

# Monitoring of urban forests using 3D spatial indices based on ALS point clouds: a city-level analysis

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By 2050, nearly 70% of the entire population will live in urban areas. Therefore cities must be appropriately shaped to be as resident-friendly as possible, paying particular attention to urban vegetation, which is an essential component of the suitable quality of life. So far, research often relied on two-dimensional (2D) mapping of urban vegetation using remote sensing imageries and vegetation indicators, where the greenery was evenly distributed, regardless of the cubature. In reality, the spatial and vertical structure of vegetation varies, and the layers often overlap. As novelty, we propose in this paper a 3D approach that explores: Vegetation 3D Density (V3DI) and Vegetation Volume to Building Volume (VV2BV) indices in Luxembourg City. The goal of the study was to investigate the relationship between the volume of vegetation and buildings in a rapidly developed Luxembourg City. The vegetation volume was calculated using airborne laser scanning point clouds (ALS LiDAR) processed into voxels (0.5 m). The volume of the buildings was calculated based on the results of 3D ALS LiDAR point cloud modeling.

We used ALS LiDAR point clouds from airborne mission obtained in February 2019 for entire Luxembourg City with mean point density: 25 points/m<sup>2</sup>.

These indices have been estimated for districts, cadastral parcels, in a cell grid of 100 m and for each building individually, with a 100 m buffer. We found that in 2019 in Luxembourg City, the urban forests covered 1689 ha, which makes 33% of the entire administrative area. The 3D analyzes showed that the total volume of vegetation (> 1.0 m above ground) is about 40 million m<sup>3</sup>, indicating 328 m<sup>3</sup> of greenery per resident. The V3DI was 0.77 m<sup>3</sup>/m<sup>2</sup>. The overall VV2BV(%) index for Luxembourg showed 41.6%, and only in four districts of Luxembourg showed a high value of VV2BV index > 67%, which indicates areas with high levels of green infrastructure to contribute to the health and better quality of life.