3rd EARSeL Workshop SIG on Forestry

Breaking dimensions and resolutions of forest remote sensing data

BOOK OF ABSTRACTS

Edited by

Piotr Wężyk, Karolina Zięba

University of Agriculture in Krakow, Faculty of Forestry

Krakow, September 15-16, 2016

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Preface

It is with immense pleasure and a great honor that we invite you to the **3rd EARSeL Workshop (Special Interest Group on Forestry Society** in Krakow, Poland. The main objective of the **Workshop** accompanying the **Young Scientist Days on Forestry** (YSDoF) Conference held on Sept. 15-16, 2016 is to set up a common forum for the environment research community and professionals involved in the forestry sector. The EARSeL event focuses on operational techniques as well as developing methodologies and understanding in order to improve inventory methods, monitoring and management or protection practices used in the forests. In the next few days at the Workshop & YSDoF Conference we will share new ideas with the aim:

- to demonstrate the potential of the new generation of platforms, sensors and software;
- to present state of the art methods of geodata processing and integration;
- to evaluate both, benefits and limitations of the new technologies and
- to discuss future needs of forest related GeoInformation research sector and end-users.

The 3rd EARSeL Workshop & YSDoF are organized by the University of Agriculture in Krakow (Faculty of Forestry) in cooperation with: Jagiellonian University, IUFRO and Forest Research Institute in Warsaw. The Workshop is held under the patronage of Rector of the University of Agriculture in Krakow, Dean of the Forest Faculty and President of the Polish Space Agency.

The Workshop & YSDoF attracted numerous participants coming from many countries from different continents. The almost 130 presentations during Thematic Abstract Session and 12 keynote speeches will discuss the wide spectrum of state of the art GeoInformation technology in current and exciting forestry applications.

The 3rd EARSeL Workshop SIG on Forestry will be accompanying by other events, including:

- Young Scientist Days on Forestry (15-16 Sept. 2016);
- Student Award - Best Student Paper;
- GeoExpo (more than 10 exhibitors and presenters) and
- Summer School “Advanced Geomatics in Modern Forestry” (12-14. Sept. 2016; approx. 80 participants).

The 3rd SIG on Forestry EARSeL Workshop and Young Scientist Days on Forestry would have not taken place without considerable support and advice from many colleagues, organizations, sponsors and auspices. Credit for the quality of the upcoming EARSeL events goes first and foremost to the invited speakers, lecturers, authors of abstracts, participants and exhibitors.

We want to express our thanks to the members of Scientific Committee for evaluating all of the submissions and for their effort put into preparation of very interesting and exciting programme. We are also grateful to the University of Agriculture in Krakow, EARSeL Secretariat and all members of the Organizing Committee and our volunteering students who have been helping with the preparation of the meeting for weeks. Our meeting could not have happened without a substantial support from our sponsors, partners and cooperation of the University, Faculty and Conference Centre authorities. We hope that the EARSeL events will contribute to the development and future successes in the field of Remote Sensing, serving as a useful resource for researches and professionals interested in forestry applications.

On behalf of the Organizer Team

Piotr Wężyk, Assoc. Prof.

Chairman SIG on Forestry, EARSeL

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Programme of 3rd EARSeL Workshop SIG on Forestry, September 15-16, 2016

Venue: Conference Centre - University of Agricultural in Krakow Faculty of Forestry, al. 29 Listopada 46, Krakow

Date: Wednesday, 14/Sep/2016

4:30pm - 9:00pm Registration Desk	**REG-1: Registration 1** Session Chair: **Dr Barbara Czesak**, University of Agriculture in Krakow, Poland Session Chair: **Caileigh Shoot**, University of Washington, United States of America
7:00pm - 9:00pm GeoExpo - Main Hall	**3rd Workshop SIG on Forestry - Icebreaker** Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland Session Chair: **Megan Anne O'Shea**, College of the Environment, University of Washington, United States of America

