

Land Regularization in São Sebastião (SP): Advanced Technologies for Cadastre Update and Land Management

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Keywords: Urban Land Regularization (REURB); Geotechnologies; High-Precision Planialtimetric Cadastral Survey (LEPAC); Territorial Management; São Sebastião.

SUMMARY

The Municipality of São Sebastião (SP), with approximately 402 km² and 84,000 inhabitants, faces significant challenges of disorderly urban expansion, with irregular occupations in areas of complex topography and risk. To support the Urban Land Regularization (REURB) process, a cadastral update of several settlements was conducted through a High-Precision Planialtimetric Cadastral Survey (LEPAC), in compliance with Decree No. 9,310/2018 and NBR 13.133:2021. The methodology synergistically combined technologies such as GNSS-RTK, SLAM, and aerial imagery with 6 cm resolution (GSD), enabling three-dimensional mapping and the precise vectorization of features in densely built-up areas. The data were integrated into the Geopixel Cidades platform, generating a geospatial database for territorial analysis and decision support. Although the approach proved effective, the study acknowledges limitations such as operational field challenges and the need for continuous investment for the cadastre's sustainability. As a result, the municipality advanced in land titling, promoting legal certainty and access to services. The approach establishes itself as a replicable model, demonstrating the potential of geospatial technologies to modernize territorial management and enhance the effectiveness of land regularization policies in Brazil.

Palavras-chave: Regularização Fundiária Urbana (REURB); Geotecnologias; Levantamento Planialtimétrico Cadastral (LEPAC); Gestão Territorial; São Sebastião.

RESUMO

O Município de São Sebastião (SP), com cerca de 402 km² e 84 mil habitantes, enfrenta desafios significativos de expansão urbana desordenada, com ocupações irregulares em áreas de topografia complexa e risco. Para apoiar o processo de Regularização Fundiária Urbana (REURB), foi realizada a atualização cadastral de diversos núcleos por meio do Levantamento Planialtimétrico Cadastral com Precisão (LEPAC), em conformidade com o Decreto nº 9.310/2018 e a NBR 13.133/2021. A metodologia combinou sinergicamente tecnologias como GNSS-RTK, SLAM e imagens aéreas com 6 cm de resolução (GSD), permitindo o mapeamento tridimensional e a vetorização precisa de feições em áreas densamente construídas. Os dados foram integrados à plataforma Geopixel Cidades, gerando um banco de dados geoespacial para análises territoriais e suporte à decisão. Embora a abordagem tenha se mostrado eficaz, o estudo reconhece limitações como desafios operacionais em campo e a necessidade de investimento contínuo para a sustentabilidade do cadastro. Como resultado, o município avançou na titulação de áreas, promovendo segurança

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jurídica e acesso a serviços. A abordagem se consolida como um modelo replicável, demonstrando o potencial das tecnologias geoespaciais para modernizar a gestão territorial e aumentar a efetividade das políticas de regularização fundiária no Brasil.

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1. INTRODUCTION

São Sebastião, a municipality located on the northern coast of São Paulo, with a territorial area of approximately 402 km² and an estimated population of 84,019 inhabitants (IBGE, 2024), has faced significant challenges in its urban land regularization process. This difficulty is largely due to disorderly expansion and the irregular occupation of urban and peri-urban areas. To mitigate these problems and promote social inclusion through Urban Land Regularization (REURB), the municipality initiated a cadastral updating process in several urban settlements, conducted through a High-Precision Planialtimetric Cadastral Survey (LEPAC).



