International Cartographic Association
Association Cartographique Internationale

Automated Mapping of Urban Green Spaces Using Object-Based Image Analysis with Application to European Cities

Rafael Osvald [a,*], Hana Bobáľová [a], Vladimír Falťan [a], Alexandra Benová [a]

[a] *Comenius University in Bratislava, Faculty of Natural Sciences, Department of Physical Geography and Geoinformatics, Slovakia, osvald11@uniba.sk, hana.bobalova@uniba.sk, vladimir.faltan@uniba.sk, alexandra.benova@uniba.sk*

* Corresponding author

Keywords: remote sensing, LiDAR, high-resolution data, urban vegetation detection

Abstract:

According to the World Health Organization (WHO, 2017), urban greenery refers to all areas covered by vegetation in an urban environment and has a significant influence in protecting public health. Urban green spaces play a crucial role in improving environmental quality and mitigating the impacts of climate change in urban environments, particularly through temperature regulation, reduction of air pollution, and support of biodiversity. For this reason, accurate knowledge of their spatial distribution and structure is essential for urban planning, environmental management, and the development of adaptation strategies. In recent years, there has been a significant increase in the availability of remote sensing data, with many European countries providing open-access orthophotos, digital elevation models, and LiDAR point clouds. These data sources represent substantial potential for detailed, high-resolution mapping of urban green spaces.

The aim of this study is to evaluate the contribution of LiDAR point cloud data to object-based image analysis (OBIA) in the classification of urban green spaces. Within the research, two methodological approaches were developed and compared: (1) a digital surface model-based approach (DSM-HM), which utilizes standard elevation models freely provided by national data providers in combination with aerial imagery, and (2) a LiDAR point cloud-based approach (PC-HM), which integrates custom, more detailed elevation models derived from point cloud data along with additional characteristics such as the number of laser pulse returns. The classification focused on three basic vegetation classes: trees, shrubs, and grasslands, with emphasis placed on their precise spatial delineation.

The methodology was applied to two contrasting urban structures in Bratislava, Slovakia: a dense historical city centre and a housing estate from the 1960s, characterized by a higher proportion of open green spaces. To verify the transferability of the proposed approach, the PC-HM method was subsequently tested on datasets from additional European cities: Berlin, Germany and Tallinn, Estonia which differ in both urban structure and input data characteristics. The classification achieved high overall accuracy across all sites, ranging from 83% to 93%. The highest precision was consistently recorded for the 'tree' class (F1-score up to 0.97), while the 'shrub' class showed the most significant variation between locations.

	Tallinn - C	Tallinn - BHE	Berlin - C	Berlin - BHE	Bratislava - C	Bratislava - BHE
OA	0.89	0.93	0.88	0.83	0.91	0.91
F1 tree	0.97	0.97	0.97	0.90	0.93	0.96
F1 shrub	0.79	0.81	0.80	0.78	0.90	0.82
F1 grass	0.92	0.91	0.87	0.81	0.82	0.95

Table 1. PC-HM classification accuracy metrics for study areas. The table shows the Overall Accuracy (OA) and F1-score for individual vegetation classes (tree, shrub, and grass) across six locations: city centre (C) and block house estate (BHE) sites in Tallinn, Berlin, and Bratislava.

The results demonstrate a significant improvement in classification accuracy when LiDAR data are incorporated. The PC-HM approach achieved an overall accuracy of 91%, compared to 82% for the DSM-HM approach. The most notable improvement was observed in the shrub class, where accuracy increased from 56% to 75%. The LiDAR-based method proved particularly effective in detecting vegetation under complex conditions, such as shaded areas, vegetation obscured by buildings or other objects, as well as in identifying small and fragmented vegetation elements. At the same

https://doi.org/10.5194/ica-abs-12-106-2026

time, it enabled more precise delineation of vegetation boundaries and a more realistic representation of their spatial structure. Figure 1. provides an overview of the approaches used by DSM-HM and PC-HM, compared with orthophoto and LiDAR classifications.

