Replacing Sample Plots Forest Inventory by whole Stand Measurements based on LiDAR and Orthophoto

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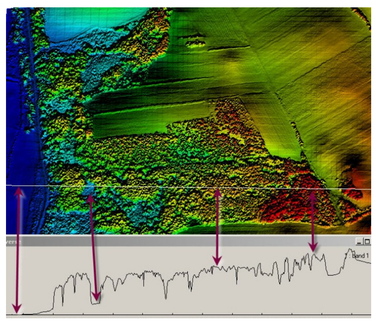
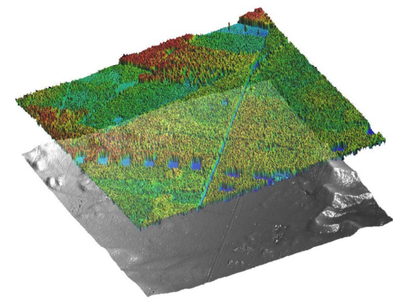


Abstract

Automatic tree counting algorithms based upon image segments are crucial for assessing the wood volume in a forest stand. The Object Based Image Analysis (OBIA) specifies unique transferable attributes of the crown 'hotspot', whose spatial characteristics are typical over a wide range of aerial photographs, orthophotos and satellite imagery. With high quality data, including LiDAR height information, a new large scale yield estimation can take place using semi and/or full automatic procedures. The method has been developed using different data sets like satellite and airborne imagery at the laboratory of RS and GIS of the faculty of forestry in Cracow. After successful testing it has been applied on three large areas and counter checked with existing field information, such as the results of a detailed terrestrial stand taxation.



Scientific Research

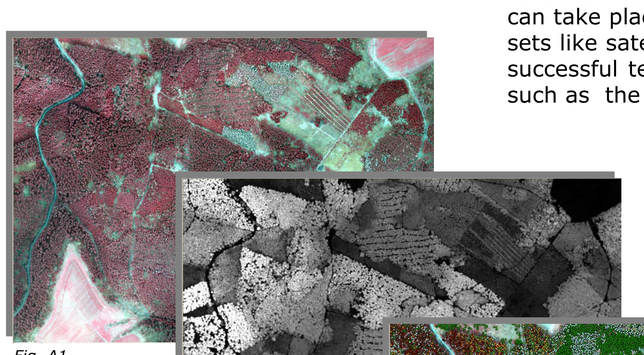


Fig. A1

Fig. A2

Fig. A3

Example on detecting single trees on larger areas using a CIR True-Orthophoto and a normalised Digital Surface Model (nDSM).
As a results of the automatic detection the crown centres including the individual tree tops plus the tree height is recorded in GIS format.

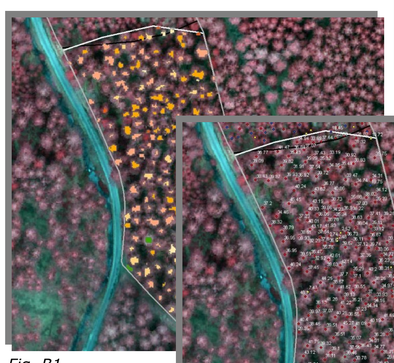


Fig. B1

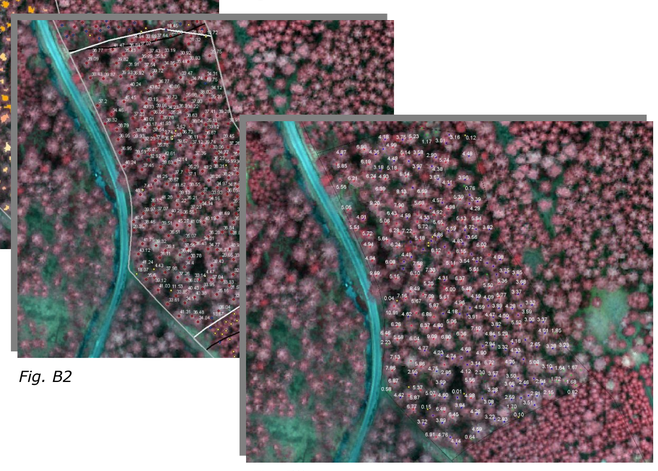


Fig. B2

Fig. B3

Example on assessing the stand volume as the sum of individual tree volumes. This approach is only successful in even aged stands. Fig. B1 shows single tree crowns and tree tops detected by the OBIA method. In Fig. B2 each tree top is labelled with the tree height in meter derived from the nDSM. The numbers in Fig. B3 indicate the individual tree volume in cbm as a result of the calculation based on the tree height and certain assumptions on the ratio between tree height and stem diameter (BHD). Further research is needed to find valid correlations between tree height, stand density and tree volume.

