TOURISM CARRYING CAPACITY OF GEOSITES ON SANTA CRUZ ISLAND, GALAPAGOS, FOR ITS SUSTAINABILITY

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ABSTRACT
Galapagos was declared a Natural World Heritage Site (1976), UNESCO Biosphere Reserve (1984), and Ramsar Site (2001) because of its unique flora, fauna and landscapes, which inspired Charles Darwin. Due to the variety of tourist sites around the four large inhabited islands, there is an increase in national and foreign tourists (267,688 people in 2022), which may cause deterioration of the tourist facilities if not adequately monitored or regulated. This study aims to evaluate the tourism carrying capacity of 15 geosites on Santa Cruz Island, Galapagos, through qualitative and quantitative information for the sustainable enhancement and optimal use of geotourism. Field visits were made to collect data and information from each of the 15 geosites, and the tourism carrying capacity was calculated and evaluated using a methodology proposed by several authors for the development of sustainable geotourism strategies. In the evaluation of the carrying capacity, the visitor numbers varied between 500 and 2,000 per day, with Tortuga Bay and Playa 'El Garrapatero' standing out for their large size to accommodate tourists and adequate geotourism facilities. This analysis and evaluation allowed us to propose improvement strategies to promote and optimise the use of geosites based on geotourism, geo-education and geoconservation pillars. A fundamental axis is governmental participation through plans that motivate awareness-raising and sustainable tourism, as well as geocommunication of the unique values of each geosite, to argue technically for the sustainability of natural heritage.
Keywords: geotourism, geological sites of interest, sustainability, ecotourism, environmental protection, Galapagos.

1 INTRODUCTION

Geotourism is a type of tourism that highlights and gives importance to the geology and landscape of destinations for the promotion of sustainable tourism development to improve the local economy, well-being of communities, and conservation of the destination [1], [2]. Geotourism, proposed as a valuable tool for promoting natural and cultural heritage, enables sustainable economic and social growth in a region [3], [4]. Geotourism also seeks to minimise the negative impacts of mass tourism on geographically or geologically sensitive tourism ecosystems, while supporting sustainable rural development [5], [6].

Geotourism focuses on showcasing a destination's unique natural and cultural heritage and preserving and protecting its authenticity [7]. The set of unique geological features that are the product of the Earth's history can be seen in various forms (rocks, minerals, fossils, and soil), which bring together a diverse landscape system known as geodiversity [8], [9]. Therefore, quantitative or qualitative geoheritage assessment is an essential topic worldwide, as it allows proper monitoring and sustainable development planning of sites with geological potential [10], [11].

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Interest in conserving abiotic landscapes and landforms for tourism, heritage or recognition of natural values has been both dynamic and uneven [12]. The growing interest in geoconservation has been demonstrated by numerous inventories of sites of interest conducted in different countries [4], [13]. Some sites of geological interest (SGIs) are at risk due to their vulnerability to natural and anthropogenic degradation (e.g. mines and construction of civil works) [14].

The tourism development of geological sites of interest can bring considerable economic benefits, but it will also put tremendous pressure on public resources, the cultural atmosphere, and the ecological environment, jeopardising the sustainable promotion of the destination [15], [16]. As a basis for tourism development planning, academics, industry professionals, and governments have proposed a tourism carrying capacity (TCC) [17], [18]. TCC is the maximum tourist presence at a destination that does not disrupt the ordinary activities of residents or prevent tourists from appreciating the destination, causing overtourism [19], [20].

In terms of biodiversity, Ecuador ranks 17th globally. In recent years, Ecuador has maintained increased tourist arrivals because of its natural beauty [21]. According to the Ecuadorian environmental legislation, the conservation of geological heritage is linked to protected natural areas [22]. The term geoheritage was unknown until recently [23]; however, since the creation of the Ecuadorian Geoparks Committee in 2019, the dissemination of the topic has gained greater public attention [24].