Figure 1. Informal Urban Settlements in the Municipality of São Sebastião, with emphasis on the Topolândia Settlement

The technical process followed the guidelines of Federal Decree No. 9,310/2018, which regulates Law No. 13,465/2017, and the Brazilian Standard NBR 13.133:2021, which defines the requirements for topographic surveys (BRASIL, 2018; ABNT, 2021). Field data collection was performed using advanced technologies such as GNSS (Global Navigation Satellite System) and SLAM (Simultaneous Localization and Mapping), integrated into the Geopixel Cidades platform. Additionally, orthophotos generated from aerial images with a 6 cm spatial resolution (GSD) were used, providing superior detail in identifying urban features—such as roofs, walls, and stairways—in densely built-up areas, meeting the 1:1000 representation scale (GEOPIXEL, 2024).

2. RELATED WORK

The application of geospatial technologies in land regularization is a consolidated field, but the integration of tools like SLAM represents a recent evolution. Studies in Brazil, such as those by Souza and Zipf (2022) and Freitas and Cunha (2021), have already demonstrated the potential of using RPAS (drones) for mapping informal areas, highlighting gains in speed and cost-efficiency. Internationally, works in Colombia (Reyes et al., 2021) and South Africa (Chitonge and Mfuné, 2021) have explored the use of GNSS and high-resolution imagery to ensure security of tenure in contexts of rapid urbanization.

The key differentiator of the present study lies in the synergistic combination of GNSS-RTK, SLAM, and very-high-resolution imagery (6 cm GSD), demonstrating an integrated workflow that specifically addresses the challenges of densely built-up areas with complex topography, such as those found in São Sebastião.

3. CHALLENGES AND CONTEXTS OF LAND REGULARIZATION IN SÃO SEBASTIÃO

The municipality exhibits accelerated urban growth, with over 100 Informal Urban Settlements, especially in hard-to-reach areas such as riverbanks, hills, and slopes, which are often located in risk-prone areas. The absence of accurate records and the informal nature of these occupations hinder urban planning and the implementation of public policies. In this context, land regularization is fundamental to ensure legal certainty, access to basic infrastructure (water, sewage, electricity), complementary infrastructure to eliminate risks or develop resettlement plans when necessary, and the inclusion of regularized properties into the municipal tax system (BRASIL, 2017).

4. TECHNOLOGIES USED FOR LAND REGULARIZATION: GNSS, SLAM, AND AERIAL IMAGERY

The cadastral update was carried out according to LEPAC parameters, using GNSS in RTK (Real-Time Kinematic) mode to ensure the positional accuracy required for georeferencing properties. The field technical team collected the georeferenced vertices that constitute the validated technical product of the LEPAC.

The use of SLAM enabled the three-dimensional mapping of urban and natural features, proving particularly effective in hard-to-reach areas with dense vegetation or steep slopes and in obtaining measurements of existing infrastructure. This was complemented by 6 cm GSD aerial imagery, which allowed for the representation of features with high geometric and visual fidelity, contributing to the vectorization of elements with precision compatible with the 1:1000 scale, especially in consolidated and high-density constructive areas (GEOPIXEL, 2024).

