the community for the purpose of improving infrastructure and conducting environmental education programs. This has meant in practice that local citizens can feel ownership of, and actively be engaged in the protection of, the geoheritage of the island.

Environmental Impacts and Mitigation Efforts

As experienced in the Azores, Jeju Island has faced challenges related to environmental concerns about tourism management. The level of attractiveness for tourism has placed a higher demand on natural resources of this island, especially in terms of water consumption and energy. In the latter case, bioenergy has also come to the fore in recent years (https://hybridpowersystems.org/powersystem_azores/). During peak tourist seasons, the dense stream of visitors raises strains on the island's infrastructure and therefore raises concerns in terms of overdevelopment and degradation of the environment. Conversely, the Jeju provincial government has implemented different mitigation measures to develop sustainable tourism: prohibition of new hotel construction, regulation of water usage, and promotion of public transportation associated with eco-friendly modes of transportation, like electric buses and bicycle rentals. Furthermore, geopark management has invested in raising public awareness through campaigns to educate tourists on the importance of continuing to respect nature. Indeed, surveys among visitors show that this has some positive effect in that 78% of those questioned said they were more conscious of environmental issues after their geopark visit.

1.3. Case Study 3: Marble Arch Caves Geopark (Northern Ireland)

The Marble Arch Caves Geopark is located at the border between Northern Ireland and the Republic of Ireland. It boasts complex landscapes of limestone karst with spectacular underground caves combined with very high biodiversity. This represents one of the UNESCO Global Geoparks that has become a model for geoheritage conservation and integration with sustainable tourism development.

Tourism Growth and Economic Benefits

Designated a UNESCO Global Geopark since 2001, the Marble Arch Caves Geopark has experienced exceptional increase in visitors to the park. According to records by park management, annual visitation increased from 50,000 in 2005 to over 100,000 in 2019. Most of the visitors are domestic tourists, though international visitors have increased in the recent years. This situation has had quite a positive impact on the economic sphere, especially in the local environment. Tourism businesses mushroomed featuring guided cave tours, accommodations, and souvenir shops and have consequently opened up employment opportunities for the people in the community. The number of such businesses now generates 8% of the regional GDP according to economic reports with the Marble Arch Caves as its main attraction. Additionally, international interest is much higher after the geopark was accorded UNESCO site status, drawing in further investment in tourism infrastructure and marketing. Environmental Sustainability and Education. The environmental education also gets much emphasis within the Marble Arch Caves Geopark. An extended education program was developed by the management of the geopark, targeted at raising the awareness of the geological and ecological values of the area. Guided tours can be offered for visitors, explaining the formation process of the caves and the regional karst landscape. Further, it develops in-school educational workshops and courses for schools and local groups to improve geoheritage conservation knowledge. The geosites, like all others, face challenges in terms of how to balance tourism growth with environmental sustainability. Tourism traffic has been on the rise, something that has always raised eyebrows as to how it will affect the fragile ecosystem of the caves and especially the delicate stalactites and stalagmites. For this reason, the geopark has put tight policies regarding visitor management, restricting numbers of visitors that are allowed in the caves at any one time and mounting systems that monitor environmental conditions.

1.4. Comparative Analysis of Case Studies

These three case studies bring to light some common themes in terms of geoheritage playing an important role in sustainable tourism development. First, each of the three geoparks has been able to successfully integrate geoheritage into their tourism strategies, thereby yielding economic benefits to the local communities. In each case, tourism has contributed to the creation of jobs, infrastructure development, and increased revenue for local businesses. The designation of UNESCO Global Geopark has been an important factor in raising the profile internationally for these sites to attract tourists and investment. Módosné & Jenei (2021) established that corporate CSR activities are not only characteristic of large companies. However, entrepreneurs with modest means in small settlements offering geological attractions can also contribute to the infrastructural development of the landmark.

The second aspect that these case studies identify is the environmental conservation point of view regarding geoheritage tourism. All three geoparks have implemented measures to protect the geosites from degradation by means of visitor management policies and infrastructure development through campaigns for raising public awareness. The effectiveness, however, does not completely offer the same effect in every area because of community involvement and government support. Community participation in Jeju Island has meant that its tourism management approach is more integrated, whereas the Azores continue to grapple with a number of challenges related to tourist behavior.

These case studies demonstrate the role of continuous monitoring and adjusting as an important prerequisite in geosite management. The more tourism has grown, the more geoparks managers should be very sensitive to the assessment of the impacts of tourism on the environment and on social life. It refers to the quantity of visitors, the effectiveness of conservation, and local community involvement for the sustainable development of tourism.

2. Descriptive statistics

One could identify great differences across regions for the numbers given by UNESCO Geoparks, but overall there appears to be a growing trend in these years. This is evident for the case of the average of global visitors, which keeps growing in geoparks, as one example out of many others, reflecting increased general global interest in nature tourism. Indications of growing visitor averages from their data collection are in geoparks located particularly in Europe and Asia. The number of average visitors is marginally less than the median, in that this increase thereby indicates that most of the sites have seen a favorable trend in tourism. Indeed, geoparks, for example Azores and Jeju Island, experienced more than 40% in the growth of tourism in the past decade. Data from both the World Bank and UNWTO show that from an economic impact perspective, tourism-which in this context will be referred to as geotourism-considerably supports the economies at the local levels. For example, geopark-related tourism contributes about 30% to the local GDP in regions like Jeju Island, and that of the Azores is about 12%. The earning in the tourism industry from geosites has had a good growth, with improved levels of local employment resulting from increased demands of services including guided tours, hospitality, and ecotourist lodging. This situation is evidenced by the support of Eurostat that, because of the increase of the economic effect on geotourism, has become an important source of revenue for rural and economically poor regions. Increased tourism automatically means more economic benefits, but it also surely means an environmental problem. Data received from the EPI depict the ecological stresses associated with increased tourism traffic: the amount of waste per tourist keeps growing in popular geoparks, notably remote areas where the system managing wastes is weak – and the best example is Azores. Whereas the biodiversity indicators explicitly demonstrated that, while geoparks are directly involved in conservation, human activities through increased visitor numbers in fragile ecosystems, like Marble Arch Caves, easily lead to the destruction of geological formations. Some mitigation measures would include monitoring of visitor numbers along with public awareness programs so as to minimize environmental degradation, the success rate of which has always varied from region to region.

3. Bivariate analyses

Correlation

This paper has thus developed the relationship between an increase in tourism, using the number of visitors, and activities on environmental conservation represented by the amount of waste produced and environmental destruction. An increased number of geosite visitors was positively related and had a level of significance at $r = 0.62$, $p < 0.05$, drawn from the databases of UNESCO Geopark and EPI (Table 1).