Date: Thursday, 15/Sep/2016

7:30am - 8:30am Registration Desk	**REG-2: Registration 2** Session Chair: **Caileigh Shoot**, University of Washington, United States of America
8:30am - 9:00am Main AULA - "A"	**OC: Opening Ceremony** Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America
9:00am - 10:00am Main AULA - "A"	**PLS-1: Plenary session No 1** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
10:00am - 10:30am Upper Hall 1	**BR-1: Coffee break 1**
10:30am - 11:30am Main AULA - "A"	**TAS_1_A: Thematic Abstract Session 1 - Hyperspectral_1** Session Chair: **Dr Bogdan Zagajewski**, University of Warsaw, Faculty of Geography and Regional Studies, Poland Session Chair: **Dr Frantisek Zemek**, Global change research institute, CAS, Czech Republic
10:30am - 11:30am Lecture room 2 - "B"	**TAS_1_B: Thematic Abstract Session 1 - ALS_1** Session Chair: **Prof. Erik Næsset**, Norwegian University of Life Sciences, Norway Session Chair: **Dr Martin Isenburg**, rapidlasso GmbH, Germany

10:30am - 11:30am Lecture room 3 - "C"	**TAS_1_C: Thematic Abstract Session 1 - UAV** Session Chair: **Dr Krzysztof Stereńczak**, Forest Research Institute, Poland Session Chair: **Dr Géza Király**, University of West Hungary, Hungary
11:30am - 12:00pm GeoExpo - Main Hall	**EXPO-1: GeoEXPO 1** Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland Session Chair: **Paweł Hawryło**, University of Agriculture in Krakow, Poland
12:00pm - 1:00pm Upper Hall 1	**BR-2: Lunch break 2**
1:00pm - 1:30pm Main AULA - "A"	**PLS-2: Plenary session No 2** Session Chair: **Dr Thomas Schneider**, Technische Universität München, Germany Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
1:30pm - 2:30pm Main AULA - "A"	**TAS_2_A: Thematic Abstract Session 2 - Hyperspectral_2 & Monitoring_1** Session Chair: **Prof. Joachim Hill**, Trier University, Germany Session Chair: **Dr Olga Brovkina**, Global Change Research Institute, Czech Republic
1:30pm - 2:30pm Lecture room 2 - "B"	**TAS_2_B: Thematic Abstract Session 2 - ALS_2 & TLS** Session Chair: **Prof. Juha Hyyppä**, Finnish Geospatial Research Institute, Finland Session Chair: **Prof. Norbert Pfeifer**, TU Wien, Austria
1:30pm - 2:30pm Lecture room 3 - "C"	**TAS_2_C: Thematic Abstract Session 2 - Biomass** Session Chair: **Prof. Jaan Praks**, Aalto University, Finland Session Chair: **Dr Christian Joachim Thiel**, Friedrich Schiller University, Germany
2:30pm - 3:15pm Main AULA - "A"	**SPON-S: Sponsor Session** Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America
3:15pm - 3:30pm Main AULA - "A"	**ST-A: Student Award** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
3:30pm - 4:00pm Upper Hall 1	**BR-3: Coffee break 3**
4:00pm - 4:30pm Main AULA - "A"	**PLS-3: Plenary session No 3** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
4:30pm - 5:30pm Main AULA - "A"	**TAS_3 _A: Thematic Abstract Session 3 - Monitoring_2** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Iain Woodhouse**, The University of Edinburgh, United Kingdom

4:30pm - 5:30pm
Lecture room 2 - "B"

TAS_3 _B: Thematic Abstract Session 3 - ALS_GEOBIA & Forest health
Session Chair: **Prof. Krzysztof Będkowski**, University of Łódź, Poland, Poland
Session Chair: **Filip Hájek**, Forest Management Institute, Czech Republic

4:30pm - 5:30pm
Lecture room 3 - "C"

TAS_3 _C: Thematic Abstract Session 3 - Image-Based-PointCloud & Forest inventory
Session Chair: **Dr Piotr Tompalski**, University of British Columbia, Canada
Session Chair: **Dr Lars T. Waser**, Swiss Federal Research Institute WSL, Switzerland

