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

Claudia Robbi Sluter [a,*], Luana Daniela da Silva Peres [a], João Igor Oliveira Dorneles [b], Luiz Felipe Velho [c], Marildo Guerini Filho [a]

[a] *Federal University of Rio Grande do Sul (UFRGS), Graduate Program on Remote Sensing – robbi.sluter@ufrgs.br, luana.peres@ufrgs.br, guerinimarildo@gmail.com*
[b] *Federal University of Rio Grande do Sul (UFRGS), Cartographic Engineering - joaoigordorneles@gmail.com*
[c] *Federal Institute of Education, Science, and Technology of Rio Grande do Sul (IFRS), luiz.velho@poa.ifrs.edu.br*

* Corresponding author

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Abstract:

This research aims to describe a proposal for mapping Brazilian protected areas at scales larger than 1:50.000 with a fast and practical solution using open data, software, and services. The lack of up-to-date topographic mapping at different scales is a serious problem for environmental protection in Brazil. In 2018 the official mapping agencies had mapped only 24% of Brazilian territory at 1:50.000. However, just 39% of those maps were published after 2008 (Sluter et al. 2018). Today the Brazilian territory is completely mapped at 1:250.000 and 1:1.000.000. Most maps are out-of-date because Brazilian official mapping agencies have never had a map revision program. Besides the problem of map revision, mapping agencies have never produced topographic maps by map generalization. Only 5% of Brazilian territory has been mapped at a 1:25.000 scale, the basic scale for topographic mapping, showing no map generalization work. Considering the level of detail (map scale) and completeness, most topographic maps are unsuitable for environmental protection management. When the government does not provide topographic maps for society, private enterprises hire companies to map their properties, such as mineral companies, reforestation companies, pools of agriculture farmers, etc. This situation leads to some consequences: the private enterprises own their mapping products, and therefore those maps are not available to any citizen. Some Brazilian states or municipalities produce topographic maps of their territories; those are sporadic initiatives. Consequently, it is common for some local governments and businesses to use collaborative platforms such as Google Maps (https://www.google.com.br/maps/) or OpenStreetMap (OSM) (https://openstreetmap.org) when they need up-to-date and large-scale maps.

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, the least mapped locations by official mapping agencies or collaborative mapping platforms are environmentally protected areas. Brazilian Law #9985 (BRASIL, 2000) defines national parks as an environmental protection area (EPA) classified as a strict nature reserve. In Brazil, the number of visitors to national parks grows yearly. In 2018, the Brazilian Ministry of Environment registered 8.7 million visitors to the national parks, and 9.8 million in 2019. Consequently, it is necessary to monitor visiting national parks to minimize the negative impacts on environmental protection. Efficient monitoring of national parks demands large-scale and updated maps. Therefore, the problem addressed in this study is how to create maps at scales suitable for monitoring the impacts of visitors' activities in national parks in a short time and low cost. Our hypothesis is that we can generate planimetric maps from georeferencing satellite images with collaborative data at scales larger than 1:25.000 since there are satellite images with a spatial resolution larger than 10 meters and collaborative maps of rivers, pathways, and trails of the areas of the national parks.

Because we propose a low-cost solution, we decided to use CBERS 4A images and QGIS software. CBERS 4A is the most recent imaging satellite of the CBERS program, a partnership between Brazil and China since 1988. The primary purpose of CBERS 4A is environmental monitoring. It has three sensors with three visible spectrum bands and one near-infrared band: a multispectral camera (MUX) with 16 meters spatial resolution; a widefield imager (WFI) with 55 meters spatial resolution; and a multispectral camera and panchromatic wide scan (WPM) with 8 meters and 2 meters spatial resolution, respectively. This study used a WPM sensor image acquired on July 22nd, 2022, from the National Institute for Space Research – INPE (Instituto Nacional de Pesquisas Espaciais, in Portuguese).

To verify our hypothesis, we develop our study in the following steps: (1) knowing the study area; (2) comparing Google Maps and OSM in the study area; (3) georeferencing the CBERS 4A images; (4) digitizing the elements of the planimetric mapping; (5) verifying the positional accuracy of OSM in the study area region and determining the range

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of possible map scales. The study area is the National Park called *Aparados da Serra* (in Portuguese). The *Aparados da Serra* Park is a strict nature reserve between the *Rio Grande do Sul* and *Santa Catarina* states of Brazil. The main goal of creating the park is to protect the natural ecosystems of great ecological relevance and landscape beauty. The long and high canyons are an essential element of landscape beauty (<https://www.icmbio.gov.br/parnaaparadosdaserra/>). After knowing the main characteristics of the study area, we compared the OSM and Google Maps solutions for that region. Looking at the study area in both platforms, we can easily see that OSM depicts more elements than Google Maps. In OSM, the rivers and pathways are in more significant numbers and more detailed and accurately represented, which allows the CBERS 4A image georeferencing.

As mentioned, we developed our study work with QGIS software, particularly version 3.22. Firstly, we generated a colored composition combined with the green (0,52-0,59 µm), red (0,63-0,69 µm), and near-infrared (0,77-0,89 µm) bands. Secondly, we created an image fusion with the colored composed image and panchromatic band (0,45 - 0,90 µm), which has a 2 meters spatial resolution. We developed the image georeferencing with the Georeferencer tool of QGIS. We used affine transformation for the coordinates' adjustment and the nearest neighbor method for resampling images. We used 27 ground control points (GCP) for which the root mean square error (RMSE) is 3.7 meters, the most significant error is 6.4 meters, and the smallest is 0.3 meters. Considering that the resolution of the fusion image is 2 meters, and the colored composed 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. We organized the map elements in vector layers in shapefile format files. The layers are (1) roads, pathways, and trails; (2) bridges; (3) rivers and lakes; (4) buildings; and (5) forests, meadows, and agriculture.

We georeferenced the CBERS 4A images with OSM homologous elements instead of GNSS points because most of the protected areas in Brazil are very large. As an example, the Aparados da Serra park is around 131.48 km². Besides, there are difficult access areas in national parks. Considering that we intend to verify the efficiency of this method in at least two other parks in Brazil, we propose to create topographic maps from satellite images georeferenced with OSM and verify the range of map scales based on the positional accuracy of OSM related to GNSS survey. We organized the GNSS survey in two parts. The first part was the GCP survey on the park's two trails. The second was the GNSS survey in areas further from the trails to improve the spatial distribution of the GCP. We set a GNSS base station for those surveys on a geodetic benchmark located at the park administration area. The criteria for choosing the GCP location were the spatial distribution, easy identification in the image and the OSM, and the possibility of arriving at the point location. To verify the possibility of defining the range of scales, we calculated the positional accuracy of OSM in the canyon's trail region as a first test. We calculated the root mean square error (RMSE) of 13 points, which resulted in 2.19 meters. The largest distance error is 3.98 meters, and the smallest is 0.78 meters. Considering the Brazilian standards for topographic mapping, the OSM positional accuracy in that region is suitable for 1:10.000 or smaller scale mapping.

The study described here is the first step of broader research to verify this proposed method for quickly mapping protected areas in Brazil at large scales using open data, GIS software, and collaborative mapping platforms. We do not intend to propose a replacement method for the photogrammetric and remote sensing approaches for topographic mapping. As we affirmed at the beginning of this abstract, our objective is to set and test a method necessary today in Brazil, mainly for those institutions or enterprises responsible for environmental protection, because it is fast and low cost. Our next step is to verify the OSM positional accuracy in a larger park area and to map the terrain with contour lines from SRTM and Copernicus DEM data.

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