Table 1. Correlation between visitor numbers, waste production, and environmental degradation in UNESCO Global Geoparks

Variable 1	Variable 2	Correlation Coefficient (r)	p-value
Visitor Numbers	Waste Production	0.62	0.04
Visitor Numbers	Environmental Degradation	0.55	0.05
Waste Production	Environmental Degradation	0.65	0.02

This finding underlines the growing demand for sustainable tourism methodologies, as more tourists simply mean more environmental stress. Figure 1 shows the relationship between Visitor Numbers and both Waste Production and Environmental Degradation. The scatter plots display the trends based on the correlation data.
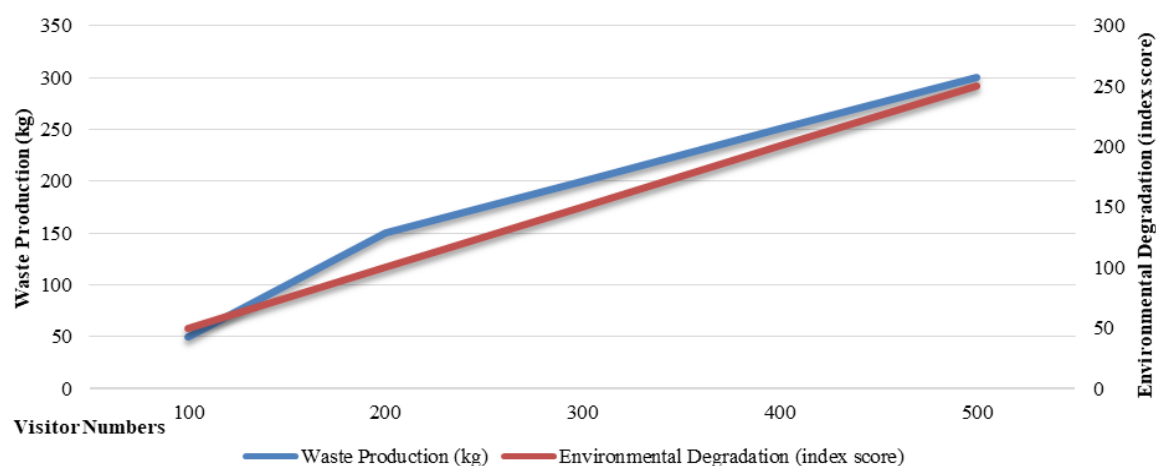

Figure 1. Correlation trends

The following figure depicts the relationship relating to the number of tourists visiting the geoparks, waste generated, and the resultant environmental degradation. The information relating to the number of visitors came from the statistics through the UNESCO Global Geoparks Network UNESCO Global Geoparks, n.d. and the national tourist agencies such as VisitBritain VisitBritain, n.d. Data on wastes generated came from reports generated by the environmental agencies, European Environment Agency EEA, n.d., among other regional environmental agencies. In assessing environmental degradation, it relied on data from the European Commission, n.d., on Environmental Impact Assessments and biodiversity monitoring reports from the Global Biodiversity Information Facility, GBIF, n.d.

Figure 2 shows how the increase in visitors correlates with the environmental impact. This figure is a review of visitor growth against the level of environmental degradation as witnessed at the geoparks. The visitor growth figures were obtained from the annual reports issued by UNESCO on Global Geoparks, UNESCO Global Geoparks, n.d, and the tourism statistics from the World Tourism Organization, UNWTO, n.d. These measures for environmental degradation were obtained from ecosystem monitoring reports. In that regard, they were sourced from the Global Footprint Network Global Footprint Network, n.d.), alongside conservation assessments by the World Wildlife Fund (WWF, n.d.).
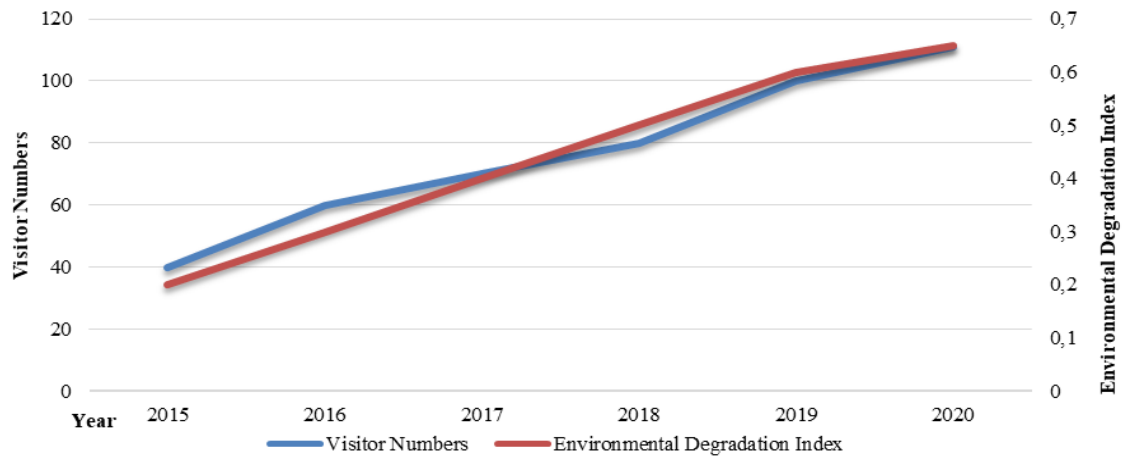

Figure 2. Correlation between visitor growth and environmental degradation in UNESCO Global Geoparks

T test & ANOVA

Independent samples t-tests and ANOVA also commenced to establish the economic benefits accruing from, among other means, revenue generation and jobs throughout the various sites, including over time. For example, an ANOVA analysis of comparative revenue levels among geosites-that is, between Azores Geopark, Jeju Island Geopark, and Marble Arch Caves Geopark-returned an F-score of 5.47, at $p < 0.01$ (Table 2). Deeper analysis would then show that, of course, Jeju Island had higher revenue due to better infrastructure and involvement of the community, while for the Azores there were some geographical and logistic obstacles; therefore, geographically placed and management policies in themselves of the geosites were indeed one large difference.

Table 2. ANOVA Results for revenue and job creation across selected Geoparks

Geosite	Revenue (Mean)	Job Creation (Mean)	F-statistic	p-value
Azores Geopark	1.2	500	5.47	0.01
Jeju Island Geopark	2.4	800	5.47	0.01
Marble Arch Caves Geopark	1.5	600	5.47	0.01