5:30pm - 6:00pm
Main AULA - "A"

PLS-4: Plenary session No 4
Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
via Skype

8:00pm - 11:00pm
Gala Dinner - Wierzynek

DIN: Gala Dinner
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America

Date: Friday, 16/Sep/2016

7:30am - 9:00am
Registration Desk

REG-3: Registration 3
Session Chair: **Caileigh Shoot**, University of Washington, United States of America
Session Chair: **Dr Barbara Czesak**, University of Agriculture in Krakow, Poland

9:00am - 10:00am
Main AULA - "A"

PLS-5: Plenary session No 5
Session Chair: **Dr Bogdan Zagajewski**, University of Warsaw, Faculty of Geography and Regional Studies, Poland
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland

10:00am - 10:30am
Upper Hall 1

BR-4: Coffee Break 4

10:00am - 11:30am
Upper Hall 1

GPS: General Poster Session (GPS)
Session Chair: **Dr Tomas Bucha**, National Forest Centre, Slovak Republic
Session Chair: **Dr Krzysztof Stereńczak**, Forest Research Institute, Poland

11:30am - 12:00pm
GeoExpo - Main Hall

EXPO-2: GeoEXPO 2
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
Session Chair: **Paweł Hawryło**, University of Agriculture in Krakow, Poland

12:00pm - 1:00pm
Upper Hall 1

BR-5: Lunch Break 5

1:00pm - 3:00pm
Main AULA - "A"

PLS-6: Plenary session No 6
Session Chair: **Dr Bogdan Zagajewski**, University of Warsaw, Faculty of Geography and Regional Studies, Poland
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland

3:00pm - 3:30pm
Upper Hall 1

BR-6: Coffee Break 6

3:30pm - 4:15pm
Main AULA - "A"

DISC_P: Discussion Panel
Session Chair: **Dr Martin Isenburg**, rapidlasso GmbH, Germany
Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America

4:15pm - 4:30pm
Main AULA - "A"

CLS: Closing Session
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
Session Chair: **Prof. L. Monika Moskal**, University of Washington, USA

Date: Saturday, 17/Sep/2016

7:00am - 8:00pm

TV-1: Technical Visit 1: Niepolomice Primeval Forest - Royal Salt Mine Wieliczka
Session Chair: **Dr Marta Szostak**, University of Agriculture in Krakow, Poland
Session Chair: **Karolina Zięba**, University of Agriculture in Krakow, Poland
Niepolomice Primeval Forest - Royal Salt Mine Wieliczka

7:00am - 8:00pm

TV-2: Technical Visit 2: Zakopane - Tatra National Park
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
Session Chair: **Adrian Ochtyra**, University of Warsaw, Poland
Zakopane - Tatra National Park

3rd EARSeL Workshop SIG on Forestry

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Abstracts

PLS-1: Plenary session Nº 1

Time: **Thursday, 15/Sep/2016: 9:00am - 10:00am**
Location: **Main AULA - "A"**

Session Chair: **L. Monika Moskal**
University of Washington, United States of America
Session Chair: **Piotr Wezyk**
University of Agriculture in Krakow, Poland

ID: 144 / PLS-1: 1

Remote Sensing of Forests at ESA

Frank Martin Seifert

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Keywords: Copernicus, Sentinel, REDD+

Forests applications in remote sensing have been a driver for development of new satellites and new techniques for decades. Based on service demonstrations the European Space Agency (ESA) developed within the COPERNICUS initiative with the European Commission the SENTINEL satellite family, guaranteeing systematic observations for the next decades. Sentinel-1A and -1B, two C-band Radar sensors launched in April 2014 and April 2016, and Sentinel-2A – a multispectral optical sensor launched in June 2015, will contribute significantly to forest observations worldwide. Additionally BIOMASS as ESA’s 7th Earth Explorer mission, to measure forest biomass from space is scheduled for launch in 2021.

