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USING AIRBORNE LASER SCANNING DATA FOR AUTOMATION LAND COVER MAPPING IN THE ASPECT OF MONITORING FOREST SUCCESSION AREAS

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Abstract

Paper concerning possibilities of using airborne laser scanning (ALS) data for monitoring land cover changes, mainly land abandonment, especially for the aspect of detection forest succession area. Automated method was developed based on the product of ALS data processing – normalized Digital Surface Model (nDSM). The results of ALS data processing were compared with the official cadastral data and the result of photointerpretation and manual vectorization orthophotomap.

As a test site was chosen area in Wieliczka district (Małopolska voivodship, south of Poland). The area of study consisted of several plots listed in the cadastral database mainly as agricultural areas, meadows or pastures but most of them not used for agriculture, but abandoned and covered by process of the secondary forest succession. Detailed information about actual land cover was determined for year 2012 based on ALS data from ISOK project (Head of Geodesy and Cartography).

Research showed discrepancy between the cadastral data and actual state for plots. Using ALS data, there was possibility in the semi-automatic way to confirm the process of forest succession in the analysed area, according to the results of vectorization orthophotomap.

ZASTOSOWANIE DANYCH LOTNICZEGO SKANOWANIA LASEROWEGO DLA AUTOMATYZACJI OKREŚLANIA POKRYCIA TERENU W ASPEKCIE MONITOROWANIA OBSZARÓW SUKCESJI LEŚNEJ

Słowa kluczowe: lotniczy skaning laserowy, zNMPT, analizy przestrzenne, wektoryzacja ortofotomapy

Abstrakt

Artykuł dotyczy oceny możliwości zastosowania danych z lotniczego skanowania laserowego (ALS) do monitorowania pokrycia terenu, głównie w aspekcie detekcji zmiany użytkowania rolniczego gruntów i postępującego procesu sukcesji leśnej. Metoda zautomatyzowana została opracowana w oparciu o produkt przetwarzania danych ALS − znormalizowany Numeryczny Model Pokrycia (zNMPT). Wyniki porównano z danymi ewidencyjnymi oraz wynikiem fotointerpretacji i wektoryzacji ortofotomapy.

Jako obszar testowy wybrano teren w powiecie wielickim (woj. małopolskie). Obszar badań obejmował kilkadziesiąt działek wyszczególnionych w ewidencji gruntów jako tereny rolnicze, łąki lub pastwiska Większość analizowanych działek nie była użytkowana rolniczo, lecz objęta procesem wtórnej sukcesji leśnej. Szczegółowe informacje o aktualnym pokryciu terenu określono na rok 2012 w oparciu o dane ALS z projektu ISOK (Główny Urząd Geodezji i Kartografii).

W wyniku opracowania wskazano rozbieżności pomiędzy danymi katastralnymi a stanem rzeczywistym. Wykorzystując dane ALS, w zautomatyzowany sposób można było potwierdzić postępujący proces sukcesji leśnej na analizowanym obszarze w odniesieniu do wyników wektoryzacji ortofotomapy.

INTRODUCTION

Dynamically progressing land use changes (Bergen, Dronova 2007; Bowen et al. 2007; Lasanta et al. 2017; Lieskovský et al. 2015; Navarro, Pereira 2012) result in undertaking scientific works and implementations, among on the topics of forest succession (Kolecka et al. 2016; Śmigielski et al. 2017; Szostak et. al. 2018), CO_2 sequestration and biomass (Susyan et al. 2011) in the ecosystem including in particular: analyses of their spatial distribution, seasonal variability, dynamics of changes in availability, as well as strategies for shaping renewable energy resources and their usage (e.g. calorific value).

Monitoring land use/ land cover (LULC) changes is also extremely important in relation to European Union agricultural programs and policy, including proper management of agricultural areas by maintaining them in good agricultural culture. European Union member countries are obliged to carry out a series of check-ups in farms and agricultural holdings in the framework of the Integrated System of Management and Control, which makes sure that all the payments for farmers from European Union budget are correctly administered. New regulations (European Commission, 2018) allow the willing states to replace or supplement the control system is the agricultural holdings with automated and less stressful actions. Several member states have already expressed the will to start new technologies – the European Commission informs. Countries will be free to choose whether to apply a new monitoring approach. They will be able to decide if this should be applied in specific aid programmes and extend the area covered by monitoring within the first two years of the implementation of these techniques.

