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Special Thematic Issue

Land abandonment mapping in the Polish Carpathians

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Abstract: Over the past decades, agricultural land in Europe has declined due to land abandonment, mostly pronounced in marginal areas where agriculture has become economically inefficient. Though in the long run land abandonment significantly changes landscapes due to consequent natural vegetation (forest) succession, automated mapping of land abandonment is extremely difficult. This study aimed at estimating current abandonment rates manifested through various stages of forest succession in the Polish Carpathians. For two small test areas, visual analysis of orthophotomaps demonstrated that delineation of forest and forest succession areas is subjective, extremely tedious and may be error-prone. Therefore, we developed a procedure using object-based image analysis (OBIA) and light detection and ranging (LiDAR) data. Variables derived from the LiDAR point cloud data were used to segment and classify various forest succession stages: point cloud classification, normalized digital surface model and intensity. The procedure provided an accuracy of 85% as compared to the outputs of visual interpretation of a time series of orthophotos. While multi-temporal imagery can significantly support the interpretation of land abandonment patterns, the proposed LiDAR-based procedure allows to quickly process data and receive reliable estimates over large areas.
Keywords: forest, LiDAR, OBIA, succession.

1. Introduction

Over the past decades agricultural land in Europe has declined and forest area has expanded considerably. Recent trends of land abandonment have been mostly pronounced in marginal areas, like the Alps and Carpathian mountains, where agriculture became economically inefficient resulting in a decrease of cropland or grassland area and an increase of forest cover. Though in the long run land abandonment significantly changes landscapes due to consequent natural vegetation (forest) succession, automated mapping of land abandonment is extremely difficult. Preliminary analysis, conducted for this study on two small test sites confirm that delineation of forest and succession areas based on visual analysis of orthophotomaps is subjective, extremely tedious and may be error-prone. When mapped only on the base of spectral information, dense vegetation may be interpreted either as mature forest or as forest nursery, whereas small trees and shrubs may not be distinguishable from surrounding vegetation, e.g. grassland (Hellesen and Matikainen, 2013). Contrary to that, research using light detection and ranging (LiDAR) data has demonstrated their capability to describe forest in various scales by means of accurate estimation of forest structural attributes, height of various terrain objects including vegetation, as well as intensity of laser pulse reflection (Alberti et al., 2013; Falkowski et al., 2009; Hellesen and Matikainen, 2013).

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Nowadays, object-based image analysis (OBIA) is frequently applied for land cover classification (Burnett and Blaschke, 2003; Blaschke, 2010; Hay et al. 2005; Hellesen and Matikainen, 2013). Segmentation and subsequent classification allows integration of the rich information for recognition of homogeneous land cover patches that represent the real world objects.

LiDAR data for most of Poland were collected in years 2011-2013 for the ISOK project (IT System of the Country's Protection against extreme hazards). As the LiDAR data have been available for a short time, there is still little research exploring their potential of mapping forest succession by means of object-based analysis. Moreover, in a large area mapping perspective, it is relevant to investigate which approach – automatic or manual – produces better results, regarding accuracy and effort. Therefore, in this study, we investigate the potential of mapping forest succession for a small commune located in a rural landscape in the Polish Carpathians, using LiDAR data. The underlying principle is to minimize the number of features that are used for both segmentation and classification of objects, in order to produce as universal solution as possible (non-depending from vegetation period/acquisition time).

2. Materials

The study area is located in the northern half of Budzów commune (45 km^2) in the Polish Carpathians, Małopolska province. The hilly terrain is largely covered by various size forest patches and agricultural land. Many abandoned fields and grasslands have been invaded by shrubs and young trees (Fig. 1). This particular area was chosen due to existence of manual landcover vectorization and availability of LiDAR data.

a. b.

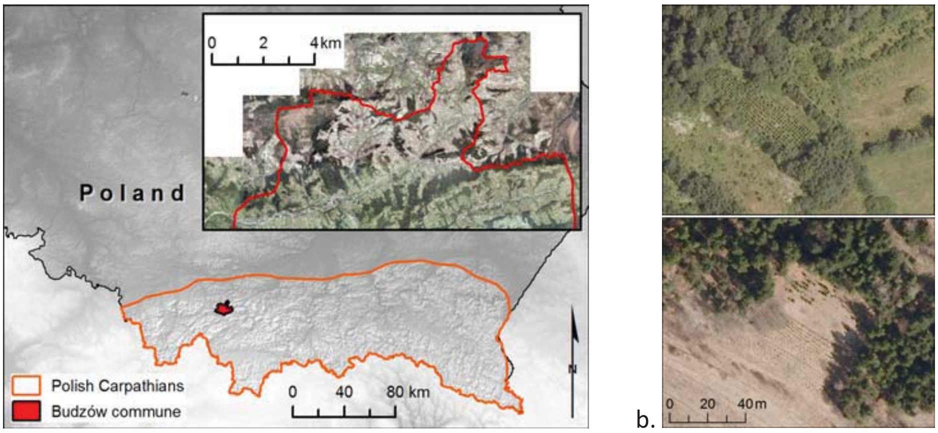

Figure 1. The study area (a) and examples of forest succession (b).

