UTILIZATION OF AERIAL LASER SCANNING POINT CLOUD DATA FOR THE STUDY OF HABITATS

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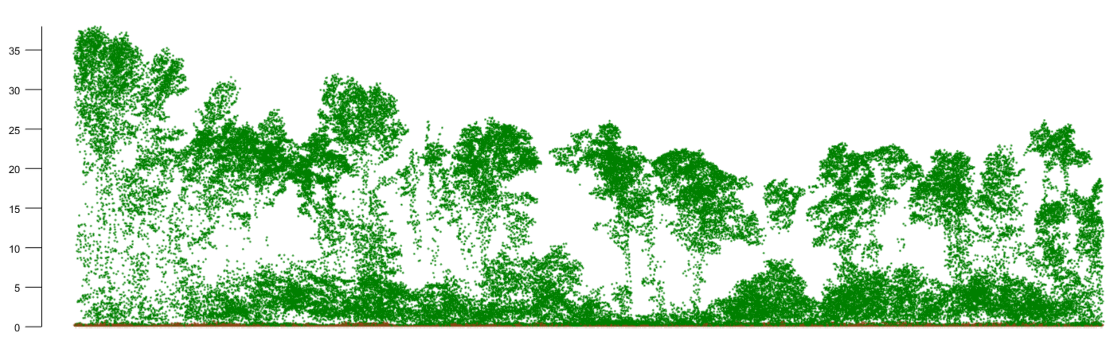
Motivation

Natura 2000 is a network of protected areas set up by the European Union that plays a crucial role in preserving Europe's most valuable species and habitats. Therefore, it is important to map and monitor these regions. However, it can be challenging to accurately define and keep track of these habitats as it requires specialists to inspect the areas in person. With the emergence of advanced remote sensing methods such as the Sentinel 2 mission, we have access to high-resolution multi-spectral satellite images. This enables us to observe the habitats without actually going there.

But despite its numerous advantages, the satellite images lack height information. Fortunately, thanks to nation-wide aerial laser scanning surveys using LiDAR technology, we have also access to 3D point cloud data describing the surface of Earth and objects on it in great detail.

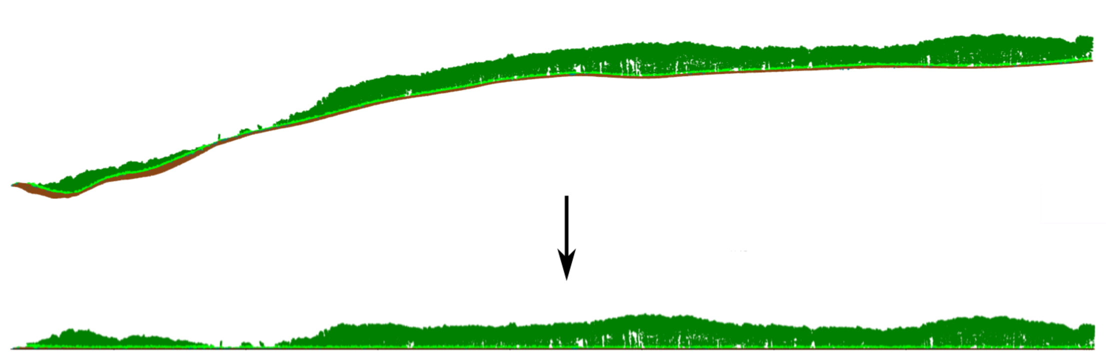
Classified Point Cloud

Between the years 2017 and 2023, a large-scale ALS survey of the entire territory of Slovakia was carried out in the project titled "Airborne Laser Scanning and DTM 5.0" by ÚGKK SR. One of results is the classified point cloud, a set of points described by x, y, z coordinates, where each point is also classified according to what it represents. For the purposes of this thesis, we focused on the points classified as ground and vegetation.