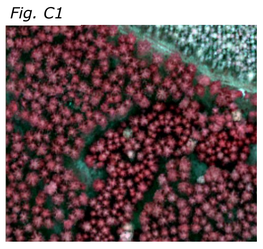


Fig. C1

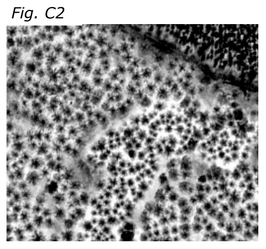


Fig. C2

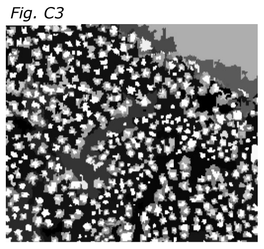


Fig. C3

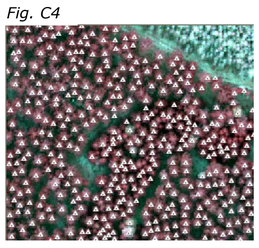


Fig. C4

Fig. C1; The ‚Hotspot' on the crown is a brighter area facing the sun. The image is segmented after amplifying this pixel-group using a negative principal component (Fig. C2). The crown-neighbourhood after segmentation is unique for centre of the crowns. The hotspot is always nearly completely surrounded by crown and background objects with a lower brightness value and therefore a larger value in the negative pc1. This is shown in Fig. C3. Here the crowns of trees higher than 12 meters become white spots surrounded by darker grey neighbouring objects. It is less relevant if these neighbours are also crown areas or background and shadow parts of the image. Therefore the feature is less prone to deviations in the image because only relative and not absolute grey values are evaluated.

This phenomena is universal for CIR, RGB and Multispectral VHRS satellite data. In Fig. C4 the output is shown as symbols on top of the centroide per object-polygon.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Area			Forest inventory - number of trees				Definiens		Results		
2	compartment number, first, september image, 2e october image	height class	crown density	number of trees	trees with "solitair" crown	trees with crown in touch with another crown	trees with NON-visible crown	detected by Definiens in CIR imagery	non-detected trees;difference (column [8]-[4])	automatic detection versus total number of trees from field inspection ([8]/[4])*100%	automatic detection versus total number of trees from field inspection([8]/[5])*100%	([8]/([5]+([6]/2)))*100%
3	1	2	3	4	5	6	7	8	9	10	11	
4	75o	10 m	full	803	210	509	94	33	-770	4.11%	15.71%	7.10%
5	89g	15 m	full	394	240	110	44	194	-200	49.24%	80.83%	65.76%
6	68t	20 m	full	1226	793	339	94	913	-313	74.47%	115.13%	94.86%
7	68t	20 m	full	1226	793	339	94	973	-253	79.36%	122.70%	101.09%
8	30a	15 m	moderate	577	472	35	70	312	-265	54.07%	66.10%	63.74%
9	30a	15 m	moderate	577	472	35	70	353	-224	61.18%	74.79%	72.11%
10	19c	20 m	moderate	324	304	7	13	303	-21	93.52%	99.67%	98.54%
11	19c	20 m	moderate	324	304	7	13	277	-47	85.49%	91.12%	90.08%
12	1k	25 m	moderate	1110	1083	21	6	1073	-37	96.67%	99.08%	98.13%
13	1k	25 m	moderate	1110	1083	21	6	991	-119	89.28%	91.51%	90.63%
14	110d	20 m	broken	248				209	-39	84.27%		
15	31i	25 m	broken	347	345	1	1	398	51	114.70%	115.36%	115.20%
16	31i	25 m	broken	347	345	1	1	407	60	117.29%	117.97%	117.80%
17	137i	30 m	broken	437	432	4	1	469	32	107.32%	108.56%	108.06%
18	137i	30 m	broken	437	432	4	1	365	-72	83.52%	84.49%	84.10%
19			Total-trees above 15 m ==>	4663.00					TOTAL above 15 Meter in % ==>	85.028	90.522	85.721

A table from the Polish test forest in ‚Chojna', where a full stand taxation over 5000 trees has been assessed. Due to the type of aerial photography (8-bit and 50 cm resolution) the algorithm starts to function for trees higher than 12 meters. Trees recognized in the field as well as in the visual interpretation of the orthophotos are compared to the number of trees encountered by the algorithm developed on a Definiens (semi) automatic protocol. For solitary crowns, over 90% recognition becomes possible using pre-dominantly optical data.