Galapagos, known for its volcanic origin ('hotspot'), was declared a UNESCO World Heritage Site in 1978 [25], because of its extraordinary biodiversity and natural surroundings. It is located 972 km off the mainland coast of Ecuador and consists of 13 main volcanic islands and more than 300 islets and rocks [26]. Santa Cruz, San Cristóbal, Isabela and Floreana islands have permanent human settlements [27]. Galapagos is a well-known tourist destination where authorities seek strategies to promote conservation and community interests through tourism [28] (Fig. 1).

Santa Cruz Island is a 990 km^2 elliptical shield volcano that rose 950 m.a.s.l. approximately 2 million years ago [29]. The most notable topographic features are steep volcanic cinder cones, large pit craters (more than 100 m in diameter and 100 m deep), and deeply incised ephemeral or permanent river channels [30], [31]. Soils developed from the in situ weathering of volcanic rocks and pyroclastic materials [32], [33].

Kelley and Salazar [34], Kelley et al. [35], and Carrión-Mero et al. [36] qualitatively explored the geodiversity and geoheritage of the islands, including their origin, geological context and conservation on the islands. Specifically, these authors proposed an inventory covering 15 geosites on Santa Cruz Island, which is essential for the sustainable management of the national park and its surroundings.

The Galapagos National Park Administration (GNP) prepares an annual report on the number of tourists visiting the Galapagos Islands, noting that visits have increased by 23% from 2022 to 2023 (267,688 and 329,475 tourist arrivals, respectively) [37], [38]. Authorised visitor numbers have increased under demand without the necessary studies to justify such increases, and this excess has caused degradation and deterioration of the number of tourist sites visited.

Therefore, how to evaluate the adequate tourism capacity at these SGIs to guarantee a correct monitoring and management system for the GNP? To answer the research question, the objective of this research is to evaluate the TCC of 15 SGIs suggested by Carrión-Mero et al. [36] using a physical, real and practical tourism calculation for the proposal of political, economic, social and environmental solutions that allow the correct management of these sites.

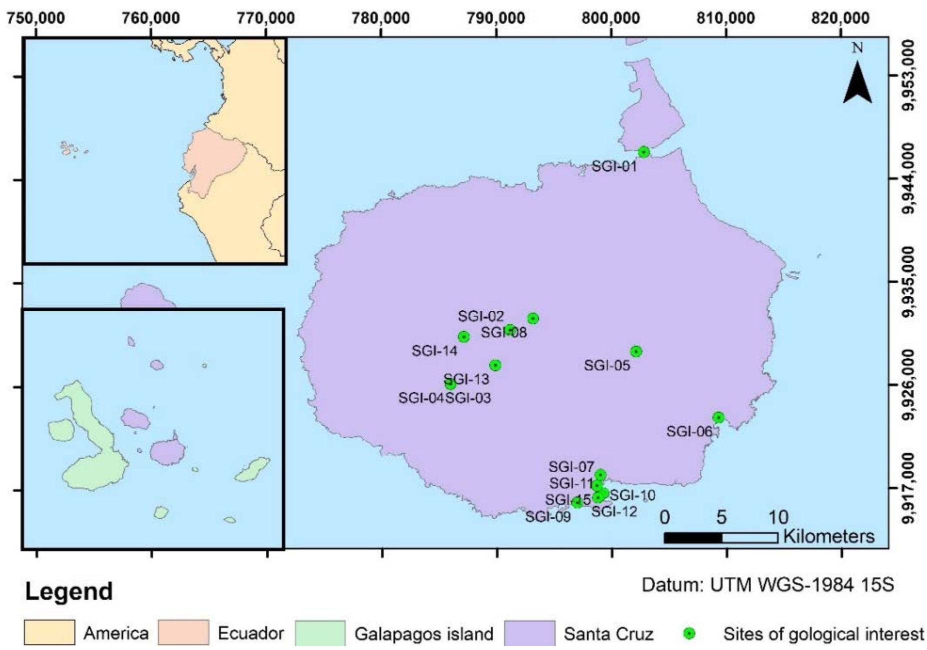


Figure 1: Location map of Santa Cruz Island, Galapagos, and its sites of geological interest (SGIs) (see Table 1).