Point cloud normalization

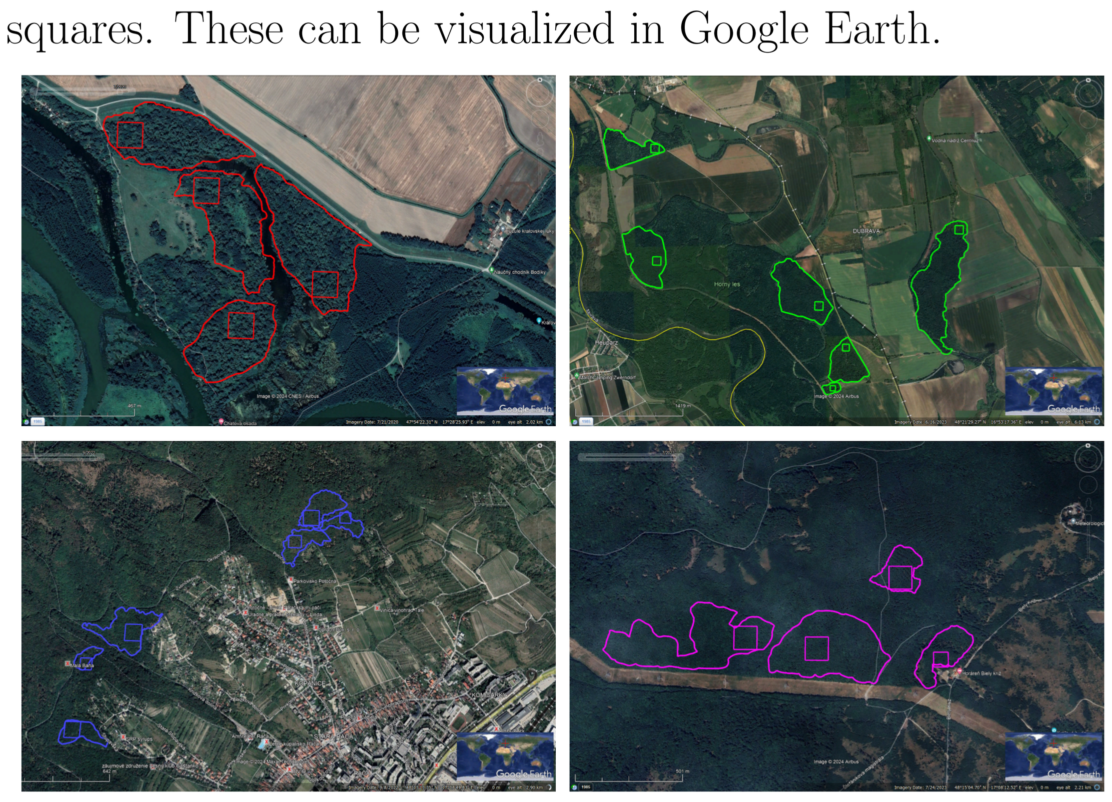
PC data typically have the z coordinates (height) as the absolute height with respect to some vertical reference system. We need it, however, as height relative to the ground. The normalization, in this context, means to eliminate the influence of the terrain.



Normalization can be done, for example, by subtracting the minimum height of all the points within a $1 \times 1\,\mathrm{m}$ pixel.