The general aim of this work was to define the possibilities of using airborne laser scanning (ALS) data and geoinformation technologies for automation in LULC classes monitoring, in the aspect of land abandonment and the exclusion of land from agricultural production to forest succession areas. Due to available for the whole Poland ALS data from ISOK project (*pl. „Informatyczny System Osłony Kraju przed nadzwyczajnymi zagrożeniami”)* and taking into account the possibility of using the remote sensing data (satellite laser scanning data – Global Ecosystem dynamics Incestigation – GEDI and ICESat-2 have just started mission), it is reasonable to develop methods their automatic processing for the implementation of comprehensive study. Using laser scanning data will enable the development of automated methods for generating databases and maps e.g., forest areas / non-forest areas, forest biomass distribution maps, LULC changes and forest height (Ewijk et al. 2011, Falkowski et al. 2009, Kolecka et al. 2015).

Fig. 1. The study area: general range – red colour; parcels analysed in details – green; background: orthophoto
Rys. 1. Obszar badań: zakres opracowania – kolor czerwony, analizowane szczegółowo działki – zielony; tło: ortofotomapa

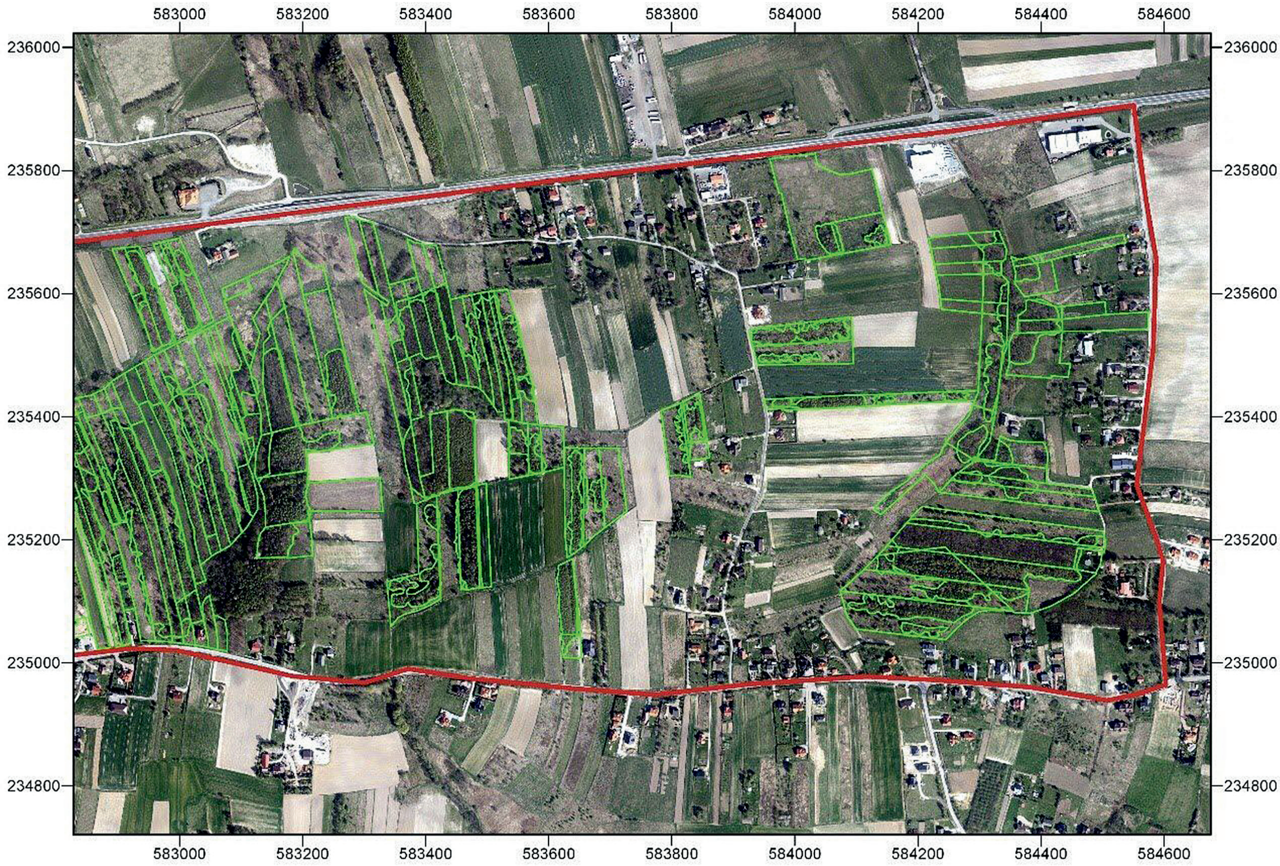

Fig. 2. Detailed view for the part of study area; background: orthophoto
Rys. 2. Szczegółowy widok fragmentu terenu badań; tło: ortofotomapa

Study area, Materials and Methods