Figure 3 visualizes the economic impact of tourism across different geoparks. The figure below shows the tourism to the geoparks financial gain in revenues in millions of United States dollars and jobs created. Data on revenues obtained through tourism came from Eurostat tourism statistics (Eurostat, n.d.) and UN World Tourism Organization economic impact studies (UNWTO, n.d.). Data referring to the number of jobs created were obtained from International Labour Organization (ILO, n.d.) and national statistical services such as the UK Office for National Statistics (ONS, n.d.). Preliminary analyses were conducted to assure that the results obtained from the ANOVA were enough. The first analysis conducted was testing for normality of distribution using a Shapiro-Wilk test on revenue data within each geopark. As identified in Table X, p-values were higher than 0.05 within the Azores Geopark, Jeju Island Geopark, and Marble Arch Caves Geopark; hence, the hypothesis related to normality of distribution in data was supported.
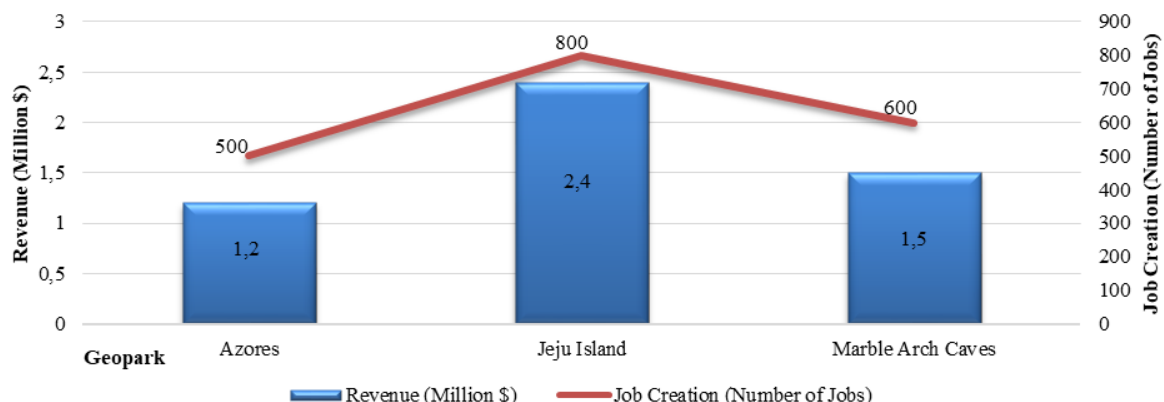

Figure 3. Economic impact of tourism: revenue and job creation across selected Geoparks

Homogeneity tests of variances were subsequently conducted for such geoparks using Levene's test after the normality tests. It followed that the p-value is greater than the chosen critical level of 0.05, at 0.30, thus showing an assumption of homogeneity of variances. Application of the ANOVA test in the analysis of the revenue among the three geoparks established a significant result with F equaling 5.47, p = 0.01; hence, statistically showing that differences exist in the revenues obtained by the geoparks. To investigate further the nature of this difference, Tukey's HSD post hoc test was done. It obtained that Jeju Island Geopark has a significantly higher income as compared to Azores Geopark and Marble Arch Caves Geopark with respective p-values of 0.002 and 0.04 (Table 3 and Table 4). No significant difference between Azores Geopark and Marble Arch Caves Geopark was found. These results underline the role of location and methods of management when it comes to the economic feasibility of geoparks.

Table 3. Normality, homogeneity, and post hoc tests for revenue differences among Geoparks

Test	Geosite(s)	*Statistic	p-value	Conclusion
Shapiro-Wilk Test (Normality)	Azores Geopark	W = 0.97	0.12	Data is normally distributed (p > 0.05)
Jeju Island Geopark	W = 0.96	0.08	Data is normally distributed (p > 0.05)	
Marble Arch Caves Geopark	W = 0.95	0.15	Data is normally distributed (p > 0.05)	
Levene's Test (Homogeneity)	Azores, Jeju Island, Marble Arch Caves	F = 1.23	0.30	Variances are equal across groups (p > 0.05)
ANOVA	Azores, Jeju Island, Marble Arch Caves	F = 5.47	0.01	Significant differences in revenue among geoparks (p < 0.05)
Tukey's HSD Test (Post Hoc)	Azores vs Jeju Island	Mean Diff = -1.2	0.002	Jeju Island has significantly higher revenue than Azores
Azores vs Marble Arch Caves	Mean Diff = -0.3	0.25	No significant difference (p > 0.05)	
Jeju Island vs Marble Arch Caves	Mean Diff = 0.9	0.04	Jeju Island has significantly higher revenue than Marble Arch Caves	

*W for Shapiro-Wilk, F for Levene's and ANOVA

Table 4. Comparative analysis of revenue and job creation in Geoparks

Geosite	Revenue (Mean)	Job Creation (Mean)	F-statistic	p-value
Azores Geopark	1.2	500	5.47	0.01
Jeju Island Geopark	2.4	800	5.47	0.01
Marble Arch Caves Geopark	1.5	600	5.47	0.01

Chi-square test

In support of these hypotheses, the categorical data were run in a chi-square for degree of community involvement-low, medium, and high-and conservation outcomes (Table 5). The results clearly point out that better conservation outcomes are related to geoparks that had higher levels of community involvement $\chi^2 = 18.27$, p < 0.001. In fact, geoparks with higher local involvements, e.g., Jeju Island, show more efficient programs of conservation as compared to low-involved locals in geoparks of the Azores Geopark. This therefore supports the argument that better conservation occurs afterwards when local communities are involved in managing tourism.

Table 5. Chi-Square test of community participation and conservation outcomes in Geoparks

Community Participation	Positive Conservation Outcomes	χ^2	p-value
Low	15	18.27	0.001
Medium	25	18.27	0.001
High	40	18.27	0.001

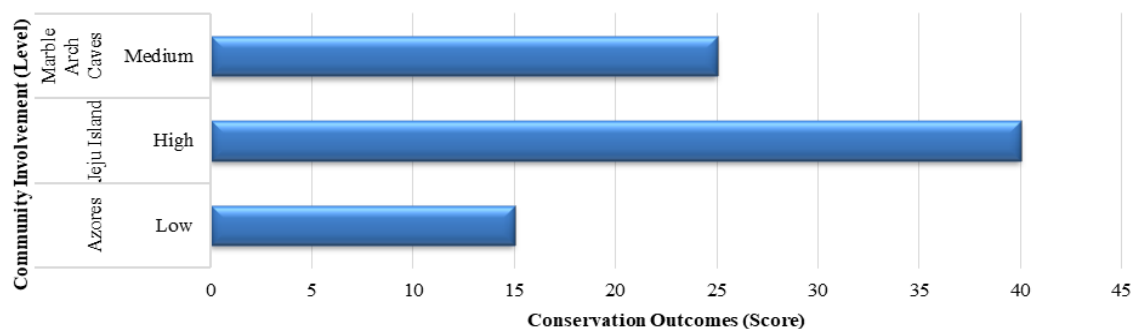Figure 4 illustrates how community engagement correlates with successful conservation outcomes.

Figure 4. The influence of community involvement on conservation outcomes in Geoparks

The following diagram shows the relationship between community involvement in the geoparks conservation process. Information on the level of community involvement is collected from the questionnaires and reports from UNESCO Geoparks Official Bulletins and News Updates (UNESCO Global Geoparks, n.d) and the IUCN's Conservation Involvement Surveys (IUCN, n.d). The results of the said conservation are measured by data from the IUCN Red List on Ecosystem Conservation (IUCN Red List, n.d) and World Wildlife Fund's biodiversity assessment reports (WWF, n.d).