Habitat curves

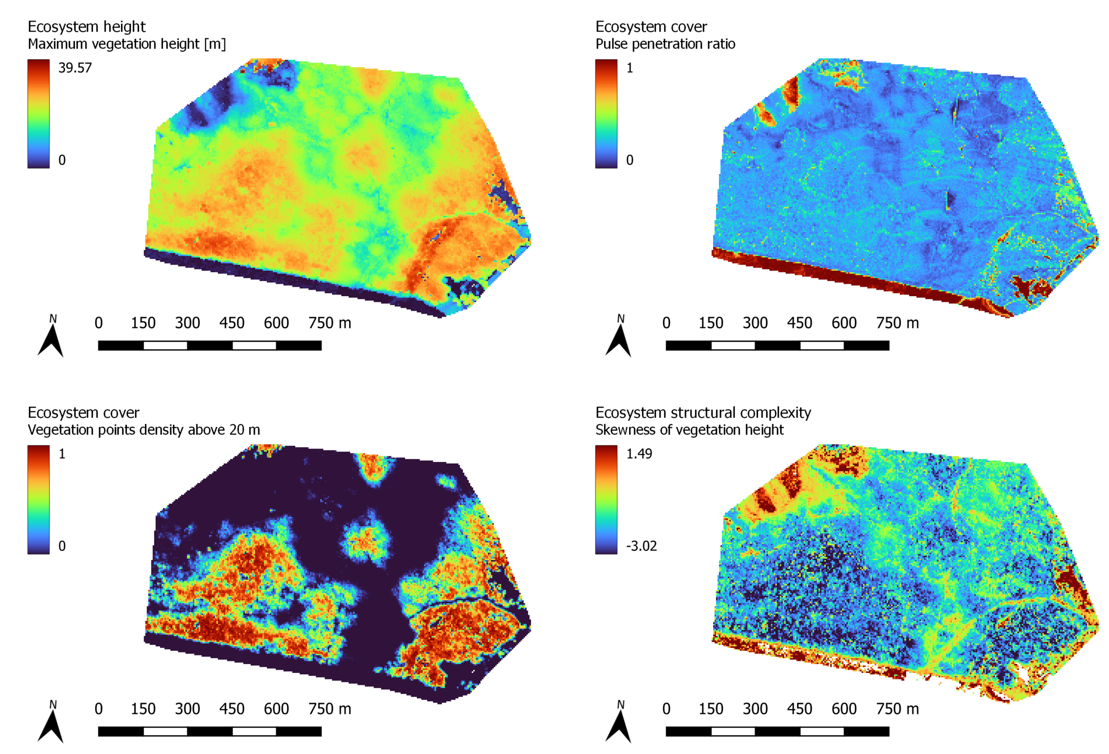
We were provided with the segmented curves of the protected Natura 2000 habitats together with the representative squares. These can be visualized in Google Earth.



- The red curves showcase mixed alder-ash alluvial forests located around the Danube river (code 91E0).
- The green curves represent riparian mixed oak-elm-ash forests near the village Vysoká pri Morave (code 91F0).
- The blue curves show the Pannonic oak-hornbeam woods above Bratislava-Rača (code 91G0).
- The magenta curves indicate the acidophilous beech forests near Biely kríž (code 9110).