The study area (Fig. 1) is a part of Biskupice community – Wieliczka district, Małopolska voivodeship (south of Poland). Analysed parcels were situated in the area where we can observe LULC changes dynamics – land abandonment and increasing process of secondary forest succession. The total area of analysed parcels was 139.77 ha.

The study was carried out based on the orthophotomaps (coordinates system: PL-PUWG1992, GSD: 0.25 m) and airborne laser scanning (ALS) point clouds (6 points/m^2) from ISOK project – *pl.* „*Informatyczny System Osłony Kraju przed nadzwyczajnymi zagrożeniami*”*,* source: Main Office of Geodesy and Cartography (*pl. Główny Urząd Geodezji i Kartografii; GUGiK*).

For analyse were chosen parcels listed in the ground cadastre mainly as *Arable land* (A) – *pl. Grunty orne* (R), *Meadow* (M) – *pl. Łąki trwałe* (Ł) or *Pasture* (P) – *pl. Pastwiska trwałe* (P) but not used as agricultural land – areas of secondary forest succession. Detailed view for the part of study area is presented in Fig. 2.

Airborne laser scanning point clouds (2012) processing was carried out in FUSION Version 3.50 (R.J. McGaughey, Pacific Northwest Research Station; McGaughey, 2012) with LAStools (Rapidlasso GmbH). The first step was to generate a DTM (Digital Terrain Model) and a DSM (Digital Surface Model). This was done by using *GridSurfaceCreate* and the *CanopyModel* function. Normalized DSM (nDMS=DSM-DTM) was prepared using *Raster Calculator* (ArcGIS, Esri). Reclassification of the nDSM (*Reclassify*, ArcGIS) was carried out using > 1m, >2m and >3m for the pixel value, representing the height of vegetation above the ground (Szostak et al., 2014; Szostak et al., 2018; Wężyk et al. 2009). To prepare the area nDSM>1m inventory in the whole study area, *Zonal Statistics as*

