International Cartographic Association
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Designing and validating a geoinformation system for managing the visitor's impact in Brazilian natural parks

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Keywords: geoinformation, Geographic Information System, protected areas

Abstract:

Visitors to protected areas in Brazil constantly increase (Semeia Institute, 2023; MMA, 2022). As a result, it is necessary to implement approaches that promote positive experiences for visitors while monitoring the physical, biological, and social impacts. Monitoring visitation using indicators is critical to prevent and detect potential environmental impacts (ICMBIO, 2011). Geospatial technologies, such as remote sensing (RS), geographical information systems (GIS), global navigation satellite systems (GNSS), and geographic database systems, have the potential to support the management of visitor impacts in protected areas. However, we have noticed a lack of geoinformation systems that integrate the needs of the park managers with the tools designed for the geoinformation system. An important aspect of the designed tools is the user interface and tutorials that could help the users to better decide the sequence of the geoinformation system tools for accomplishing the spatial analysis they need. This study aimed to integrate the users' needs into the geoinformation system design and implementation to manage the visitors' impact in Brazilian natural parks.

This research is a follow-up to a study that aimed to define the characteristics of a geoinformation system (GIS) designed to minimize the impacts on visitors in natural parks. In that research work, we adopted the methods and techniques of Requirements Engineering (Sluter et al. 2016) to design and implement a system. As a result of the first research part, we identified that the GIS should store data related to the biophysics characteristics of the trails and support the visual analysis demanded by the users. We also defined the functional requirements described in the system requirements documentation. The requirements documentation was the basis for designing a geoinformation system for a Brazilian national park called *Aparados da Serra* (in Portuguese). We learned that using requirements elicitation and analysis, complemented with the guidelines proposed by Sluter et al. (2016) as the first step of the GIS design, made it possible to identify the essential components of the system to be built (Peres et al., 2023).

In the sequence of that research work, we validated the system requirements with some GIS users. Creating use scenarios for system validation (Robertson e Robertson, 2012) makes it possible to clearly understand the real conditions for using the system, and to identify possible errors and omissions in the system design (Pressman e Maxim, 2016). We developed the system validation in three scenarios comprising some tasks. We established a goal for each scenario, and the participants (users) should achieve the goal by developing those tasks. The three participants in the validation step of the system design are experts in environmental protection and natural park management, but they have different levels of skills in GIS software. One has advanced knowledge of Geoinformation Science and, consequently, GIS software tools. Another participant has a basic understanding of Cartography and Remote Sensing, and little experience with GIS software. Although the third participant is not an expert on Geoinformation Science, he has vast practical knowledge of using QGIS software.

We installed the QGIS software (gis.org) version 3.28 (the most stable version at the time) on the participants' computers. The participants developed the tasks of each scenario by reading the explanations in an instructions document. In the first scenario (Figure 1), the participants should identify the non-official trails exposed to environmental vulnerability, which they would verify in fieldwork. The non-official trials are those that the visitors opened in the woods without permission from the park management office. The participants needed to locate those trails, measure the distances between them, and identify those closer to the rivers. The second scenario was intended to simulate fieldwork for collecting geographic data based on a methodology already used by the participants in their daily jobs. The purpose of this scenario is to use a GIS to develop the same tasks they have already performed on a collaborative map. To achieve the scenario's goal, the participants needed to store, in the GIS, some data from simulated fieldwork using photos of the trails and their geographic coordinates. The goal of the third scenario (Figure 2) was to verify the existence of erosion and its consequences. The participants had to identify the location of the erosion to measure the distance between the biophysics characteristics of

the trail and the vertical volcanism locations. To finish the scenario tasks, the participants had to measure the distance between the trail erosion and the canyon edge, rivers, and waterfalls.

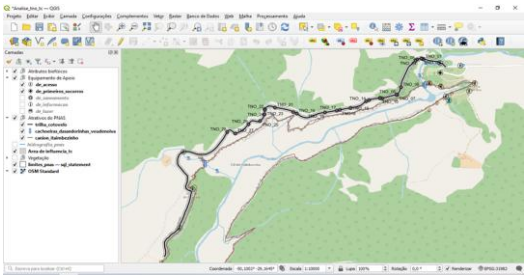

Figure 1. QGIS screen showing the geospatial data needed for scenario 1.

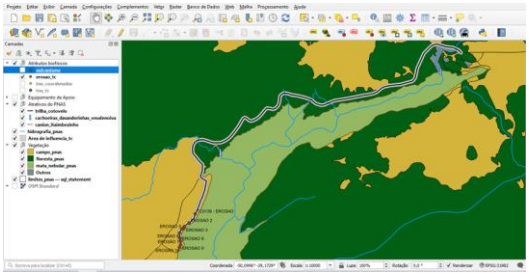

Figure 2. QGIS screen showing the geospatial data needed for scenario 3.

After validating the requirements, the participants individually evaluated each scenario through specific questionnaires to verify whether the activities carried out with the GIS met their needs. The evaluation included questions about their perception of the contribution of the GIS functions and tools for accomplishing each task, aiming to manage the impacts of visitation on the trails. All activities performed in the three scenarios were considered satisfactory by the participants, meeting the established requirements. They also highlighted that the GIS functions have great potential to support the management of impacts on the trails. The results confirmed the commitment to developing a practical solution that meets users' needs and promotes trail preservation and sustainable management.

Among the main results achieved, we emphasize the system's ability to support identifying vulnerable trails, collecting geographic data, and analyzing environmental risks, regardless of whether the user is a GIS expert. In conclusion, requirements elicitation and documentation are fundamental to designing and implementing a GIS. The participants with different experience levels in GIS allowed for a comprehensive evaluation, highlighting usability challenges and guiding necessary adjustments to meet different skill levels and familiarity with the software. The requirements validation we carried out through scenarios based on the main attributes indicated by the participants demonstrated the efficiency of the GIS. This methodological approach allowed a careful and objective evaluation of the developed application, enabling the identification of strengths and possible improvements, contributing to the efficiency and effectiveness of the system.

Acknowledgements

ICMBio – Chico Mendes Institute for Biodiversity Conservation, Environment Ministry, Brazil. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) - Finance Code 001

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