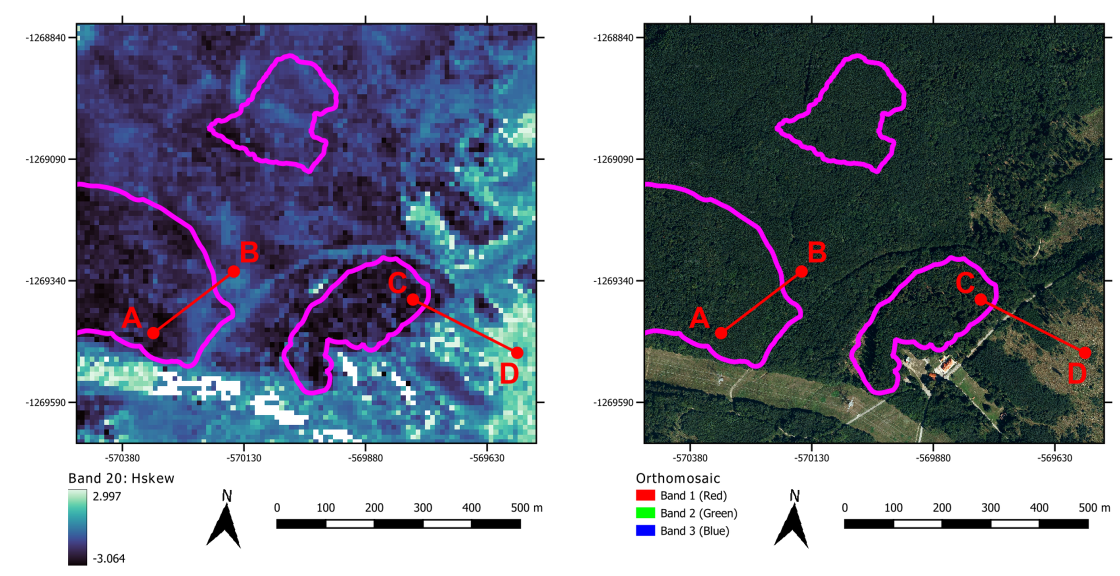
LiDAR metrics

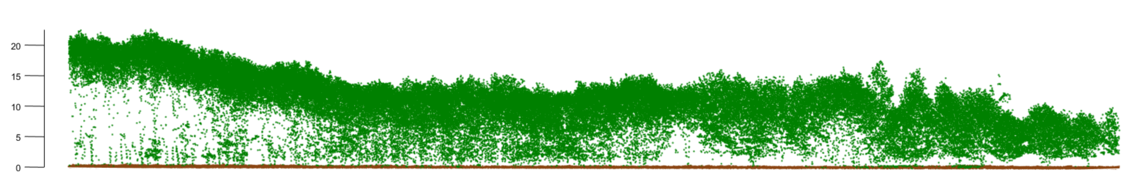
The utilization of a classified PC to describe the vegetation structure of selected Natura 2000 habitats was inspired by the workflow called *Laserfarm*. Its authors developed it in order to process large-scale PC data into ecologically meaningful information in the form of multi-band geo-referenced raster images. These images contain various statistical metrics, e.g. maximal height of vegetation or vegetation density within different height layers.



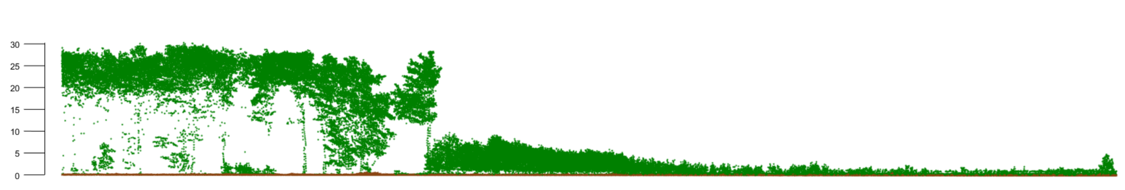
LiDAR metrics with PC view

Below, we provide an example of how we can visually analyze the vegetation structure using a combination of LiDAR rasters and the normalized PC. Here, each pixel represents an area of $10 \times 10\,\mathrm{m}$ in the real world. For reference, we have also provided an orthomosaic view for the selected region.