Point clouds in LAS format were acquired in May 2012. They are classified according to ASPRS specification (ASPRS, 2010) and the approximate point clouds density equals to 4 points/m^2.

To help with the visual analysis, we used RGB orthophotomaps from year 2009, of 0.25 m resolution, available from the Main Centre of Geodetic and Cartographic Documentation (CODGiK).

3. Methods

The algorithm consists of LiDAR processing, segmentation and classification. We used the commercially available software eCognition (URL 1) which offers a multiresolution segmentation that consecutively merges pixels or existing image objects on the basis of local homogeneity criterion (Blaschke et al., 2003; Trimble, 2013).

First, the LAS files were converted to image layers of 1 m resolution considering average points density in the clouds. The primary layers were then interpolated to remove no-data pixels which result from lower points density in some areas. On the basis of the interpolated layers we created images that were used as input for segmentation and classification. The most appropriate features derived from LiDAR data were found by trial and error method. These are: ASPRS class of LAS point (Class), normalized digital surface model (nDSM) and intensity value (Int). At all stages different segmentation parameters were applied, determined either by means of trial and error or using computational methods (ESP tool; Dragut et al., 2010).

Afterwards, segmentation and classification steps were executed in order to sequentially: 1) obtain buildings from LiDAR classification, 2) detect big forest patches (large segmentation scale), 3) classify gardens (small segments adjacent to buildings), 4) detect ground, high trees and succession and improve forest class delineation (by including small patches into surrounding class) and finally, 5) merging results. On the basis of previous analysis using classification and regression trees (CART), mean value of nDSM was sufficient to distinguish non-vegetated areas, succession and forest. Assuming that points below 1 m were often noise or grass, the threshold between ground and succession was set to 1 m, while the threshold between succession and forest was set to 10 m. Moreover, we considered forest definition of Polish State Forests, where minimum area of a forest patch is 0.1 ha (1000 m^2).

Accuracy assessment was performed by comparison the results against manual vectorization of forest and succession from 2009 orthophotomaps. Due to different class definition in both methods, we took into consideration only three classes from OBIA analysis: forest, succession and ground (refers to non-forest and non-succession class from manual vectorization).

4. Results

According to manual vectorization, the analysed part of the commune was mainly covered by forest (46.3%) and others (45.5%), whereas succession constituted 8.1% of the area. Automatic mapping (Fig. 2) gave slightly different results. Forest was still dominant, but covered 43.6% of the area. Bare ground (corresponding to *others*) constituted 40.7% of the area. The most significant difference pertained to succession with coverage of 15.7%. Overall accuracy equalled to 85%, whereas within class accuracy equalled to 88.4% for forest, 84.9% for ground and 68.7% for succession. Considering differences in classification, 10.3% of manual forest was included into succession and only 1.3% into ground using OBIA; 12.9% of manual succession was classified as forest and 18.4% as ground using OBIA; 11.6% of manual others class (including ground) was included into succession and 3.5% into forest using OBIA.

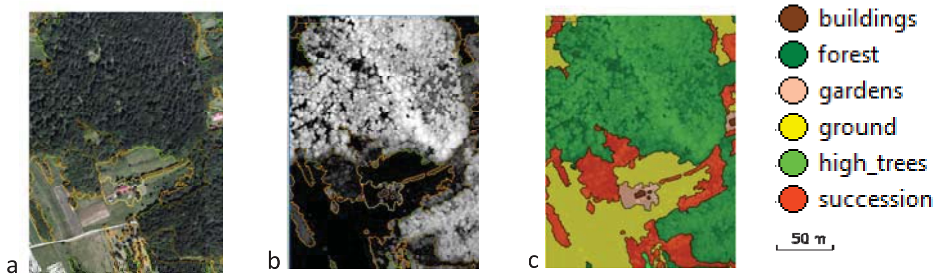

Figure 2. Classification results: (a) on the RGB raster, (b) on the normalized DSM, (c) polygons of classified land cover types.

5. Conclusions

Difficulties in mapping succession may result from the fact that this landcover type is the most difficult to distinguish on the base of visual interpretation of aerial imagery, not aided with information on vegetation height. As seen from above, both high and low or mature and young vegetation often looks similar, which leads to succession being classified as forest. On the other hand, very sparse and low vegetation (e.g. bushes), which can be visually identified as bare ground, may be classified as early succession using the automatic method. In some cases, date of acquisition of aerial imagery (2009) and LiDAR point clouds (2012) may be essential, due to real changes occurring in the landcover.

While multi-temporal imagery can significantly support the interpretation of land abandonment patterns, the proposed LiDAR-based procedure allows for quickly processing data and deriving reliable estimates over large areas.

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Useful Links (accessed March 2014):

URL 1: http://www.ecognition.com/

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