# Natura 2000 Habitat Quality mapping in a Pannonic salt steppe from full-waveform Airborne Laser Scanning

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## 1. Introduction

Natura 2000 is the largest network of protected terrestrial habitats worldwide in terms of area, and is one of the most important conservation initiatives of the European Union. The Habitats Directive prescribes regular monitoring of habitat and species conservation status every six years to be undertaken by the corresponding member states. However, the sheer size of the habitats to be mapped, and the wide variety of assessment rules means that large areas are left unchecked, and the result of the evaluations is difficult to compare.
Remote sensing methods promise more standardized evaluation and better area coverage, especially in an optimal combination of sensor data processing and fieldwork.
In most cases, raw remote sensing data is used as an aid in field navigation and as a mapping background. Rarely, habitat mapping is supported by remote sensing-derived maps of the extent of specific habitats, or some environmental variables that influence habitat status. There are also some rare studies where remote sensing data was processed directly to the level of the habitat quality classification required by the directive, with encouraging accuracies.
With increasing point densities and the onset of full waveform processing and radiometric calibration, Airborne Laser Scanning (ALS aka. LIDAR) has capabilities to map not only vegetation structure but also a number of biotic and abiotic factors influencing habitat quality. By GIS analysis of these variables, it is possible to quantify conservation status of a study area.
In a general habitat mapping case, this would raise questions of which variables to take into account and how to weigh them against each other. The Natura 2000 habitat monitoring guidelines provide an answer to these questions, albeit from the perspective of terrestrial vegetation mapping and analysis.

### 1.1 Objectives

Our objective was to calculate Natura 2000 Habitat Quality for a grassland study site, adhering as closely as possible to the evaluation scheme of the local Hungarian grassland monitoring guidelines. This involved mapping all the variables listed by this scheme from sensor data, creating a GIS framework that compares and evaluates these datasets according to the Natura 2000 rules, and finally processing a habitat map theoretically ready for inclusion in a national report. We intended to test whether this is possible using only LIDAR data and field references.

## 2. Data and methods

### 2.1 Study site

Our study site was in Ágota-puszta (Hortobágy Special Area of Conservation Natura 2000 site) in south-eastern Hungary, which is characterised by Pannonic salt steppes and salt marshes (N2000 habitat code 1530). Additional Annex I habitat in the area – even with a smaller extent - is the Pannonic loess steppic grasslands (6250). Beside these grassland habitats planted forests, agricultural fields and wetlands are also present in the landscape. Micro-topography and soil conditions have an important effect on vegetation pattern, resulting in a very complicated mosaic of different associations.

### 2.2 Sensor data and field survey

Flight dates were timed to the peak of the biomass production before the summer droughts for leaf-on data, and very early spring for the leaf-off flight. A Riegl LMS-Q680 system was used, flown at an altitude of ca. 500 meters above ground. The sensor operated at the wavelength of 1550 nm with full waveform recording and a nominal ground point density of 22 pt/$m^2$.

The acquisition of field data was also carried out in several field visits, with most plots double-checked in an interval of several months. Habitat quality monitoring according to the standard Hungarian Natura 2000 protocol was carried out for 20 plots of 50×50 m, and in addition, patches of homogeneous vegetation were mapped with a differential GPS. Special attention was taken to represent the full spectrum of microhabitats as derived from the topography in transects perpendicular to the local slope. Reference points were also collected from anthropogenic features influencing habitat quality, such as vehicle tracks, trampling marks and crop fields, in a system of 60 micro-classes

### 2.3 Data processing and classification

Due to the final target of habitat quality mapping, we had to move beyond the classical raster model where one pixel belongs to one class. On one hand, this was due to the smooth transitions between different habitats (such as wetland and grassland), on the other hand, to the fact that not only vegetation was mapped. A single pixel was assigned a set of membership probabilities for different vegetation classes, but could also belong to e.g. a tread mark or have a certain coverage of weeds. This was solved by creating several different unique sets of classes (“scenarios”) for the same study area, each focused at different aspects of the habitat, (anthropogenic features, land cover, plant communities, tree species), and each processed both to single-class membership rasters and fuzzy class membership probabilities. Terrestrial data was split into calibration and validation polygons (50-50%), and classification was carried out by a random forest machine learning script working on data products of the LIDAR point cloud.

The main Natura 2000 habitats could be identified with accuracies around 75%, and the main plant associations within these classes could also be detected with considerable accuracy. Analysis of the Digital Terrain Model led to detection of micro-topographic features and human-induced erosion as well.

Based on the Hungarian Natura 2000 monitoring scheme for grasslands, a network of 50×50 m plots was established, and the following variables were evaluated in ArcGIS:

-Extent of alkali and loess grasslands within each plot was read from the respective hard classification rasters. Only plots with at least 5% of their area occupied by one of these habitats were further analysed.
-Naturalness of a habitat was calculated based on the fuzzy class probability rasters: if the probability of belonging to the grassland class was high, it was assumed that the species pool corresponds to the habitat.
-Patchiness of the habitat: the typical patch sizes and the patch diversity of each study plot were calculated from the classification layer representing the sub-habitat associations.
-Vertical structure: NDSM height and echo width values were averaged within each plot and positive scores were assigned to the plots where these were close to the mean value.
-Species pool: Information on the associations indicates the most typical species present, therefore the presence or absence of each association typical for the respective grassland habitat was checked, keeping in mind that this is only a proxy of the full species pool
-Erosion: for alkali meadows, the presence of erosion channels and salt flats resulted in a positive score
-Weeds: The proportion of the plot affected by weed probabilities above a threshold value was calculated
-Disturbance: Buffer distances were calculated for each anthropogenic disturbance feature, and a negative score was assigned to plots affected by the buffer
-Neighbourhood: The distance to the nearest similar habitat plot was calculated, and connecting features where checked including watercourses and wetlands
-Tree and shrub encroachement: Plots with invasive trees (*Eleagnus angustifolia, Tamarix tetrandra*) were given negative scores. Sparsely distributed non-invasive shrubs were considered positive, while dense shrubs and trees were assigned a negative score.
The output map of habitat quality (favourable, unfavourable, bad) was compared with the habitat quality surveys made in the field (which were not used to calibrate the algorithm), and the accuracy evaluated for the overlapping plots.

## 3. Results and discussion

The clearly and strictly defined rules of the Hungarian Natura 2000 mapping system together with the scheme of aggregating positive and negative scores was suitable for direct representation with GIS operations. The most important monitoring parameter, the coverage of different species could not be directly mapped by laser scanning, but the individual plant associations and communities which are the sub-units of the habitat types were detected, and this information was used to represent species composition.
While the accuracies of the input rasters are not always very high, the aggregation of spatial information from high resolution input data to the evaluation plots reduced noise. Since the evaluation scheme only contains three categories, it is not surprising that most reference plots were correctly categorized. However, the main benefit of this approach is that it delivers full coverage of the habitat map instead of the sampling plots typical for field studies. This allows understanding spatial trends in habitat quality, and selecting both the most threatened and the best preserved patches for conservation management.
Another important advantage is that for each study plot, the input maps allow checking why the habitat quality has been evaluated to the respective value. Vegetation classes, human influence, terrain properties and other factors can be checked in the respective raster products.

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