Towards operative habitat mapping using airborne laser scanning – The ChangeHabitats2 project

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Bulleted list of abstract highlights:

- Habitat monitoring is compulsory for all EU member states due to the Habitat Directive. It is currently achieved through time-consuming field work. Within the "ChangeHabitats2"project strategies for supporting field work with airborne laser scanning (ALS) are developed. Metrics relevant for habitat quality assessment are derived from ALS data.
- The strategy for assessment of habitat quality is based on evaluation of 3 criteria: habitat typical structure, habitat typical (plant-) species and anthropogenic disturbances. Point cloud and raster based methodologies for the extraction of proxy information for the above stated criteria are described.
- Semi-automated methods for the derivation of these proxies using novel ALS processing software are described. Maps of biodiversity relevant indicators such as vegetation stratification, age classes, fallen dead trees or artificial buildings are created.
- The methodologies support conventional field work, are cost-effective, time-saving and thus highly relevant for habitat monitoring.

Extended Abstract:

Introduction

The Flora-Fauna-Habitat (FFH) directive, established by the European Union in 1992, aims at sustaining important habitats. Its primary pillar is a European network of protected sites, called Natura2000, which are designated as areas of community interest and therefore deserve conservation. Currently, about 18% of the EU's land surface is protected by Natura2000, an area of approximately 778000 km².

The FFH directive requires constant monitoring of quality and sustainability of Natura2000 sites, with a legally binding commitment to report on their condition every 6 years. Habitat quality is to be evaluated by field ecologists based on pre-defined criteria. However, the field work necessary for complete monitoring is time-consuming and expensive, and because of the vast area to be monitored, many field workers are needed and inter-operator errors are introduced.

Some habitats are very remote, dangerous or host wildlife sensitive to human presence and are therefore difficult to access. Remote sensing can support, simplify and harmonize biodiversity and habitat quality assessments for Natura2000 monitoring.

State of the art in habitat monitoring is the usage of true colour aerial photographs for basic geospatial analysis or as printed maps to help with orientation in the field. Airborne laser scanning (ALS) can operatively supply relevant information for habitat quality assessment. The obvious advantage of ALS compared to passive imagery is the ability of penetrating the canopy and determining direct 3D measurements of habitat structure. Within the ChangeHabitats2 (CH2) project we make use of this 3D mapping capability for measuring variables that are difficult to represent by field-measurable indicators and for the derivation of novel landscape metrics providing biodiversity relevant information. A monitoring protocol is developed which addresses three main parameters of a habitat patch: (1) species composition of the vegetation, (2) horizontal and vertical structure of the habitat and (3) human influence. A novelty of the CH2 approach is that all relevant parameters are mapped simultaneously from the same remotely sensed dataset.

Study area and data

Ground truthing

The ground truthing within CH2 addresses the identification of all features of a habitat that are relevant to habitat quality mapping. A checklist of relevant habitat patches, species, natural and artificial landscape features was compiled for each habitat type occurring in the study areas. Field efforts were aimed at surveying as many as possible of these.

Laser scanning data

Five different Natura2000 sites holding different habitat categories were captured with a RIEGL LMS-Q680, the latest generation of commercially available full-waveform laser scanners. The areas were surveyed twice, under leaf-on and leaf-off conditions. The maximum pulse repetition rate of 400 kHz and a strip overlap of minimum 50% were chosen to create a high density point cloud as an ideal basis for further analysis.

Methodology

Species composition

Within CH2 species forming homogeneous spatial units larger than the sensor resolution are mapped, e.g. wetland vegetation, stand-forming trees, tall grasses, etc. Species specific parameters are calculated from radiometric and geometric features obtained with full-waveform ALS data (see figures a and b).

Indicator species typically observed by biological field surveys signify certain features of the habitat. Some of these species require in-situ expert knowledge for identification and so remote sensing in general is an improper technique. Therefore a different approach is chosen to reproduce their explanatory power. In many cases these indicated features can be measured from the remotely sensed dataset itself (e.g. shading, exposition, presence of runoff), without the need of identifying the species beforehand.

Horizontal and vertical habitat structure

Research has shown that structural diversity is a crucial indicator for habitat quality, because diversity of structure indicates diversity of micro habitats. The distribution of laser echoes in taller vegetation allows us to draw conclusions on its structural complexity. A so-called penetration index for different vegetation height intervals is calculated based on the 3D point cloud as a measure of geometric structure. From this index the layer structure is derived on a raster basis (see figure c, d and e).

For lower vegetation, such as a shrub layer or grasslands, the spatial variability that creates vertical structure is often below the range resolution of ALS measurements. In this case the geometric information contained in the width of the backscattered echo, i.e. echo width, which is obtained by full-waveform ALS, is used in order to describe height variations of a few centimetres to decimetres.