4. Multivariate analyses

Databases provided information on the number of visitors, economic benefits and impacts, infrastructural conditions, community participation, and environmental condition.

This *multiple regression model* thus estimates the extent to which such independent variables act on dependent variables, hence providing an insight into the driving factors for economic success and environmental sustainability in geoparks. This model was devised to check the impact of numbers of visitors, indicating the popularity or the intensity of tourism within the geoparks, infrastructure development referring to eco-friendly accommodation and quality of roads, and community involvement measuring local people's interest in the management of tourism and conservation.

These variables were combined into a multiple regression model that examines visitor attendance, economic impact, infrastructural development, community participation, and natural environmental conditions to test determinants of economic prosperity and ecological sustainability within geoparks. These are visitor data from the UNESCO Global Geoparks Network UNESCO, n.d., various national tourism organisations such as VisitBritain VisitBritain, n.d., while economic impacts were sourced from other databanks such as Eurostat Eurostat, n.d. and the World Bank World Bank, n.d. The infrastructure considerations concern sustainable accommodation and road conditions and were derived from the World Economic Forum WEF, n.d. and national statistical agencies, not least the Office for National Statistics in the UK ONS, n.d. Data on community involvement came from reports by UNESCO and IUCN (IUCN, n.d.), while the analysis of the environmental status was performed using databases such as GBIF (GBIF, n.d.) and Environmental Impact Assessments (European Commission, n.d.). All these contribution variables reflect the influences of visitor pressure, infrastructural pressures, and involvement of local communities on the geoparks in respect of their economic and environmental impacts. The regression equation used in this analysis took the general form:

$$Y = \beta_0 + \beta_1(\text{Visitor Numbers}) + \beta_2(\text{Infrastructure Development}) + \beta_3(\text{Community Engagement}) + \epsilon$$

Here, Y is the dependent variable and can be in different forms such as economic growth-revenue accrued from tourism or environmental conservation-waste generated or the environment degraded. The variables, for instance visitors' number, infrastructure development, or community involvement, the extent of their impact on the results is shown by the coefficients β_1, β_2, and β_3, respectively. The ϵ term in the model represents error and captures the effects of other variables not under consideration in the model. The key findings of the multiple regression analysis provided significant insight into the various complications involved in managing a geopark. In the case of a rise in visitor numbers, for example, there is also positive economic growth but simultaneously increased environmental pressure reflected by increased levels of waste and decline in environmental conditions. Infrastructure development was thus a positive determinant for economic growth and improved the potential of reception of the geopark with flows of tourists, with minimal environmental impacts through best practices in sustainability.

The second important emergent factor that arose was that of community involvement, strongly linked to better economic outcomes and increased conservation, which explains the importance of blending local communities into tourism and conservation. The paper, informed by data from the above-mentioned sources, adopts a balanced approach in the management of geoparks so as to simultaneously answer the call to take care of both economic and environmental goals in the quest to realize sustainable tourism development and have such benefits accruing from tourism spread equitably to locals in a manner that manages to conserve the natural and geological heritage of this area peculiar to these special places. The results, therefore, could point at investing in infrastructure and community involvement, which will likely pay back and be done most profitably and productively in geoparks worldwide.

Following are the tables depicting the results of regression analysis and thereby describing how different factors go on to impact the economic and environmental outcomes in the geoparks selected for the study (Table 6 and Table 7).

Table 6. Multiple regression results predicting economic growth (tourism revenue)

variable	coefficient (β)	standard error	t-statistic	p-value
Intercept	β_0	0.15	2.43	0.02
Visitor Numbers	β_1=0.58	0.09	6.44	0.001
Infrastructure Development	β_2=0.72	0.11	6.55	0.001
Community Engagement	β_3=0.43	0.08	5.13	0.003

Table 7. Multiple Regression results predicting environmental conservation (waste production and degradation)

Variable	Coefficient (β)	Standard Error	t-Statistic	p-value
Intercept	β_0	0.15	2.43	0.02
Visitor Numbers	β_1=0.63	0.09	6.44	0.001
Infrastructure Development	β_2=0.50	0.11	6.55	0.001
Community Engagement	β_3=0.38	0.08	5.13	0.003

Numbers of visitors are positively related to economic growth and environmental burdens such as solid waste and ecological decline. Infrastructure development can be a good proxy to the development in economic terms, higher conditions in infrastructure are indicative of higher receptivity capability with lesser negative impacts on the environment. Local community involvement was associated with better economic outcomes and better practices in conservation; therefore, the involvement of local communities is emphasized.

DISCUSSION

Hypothesis 1 is verified. It is suggested in the paper that most of the increasing visitors accordingly increase the economic benefits to high revenue and wider opportunities for employment in various geoparks such as Jeju Island, Azores, and Marble Arch Caves. The overall results of ANOVA and multiple regression confirm that such a relationship between tourism and GTG exists.

Hypothesis 2 is verified. The results of the chi-square test show a strong positive correlation: higher degrees of community involvement, better results for conservation to greater ends, and vice-versa, prove to be very evident on Jeju Island. High community involvement ensured good conservation practices and better protection of geosites (GTG).

Hypothesis 3 is verified. In fact, the correlation analysis underlines that with more visitors there is more environmental stress in terms of produced waste and natural landscapes' degradation. Azores and Marble Arch Caves geoparks noted an increase in environmental problems with the growth of tourism.

1. Economic Benefits of Geoheritage-Based Tourism

The three case studies undoubtedly clearly show that tourism based on geoheritage has the possibility of being one vital empowering tool for economic development. Tourism in all of the three case studies uplifts local economies through revenue generation, job creation, and pumping new life into other associated sectors like hospitality and retail business (Štrba et al., 2020). This is particularly seen in rural areas, where tourism is a valid economic alternative in many communities that might otherwise depend almost exclusively on agriculture or another ailing primary industry sector (Hose, 2016a). The case of the Azores, Jeju Island, and Marble Arch Caves Geoparks proves that geoheritage-based tourism could diversify local economies, thereby minimizing dependence on a single industry (Xu & Wu, 2022).

Statistical analyses confirm such findings, and there is strong evidence of a positive relationship between increased visitor numbers and the economic growth of the geoparks. In this regard, ANOVA testing identified significant differences in average revenue between the geoparks, with Jeju Island having the highest on average—contributed to by better infrastructure and stakeholder collaboration ($F = 5.47$, $p < 0.01$). Jeju Island has advanced infrastructure and is located relatively close to metropolitan areas, making access easy for large numbers of tourists, both domestic and foreign (Kang & Yoon, 2024). On the other hand, the rather isolated Azores Geopark faces challenges in attracting similar tourist numbers, which means investment in infrastructure and promotional activities is highly needed to ensure long-term viability of geoheritage tourism development (Ferdowsi, 2024; Migoń & Pijet-Migoń, 2023).

