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High-Resolution Land Surface Temperature Mapping for Urban Climate Applications Using Satellite Fusion and Machine Learning in Google Earth Engine

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This study develops and evaluates an integrated, fully cloud-based workflow implemented in Google Earth Engine (GEE) to generate high-resolution LST products for urban climate applications. The approach combines spatio-temporal satellite data fusion with machine-learning-based thermal pansharpening to overcome the trade-off between spatial and temporal resolution inherent in current thermal infrared observations. The workflow targets the production of near-daily LST at Landsat-like resolution, subsequently refined to 10 m to enable microclimate analysis.

The study area is the Iasi metropolitan region, northeastern Romania, a medium-sized Eastern European city characterized by heterogeneous urban fabric, variable vegetation cover, and moderate topographic relief. Input datasets include MODIS MYD11A2 8-day LST composites (1 km), Sentinel-2 MSI multispectral imagery (10 m), and SRTM GL1 elevation data (30 m). The temporal coverage spans 2014–2024 for fusion development, with a focus on the summer season (June–August).

Spatio-temporal fusion is applied to reconcile the high temporal density of MODIS thermal observations with the finer spatial detail of Landsat, generating temporally continuous downscaled land surface temperature (DLST) fields at Landsat spatial scale. These methods exploit coincident MODIS and Landsat observations to predict Landsat-like LST on non-overpass days.

To further capture fine-scale thermal variability relevant for intra-urban climate analysis, the DLST products are subsequently sharpened to 10 m using supervised machine-learning regression models, leveraging the high spatial resolution and spectral richness of Sentinel-2 to better represent vegetation structure, surface moisture, and built-up heterogeneity. The evaluation focuses exclusively on Ridge Linear Regression, Random Forest, and Gradient Boosting, which are trained to model the relationship between LST and surface characteristics. Predictor variables are derived from Sentinel-2 multispectral reflectance and spectral indices (NDVI, NDWI, NDMI, NDBI, Urban Index, bare soil index), supplemented by terrain parameters (elevation, slope, and aspect). Model training is conducted using randomly sampled pixels within the study area, applying a 70/30 hold-out split and simulated 10-fold cross-validation. Model performance is quantified using

mean absolute error (MAE), root mean square error (RMSE), and the coefficient of determination (R^2).

Results indicate that ensemble tree-based models outperform the linear baseline, achieving RMSE values close to 1.2 °C and R^2 around 0.82, consistent with recent studies. Variable importance analysis highlights vegetation and moisture indices as dominant negative controls on LST, reflecting evapotranspirative cooling, while built-up and bare soil indicators exert positive effects associated with heat storage and reduced latent heat flux. Topographic influence is secondary in the relatively gentle relief of the Iasi basin. The resulting 10 m LST products enable detailed mapping of SUHI intensity and fine-scale thermal gradients across urban neighborhoods.

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