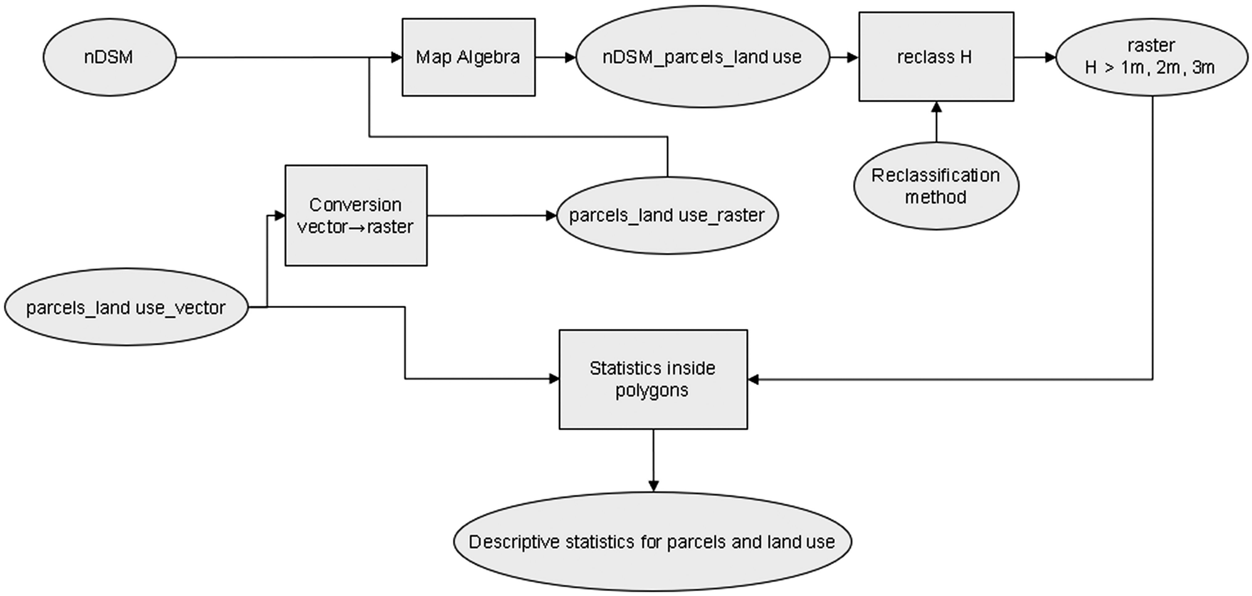

Fig. 3. The scheme of analysis
Rys. 3. Schemat analiz

Table function (ArcGIS) was applied. The scheme of analyses is presented in Fig. 3.

The graphical results and the value of total area detected as forest succession based on reclassify nDSM were compared to the results of photointerpretation and manual vectorization orthophotomap. This allowed for analysis of the occurrence of succession processes in the studied area – in detail, the areas of progressive land abandonment.

Using airborne laser scanning data gives precise spatial characteristics of forested, wooded and bushy areas (Kolecka 2018, Naesset, Okland 2002, Tompalski 2012). This diversity is visible in the surface size (2D), the vertical vegetation structure (3D) and in the time dimension (4D).

RESULTS

The graphical result of the photointerpretation and vectorisation orthophotomap and on the other side reclassification of nDSM>1m for some part of study area is presented in Fig. 4.

The results of processing ALS data – reclassification of nDSM >1m, >2m and >3m for the whole analysed area, connected to the official cadastral data and the results of vectorization orthophotomap are collected in Table 1.

In the analysed area (Tab. 1; total area: 139.77 ha), official cadastral data showed the total of *Forested area* (F) – *pl. Lasy* (Ls) and *Grunty zadrzewione i zakrzewione* (Lz) as 6.37 ha (4.56% of the analysed area). As a result of photointerpretation and manual vectorization of the orthophotomap there was 29.92 ha – 21.41% of the analysed area, so forest succession areas had value 23.55 ha –16.85% of the analysed area. Based on the reclassified nDSM>1m forest succession areas had a little bit smaller value 19.07 ha – 13.64%. The real use of the areas of *Arable land* (A) and *Meadow* (M) based on orthophotomap was about 12.18% and 4.29% less of that figured in the cadastral data. Based on nDSM>1 it was decreased value: 10.68% for *Arable land* (A) and 2.48% for *Meadow* (M).

Value of reclassified nDSM confirmed the results from previous papers (Szostak et. al, 2014, Szostak et. al., 2018) for another analysed area (Milicz district, central west part of Poland) – analyses based on reclassified nDSM>1m give the closest results to the vectorization of orthophotomap. At the study area (Tab.1) it was difference for *Forested area* (F) in value 3.21% of the analysed area, 1.50% for *Arable land* (A) and 1.82% for *Meadow* (M).

Differences between the result of total area for reclassification nDSM>1m, >2m and >3m showed differences in height of forest succession vegetation. Dif-