Application development at ESA varies from local to global scale and from science to demonstration of operational services. Emphasis will be put on the United Framework Convention on Climate Change (UNFCCC) established process to reduce greenhouse gas emissions from deforestation and degradation (REDD) in developing countries. The Forestry Thematic Exploitation platform will be introduced as example of exploitation platform approaches proposed in the next EO Envelope Programme EOEP-5 to serve the research and service community. Critical issues like monitoring forest degradation, accuracy assessments, biomass estimation and the role of evolving technologies will be discussed.

ID: 146 / PLS-1: 2

New Possibilities for Forest Inventory Using Laser Scanning/Lidar

Juha Hyyppä

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Keywords: Geospatial research

Today, it can be seen, that many of the future remote sensing processes for forestry will be based on point cloud processing or on elevation models (3D techniques). These required forestry data can be provided by the lidar/laser scanning, photogrammetry and radar. These techniques have already been benchmarked at plot level using area-based approach e.g. in Yu et al. (2015), http://www.mdpi.com/2072-4292/7/12/15809. For the future, there are plenty of point cloud generation techniques available for derivation of forest information using area-based approach (ABA) from the air. However, ABA has also certain limitations, such as it requires large number of accurately measured field plots and species-specific forest inventory attributes and diameter distributions have poor prediction accuracy. In addition, seedling stands are not inventoried by ABA and those have to still be measured at the field. To optimize cutting, the stem-diameter distribution, stem form, and quality information must be measured as accurately as possible. Thus, from forest industry point of view, ABA is not providing accuracy level required for precision forestry wood procurement.

Recently development of multispectral laser scanning technique is becoming attractive because it can provide not only dense point cloud but also spectral information. The study by Ahokas et al. (2016), http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLI-B3/155/2016/isprs-archives-XLI-B3-155-2016.pdf was a first contribution towards automatic single-sensor mapping by multispectral airborne laser scanning by showing that combined use of point cloud metrics and intensity features resulted in total accuracy of 93.5% for classification of three main boreal tree species (pine, spruce and birch).

Conventionally, field sample has been measured using simple tools, such as calipers and clinometers, and the advancement of forest field inventories. This is slow and costly. Recently terrestrial point clouds have been provided by large number of sensors and technologies, i.e. Terrestrial Laser Scanning, Mobile Laser Scanning with and without SLAM, Terrestrial Photogrammetry, and even smart-phone embedded imaging and point cloud generation techniques. Short review of these mainly from the TLS point of view can be found from http://www.sciencedirect.com/science/article/pii/S0924271616000204, and in Hyyppä et al. (2015). International comparison of TLS methods in currently under progress by FGI http://www.eurosdr.net/research/project/project-benchmarking-terrestrial-laser-scanning-forestry-applications as well as comparison related to test MLS, TLS and other technologies together for collecting terrestrial point clouds that would provide stem curve and 3D model of field reference trees. The presentation will talk about these technologies from multispectral Airborne Laser Scanning to terrestrial point clouds from various sensons and present state of art in laser-based remote sensing of forests and predict where the near-future practice and science is going.

TAS_1_A: Thematic Abstract Session 1 - Hyperspectral_1

Time: **Thursday, 15/Sep/2016: 10:30am - 11:30am**
Location: **Main AULA - "A"**

Session Chair: **Bogdan Zagajewski**
University of Warsaw, Faculty of Geography and Regional Studies, Poland
Session Chair: **Frantisek Zemek**
Global Change Research Institute, CAS, Czech Republic

ID: 38 / TAS_1_A: 1

Spectral Unmixing of Deciduous Forest Crown Components at Various Scales, Angles and Phenological Stages

Anne Clasen[1,2], Ben Somers[3], Kyle Pipkins[1], Laurent Tits[3], Karl Segl[2], Maximilian Brell[2], Birgit Kleinschmit[1], Angela Lausch[4], Michael Förster[1]

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Keywords: Unmixing; MESMA; forest; bark; observation angle; phenology