Applied Science

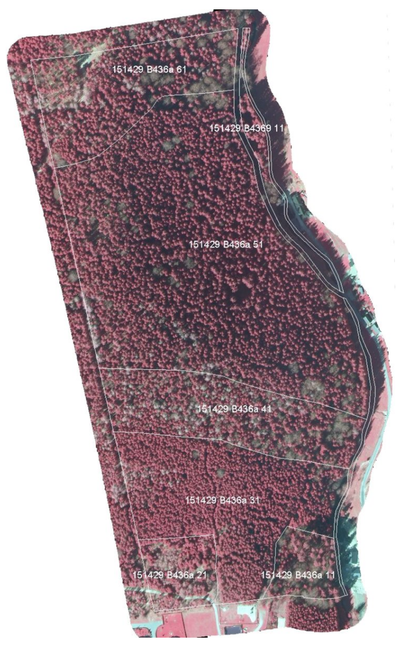


Fig. D1: CIR Mosaic showing the different stands in a 21 hectare small compartment within the 250 ha big test site.

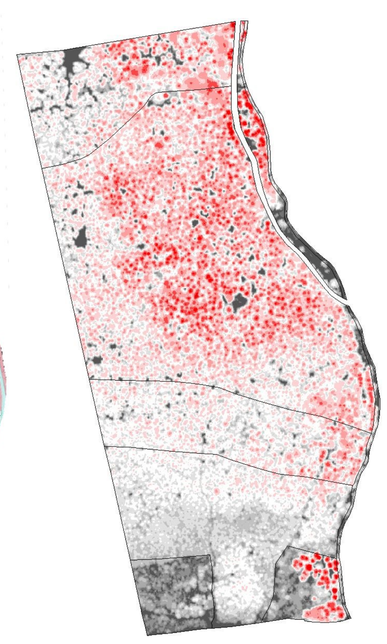


Fig. D2: nDSM created from LiDAR data with ca. 1.4 points per sqm. Red areas are high values representing the biggest trees, black pixel represent the bare ground.

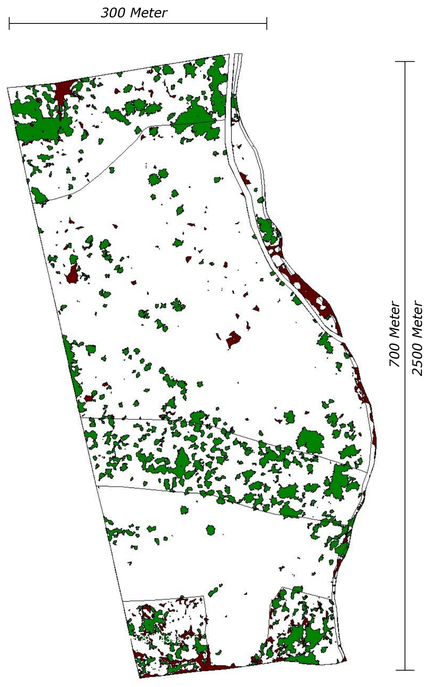


Fig. D3: Areas with deciduous trees (green spots) derived from the CIR information and openings (brown spots) processed from the nDSM data (pixels below 2m).

