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Harnessing solar energy from rooftops in Jeffersville informal settlement (City of Tshwane Metropolitan Municipality, South Africa)

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Abstract:

In 2022, South Africa recorded a population of 62 million people, constituting 17.8 million households. A proportion of 8.1% of these households reside in informal settlements (Stats SA, 2023). Energy poverty is a growing concern in these informal settlements, with many households lacking access to modern and reliable energy services (Monyai et al., 2023). Although the South African government is bound by the constitution to provide access to energy to every citizen, most households in informal communities are not eligible for grid connection. To be eligible for grid electrification, a settlement needs to be close to the existing infrastructure where electrification is practical, and no improvements, developments, or relocations should be planned in the area within the next three years. This is because government subsidies, such as basic electricity services, are less likely to be awarded to settlements in impermanent locations (Runsten et al., 2017). Extending the city's electrical grid to these areas poses several challenges for both municipal planners and electricity providers because informal settlements are often established on an as-needed basis by individuals with minimal control to ensure that the settlement grows cohesively (Lemaire & Kerr, 2016). Residents of these communities, therefore, usually turn to unsafe alternatives such as illegal electricity connections (Hassim et al., 2018), which often result in inadvertent power outages, electrocution from live cables, and shack fires (Kimemia & Van Niekerk, 2017).

Renewable energy has emerged as a viable alternative to traditional sources, promising to not only alleviate the utilisation of fossil fuels to produce electricity but also pave the way to a more sustainable energy future. This study computes the average solar radiation (in kWh/m^2) in selected rooftops in Jeffersville informal settlement located in the southwestern part of the City of Tshwane Metropolitan Municipality at coordinates 25°46'57" S, 28°04'02" E, approximately 10 kilometers west of Pretoria's central business area (see Figure 1, map indicator on the map inset). In recent years, the Jeffersville informal settlement has approached saturation, with many households clustered in large compounds due to the increasing housing demand and rapid inward migration (Everatt and Valodia, 2023).

The study began by detecting the rooftops of selected informal settlement structures in Jeffersville. The 2022 original aerial photograph of a 0.05m by 0.05m resolution that provided the basis for image detection only covered a part of Jeffersville. A digitized training sample of 1833 examples of rooftops was then produced to train a deep-learning model that detected a total of 5788 rooftops. This analysis was performed in ArcGIS Pro using the 'Train Deep Learning Model' tool to train the model, and the 'Detect Objects Using Deep Learning' tool for prediction (or classification). The obtained deep learning model achieved an average precision score of 0.74, a relatively satisfactory measure of model performance.

The computation of the total solar radiation on top of each of the 5788 roofs was performed based on a digital surface model (DSM) derived from LiDAR data collected in 2022. The 'Raster Solar Radiation' tool in ArcGIS Pro was used to produce a raster dataset whose cells (i.e., pixels) display solar radiation in kilowatt-hours per square meter (kWh/m^2) respectively. The 'Zonal Statistics' tool was later used to calculate the mean solar radiation harnessed on each rooftop based on the solar radiation raster. The lowest observed rooftop solar radiation potential was 0kWh/m^2, and the highest was 1849kWh/m^2. Furthermore, more than 80% (i.e., 4608 of 5788) of the rooftops recorded a solar radiation potential between 1569kWh/m^2 and 1849kWh/m^2, suggesting that most rooftops in Jeffersville can harness a relatively high solar radiation potential (see Figure 1).

The results presented in this study can inform future plans for alternative energy provision in Jeffersville. Besides being useful for the Jeffersville informal settlement, the methodology employed in this study can be emulated in other informal settlements in South Africa to produce green, safe, and sustainable energy.

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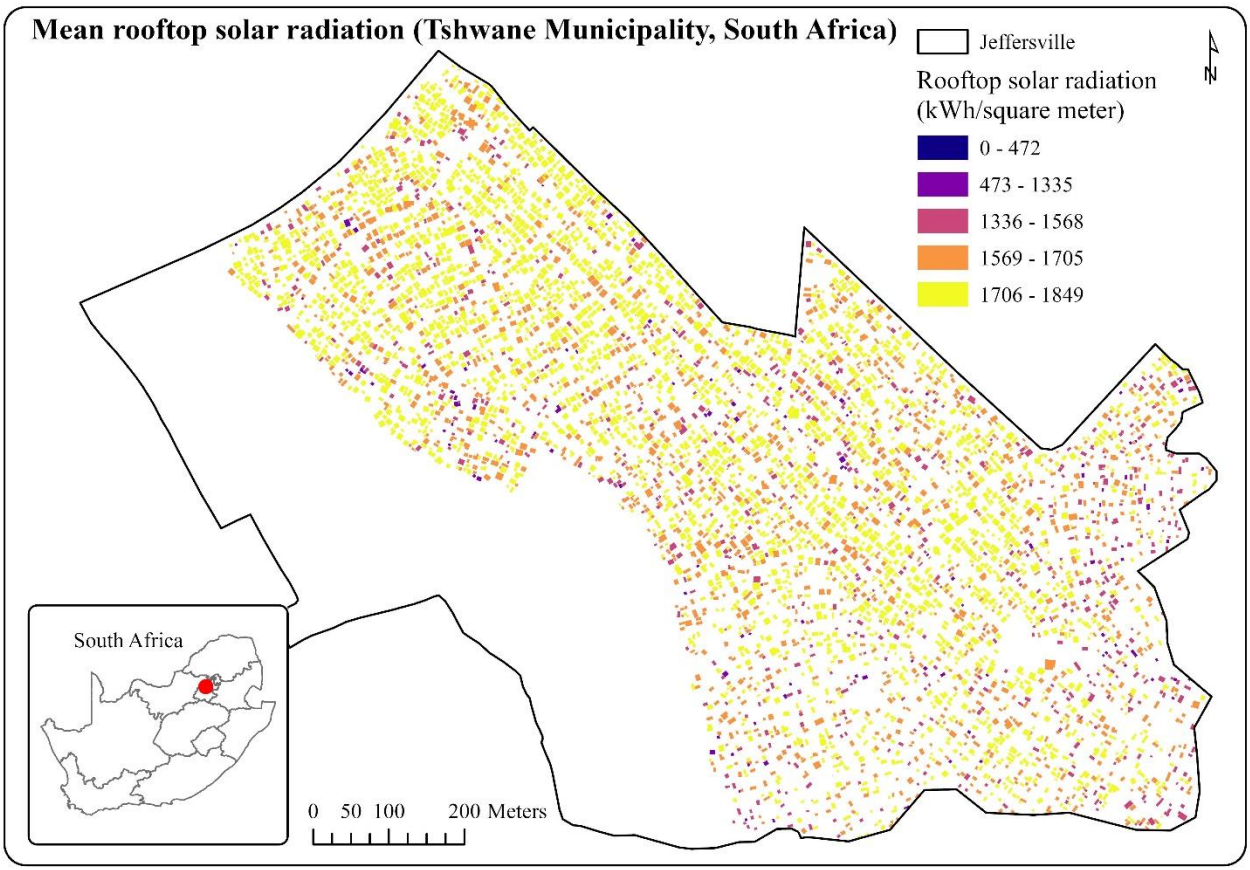

Figure 1. Average rooftop solar radiation potential in Jeffersville.

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