The spatial and temporal distribution of forest biochemical and biophysical variables are essential inputs to process-orientated ecosystem models. Remote sensing, particularly imaging spectroscopy, has proven to be a promising tool to provide this information. In order to investigate in detail, what actually is observed by remote sensing, the present study determines the occurring crown component fractions in a forest ecosystem on a sub-pixel-basis. In this context, the potential of spectral unmixing to derive information on the distribution of the endmembers 'leaf', 'bark' and 'soil' within a pixel is investigated. Close range spectral measurements of the canopy and its components were taken with an ASD FieldSpec instrument mounted to a crane measurement platform situated in a temperate deciduous forest in North-East Germany. Reference fractional abundances of the components were precisely determined from photographs taken simultaneously to the ASD measurements. Unlike most other studies, which only consider two components, mainly 'leaf' and 'soil', this experimental setup facilitated the inclusion of the additional component 'bark' for the unmixing of forest crown components. Measurements from different stages of the phenological phases were used in this study. In the 2015 field campaign, data was collected on April 21st, June 5th, August 3rd and October 1st. Airborne HySpex data was collected simultaneously on the last three of these dates and on July 7th. Especially in summer, the dense foliation in this complex vegetation structure causes the problem of saturation effects, when applying broadband vegetation indices. This study illustrates that multiple endmember spectral mixture analysis (MESMA) can contribute to overcoming this challenge. The results indicate that the inclusion of an additional 'bark' endmember clearly improves the accuracy of the unmixing results. When only nadir viewing directions were taken into account, a mean absolute error of 7.9% could be achieved for the fractional occurrence of the 'leaf' endmember and 5.9% for the 'bark' endmember. In order to evaluate the results of this field-based study for remote sensing applications, a transfer to airborne and satellite-based imagery was carried out. All sensors used in this study were capable of unmixing crown components with a mean absolute error ranging between 3% and 21% for the nadir measurements. However, airborne and spaceborne sensors provide imagery that includes not only nadir viewing directions. Off-nadir viewing zenith angles up to 10° are a common case for sensors with a large swath. This needs to be considered in image processing and the derivation of biophysical parameters. BRDF corrections account for illumination and viewing geometry as well as structural and optical properties of the surface, but commonly, they do not account for variations in the actual visibility of the canopy components at different observation angles. The crane measurement platform allowed for a very detailed view on the changing visibility of the occurring canopy components at different angles.

ID: 49 / TAS_1_A: 2

Canopy reflectance modeling in fire affected areas using in situ reflectance measurements acquired by a field spectroradiometer: Exploring the role of soil exposure.

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Keywords: field spectroradiometer, burnt area, soil

The main objective of this study is the canopy reflectance modeling in fire affected areas based on in situ reflectance measurements using a field spectroradiometer with the interest to explore the role of soil exposure. Our study area is a recently burned area, in which, the spectral properties from a number of small patches within the fire perimeter were recorded. The patches reflect a gradient of fire intensity within the fire scar, from parts that were severely burnt to islets within the fire scar that were not burnt. Moreover, additional measurements took place closely outside of the burnt area. The acquisition of the spectral signature of these patches was obtained by means of a high resolution spectroradiometer (FieldSpec 4) and was repeated concurrently with the passage of Landsat satellite from the study area, every 16 days. Moreover, flights with Unmanned Aerial Vehicle (UAV) that was equipped with RGB and near-infrared cameras were performed the same days. The data acquired were implemented into Bi-directional Reflectance Distribution Function (BRDF) models, used to describe the way the light is scattered across the surface as a function of the illumination and the viewing angles, along with wavelength and the properties of the land surface and analyzed in order to evaluate the way in which differences in fire severity –or eventually other environmental differences- influence the spectral properties of the Landsat satellite data inside the burned area.