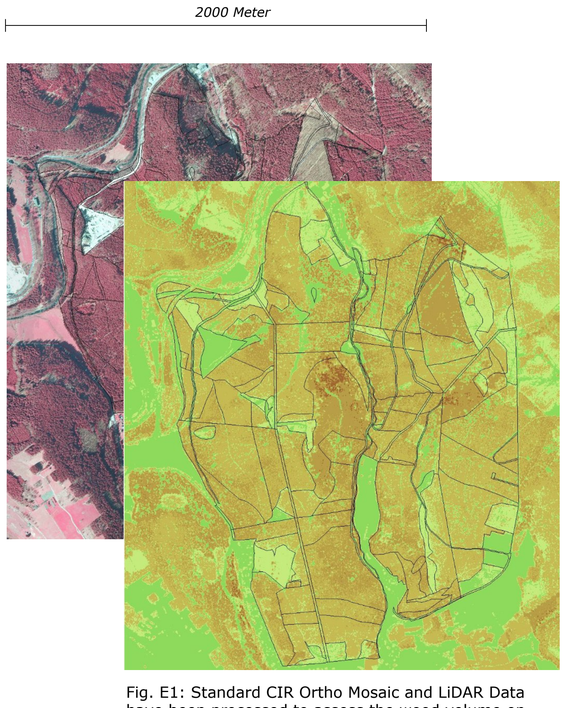


Fig. E1: Standard CIR Ortho Mosaic and LiDAR Data have been processed to assess the wood volume on some 250 ha mixed forests.

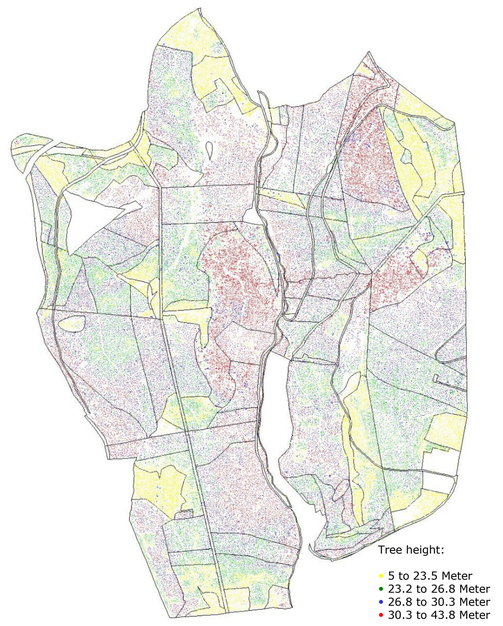


Fig. E2: Some 35.000 trees have been automatically detected, classified and height measured.

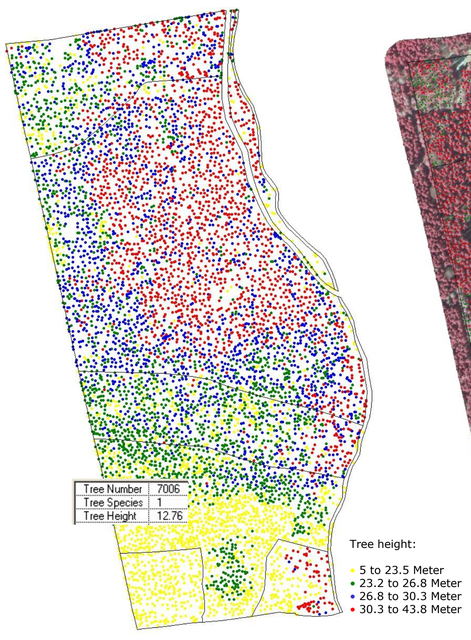


Fig. D4: Individual tree tops and tree height after processing the nDSM with a *local maxima* algorithm. From the individual tree heights, the mean average height of all trees and the maximum height of the hundred highest trees per ha and per stand will be calculated.

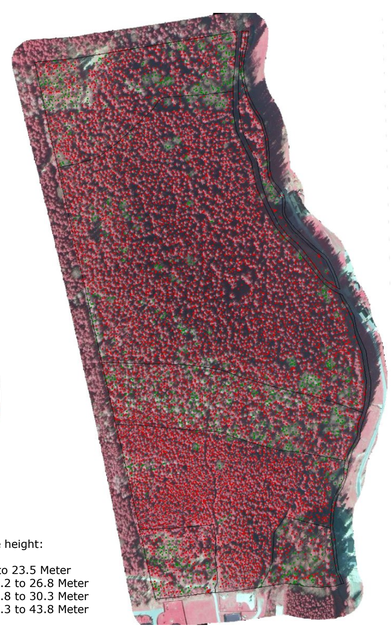


Fig. D5: CIR Mosaic with individual trees (red dots are conifers, green dots are broadleaf trees).