Table 1: Selection of sites of geological interest (SGIs) on Santa Cruz Island.

Code	Name	Coordinates (UTM WGS-1984 16S)
SGI-01	Itabaca channel	x: 802844; y: 9946335
SGI-02	Los Gemelos	x: 791177; y: 9930863
SGI-03	Primicias tunnel	x: 785994; y: 9926161
SGI-04	Turtle lagoon	x: 785994; y: 9926161
SGI-05	Mesa hill	x: 802151; y: 9928951
SGI-06	‘El Garrapatero’ beach	x:809298; y:9923185
SGI-07	‘Misión Franciscana’ crack	x: 799020; y: 9918220
SGI-08	Quarry	x:793167; y:9931858
SGI-09	Tortoise bay	x: 796975; y: 9915803
SGI-10	‘Los Alemanes’ beach	x:799258; y:9916622
SGI-11	Salt mine	x:798998; y:9916439
SGI-12	‘Las Grietas’	x: 798795; y: 9916230
SGI-13	Royal Palm tunnels	x:789896; y:9927792
SGI-14	‘Diego Salazar’ lagoon	x: 787163; y: 9930271
SGI-15	‘Las Ninfas’ lagoon	x: 798709; y: 9917275

2 MATERIALS AND METHODS

Determining the carrying capacity (CC) of visitor sites is essential in taking the first step towards effectively managing these SGIs. This study contributes to strengthening the concept of sustainable tourism with the component of geological sites of interest by using and modifying a TCC assessment methodology. This study also provides a deeper understanding of the geological heritage of the Galapagos Islands and its potential for sustainable tourism development, scientific research, and preservation.

The present research focused on the development of the following three phases: (i) selection of geosites on Santa Cruz Island; (ii) evaluation of the TCC of the selected geosites; and (iii) proposal of geotourism sustainability strategies within the evaluated geosites. Fig. 2 shows a summary diagram of the methodology followed in this research.

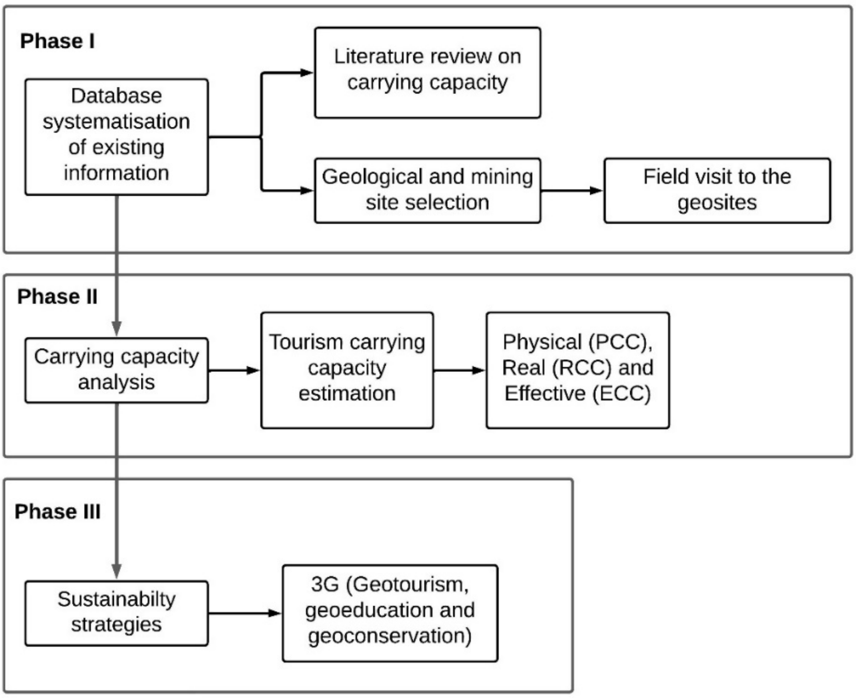


Figure 2: Methodology adopted in this research.