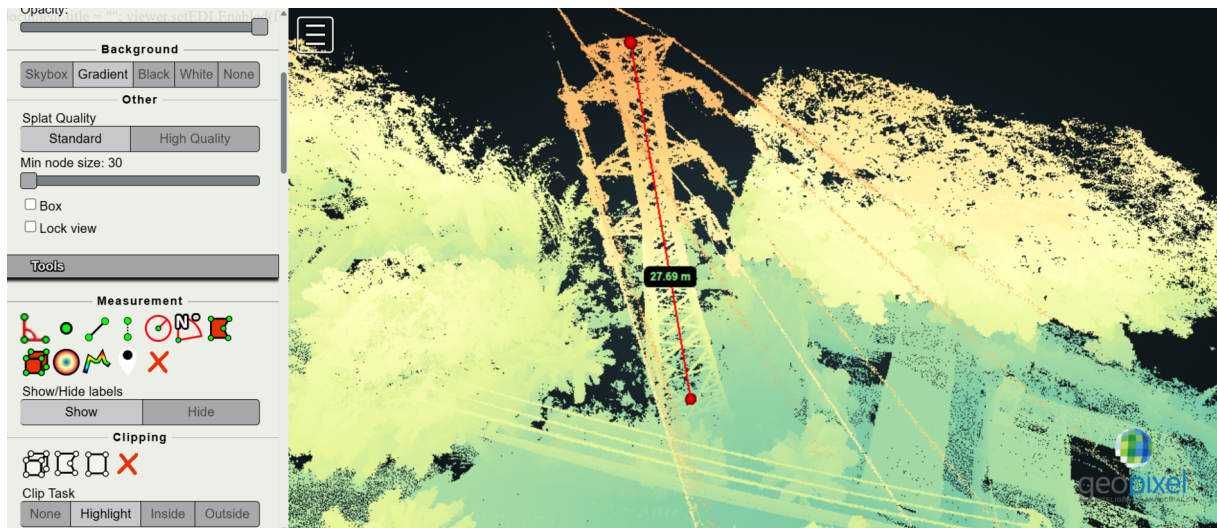


Figure 2. Collection of existing urban infrastructure measurements using the point cloud (SLAM)

5. VECTORIZATION AND DATA PROCESSING

With the processed field data and aerial images, the vectorization of features such as lots, buildings, public roads, and areas of interest was performed. The data were integrated into the Geopixel Cidades platform, enabling precise spatial visualization, verification of overlaps with risk areas, and analysis of existing urban infrastructure.

The vectorized features were enriched with attributes essential for REURB, such as lot area, land use, occupation status, and cadastral registration number. The platform allowed for real-time consultation and validation by technicians and public managers, as well as the generation of a robust geospatial database to support decision-making and the proposal of urban infrastructure improvements inherent to the land regularization process.

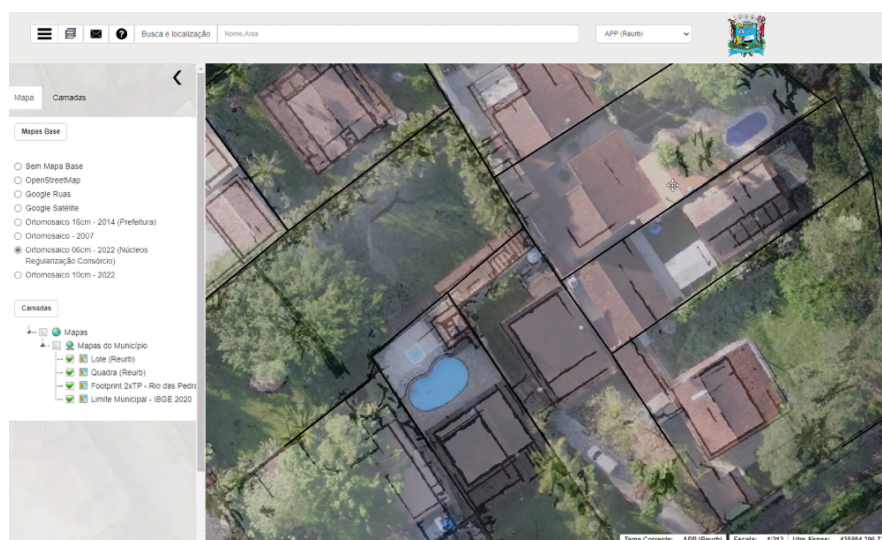


Figure 3. Example of lot and footprint data in Rio das Pedras

6. RESULTS AND IMPACTS ON LAND REGULARIZATION

The adopted methodology provided a detailed territorial overview, allowing for the identification of critical areas that require resettlement plans and areas eligible for regularization to be integrated into the municipality's formal cadastre. This process enabled the advancement of land regularization efforts, culminating in the titling procedure, which grants legal certainty to occupants and facilitates access to public services and housing policies.