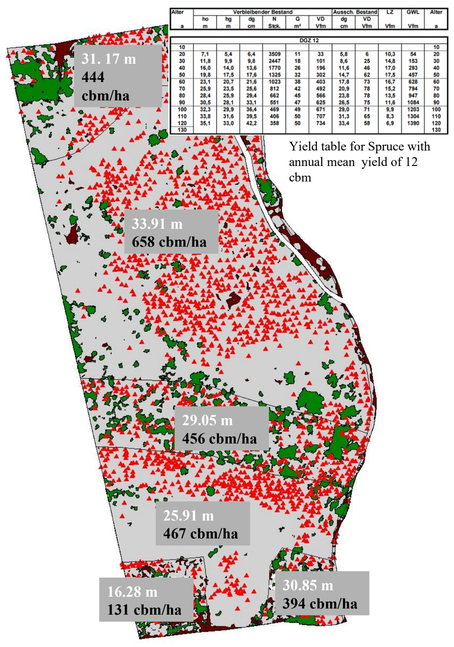


Fig. D6: Map with the calculated conifer wood volume in solid cubic meter of standing crop per ha (cbm/ha, black numbers) and the mean height of the hundred highest conifer trees per ha (in meter, white numbers). The top 100 conifers are represented by the red triangles.

The calculation in Fig. D6 is based on regional yield models (see inserted table in Fig. D6), which are suitable to assess the wood volume and the productive capacity of a stand. The height of the hundred highest trees and the stand age are used to link the yield model to the stand situation on site. The calculation is considering tree species (broadleaf areas are green, areas with conifers are grey) and openings (brown spots).

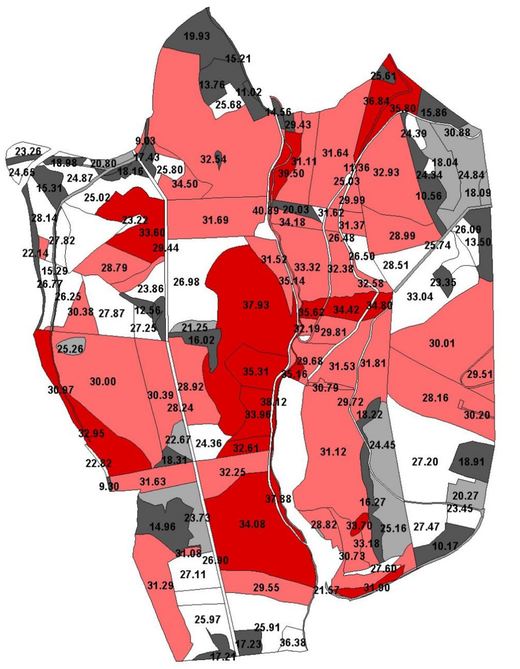


Fig. E3: The mean stand height and the top stand height have been calculated.
On the map the height of the top 100 conifer trees per stand and hectare is indicated by the black numbers (in meter). The colours refer to the mean stand height in meter (dark grey: 5 to 14; grey: 14 - 20, white: 20 – 24; light red: 24 – 28; dark red: 28 – 35).

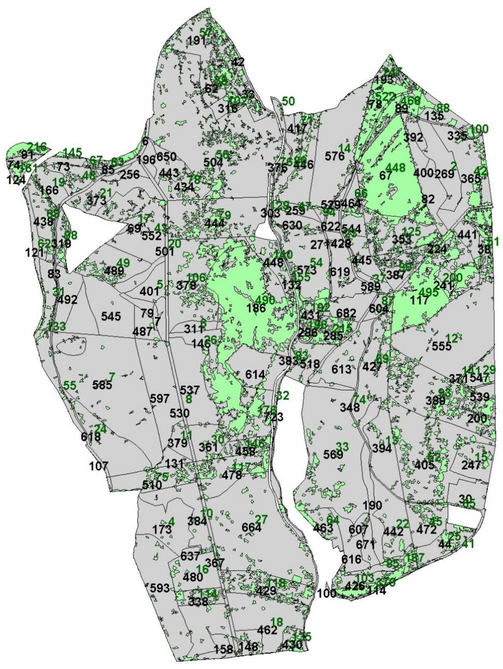


Fig. E4: By means of regional yield models the wood volume for conifer and broadleaf stands have been calculated (the numbers are indicating the standing stock volume for each stand in cbm/ha, black numbers = conifers, green numbers = broadleaf trees).
The percentage of areas with broadleaf (green spots), conifers (grey areas) and openings (black spots) has also been calculated for each stand.