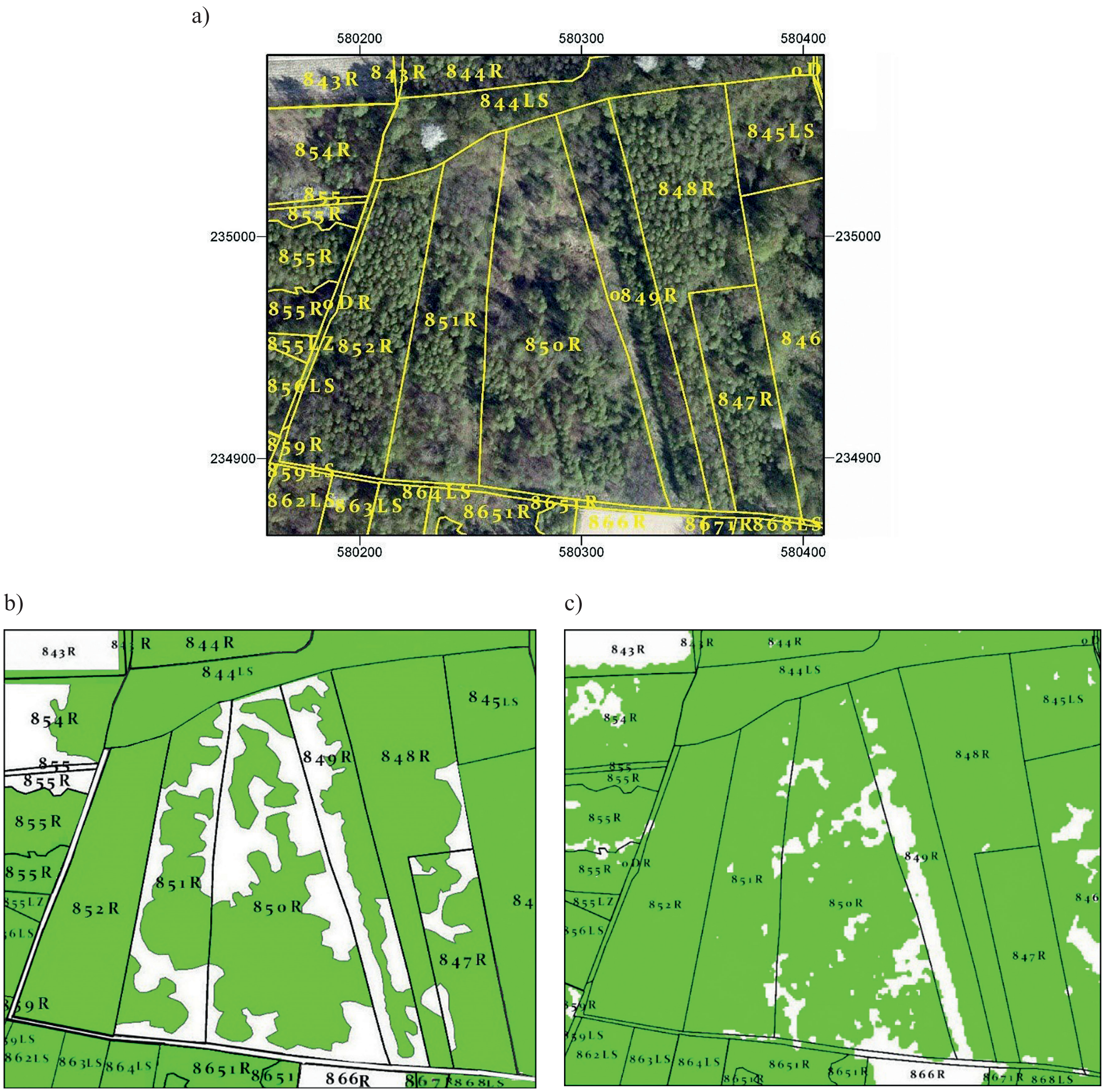

Fig. 4. Part of the study area: a) orthophotomap; b) result of manual vectorisation; green – forest succession; c) result of reclassification of nDSM, green colour – vegetation height >1m; background: cadastral data

Rys. 4. Fragment analizowanego obszaru: a) ortofotomapa; b) wynik wektoryzacji ortofotomapy; c) wynik reklasyfikacji zNMPT; kolor zielony – wysokość roślinności >1 m; tło: dane katastralne

ferences between nDSM>1m and nDSM>2m had total area (Tab.1) in value 3.58 ha (2.56% of the analysed area). For nDSM>1m and nDSM>3m it was 4.49 ha (3.21%). Therefore, it can be stated that forest succession being started some year ago but still increasing.

Part of the study area – profile from ALS data as an example of forest succession area is presented in Fig. 5.

