GIS-Based Approach for Solar Cooperative Energy Integration in High-Density Urban Areas Considering Heat Island Mapping

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ABSTRACT

This work presents a GIS-based approach to identify locations for installing solar cooperatives in a densely populated urban neighborhood. This approach allows the planners to reduce the impact of heat islands on energy consumption growth in urban areas. The regions identified by the approach are close to the power distribution network and seek to reduce power losses. The findings show the feasibility of integrating solar cooperatives in high-density urban environments, where strategic site selection can optimize solar energy generation and improve power distribution efficiency.

Keywords: Photovoltaic Energy; Solar Cooperative; Urban Heat Islands.

INTRODUCTION

Tall buildings can create shadows on rooftop photovoltaic (PV) systems, reducing sunlight exposure and efficiency in high-rise areas [1, 2]. Shading on one PV system can also affect interconnected solar panels [3, 4].

Additionally, verticalization limits rooftop space, impacting PV performance [5]. This issue drives the pursuit of solutions to identify available space utilization and ensure solar energy's viability in densely urbanized environments [6].

To address these challenges, solar cooperatives in urban zones offer a promising solution [7, 8]. However, heat islands increase local temperatures, leading to higher energy demand for cooling. These urban heat islands form due to city design and activities that trap heat, especially around high-rise buildings [9]. Solar energy can be shared among multiple users through cooperatives, providing market expansion, economies of scale, and cost savings [7, 8].

Thus, this work presents a GIS-based approach to identify locations for installing solar cooperatives in a densely populated urban neighborhood considering heat islands.

MATERIALS AND METHODS

This work used a Geographic Information System (GIS) to identify locations for solar cooperative installation applied in Santo André, SP, Brazil. The spatial database included base maps, building footprints, and land use from the Open Buildings V3 dataset via Google Earth Engine (GEE). Digital Elevation Models (DEMs) from GMTED2010 and ALOS World 3D - 30m provided slope and aspect information. All spatial data were projected into the SIRGAS 2000 / UTM Zone 23S coordinate system.

The approach identifies urban heat islands using Landsat 8 satellite data on GEE, highlighting temperature differences to identify heat zones. The multi-criteria evaluation in QGIS intersected criteria like available free space (minimum $50m^2$), proximity to the electrical grid, and distance from heat islands. The suitability map was generated by combining these factors, ensuring selected locations met all conditions for solar cooperative installation.

RESULTS AND DISCUSSION

The analysis conducted in this work focused on identifying locations for installing solar cooperatives in a high-density urban environment. By mapping the neighborhood and analyzing spatial factors, the approach allows distribution and urban planners to determine the regions for installing solar cooperatives.

The study began with mapping the study area, which included defining the neighborhood boundaries and documenting the rooftop PV system within the region. In **Fig. 1**, this mapping is the foundational step for assessing the spatial layout and buildings as rooftop areas near public locals with available space for solar panel installation.

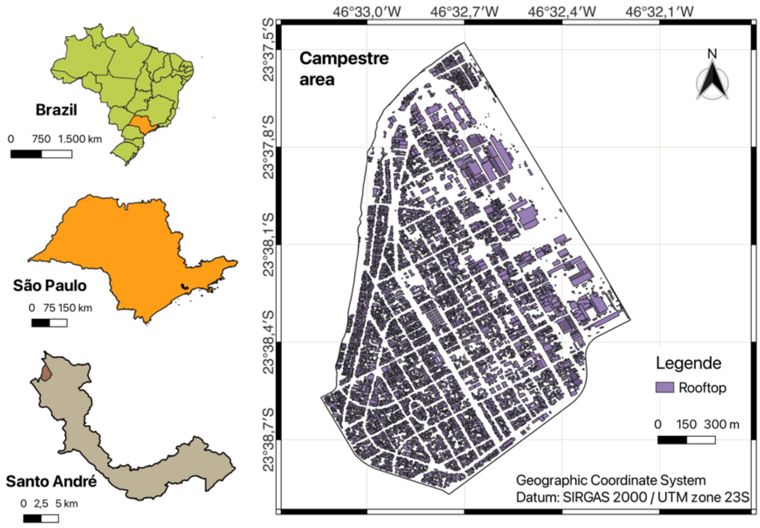

Figure 1. Study area map with neighborhood boundaries and rooftop footprints.