Line segment A-B

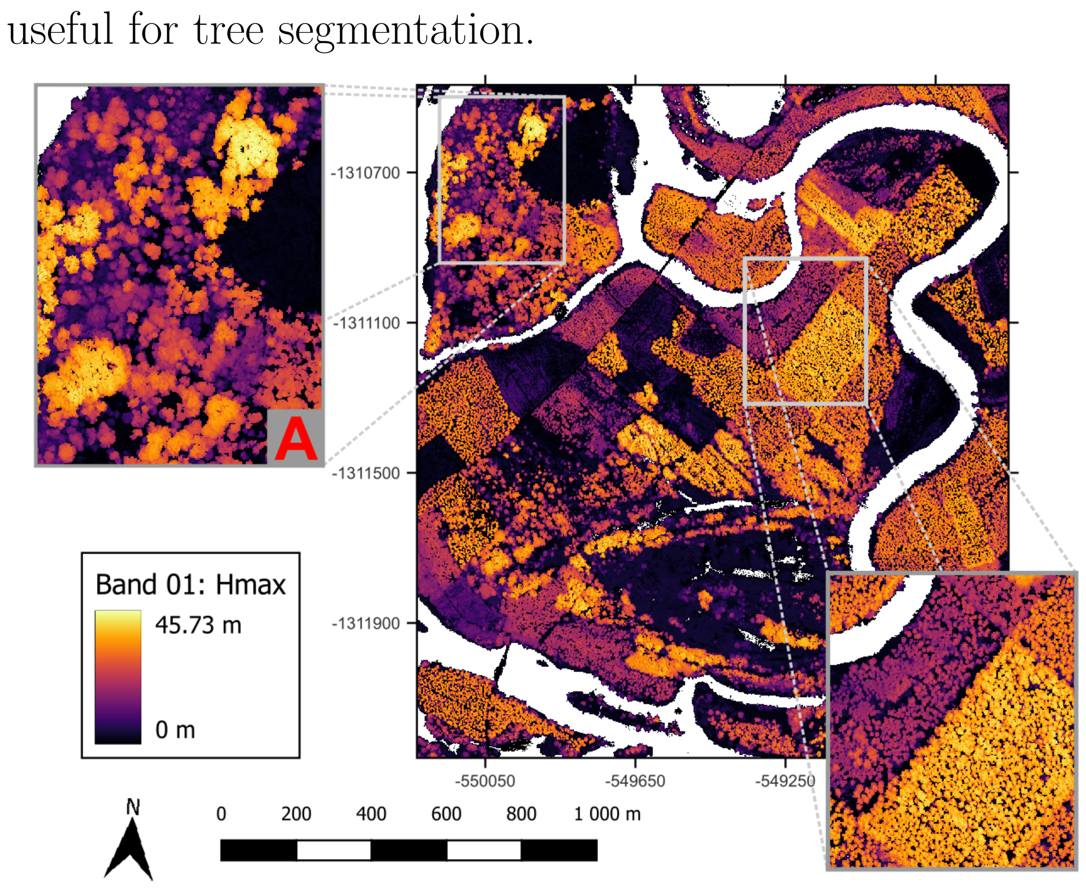


Line segment C-D

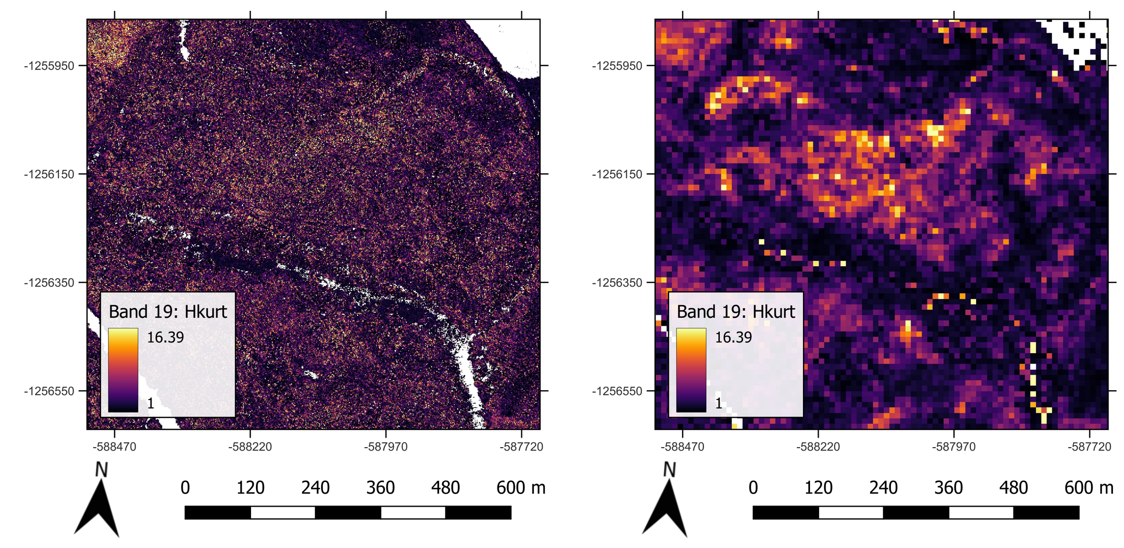
As we can see, negative skewness corresponds to higher trees with dense canopies, whereas areas with positive skewness have mostly lower vegetation.

High-resolution computations

We also tried to obtain images with a resolution of $1 \times 1\,\mathrm{m}$ per pixel. Thanks to the higher resolution, we can even distinguish shapes of individual trees, which could be potentially useful for tree segmentation.