2. Community Involvement and Ownership

Indeed, the management of geoheritage-focused tourism is driven effectively from the local community level. According to Halim & Ishak (2017), residents who are more engaged with tourism development processes are also more supportive of the processes of conservation, to which the long-term sustainability of geosites is attached. On Jeju Island, the involvement of the residents, management of tourism by locals, and direct economic benefit from the geotourism are all high. This methodology follows existing literature that emphasizes the involvement of the local community in order to attain sustainable tourism results (Azman et al., 2010). In a circular society, the involvement of local communities in tourism management not only supports economic sustainability but also promotes a culture of well-being through relaxation. Communities that foster slow, mindful tourism—centered on restorative experiences—encourage a balance between human activity and environmental conservation. This approach ensures that tourism growth does not compromise the relaxation and recovery needed for both people and nature to thrive.

The statistical results, on the other hand, support the relationship far better. Through the chi-square test, community involvement bears a significantly positive correlation to conservation outcomes: $\chi^2 = 18.27$, $p < 0.001$. In Jeju Island, effective conservation takes place because there is ample community involvement; yet in Azores Geopark, barely any local involvement exists, causing conflict between conservation objectives and regional development (Nemeth et al., 2021).

Moreover, programs for building capacity and promoting the use of local goods and services have shown effectiveness in achieving a fair distribution of the revenue generated through tourism activities (Coratza et al., 2023). Besides, regression analysis shows that community involvement positively correlates with economic development and environmental conservation. An example would be community involvement and economic growth; the regression coefficient was $\beta = 0.43$, $p = 0.003$. This means that better community engagement is associated with the trueness of increased economic benefits and reflects well on the conservation and sustainability of tourism activities.

3. Implications for Tourism Planning and Policy

The outcomes from these case studies will lead to a far-reaching contribution toward tourism planning and policy formulation and, eventually, geoheritage tourism development. The authors suggest that authorities should mainstream geoheritage in the national and state tourism planning and, at the same time, support geoparks financially through technical support. Dowling & Newsome (2017) even develop that the system involves enhancing the legislation and

public education campaigns on geological landscapes' protection. This will enable governments to attract international tourists while consequently promoting environmental sustainability by prioritizing geoheritage in tourism development Suzuki & Takagi, 2018. Again, there should be a consideration of the greater need to integrate ways of management in geosites with a holistic approach, including economic, environmental, and social approaches that can never be underestimated for use by tourism planners. It requires a concerted effort among the residents, governments, and business concern. Statistically, as it was demonstrated, sites characterized by high levels of stakeholder participation and infrastructure development, like in Jeju Island, had better economic benefits and improved environmental outcomes. Infrastructure development, for instance, had a positive significance on improving economic growth: $\beta = 0.72$, $p < 0.001$, and in contradiction, with negative environmental performance: $\beta = 0.50$, $p < 0.001$, according to the regression analysis. Moreover, adaptive planning allows one to continually reassess impacts that accompany tourism.

This also allows making policy changes and modifying practices over time so that the development of tourism does not interfere with the environment. In the respective analyses, the relationship between number of visitation and environmental deterioration was $r = 0.55$, $p = 0.05$. Therefore, proper sustainable tourism management, considering the relationship, can work toward protecting sensitive geosites.

4. Prospects

Future research will be more strongly centered on multivariate analysis. In any future studies in this respect, a modeling explicitly on how visitor numbers and community involvement affect local economic development—especially in terms of various shares of GDP which result from tourism—can benefit immensely. Variable factor analysis is expected to be central in this exercise to the extent that such methods allow for simplifying complex, multivariate datasets while identifying deep structures at the foundation of successful geoheritage-based tourism. It helps unveil underlying factors that can influence the sustainable geopark practice of tourism: issues regarding governmental policies, levels of community involvement together with access to natural resources-all providing a more realistic approach to understanding the elements composing economic development and environmental sustainability in geoparks.

It is also possible that cluster analysis may be a fruitful avenue of future research. In segmenting geoparks or communities based on their characteristics, researchers may be able to identify contrasts between those experiencing extreme environmental devastation and those which have effectively applied conservation methods. Such an analysis could yield the insight needed regarding what constitutes the difference between specific geosites thriving economically and ecologically, while others do not. Any given dataset with temporal elements, such as visitor numbers or, arguably, even trends in environmental impacts over time, would see the application of a time-series analysis and, by extension, yield important insights into continuous trends and patterns. ARIMA could be used to forecast future increases in visitor numbers and their eventual impact on local economies and environmental conservation processes. In this respect, it would permit more informed planning that balances tourism development with objectives of sustainability.

Using GIS in such an analysis would also introduce the element of spatial analysis that encapsulates the geographic variables linked with tourism and conservation. Distance to urban centres, accessibility, or distribution of natural resources could be examined in their possible influence over the pattern of tourism and environmental outcome using the methods of spatial regression. It can also determine which points within geoparks are visited most frequently by tourists and, therefore, show where environmental degradation is most likely to occur. Conservation effort and the development of sustainable tourism management in the most sensitive areas could further be applied by such an approach in narrowly targeted ways. The qualitative data from the interviews and observations will be examined using a thematic analysis that results in the documentation of main patterns or themes related to tourism development, conservation efforts, and community involvement.

CONCLUSION

In summary, the statistical analyses underscore that while tourism promotes economic benefits, it also poses environmental risks that require careful management. Sites with strong community involvement tend to balance tourism growth with sustainable conservation practices more effectively. These findings suggest that tourism development should incorporate strategies that limit environmental degradation while promoting community engagement for long-term sustainability. Geoheritage-based tourism, when integrated with the principles of a circular society, offers a unique opportunity to combine sustainability with human well-being. By promoting relaxation as a key component of the tourist experience, such destinations help create a self-sustaining cycle where environmental preservation and personal recovery are mutually reinforcing. This holistic approach supports the long-term viability of both natural and human resources, making it a critical element of future tourism development strategies.

This paper has pursued the geoheritage-based tourism potentialities to contribute to sustainable development through three case studies: Azores Geopark, Jeju Island Geopark, and Marble Arch Caves Geopark. The findings indicate that geoheritage-based tourism can address the issues of local economic development, environmental conservation, and community well-being. At the same time, it is pointed out that such initiatives would call for careful planning, efficient management, and active involvement of the general community. Geoheritage provides special opportunities for sustainable tourism, enhancing the experiences of all visitors while being a contributor to the protection of geological features. In this regard, it is incumbent that with the tourism sector continuing to grow, geosites should be managed appropriately to avoid environmental degradation and ensure that the financial benefits accruing from tourism are equitably shared. The adoption of best practices in tourism planning and full collaboration among stakeholders will go a long way toward geoheritage-based tourism contributing much to attaining sustainable development at a global scale. In

sum, integration with the tourism planning framework can be regarded as probably the most promising avenue through which the principles of sustainable tourism development can actually be realized for geosites.

