SOIL EROSION ON TRAILS AND THE ROLE OF GEOCONSERVATION IN THE MANAGEMENT OF CONSERVATION UNITS

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Abstract

Geotourism offers a means of conserving the natural environment. However, geotourism has environmental impacts, especially within Conservation Units (UCs), which are legally protected natural spaces in Brazil. One of the most relevant impacts resulting from visiting UCs is soil degradation, due to erosion on trails. This research aims to promote the relevance of geodiversity within UCs, to map trails and identify associated erosion processes. In particular, geodiversity is investigated on the Mirante do Caeté trail, located in the Prainha Municipal Natural Park (PNMP). Initial research demonstrates the need to conduct more conservation activities and to improve accessibility and the dissemination of geoeducational information to visitors, especially geotourists.

Keywords

Soil Erosion, Trails, Geodiversity, Conservation Areas

1. Introduction

The search for sustainable development is guided by three fundamental principles that encompass environmental, economic and social dimensions. In September 2015, global leaders gathered at the United Nations Headquarters in New York with the purpose of establishing an action plan aimed at eradicating poverty, protecting the planet and ensuring peace and prosperity for all. This plan was formulated as the '2030 Agenda for Sustainable Development,' covering 17 Sustainable Development Goals (SDGs).

The 2030 Agenda and associated SDGs emphasize the pressing need for bold and transformative actions to lead the world towards sustainable development. The SDGs constitute an ambitious list of goals to be achieved by 2030, and by achieving them, we will have the honor of being the first generation to eradicate extreme poverty and protect future generations from the most severe impacts of climate change.

In 2023, the Federal University of Rio de Janeiro (UFRJ) was certified for the second consecutive year with the SDG Education Seal, which represents SDG4 (Quality Education). The SDG Education Seal is a component of the SDG territorialization strategy of Brazil, aiming to share experiences and encourage participation.

In this context, this research focuses on geodiversity, geotourism and geoconservation, promoting the relevance of trails and their erosion processes. The geoconservation of natural elements, composed of abiotic elements, is necessary for maintaining the quality of life of species on the planet, and for advancing understanding of the origin and evolution of Earth (Jorge and Guerra, 2016). The study is in progress at Prainha Municipal Natural Park (PMNP), a periurban park in Rio de Janeiro City (Figure 1). According to Environmental State Institute (INEA), this Park is one of 40 Conservation Units (CUs) in Rio de Janeiro (RJ) State and represents a place of notable tourist interest, with considerable potential to attract visitors.

The chosen trail was the Mirante do Caeté trail, because of its geoconservation elements and evidence of erosion processes. The growing flow of visitors that walk the trails of the PNMP, combined with the physico-chemical characteristics of the local soil, contributes to soil degradation. Degradation processes include soil compaction and soil erosion. This article addresses these issues in a comprehensive and structured way, proposing strategies and solutions to promote sustainable development in the area, and the preservation of this important natural and cultural heritage.

2. Methods

Study Area Characterization

The Prainha Municipal Natural Park (Figure 1) was officially created on March 25, 1999, through Municipal Decree No. 17,426, which established its limits, objectives and zoning. The Park has multiple ecosystems, including sandbanks, rocky coast, sandy beach, wetlands, and dense rainforest (SMAC, 2022). With a total area of 126.30 hectares, the Park offers visitors two distinct trails: the 500 m long Circular Trail, which is relatively level and surrounds the Park Use Zone and the ~800 m long *Mirante do Caeté* Trail, located within the PNMP (Figure 2).