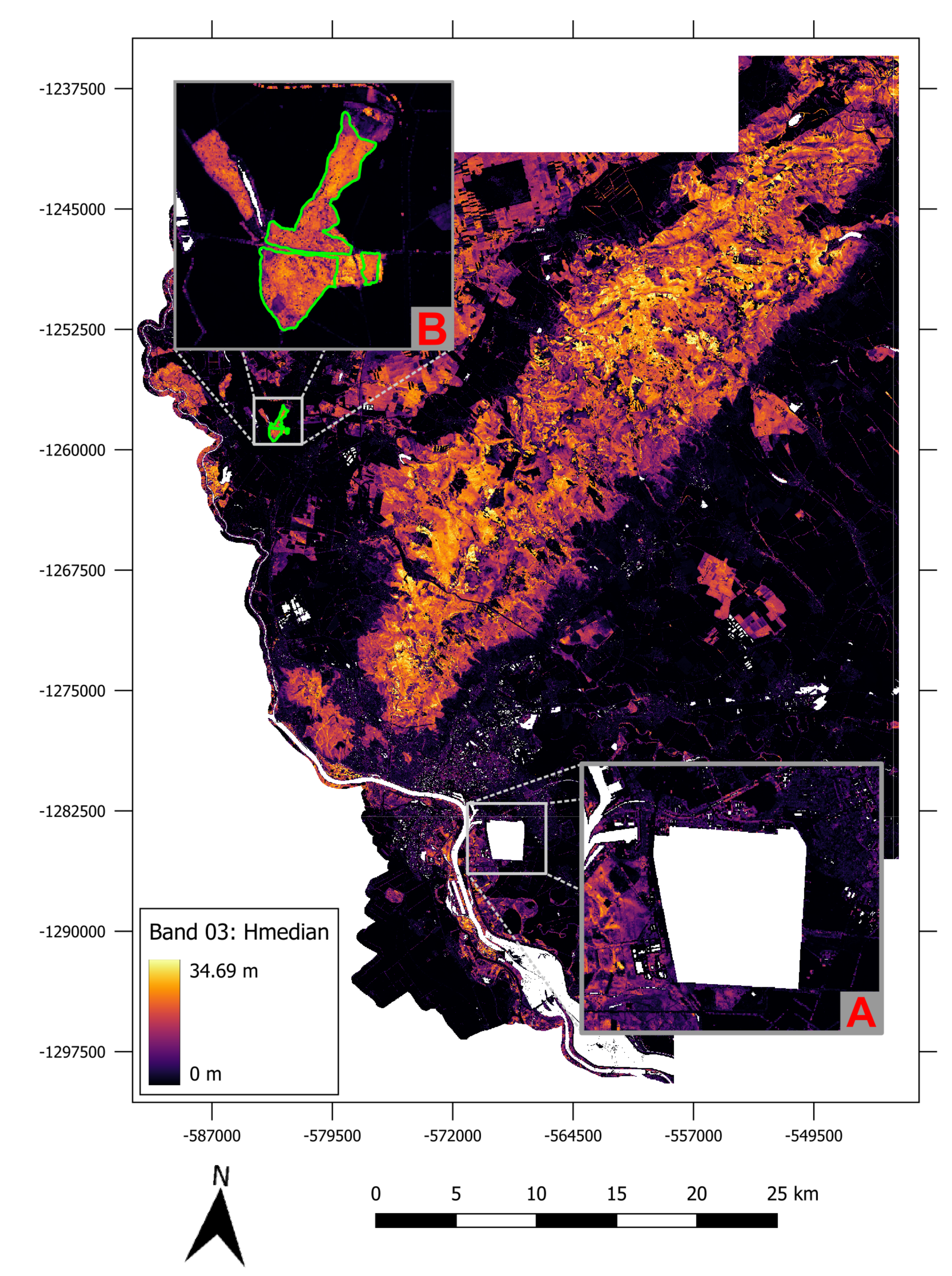


It is also worth noting that a finer grid is not always the best choice, as the resulting image might appear noisy. On the other hand, with a coarser grid used, we can see some patterns that can be further investigated by plotting the PC.