CONCLUSIONS

The study presents assessment of using airborne laser scanning data for monitoring LULC changes mainly in the aspect of forest succession and afforestation of agricultural land. Public registers in the field of cadastral maps and land cover and use in Poland are of-

Tab. 1. Land use in the study area – result of ALS data processing (reclassified nDSM). Classes: *Forested area* (F), *Arable land* (A), *Meadow* (M) *Pasture* (P) and Other (O).
Tab. 1. Klasy pokrycia terenu w obszarze badań – wynik przetwarzania danych ALS (reklasyfikowany zNMPT). Klasy: *Lasy* oraz *Grunty zadrzewione i zakrzewione* (F), *Grunty orne* (A), *Łąki* (M); *Pastwiska* (P) i *Inne* (O).

Land use	Area [ha]					Difference [ha]		
	Percentage [%]					Percentage [%]		
	Cadastral data	Ortho	nDSM >1m	nDSM >2m	nDSM >3m	Orthophoto – Cad. data	nDSM>1m – Cad. data	nDSM>1m – Orthophoto
F	6.37	29.92	25.44	21.86	20.95	23.55	19.07	–4.48
	4.56	21.41	18.20	15.64	14.99	16.85	13.64	–3.21
A	101.68	84.65	86.75	89.69	90.3	–17.03	–14.93	2.10
	72.75	60.56	62.07	64.17	64.61	–12.18	–10.68	1.50
P	1.65	1.13	0.97	1.02	1.04	–0.52	–0.68	–0.16
	1.18	0.81	0.69	0.73	0.74	–0.37	–0.49	–0.11
M	24.74	18.74	21.28	21.87	22.15	–6.00	–3.46	2.54
	17.70	13.41	15.23	15.65	15.85	–4.29	–2.48	1.82
O	5.33					0.00		
	3.81							
Total	139.77							
	100.00							

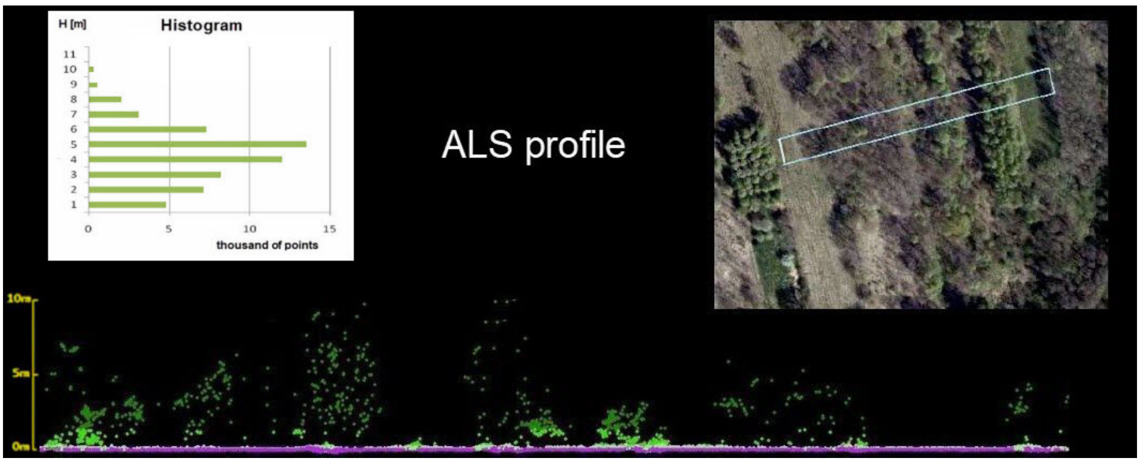

Fig. 5. ALS profile – example of forest succession area
Rys. 5. Profil z danych ALS – przykład obszaru sukcesji leśnej

ten outdated, which results from the high dynamics of changes taking place in agriculture as well as infrastructural and socio–economic changes taking place in rural areas. These are processes leading to an increase in the forest cover of the country, which is often not properly determined in the region, as it is based mainly on statistical and geodetic data – and not on currently acquired remote sensing data.

Verification and updating data about dynamically increasing processes of secondary forest succession on post-agricultural land where agricultural use was stopped are very difficult and extremely costly in terms of using traditional methods. Therefore, it seems necessary to develop up-to-date biomass map of forested areas, bushes/shrubs for the entire country in order to verify available statistical data e.g. about forestation or about biomass. It is not without significance to develop a model based on current data on land cover and use. It is essential in terms of European Union programmes, including land management and the granting of direct subsidies to agriculture but also very important as a theme for the assessment of biomass.

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