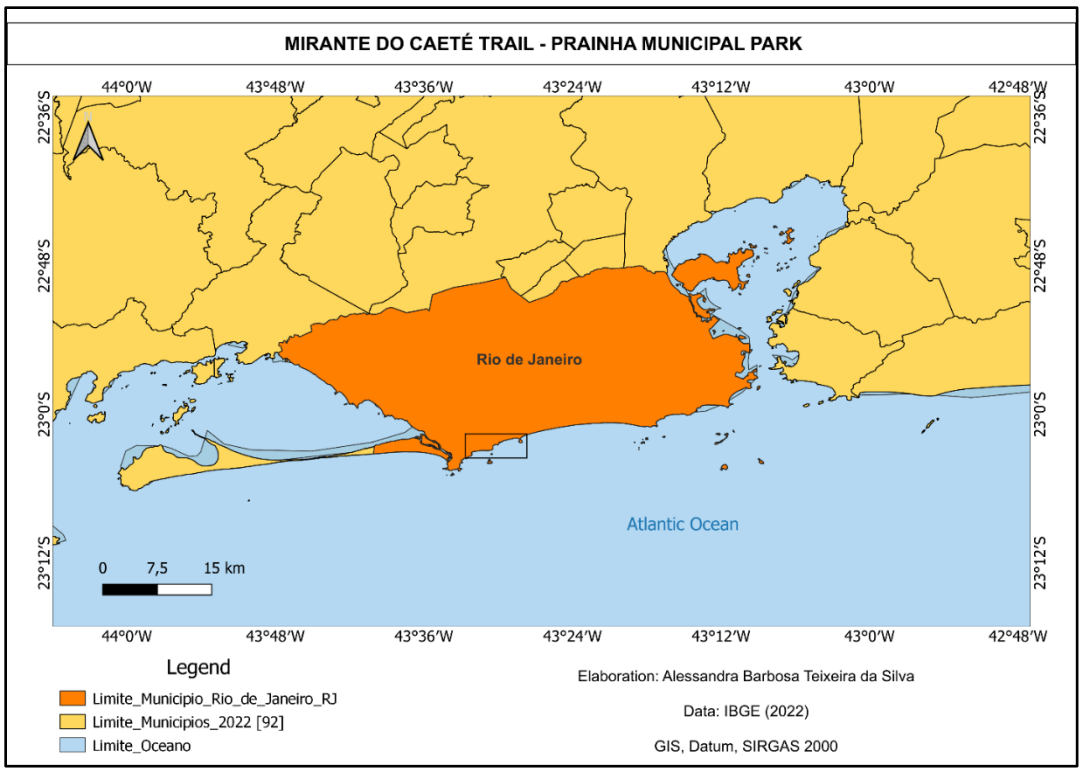

Figure 1. Location of the study area.

Figure 2. Location map of the Mirante do Caeté Trail (red line) and observation points (yellow markers).

Methodological Procedures

The research methodology of adopts concepts proposed by Loureiro and Guerra (2023), Guerra and Jorge (2018), Jorge and Guerra (2016), Guerra (2015), Moreira (2014), and Brilha (2005, 2016). These concepts address multiple topics, including geodiversity, geoconservation, geotourism, trails and soil erosion. Furthermore, an inventory of geosites (Brilha, 2016) was conducted in the PMNP, identifying information about local geology and geomorphology. Geosites have been selected based on their scientific value and educational and tourism potential.

Geodiversity

Generally, geodiversity refers to the non-living elements of Planet Earth, encompassing both aspects linked to the geological past (*e.g.*, minerals, rocks and fossils) and current natural processes. The term "geodiversity" is relatively recent and began to be adopted by geologists and geomorphologists in the early 1990s, with probable origins in Australia, especially Tasmania (Sharples, 2002)

Geoconservation

Geoconservation aims to protect geodiversity related to important geological (substrate), geomorphological (landscape) and soil processes and features, ensuring the maintenance of the history of its evolution, in terms of speed and magnitude (Sharples, 2002). Brilha (2005) added to this concept, including in its definition the management of geological heritage associated with natural processes. In a broader sense, the term geoconservation has been used to encompass various activities related to the protection of geological heritage, from basic surveys to management practices.

In Brazil, initiatives emerged in the 1990s, with the creation of the Brazilian Commission of Geological and Paleontological Sites (SIGEP) in 1997. In 2006, the Brazilian Geological Service (CPRM) launched the Geoparks Project, which aimed to identify, describe, catalog and publicize areas with potential for geotourism and geoconservation, and thus contribute to sustainable development (Schobbenhaus and Silva, 2010). Despite the enormous geodiversity of Brazil, there is still an insufficient knowledge base (Vallerius et al., 2020). Geoparks are places of singular beauty and great scientific, educational and touristic importance (Guerra and Jorge, 2018). They provide case studies of the geological history of a region and combine the conservation of geological heritage with potential for local socioeconomic development. These sites have multiple facets, including geology, geomorphology, soils, biodiversity, archaeology, ecology and culture.

Conservation Units are areas designated by the Ministry of the Environment (MMA) and include their associated environmental resources. However, unlike UCs, geoparks deliberately involve local people in their development and sustainability strategy (Oliveira et al., 2014).

Geotourism

The concept of geotourism has generated much debate. Some regard geotourism as an aspect of ecotourism, while others consider it to be a separate phenomenon. This debate is related to the concepts established and used nationally to define "ecotourism" and "natural heritage" (Nascimento et al., 2007). The creation of itineraries for geotourists has

become a highly effective tool in promoting geological heritage, providing new opportunities for local development and meeting growing tourist demand (Jorge, 2017).

Trails

Trails are probably the most widespread travel routes in the world (Lechner, 2006), and often may be the only way to access natural attractions (Jorge and Rangel, 2023). Despite their relevance, situations in which trails are implemented and managed appropriately are rare. Management strategies should aim to align the conservation of the natural environment with the significant experience of raising awareness for users, reducing impacts and risks and developing appropriate public use (Jorge and Rangel, 2023).