This work identified urban heat islands as a significant factor in selecting the location for the solar cooperative. While high temperatures can negatively impact the efficiency of solar panels, the white circular area indicated in **Fig. 2** presents a set of characteristics that make it ideal for installing solar cooperatives. The proximity to heat islands, coupled with a high density of buildings and the availability of public spaces, indicates a high potential for electricity consumption and, consequently, a significant demand for sustainable solutions. Solar cooperatives can help reduce local energy costs by using clean energy.

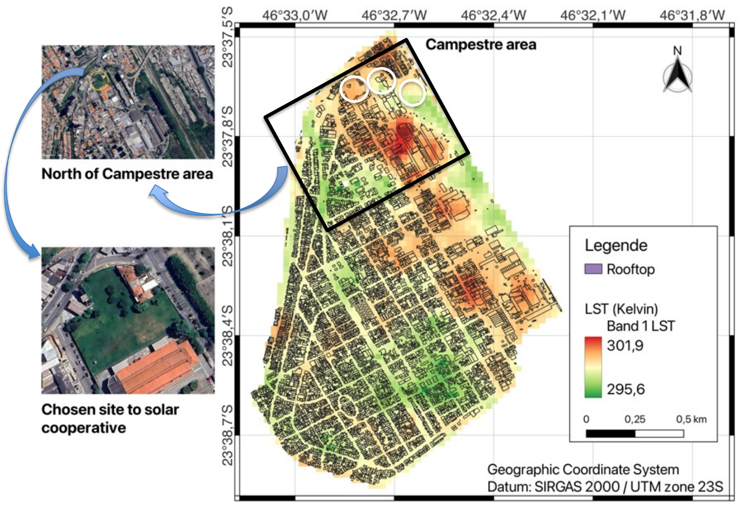

Figure 2. Urban heat island map with the proposed cooperative location.

The proximity of the selected site to the power distribution network was also analyzed, as shown in Fig. 3, to improve efficient power distribution. The existing infrastructure of the CPE_0102 distribution network, with MV/LV transformers and nodes around the proposed location, facilitates the effective injection of generated solar PV energy into the power distribution network, minimizing power losses and enhancing overall efficiency. Additionally, considering the solar irradiance of Santo André, which is 781.87 W/m^2, it is possible to install the cooperative with a nominal capacity of 635 kWp, further contributing to the system's overall performance.

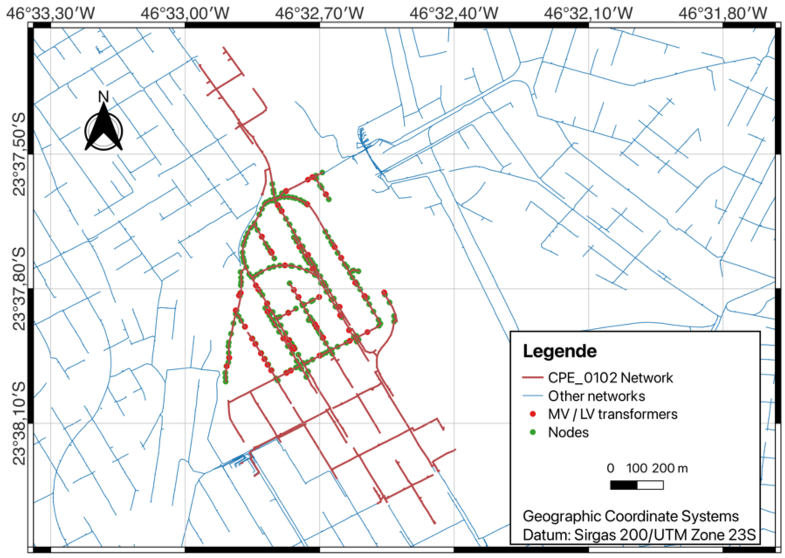

Figure 3. Electrical grid map showing proximity to the proposed cooperative.

The spatial information in **Fig. 2** and **Fig. 3** shows that the chosen sites for the cooperative are located near urban heat islands, influenced by the dense concentration of buildings. These sites offer strategic proximity to the distribution network, enabling efficient energy injection. The 4832 m^2 area is free from shading, has few trees, and features a low rooftop area, making it ideal for the cooperative.

CONCLUSION

This work identified locations for installing solar cooperatives in a densely populated urban neighborhood by integrating spatial analysis techniques. The analysis identified areas near heat islands and considered proximity to the electrical network, available open space, and minimal shading. Although not within a heat island, the selected site is strategically located near one, benefiting from the dense urban environment while ensuring efficient energy injection into the existing power distribution network. These findings highlight the potential of urban sites to boost energy generation and distribution in dense areas.

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