2.1 Geosite selection

This first phase consisted of a literature review of the geosites inventoried and evaluated in the study area for their geological and mining relevance in scientific publications. In this study, the 15 inventoried and evaluated sites of Carrión-Mero et al. [36] were the SGIs chosen.

After selecting the geosites, the authors visited each site to obtain data and information for assessment during this phase.

2.2 TCC assessment

Several authors have proposed a methodology for estimating and assessing the TCC [40]–[42]. The assessment consists of three components: physical carrying capacity (PCC), real carrying capacity (RCC), and effective carrying capacity (ECC). The professionals in charge of these assessments were co-authors of this study (Table 2).

Table 2: Explanation and determination on physical carrying capacity (PCC), real carrying capacity (RCC), and effective carrying capacity (ECC).

	PCC	RCC	ECC
Explanation	Maximum visits can occur at the site during a specific time within a particular space	PCC correction factors that affect the site directly or indirectly	Maximum visits to each SGI can allow for the analysis of certain variables
Determination	PCC = (V/a) × S × t where: V/a: visitors/occupied area; S: area available for visitors' access; t: necessary time for the visit	• Social factor • Solar factor • Precipitation factor • Erodibility factor • Accessibility factor • Temporary closure factor • Waterlogging factor	• Staff (guides) • Infrastructure

2.3 Proposed geotourism sustainability strategies

The results obtained from Phase II provided an analysis of the current state of each geosite, considering the impact of tourism and human activity. With this, it is intended to propose strategies that will help the tourism sustainability of the geosites and allow correct geotourism development on Santa Cruz Island. To this end, applying the modified 3G model enables the development of strategies in three main areas for sustainable tourism at geosites (geotourism, geoeducation, and geoconservation) [43], [44].

3 RESULTS AND DISCUSSION

3.1 TCC assessment

CC is a widely used tool for tourism management. CC refers to the maximum number of visitors a tourism site can support sustainably (without degradation). Table 3 presents the estimated number of people who can visit sites of geological or mining interest.

Table 3: Carrying capacity values (PCC, RCC, ECC) (visits/day) of the evaluated SGIs.

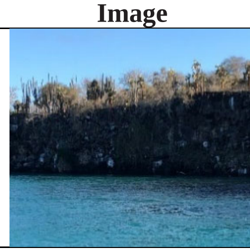
Code	Name	PCC	RCC	ECC	Image
SGI-01	Itabaca channel	28,500	3,996	2,797	

Table 3: Continued.

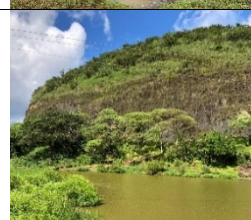
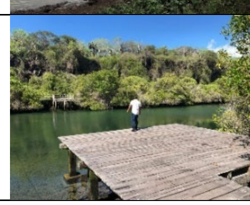
Code	Name	PCC	RCC	ECC	Image
SGI-02	Los Gemelos	1,600	377	339	
SGI-03	Primicias tunnel	550	130	97	
SGI-04	Turtle lagoon	733	194	156	
SGI-05	Mesa hill	833	132	113	
SGI-06	‘El Garrapatero’ beach	5,958	1,053	684	
SGI-07	‘Misión Franciscana’ crack	200	61	44	
SGI-08	Quarry	2,500	282	42	

Table 3: Continued.

Code	Name	PCC	RCC	ECC	Image
SGI-09	Tortoise bay	6,500	1,149	747	
SGI-10	'Los Alemanes' beach	1,200	316	205	
SGI-11	Salt mine	1,200	337	269	
SGI-12	'Las Grietas'	1,200	337	269	
SGI-13	Royal Palm tunnels	550	144	101	
SGI-14	'Diego Salazar' lagoon	667	56	47	
SGI-15	'Las Ninfas' lagoon	500	265	172	

The Itabaca channel was the geosite with the highest PCC (28,500 visitors per day), but it decreased to an ECC of 2,797 visitors per day. This decrease was mainly due to correction factors such as social (because they must be visited in groups and on boats), accessibility (as they must be on boats, people with reduced mobility are a challenge), precipitation, and solar (as it is an outdoor geosite, on days with a lot of precipitation or solar radiation, it can cause people not to make tourist visits).