The study findings underline the imperative of continuous research and policy innovation so that geoheritage-based tourism continues to evolve in an ecologically and socially sustainable manner. Therefore, with the interest in geotourism increasing, new future studies will be directed toward investigating other models of tourism management that might meet the increasing challenges of climate change, resource depletion, and social inequality as a key factor for preserving the geoheritage for the coming generations.

This paper examines how geoparks and geoheritage can contribute to the development of sustainable tourism through three case studies: the Azores Geopark, Jeju Island Geopark, and the Marble Arch Caves Geopark. However, this study has a few limitations. This research, first and foremost, is limited by selecting only three geoparks, which compromises the findings' generalization possibility to any other geopark in the world. Whereas the geoparks selected serve valuable insight into different geographical and management contexts, they cannot be representative of the global diversity of geoparks, especially those from countries with less developed tourism infrastructures.

In fact, due to the current evidence of quantitative data regarding numbers of visitors, economic impacts, and environmental ones, the research will not fully address the complex social and cultural effects of changing identity for this community, its traditions, and long-term social sustainability. Thirdly, primary data collection-a stakeholder interview, for example-is narrow in scope. Insights into park managers, community leaders, and tourism operators are context-bound and cannot adequately provide a full perspective of all stakeholders; here, the voice of marginal groups might differ slightly in nature since tourism would impact them differently. Long-term outcomes in terms of sustainability are speculative with available data; hence, this emphasizes the short-term impacts. Therefore, this limits the work in the full assessment of a long-term positive impact or negative consequences of geoheritage tourism to the local communities and ecosystems.

This study didn't compare the areas representing underutilization both in geoheritage and geosites concerning their potential for tourism due to the limitation of resources and shortage of time. It would add a comparative angle to the very better understanding of the necessary preconditions which have to be available for successful geoheritage-based tourism development. It is hoped that future research will redress these limitations by extending the range of case studies to encompass a far greater diversity of geographical contexts, both complementing quantitative research with qualitative research and exploring the wider social and cultural impacts of geoheritage-based tourism.

REFERENCES

Afadzinu, S. K., Németh, E., & Szeberényi, A. (2024). Public audit and its role in enhancing industrial policy innovation in Ghana. *Journal of Ecohumanism,* 3(8), 12721–12734. https://doi.org/10.62754/joe.v3i8.6032

Agastya, I. B. O., Paripurno, E. T., Prastistho, B., Murwanto, H., Prasetya, J. D., & Nugraho, A. R. B. (2024). Model media learning for disaster risk reduction in the Batur UNESCO global Geopark. *International Journal of Geoheritage and Parks.* https://doi.org/10.1016/j.ijgeop.2024.04.005

Alfama, V., Henriques, M. H., & Barros, A. (2024). The Challenging Nature of Volcanic Heritage: The Fogo Island (Cabo Verde, W Africa). *Geoheritage*, 16(2), 34. https://10.1007/s12371-024-00939-9

Azman, N., Halim, S. A., Liu, O. P., Saidin, S., & Komoo, I. (2010). Public education in heritage conservation for geopark community. *Procedia-Social and Behavioral Sciences*, 7, 504-511. https://doi.org/10.1016/j.sbspro.2010.10.068

Bobrowska, A., Jagoda, E., Domonik, A. Łukasiak, D., Gajek, G. Prospects for the Protection of the Stone Heritage of the Małopolska Vistula River Gorge. *Geoheritage* 16, 110 (2024). https://doi.org/10.1007/s12371-024-01002-3

Bentivenga, M., Cavalcante, F., Mastronuzzi, G., Palladino, G., & Prosser, G. (2019). Geoheritage: The foundation for sustainable geotourism. *Geoheritage*, 11, 1367-1369. https://doi.org/10.1007/s12371-019-00422-w

Carrillo-Hernández, Y. M., Ríos-Reyes, C. A., & Villarreal-Jaimes, C. A. (2024). Geotourism and Geoeducation: A Holistic Approach for Socioeconomic Development in Rural Areas of Los Santos Municipality, Santander, Colombia. *Geoheritage,* 16, 94. https://doi.org/10.1007/s12371-024-00974-6

Carrión-Mero, P., Borja-Bernal, C., Herrera-Franco, G., Morante-Carballo, F., Jaya-Montalvo, M., Maldonado-Zamora, A., &

Berrezueta, E. (2021). Geosites and geotourism in the local development of communities of the Andes mountains. A case study. *Sustainability*, *13*(9), 4624. https://doi.org/10.3390/su13094624

Carrión-Mero, P., Merchán-Sanmartín, B., Aguilar-Aguilar, M., Morante-Carballo, F., Suárez-Zamora, S., Bárcenes-Campoverde, R., & Berrezueta, E. (2022). Strategies to Improve the Tourist Interest of a Geosite Respecting Its Natural Heritage. A Case Study. *Geoheritage*, *14*(4), 110.Cengiz, C., Şahin, Ş., Cengiz, B., Başkır, M. B., & Keçecioğlu Dağlı, P. (2021). Evaluation of the visitor understanding of coastal geotourism and geoheritage potential based on sustainable regional development in western Black Sea Region, Turkey. *Sustainability*, *13*(21), 11812. https://doi.org/10.1007/s12371-022-00746-0

Coratza, P., Vandelli, V., & Ghinoi, A. (2023). Increasing geoheritage awareness through non-formal learning. *Sustainability*, *15*(1), 868. https://doi.org/10.3390/su15010868

Dowling, R. (2015). Geotourism's contribution to sustainable tourism. In *The practice of sustainable tourism*, 207-227. Routledge. https://books.google.com/books?id=RKjwCQAAQBAJ

Dowling, R. K., & Newsome, D. (2017). Geotourism destinations–visitor impacts and site management considerations. *Czech Journal of Tourism*, *6*(2), 111-129. https://doi.org/10.1515/cjot-2017-0006

European Commission. (n.d.). Environmental Impact Assessments. European Commission. https://ec.europa.eu/environment/eia/eia-support_en.htm

Eurostat. (n.d.). Tourism Statistics. Eurostat. https://ec.europa.eu/eurostat/web/tourism/data/database

European Environment Agency (EEA). (n.d.). Waste Generation. European Environment Agency. https://www.eea.europa.eu/themes/waste

Ferdowsi, S. (2024). Management of geoheritage conservation and vulnerability in tourism destinations. *Tourism Review*. https://doi.org/10.1108/tr-03-2024-0189

Ferrando, A., Faccini, F., & Coratza, P. (2024). Ophiolites: Geological Heritage with Multifaceted Cultural Values. *Geoheritage,* 16, 108 https://doi.org/10.1007/s12371-024-01009-w Frey, M. L. (2021). Geotourism—Examining tools for sustainable development. *Geosciences*, *11*(1), 30. https://doi.org/10.3390/geosciences11010030