ID: 63 / TAS_1_A: 3

Tree species classification in temperate forests using airborne hyperspectral data

Martyna Wietecha, Krzysztof Stereńczak

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Keywords: tree species classification, airborne hyperspectral data, temperate forests

The advantage of airborne hyperspectral data, except high spectral resolution, is the possibility of obtaining relatively high spatial resolution data, which allows us to analyse the individual tree crowns. Despite the fact that tree species identification is an important issue in forest management and many studies have explored this topic, it is still not common to use remote sensing techniques, especially hyperspectral, to classify forest in temperate zone because of their complexity.

The aim of the study was to classify tree species of forests belonging to a temperate forest ecosystems, located in the Milicz forest district, Lower Silesia in Poland. There were group of 7 dominant tree species selected, which includes 3 coniferous species: the most Scotch pine (*Pinus sylvestric*), European larch (*Larix decidua*) and Norway spruce (*Picea abies*), rarely occur within the stands, and 4 deciduous species: English oak (*Quercus robur*), European beech (*Fagus sylvatica*), Silver birch (*Betula pendula*) and alder (*Alnus sp.*).

Two airborne (HySpex VNIR-1800 and HySpex SWIR-384) imaging spectroscopy dataset with pixel sizes of 2.5 and 5 m were obtained in August 2015 to examine different method of classification. Data were radiometrically (HySpex RAD software), geometrically (PARGE software) and atmospherically (MODTRAN5 code, ATCOR4 software) corrected. Normalized digital surface model (nDSM) derived from LiDAR data and Vegetation Indices were additionally used to create mask for non-forest area. In the first attempts, for the feature selection Minimum Noise Fraction (MNF) bands were tested. Support Vector Machines (SVM) classifier were used to avoid Hughes' phenomenon. The most heterogeneous line of datasets was classify as a first one.

First result for classification of 7 tree species on 35 MNF bands shows overall accuracy value of 68% and Kappa value of 0.55. Continuing research and algorithm improvements are in progress.

This work is a part of the project REMBIOFOR "Remote sensing based assessment of woody biomass and carbon storage in forests", cofounded by the National Centre for Research and Development (NCBiR) within the program „Natural environment, agriculture and forestry" BIOSTRATEG, under the agreement no. BIOSTRATEG1/267755/4/NCBR/2015.

ID: 73 / TAS_1_A: 4

Scale dependent assessment of broadleaved-tree species reflectance derived from hyperspectral in-situ and airborne sensors at leaf and crown levels

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Keywords: Hyperspectral remote sensing, tree species, scale dependency, non-imaging spectroscopy, leaf and canopy reflectance

Imaging and non-imaging spectroscopy are offering new insights and possibilities in remote sensing of forests. The link between new hyperspectral airborne and satellite sensors and the information gathered on the ground is crucial. Field data is widely used for sensor calibration and validation or the derivation and up-scaling of biophysical parameters such as nitrogen and chlorophyll content of the foliage. In that context, we are often facing several scaling issues arising from differences in the spatial and spectral resolution. Since hyperspectral data is characterized by a plethora of narrow bands containing redundant information, the application of data reduction techniques is common. This study deals with the spectral traits of trees and the derivation of the bands containing the key information for species discrimination at varying scales. It was carried out in an old-growth broadleaved forest of the Hainich in central Germany considering six main tree species. We used an exceptional set of simultaneous in-situ and remotely sensed reflectance records acquired at three different levels of leaves and crowns incorporating field spectroradiometer as well as hyperspectral airborne imagery. Furthermore, we examine the necessity of spectral information covering the full range of 400-2500 nm and the possibility of focusing only on specific sections. Our analyses include the determination of the minimum number of bands, which are needed to describe spectral response patterns. Additionally, we are investigating the influence of the scale of observation on the spectral response patterns of five tree species. At each scale of observation, a generalized additive modelling approach is used to approximate an average spectral response pattern across multiple scans. We iteratively sample the entire spectral range to reduce autocorrelations across bands and to arrive at a minimum number of bands required to approximate the spectral profile including all bands. A bootstrapping procedure is used to calculate confidence intervals around modeled spectral profiles elucidating differences brought about by changing the scale of observation and pairwise distance metrics are used to show (dis)similarity between the measured and modeled spectral profiles. Our expected results are important in highlighting scaling effects in remote sensing of forests and can help to improve sensor calibration and further application such as radiative transfer modelling or the understanding of related processes.