Geosites such as Royal Palm tunnels, Quarry, 'Misión Franciscana' crack, Primicias tunnel and Mesa hill have a large surface area available for tourist visits; however, there are sections with slopes of between 10%–20%, or sections with gullies, making accessibility difficult for vulnerable groups (reduced mobility and elderly people).

The 'Misión Franciscana' crack, Quarry and 'Diego Salazar' lagoon are privately managed geosites, for the moment, which does not allow tourists to get to know them in their entirety. This means that they do not have infrastructure, or personnel hired for tourism or geotourism activities. These can help the GNP have more tourist sites in its catalogue.

3.2 Proposed geotourism sustainability strategies

Based on information on CC, this study proposes designing a 3G model (focused on geotourism, geoconservation, and geoeducation) to establish proposals for managing and conserving geosites. It shows an approach with strategic proposals that consider the unfavourable (negative) and unexploited aspects of each geosite.

- Geotourism: (i) Promote the development of geoproducts with community participation; (ii) Improve security in each geosite; (iii) Increase the diversity of tourism services in each geosite.
- Geoconservation: (i) Support the preservation of geosites with inclusive operational programmes; (ii) Seek public and private financial support for flora and fauna conservation, (iii) Foster knowledge of geotourism at all educational levels.
- Geoeducation: (i) Enhancing the community–academia–government nexus; (ii) Promote environmental education as a driver of sustainable development; (iii) Provide training for tourism service providers in geotourism issues.

Strengthening geotourism within these geosites allows progress in the development of the Galapagos Geopark proposal. Galapagos has two UNESCO designations for flora and fauna (World Heritage Site and Biosphere Reserve) but can eventually obtain the highest designation for geotourism (Global Geopark). In presenting the idea of these geosites, the authorities (decision-makers) must come together to provide security and diversify their tourism services.

Within the geoeducation axis, the political sector should include geotourism in academic curricula and strengthen the links between the actors of the three subsystems (community, government, and academia). The education industry can contribute to developing a geotourism management model by conducting research and scientific dissemination activities related to geoheritage and sustainable tourism.

4 CONCLUSION

This study comprehensively assesses the TCC of 15 geosites within Santa Cruz Island, Galapagos. These results provide valuable guidance for the sustainable management of geosites, thereby strengthening conservation for the optimal use of geotourism attractions.

The Itabaca Channel has the highest ECC, with 28,500 visitors per day. 'El Garrapatero' beach (5,958), Tortoise Bay (6,500), 'Los Alemanes' beach (1,200) and 'Las Grietas' (1,200) can attract many visitors, but their ECC decreases due to factors such as climate, accessibility and tourist operations related to lack of tour guides. Whereas, Royal Palm tunnels, Quarry, 'Misión Franciscana' crack, Primicias tunnel and Mesa Hill have a larger surface area available for tourist visits; however, the slope or uneven terrain may make accessibility difficult for certain groups of visitors, which reduces the ECC.

This study proposed an integrated 3G model (geotourism, geoconservation, and geoeducation) for the development and management of geosites. The importance of this model lies in its holistic approach, which addresses the attractiveness of tourism and environmental sustainability of geosites. The geotourism axis highlights the need to diversify and improve tourism services, increase the attractiveness of geosites, and generate employment and economic benefits for local communities. The geo-conservation axis stresses the importance of protecting biodiversity and geoheritage, which is crucial for ensuring that geosites can maintain ecosystem balance and can be enjoyed by future generations. The geo-education axis highlights the vital role of education and communication between local and tourist populations, and governments in promoting sustainable geotourism.

Future research should address geo-environmental and social assessments using complementary methodologies to understand how they change in response to management interventions, and environmental and social conditions. These efforts will improve the scientific understanding of these geosites, contribute to effective and sustainable geotourism management, benefit local communities, and promote the prosperity of the Geopark project.

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