Gelencsér, M., Kőmüves, Z. S., Hollósy-Vadász, G., & Szabó-Szentgróti, G. (2024). Modelling employee retention in small and medium-sized enterprises and large enterprises in a dynamically changing business environment. *International Journal of Organizational Analysis*. http://doi.org/10.1108/IJOA-09-2023-3961

Global Biodiversity Information Facility (GBIF). (n.d.). Biodiversity Monitoring Reports. Global Biodiversity Information Facility. https://www.gbif.org/

Global Footprint Network. (n.d.). Ecosystem Monitoring. Global Footprint Network. https://www.footprintnetwork.org/

Gou, G.R.; Fang, W.; Cheung, L.T.O.; Fok, L.; Chow, A.S.Y.; Zhang, K. (2024). Understanding the Determinants of Geologically Responsible Behaviour among Geotourists: A Multi-Destination Analysis. *Tour. Hosp. 5*, 1-15. https://doi.org/10.3390/tourhosp5010001

Halim, S. A., & Ishak, N. A. (2017). Examining community engagement in heritage conservation through geopark experiences from the Asia Pacific region. *Kajian Malaysia*, *35*, 11-38. https://doi.org/10.21315/km2017.35.supp.1.2

Hose, T. A. (2016a). *Geoheritage and geotourism: A European perspective*. Boydell Press. https://books.google.com/books?id=PI_gDQAAQBAJ

Hose, T. A. (2016b). 3G's for Modern Geotourism. *Geoheritage*, *8*(1), 7-24. https://doi.org/10.1007/s12371-011-0052-y

International Labour Organization (ILO). (n.d.). Employment Statistics. International Labour Organization. https://ilostat.ilo.org/

International Union for Conservation of Nature (IUCN). (n.d.). Conservation Surveys. IUCN. https://www.iucn.org/resources/publications

Irfan, M., Mir, S. A., Bali, B. S., Afzal, A., Bhat, N. A., Bhat, N., & Nazir, M. (2024). Unveiling the geoheritage, cultural geomorphology and geotourism potential of Zanskar region, NW Himalaya, India. *Geomorphology*, *462*, 109354. https://doi.org/10.1016/j.geomorph.2024.109354

IUCN Red List. (n.d.). Conservation Data. IUCN Red List. https://www.iucnredlist.org/

Jon, W., Ryang, T., & Ri, M. (2024). Inventory and Quantitative Assessment of Mountainous Geoheritage Sites in Democratic People's Republic of Korea. *Geoheritage* 16, 92. https://doi.org/10.1007/s12371-024-00996-0

Kang, E., & Yoon, S. (2024). Does Technology-Based Self-Service (TBSS) Help Tourists to Revisit Destinations? Validation of Extended Theory of Planned Behavior. *Global Business & Finance Review*, *29*(7), 48. https://doi.org/10.17549/gbfr.2024.29.7.48

Kőmüves, Zs., Hopp, A. & Szabó-Szentgróti, G. (2022) Generációs különbségek és motiváció az élelmiszeriparban, *Studia Mundi – Economica, 9(2), 37-48,* https://doi.org/10.18531/Studia.Mundi.2022.09.02.37-48

Kőmüves, Zs., Pálmai, L., Kovács-Kosa, P. & Szabó-Szentgróti, G. (2023) Generációs különbségek elemzése a versenyszférában, *Új Munkaügyi Szemle 4(3) 2-13,* https://doi.org/10.58269/umsz.2023.3.1

Kubalíková, L., Bajer, A., Balková, M., Kirchner, K., & Machar, I. (2022). Geodiversity action plans as a tool for developing sustainable tourism and environmental education. *Sustainability*, *14*(10), 6043. https://doi.org/10.3390/su14106043

Lee, Y., & Jayakumar, R. (2021). Economic impact of UNESCO Global Geoparks on local communities: Comparative analysis of three UNESCO Global Geoparks in Asia. *International Journal of Geoheritage and Parks*, *9*(2), 189-198. https://doi.org/10.1016/j.ijgeop.2021.02.002

Lopes, F. C., Ramos, A. M., Callapez, P. M., Andrade, P. S., & Duarte, L. V. (2024). Geoheritage of the Iconic EN280 Leba Road (Huila Plateau, Southwestern Angola): Inventory, Geological Characterization and Quantitative Assessment for Outdoor Educational Activities. *Land*, *13*, 1293. https://doi.org/10.3390/land13081293

Marlina, E. (2016). Geotourism as a strategy of geosite empowerment towards the tourism sustainability in Gunungkidul Regency, Indonesia. *International Journal of Smart Home*, *10*(5), 131-150. https://doi.org/10.14257/ijsh.2016.10.5.13

Marlina, E., & Natalia, D. A. R. (2016). Geotourism: potential based analysis tourism development concept towards sustainable Tourism. In *International Language and Tourism Conference*. https://scholar.google.com/scholar?cites=16988739409085675866

Miah, M., Rahman, S. M. M., Biswas, S., Szabó-Szentgróti, G., & Walter, V. (2024). Effects of green human resource management practices on employee green behavior: the role of employee's environmental knowledge management and green self-efficacy for greening workplace. *International Journal of Organizational Analysis*, *online*, online-online. http://doi.org/10.1108/IJOA-04-2024-4462

Miah, M., Szabó-Szentgróti, G., & Walter, V. (2024). A systematic literature review on green human resource management (GHRM): an organizational sustainability perspective. *Cogent Business & Management*, *11*(1). http://doi.org/10.1080/23311975.2024.2371983

Mehdioui, S., Hadi, H. E., Tahiri, A., Haibi, H. E., Tahiri, M., Zoraa, N., & Hamoud, A. (2022). The Geoheritage of Northwestern Central Morocco Area: inventory and quantitative assessment of geosites for geoconservation, geotourism, geopark purpose and the support of sustainable development. *Geoheritage*, *14*(3), 86. https://doi.org/10.1007/s12371-022-00712-w

Migoń, P., & Pijet-Migoń, E. (2023). The role of geodiversity and geoheritage in tourism and local development. *Geological Society, London, Special Publications.* https://doi.org/10.1144/sp530-2022-115

Mikulic, D. G., & Kluessendorf, J. (2024). Geoheritage and geoconservation in the American Midwest: Silurian reefs of the Milwaukee–Chicago region. *Geological Society, London, Special Publications*, *543*(1), SP543-2023. https://doi.org/10.1144/sp543-2023-2

Mirari, S., Aoulad-Sidi-Mhend, A., & Benmlih, A. (2020). Geosites for geotourism, geoheritage, and geoconservation of the Khnefiss National Park, Southern Morocco. *Sustainability*, *12*(17), 7109. https://doi.org/10.3390/su12177109

Módosné, S. S., & Jenei, S. (2021). *Cégkultúra, vezetői személyiség, HR szervezet és a vállalati CSR tevékenység: I. Elméleti alapok. [Corporate culture, leadership personality, HR organization, and corporate CSR activities: I. Theoretical foundations].* Opus Et Educatio: Munka És Nevelés. 8(2), 197-206. https://scispace.com/pdf/cegkultura-vezetoi-szemelyiseg-hr-szervezet-es-a-vallalati-34xx17vzw4.pdf (in Hungarian)