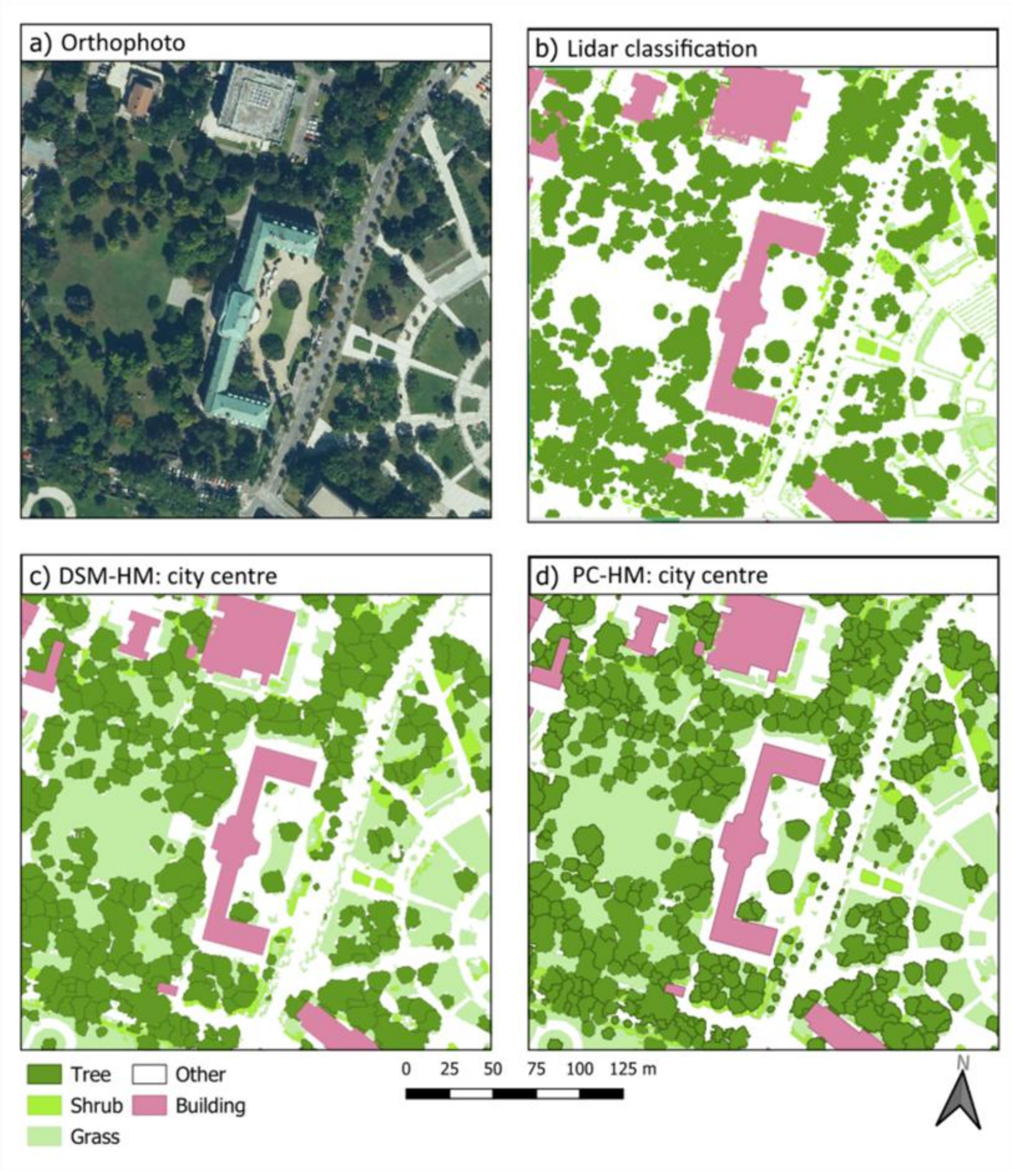

Figure 1. Comparison of classification methods: (a) orthophoto as reference (b) LiDAR point cloud classification, (c) DSM-HM classification, (d) PC-HM classification. The area shown captures the centre of Bratislava – námestie Slobody.

The obtained results confirm that the integration of LiDAR data into the OBIA approach significantly enhances the accuracy and robustness of urban green space classification. The proposed methodology, based on freely available data sources, demonstrates strong transferability across different urban structures as well as across various European locations. Its application is particularly promising in the fields of urban planning, environmental monitoring, and the design of adaptation measures aimed at mitigating the impacts of climate change in cities.

Acknowledgements

This work was supported by the VEGA grant project No. 1/0217/23 “Modern methods and actual data sources in detailed research of the landscape spatial structure.”

References

World Health Organization, 2017. *Urban green spaces: a brief for action*. WHO Regional Office for Europe, Copenhagen. Available at: https://www.who.int/europe/publications/i/item/9789289052498 [Accessed 15 March 2026

https://doi.org/10.5194/ica-abs-12-106-2026