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Using open and collaborative data to improve the Brazilian topographic mapping in protected areas

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Abstract:

This research proposes a methodology for mapping Brazilian protected areas at scales larger than 1:50,000 using a swift and practical solution involving open data, software, and services. The deficiency of up-to-date topographic maps at various scales poses a significant challenge to environmental conservation in Brazil. Presently, the Brazilian territory is fully mapped only at scales of 1:250,000 and 1:1,000,000, with most maps being outdated due to the absence of a systematic map revision program by Brazilian official mapping agencies. Furthermore, these agencies have not engaged in topographic map generalization, exacerbating the issue. One of the problems with using collaborative data in Brazil is that the completeness and updated level of the map elements tend to be better in populated areas (Camboim et al., 2015). Consequently, areas least mapped by official agencies or collaborative platforms are often environmentally protected zones. The data generated in this study is referred to as topographic mapping, which shares the characteristics of maps for general purposes. It is not within the scope of this study to propose its adaptation for the national systematic maps.

This study addresses the creation of maps at scales appropriate for environmental monitoring in protected areas. We hypothesize that it is feasible to produce planimetric maps at scales greater than 1:25,000 by georeferencing satellite imagery with collaborative data, leveraging the availability of satellite imagery with spatial resolutions finer than 10 meters and open, collaborative data on rivers, pathways, and trails in national parks.

We proposed a cost-effective solution using CBERS 4A satellite images and QGIS software. CBERS 4A, the latest satellite from the CBERS program—a Brazil-China partnership since 1988—features three sensors with varying spatial resolutions: a multispectral camera (MUX) with 16 meters, a wide-field imager (WFI) with 55 meters, and a multispectral and panchromatic camera (WPM) with 8 and 2 meters, respectively. We utilized a WPM sensor image acquired on July 22, 2022, from the National Institute for Space Research, Brazil. OpenStreetMap was selected for collaborative data due to its extensive user base (10.5 million registered users) and the substantial number of mapped objects in Brazil (over 300 million) (OSMstats, 2024; OpenStreetMap Taginfo Brazil, 2024).

Our study comprised the following steps: (1) familiarising with the study area, (2) comparing Google Maps and OSM data, (3) georeferencing CBERS 4A images, (4) digitizing planimetric mapping elements, (5) verifying OSM positional accuracy, and (6) determining possible map scales. The study area is Aparados da Serra National Park (ICMbio, 2024), a strict nature reserve between Rio Grande do Sul and Santa Catarina states (approximate latitude -29.16 S and longitude -50.10 W).

Initially, we created a color composite image using green (0.52-0.59 µm), red (0.63-0.69 µm), and near-infrared (0.77-0.89 µm) bands. Subsequently, we performed image fusion with the color composite and the panchromatic band (0.45-0.90 µm) with a 2-meter spatial resolution. During georeferencing, we applied an affine transformation for coordinate adjustment and used the nearest neighbor method for resampling. We used twenty-seven ground control points (GCPs) from OpenStreetMap for which the root mean square (RMSE) was 3.7 meters, with the largest error being 6.4 meters and the smallest 0.3 meters. Considering that the resolution of the fusion image is 2 meters, and the colored composed

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image is 8 meters, the RMSE corresponds to around 1.5 pixels of the first and 0.5 pixels of the latter. So, we accept this result and proceed to digitize the map elements.

The layers created are (1) roads, pathways, and trails; (2) bridges; (3) rivers and lakes; (4) buildings; and (5) forests, meadows, and agriculture. Considering that we intend to verify the efficiency of this method in at least two other parks in Brazil, we propose to create reference data from satellite images georeferenced with OSM and verify the range of map scales based on the positional accuracy of OSM using a GNSS field survey. According to Brazilian standards for topographic mapping, OSM's positional accuracy in the region is suitable for scales of 1:10,000 or smaller. Previous studies on OSM positional accuracy in Brazil have mainly focused on urban areas, often yielding results compatible with large-scale Brazilian topographic maps (above 1:25,000) (Elias et al., 2020; Paiva & Camboim, 2022). It is anticipated that collaborative data could help to improve aspects such as thematic accuracy by incorporating essential elements such as toponyms and other information from local knowledge, as well as improving the completeness and temporal accuracy of the data, in addition to providing positional accuracy within national parameters (Machado et al., 2022).

This study represents the initial phase of broader research to validate this proposed method for quickly mapping protected areas in Brazil using open-source GIS software and OpenStreetMap data. Our objective is not to replace traditional photogrammetric and remote sensing techniques. Still, it is to set and test a necessary, low-cost, and fast method for institutions and organizations responsible for environmental protection in Brazil. The synergy between collaborative and official data can provide mutual benefits: open official data can be integrated into OpenStreetMap to encourage volunteer data improvement. This updated data, based on better quality geometric data made by traditional mapping processes, remains within the expected spatial integrity and adds dynamic and local elements to databases, which the public authorities themselves can integrate.

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