Human influence

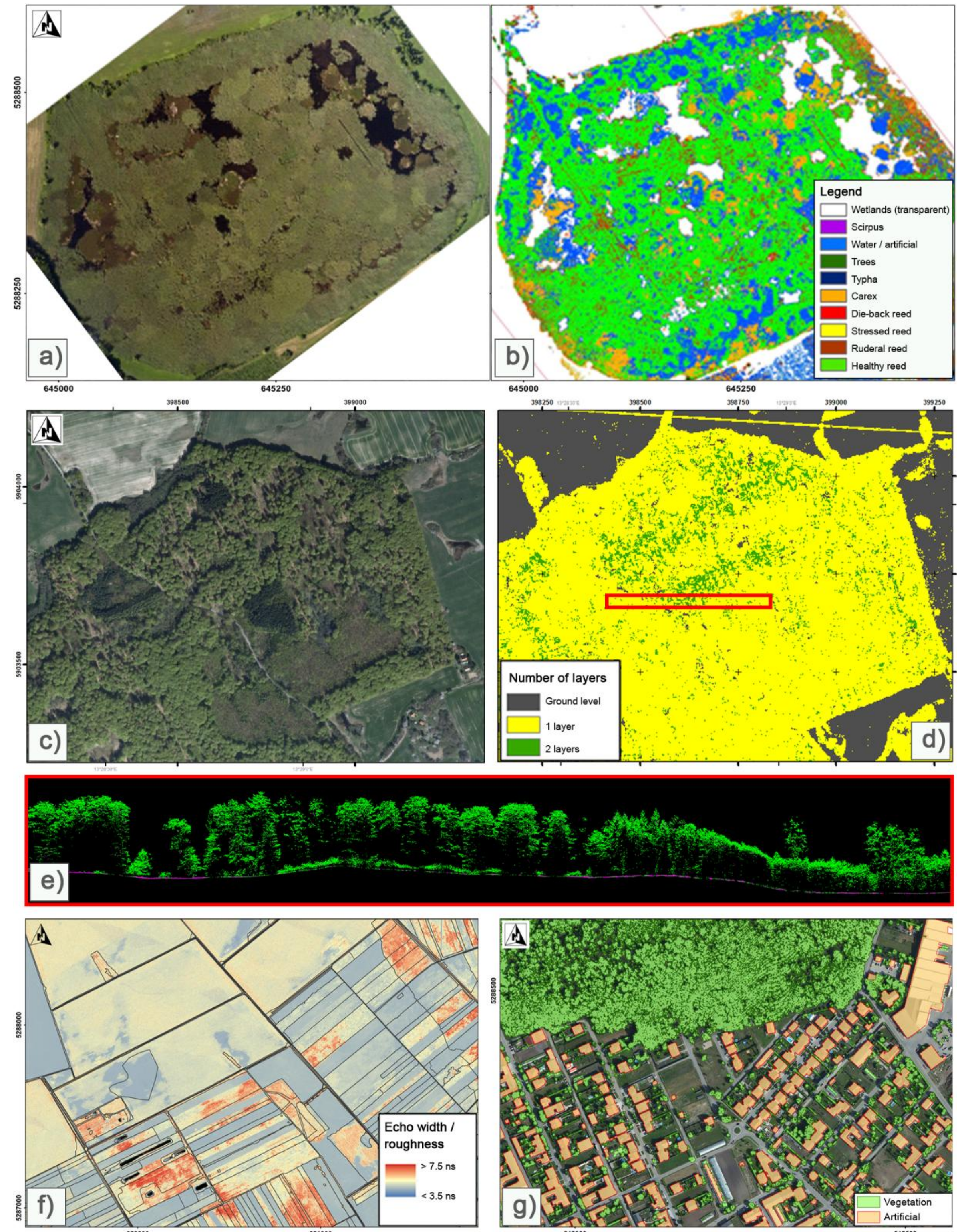
Quantification of human influence is based on the presence or absence of features indicating human pressure on the landscape, such as roads, buildings or agricultural areas. Maps of building footprints, surface roughness and land cover classification are created from the ALS data (see figures f and g). Once these objects and areas are mapped and categorised, they are weighted according to their importance and a spatial buffer is applied to them to assess their influence.

Processing workflow

A stepwise rule-based classification scheme is proposed and implemented in novel ALS processing software and standard GIS tools. Vegetation parameters are directly calculated from the point cloud and are subsequently mapped to vegetation patches, natural and man-made objects, which are physically present in the field. The presence and absence of these patches and objects is quantified to represent naturalness of species, habitat spatial structure and human influence. Based on these three input variables, manual and automatic assessment of the habitat quality is possible.

Results

Repeatable and standardized processing steps are developed which provide more sound results than often subjective estimations made in the field based on protocols that vary between regions. Also cost- and time-efficiency are increased to allow stakeholders to meet reporting goals. Visualizations are created in a way that can be understood by non-biologists, including the general public and political decision makers.



a) True-colour orthophoto of selected Natura2000 wetland study area; b) Full-waveform ALS based classification of species composition. c) True-colour orthophoto of Natura2000 forest study area; d) point cloud based derived map of layer structure indicating overgrown shrub layers; e) profile view showing vegetation stratification (location marked by red polygon in d). f) Surface roughness map created from full-waveform attribute echo width (red = rough, blue = smooth) overlaid by biotope delineation (black polygons); g) point cloud and raster based map of artificial structures. (All figures displaying preliminary results).