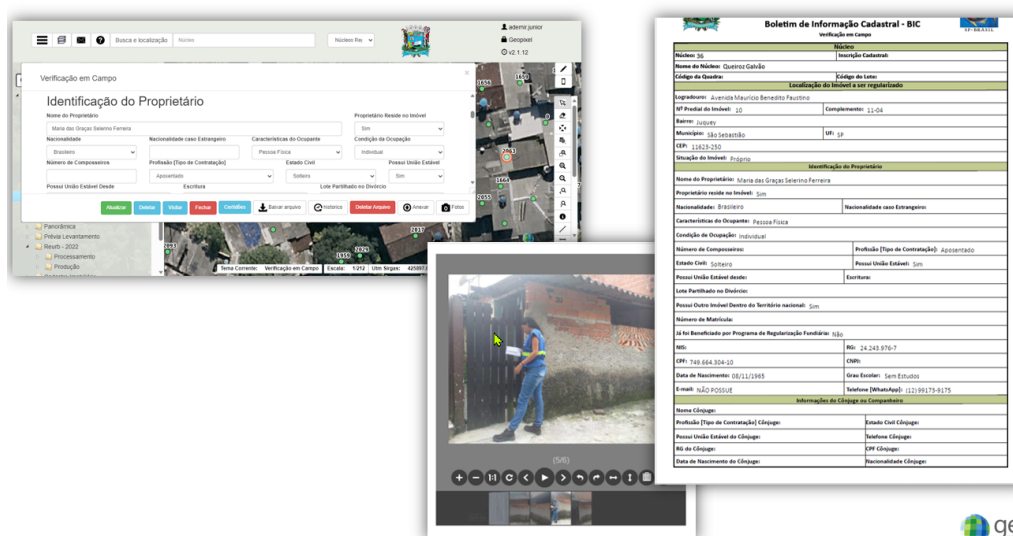


Figure 4. Social Cadastre

The integration of GNSS, SLAM, high-resolution aerial imagery, and the Geopixel Cidades platform yielded significant gains in accuracy, time savings, and operational cost reduction. The process also promoted greater transparency and facilitated community participation, as advocated in the REURB guidelines (BRASIL, 2017).



Figure 5. Example of a Community Meeting

7. INTEGRATION WITH THE MUNICIPAL SYSTEM AND URBAN PLANNING

The integration of data into the municipal territorial management system enhanced urban planning, enabling the identification of priority areas for intervention, regularization, and risk mitigation. The georeferenced database supported sustainable public policies, such as a preventive Civil Defense plan and contingency plans for risk areas, sanitation, mobility, and housing, in addition to contributing to an increase in tax revenue through the formalization of properties (BRASIL, 2021).

8. DISCUSSION AND LIMITATIONS

Although the integrated methodology proved to be highly effective, it is important to acknowledge the limitations inherent in a project of this scale. Operational challenges, such as accessing extremely dense areas or the need for continuous community engagement to ensure data collection, persisted despite the use of technologies like SLAM. Additionally, the model presupposes the long-term sustainability of the cadastral system, which will require continuous investment in updates and maintenance from the public administration. A comparative cost-benefit analysis against other advanced technology combinations, not just traditional methods, also presents itself as an area for future work to validate the model's scalability for different municipal budget realities.

9. CONCLUSION

The land regularization process in São Sebastião, structured around modern technologies such as GNSS, SLAM, 6 cm resolution aerial imagery, and the Geopixel Cidades platform, represents a milestone in the modernization of municipal territorial management. The adoption of LEPAC, in compliance with NBR 13.133/2021 and Decree No. 9,310/2018, ensured the technical quality required for the success of REURB.

This innovative approach not only enabled the titling of properties in informal areas but also establishes itself as a model for detailed territorial management, allowing for the identification of risk areas that demand specific actions, serving as a replicable model for other municipalities. The results reinforce the role of geospatial technologies as fundamental instruments for the effectiveness of public land regularization policies in Brazil

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BIOGRAPHICAL NOTES

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