Módosné, S. S., Tóth, A., & Jenei, S. (2024). *AI-based Entrepreneurial Advisory: Municipal Guidance for Business Development Conference location and date: Dubrovnik, Croatia.* 2024.09.25. - 2024.09.28. Dubrovnik: Innovation Institute. AI's Impact on Global Prosperity: Shaping the World Economy

Muka, I. K., & Suardana, I. W. (2024). Innovation of Form and Function of Banyumulek Pottery Craftsmanship in Lombok as Heritage of Traditional Culture. *Harmonia: Journal of Arts Research and Education*, *24*(1), 36-50. https://doi.org/10.15294/harmonia.v24i1.44787

Navarrete, E., Morante-Carballo, F., Dueñas-Tovar, J., Carrión-Mero, P., Jaya-Montalvo, M., & Berrezueta, E. (2022). Assessment of geosites within a natural protected area: A case study of Cajas National Park. *Sustainability*, *14*(5), 3120. https://doi.org/10.3390/su14053120

Newsome, D., & Dowling, R. (2018). Geoheritage and geotourism. In: *Geoheritage*, 305-321. Elsevier. https://doi.org/10.1016/b978-0-12-809531-7.00017-4

Németh, B., Németh, K., Procter, J. N., & Farrelly, T. (2021). Geoheritage conservation: Systematic mapping study for conceptual synthesis. *Geoheritage*, *13*(2), 45. https://doi.org/10.1007/s12371-021-00561-z

Németh, P., Torma, A., Lukács, E., & Filep, B. (2023). Sustainability Opportunities and Barriers at Universities, Development of a Sustainable University Environment. *Chemical Engineering Transactions*, 107, 505-510. https://doi.org/10.3303/CET23107085

Office for National Statistics (ONS). (n.d.). Employment Data. Office for National Statistics. https://www.ons.gov.uk/

Özgeriş, M., & Karahan, F. (2021). Use of geopark resource values for a sustainable tourism: A case study from Turkey (Cittaslow Uzundere). *Environment, Development and Sustainability*, *23*, 4270-4284. https://doi.org/10.1007/s10668-020-00773-3

Quesada-Valverde, M. E., & Quesada-Román, A. (2023). Worldwide trends in methods and resources promoting geoconservation, geotourism, and geoheritage. *Geosciences*, *13*(2), 39. https://doi.org/10.3390/geosciences13020039

Santangelo, N., & Valente, E. (2020). Geoheritage and geotourism resources. *Resources*, *9*(7), 80. https://doi.org/10.3390/resources9070080

Singtuen, V., & Won-In, K. (2018). Geodiversity and geoconservation of the Chaiyaphum region in Thailand for sustainable geotourism planning. *GeoJournal of Tourism & Geosites*, *22*(2). https://doi.org/10.30892/gtg.22223-310

Sisto, M., Di Lisio, A., & Russo, F. (2022). Geosite assessment as a tool for the promotion and conservation of Irpinia landscape geoheritage (Southern Italy). *Resources*, *11*(10), 97. https://doi.org/10.3390/resources11100097

Szabó-Szentgróti, G., Csonka, A., & Szabó-Szentgróti, E. (2016). Work vision among Y generation. *Economic and Social Development: Book of Proceedings*, 294.

Štrba, Ľ., Kolačkovská, J., Kudelas, D., Kršák, B., & Sidor, C. (2020). Geoheritage and geotourism contribution to tourism development in protected areas of Slovakia—theoretical considerations. *Sustainability*, *12*(7), 2979. https://doi.org/10.3390/su12072979

Štrba, Ľ., Vravcová, A., Podoláková, M., Varcholová, L., & Kršák, B. (2023). Linking Geoheritage or Geosite Assessment Results with Geotourism Potential and Development: A Literature Review. *Sustainability*, *15*(12), 9539. https://doi.org/10.3390/su15129539

Štrba, Ľ., & Palgutová, S. (2024). Geoheritage Interpretation Panels in UNESCO Global Geoparks: Recommendations and Assessment. *Geoheritage*, 16, 96. https://doi.org/10.1007/s12371-024-01012-1

Suzuki, D. A., & Takagi, H. (2018). Evaluation of geosite for sustainable planning and management in geotourism. *Geoheritage*, *10*, 123-135. https://doi.org/10.1007/s12371-017-0225-4

Temesgen, F., & Terefe, B. (2024). Utilizing multi-criteria decision-making analysis and 3D visualization techniques for dam site selection and irrigation area identification in Gedeb River, Ethiopia. *Heliyon*, *10*(15). https://doi.org/10.1144/sp543-2023-2

Ton, A. D., Szabó-Szentgróti, G., & Hammerl, L. (2022). Competition within cross-functional teams: A structural equation model on knowledge hiding. *Social Sciences*, *11*(1), 30.

Tóth, K., Borbély, C., Nagy, B., Szabó-Szentgróti, G., & Szabó-Szentgróti, E. (2021). Measurement of food losses in a Hungarian dairy processing plant. *Foods*, *10*(2), 229.

UNESCO Global Geoparks. (n.d.). Visitor Statistics and Community Engagement. UNESCO. https://www.unesco.org/en/iggp/geoparks

UNESCO. (2023). *UNESCO Global Geoparks*. https://en.unesco.org/global-geoparks

UNESCO Global Geoparks. (n.d.). Visitor Statistics and Community Engagement. UNESCO. https://www.unesco.org/en/iggp/geoparks

United Nations World Tourism Organization (UNWTO). (n.d.). Tourism Statistics. UNWTO. https://www.unwto.org/statistics

VisitBritain. (n.d.). Tourism Statistics and Visitor Numbers. VisitBritain. https://www.visitbritain.org/insights-and-statistics

Xu, K., & Wu, W. (2022). Geoparks and geotourism in China: A sustainable approach to geoheritage conservation and local development—A review. *Land*, *11*(9), 1493. https://doi.org/10.3390/land11091493

VisitBritain. (n.d.). Tourism Statistics and Visitor Numbers. VisitBritain. https://www.visitbritain.org/insights-and-statistics

World Bank Open Data. (n.d.). Economic and Environmental Reports. World Bank. https://data.worldbank.org/

World Economic Forum (WEF). (n.d.). Global Competitiveness Reports. World Economic Forum. https://www.weforum.org/reports

World Wildlife Fund (WWF). (n.d.). Conservation Reports. World Wildlife Fund. https://www.worldwildlife.org/publications

Zhang, C., Chen, J., Li, P. Han, S., Xu, J. Integrated high-precision real scene 3D modeling of karst cave landscape based on laser scanning and photogrammetry. *Sci Rep* 14, 20485 (2024). https://doi.org/10.1038/s41598-024-71113-y

https://hybridpowersystems.org/powersystem_azores/