Soil Erosion on Trails

Trails promote greater interaction between people and nature. However, they can also be vectors for the spread of various environmental imbalances, especially in cases of poor management. These include the introduction and dissemination of exotic plant species, the trampling of vegetation, soil exposure, compaction and soil erosion (Costa, 2006; Maganhotto, 2006; Gualtieri-Pinto et al., 2008; Neiman et al., 2009; Maganhotto et al., 2010; Figueiredo et al., 2014). Jorge (2017) highlighted the importance of recognizing the magnitude of impacts caused by trampling, which depend on several factors, including environmental conditions and the type and use of trails. Rangel (2016) emphasized the relevance of managing surface runoff, avoiding flow concentration, and suggested that the trail layout should follow the topography of the land. It is difficult to separate the impacts of the management of trails from those associated with trampling and water erosion (Cole (2004), cited by Rangel (2016)). Generally, it is only when the use of trails is notably high that the impacts caused by trampling become more evident.

Soil erosion was investigated in Ubatuba Municipality, São Paulo State. Investigations used a suite of soil characterization techniques (*i.e.*, clay mineralogy, bulk density and physicochemical analysis), together with continuous hydrological measurements and monitoring (Pereira et al., 2022).

3. Results and Discussion

The Mirante do Caeté trail is located in the PNMP (23º02'23.7"S, 43º30'21.8"W). Elements of geodiversity present in the landscape include rocks, soils and typical vegetation of the Atlantic Forest. Along the trail the type of vegetation has changed, due to the need to remove it to open the trail, but there is undergrowth and exposed soil, which is subject to rill erosion.

The analysis of erosion processes along the trail in the PMNP is essential for the conservation of this ecosystem. Firstly, a complete survey of the trail was conducted, including measuring the length, slope conditions and altitude, using a Garmin GPS. In addition, an inventory of geosites within the PMNP was compiled (Brilha, 2016), including a bibliographic and cartographic review of information about local geology and geomorphology. Then, a diagnosis of the trail was conducted, involving checking the quality of the trail structure and identifying possible problems, such as erosion, landslides, lack of conservation and obstacles that could compromise the safety and accessibility of the trail. The analysis of critical sites where eros width, ion processes occur is another crucial step.

The intensity of erosion must be assessed, considering the morphological characteristics of rills (*i.e*., depth, width and length) and associated soil degradation.

Despite the continuous and abundant presence of protective vegetation cover, three erosion processes were mapped along the trail. The first one (23º02'23.5"S, 43º30'22.5" W) (Figure 3) is a shallow rill, which is ~1 m long. Probably, during precipitation events, water discharge in this rill can be erosive, causing risks to geotourists and other visitors. Next, there is a second bridge over an ephemeral watercourse (23º02'20.3"S, 43º30'22.9"W), where the second erosive process of tunnel erosion (piping erosion) was identified (Figure 4). It is observed that in subsurface erosion, where the tunnel is already installed, the vegetation, through the roots, can be provoked due to the occurrence of specific mass movements concentrated around the roots that emerge on the roof of the tunnel.

Figure 3. Rill on the trail (Photo: Alessandra Silva).

Figure 4. Piping erosion (Photo: Alessandra Silva).

4. Conclusions

Geodiversity is essential for the conservation of abiotic characteristics, geoconservation and the promotion of geotourism. Geotourism has important socio-economic functions. In the context of municipal parks, it is imperative to promote the conservation of natural resources and associated ecosystem services. The occurrence of erosion features is attenuated by the abundant vegetation of the Atlantic Forest, but erosion features were identified, observed and recorded. The main form of soil degradation was rill erosion. It is suggested that a handrail is installed along the trail. Stakes are used to stabilize larger rocks. For the safety of geotourists, it is recommended that cautionary safety signs are displayed.

The promotion of geoeducational materials is recommended, such as interpretive trail signs and guide leaflets. To maximize information dissemination, these signs should be regularly updated and include a QR code. This

would enable updating the public and providing walkers with the latest research information. Furthermore, a continuous geosite monitoring program is recommended.

In addition, the purpose of this research work is also important in the context of the Sustainable Development and achievement of SDG Goals 2030. In view of its uniqueness, there is a challenge to carry out other dimensions of sustainability along the trails such as water conservation, material conservation and Waste Management.

This paper reports a pilot study and further research will delve deeper into the issues raised. The next step will involve collecting soil samples to analyze their physico-chemical properties in the laboratory. The creation of explanatory leaflets is an option being investigated by the research group. Progressively, the study will evolve to provide generic protocols for the initiation, preparation and monitoring of tourist trails and the dissemination of geoeducational information.

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