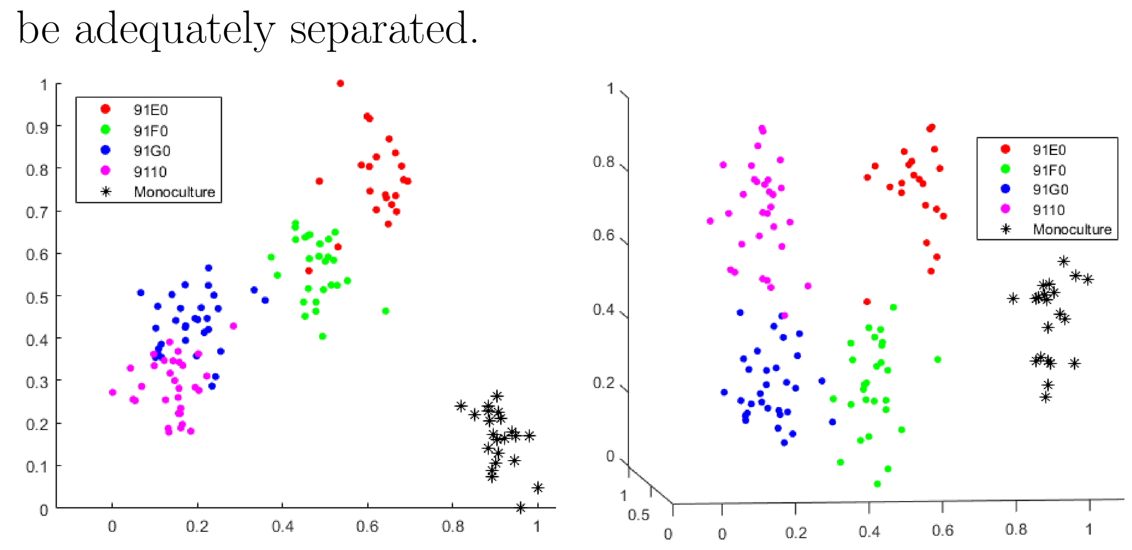
Large-scale computations

As most of the segmented curves for Natura 2000 habitats that we had access to were contained in lots 02 a 03, we decided to compute LiDAR metrics for the whole territory of these two lots. The resulting image was merged from 564 smaller areas using QGIS software. All images are available to download at `https://bit.ly/tiff_lots_2_3`.

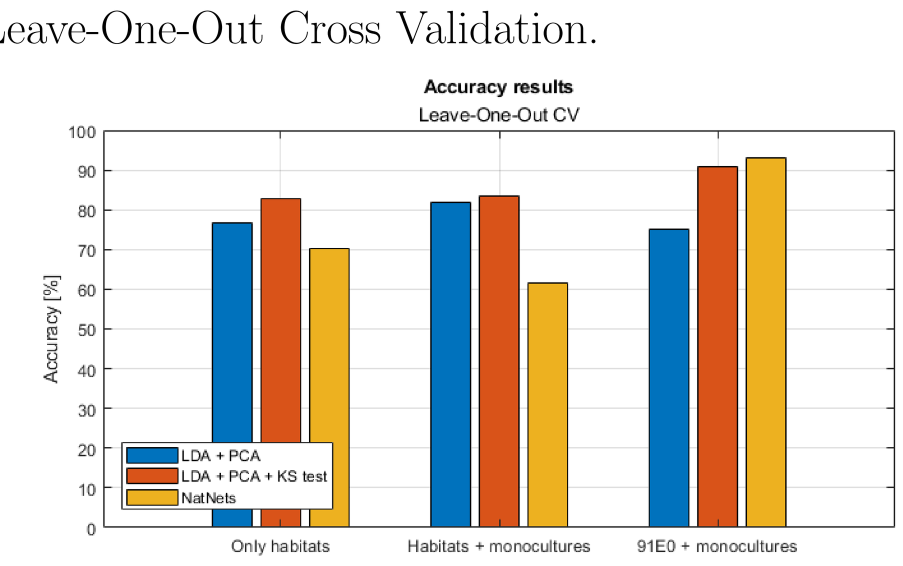


Statistical analysis

For the LiDAR metric values inside of the representative squares we computed mean, standard deviation, minimum and maximum. Thus we obtained a dataset comprising of 133 observations and 92 predictors. For dimensionality reduction we utilized the Principal Component Analysis. We used the Canonical Discriminant Analysis to project the data into a lower-dimensional space such that the classes would be adequately separated.



For classification we used Natural Numerical Networks and the Linear Discriminant Analysis. The results were obtained by Leave-One-Out Cross Validation.



All achieved results indicate that the classified point cloud can provide valuable information on the vegetation height structure of the protected Natura 2000 habitats.

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