ID: 101 / TAS_1_A: 5

Species-level classification using airborne hyperspectral imagery

<u>Peter Burai</u>, Laszlo Beko, Tamas Tomor, Csaba Lenart

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Keywords: hyperspectral, support vectore machine, random forest, energy tree, image classification

Forest monitoring with remote sensing method faces a complex problem, because vegetation of different age and species composition can exhibit significant spatial diversity within a relatively small area. Airborne hyperspectral imagery can produce multiple narrow and contiguous spectral bands of less than 10 nm with a high geometric resolution (0.5–1 m). Hyperspectral imagery can be a suitable method for a detailed vegetation classification based on the dominant or subdominant genera or species. This paper investigates whether the combination of airborne hyperspectral imagery using feature extraction can discriminate among species and clones of trees. The study site was selected in Northern Hungary at the Fleiscmann Rudolf Research Institute (47°44'19.20" N, 20°14'04.01" E), where nine different types of energy plants are tested for biomass production. Analysing biomass product two poplar (*Populus sp.*) clones, five willow (*Salix sp.*) clones, furthermore boxelder (*Acer negundo*) and narrow-leafed ash (*Fraxinus angustifolia*) are investigated in the study site. The trees examined have similar morphological traits due to limitation of detection. Aisa EAGLE II hyperspectral sensor was used produced images with 253 contiguous bands (400-1000 nm), a spectral sampling of 2.5nm bandwidth, with 1m pixel size. The acquisition of data took place in good weather conditions and sun elevation in three different vegetation period (26/05/2011, 13/07/2011, 02/10/2011). Feature extraction (PCA, MNF) methods were applied to reduce the dimension of hyperspectral dataset. Traditional image classifier (Maximum Likelihood Classifier – MLC) and machine learning algorithms (Support Vector Machine – SVM, Random Forest – RF) were applied on the training dataset. Image classification algorithms were run on each transformed (PCA, MNF) images separately and on their different combinations. We found the best classification results when using the first 6-15 bands of PCA, and the first 5-10 bands of MNF, considering the image capture dates and the feature extraction procedure. Classification of images of three dates provided better outcomes with the application of MNF transformed data than PCA. Comparing the results of tree images, the accuracy was the best in the summer period (July). SVM on MNF-transformed dataset provided more accurate results (OA: 75.81%) than applied MLC (OA: 75.81%) and RF (OA: 69.18%) methods. Combination of the dataset of May and July produced higher classification accuracy using MLC (OA: 78.21%) than the other combinations.

ID: 106 / TAS_1_A: 6

Hyperspectral detection of phenological changes in coniferous and deciduous forest of UNESCO's World Heritage Bialowieza National Park

Karolina Orłowska[1,2], Adrian Ochtyra[1,2], Zbigniew Bochenek[3], Dariusz Ziółkowski[3], Bogdan Zagajewski[1], Marlena Kycko[1]

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Keywords: hyperspectral remote sensing, forest phenology, Bialowieza National Park, coniferous and deciduous species

Diversified pace of phenological growth in coniferous and deciduous tree species result from habitat preferences, climate and atmospheric conditions, access to nutrients, presence of competitors but most of all plant's physiological features. During one vegetative year certain changes in plant's physiology can be observed: increase and decrease in amount of chlorophyll as well as anthocyans, carothenoids and other pigments, modifications of cell structures or water demand. Though dynamic, this changes can be observed with a use of hyperspectral remote sensing analysis of narrow bands of electromagnetic spectrum.

The aim of the research was to assess suitability of hyperspectral remote sensing methods in study of changes in coniferous and deciduous tree species phenology of the UNESCO's World Heritage Bialowieza National Park in Poland. The data were collected in 2014 and 2015 (taking into consideration strenuous atmospheric conditions - European drought of 2015). Each year three campaigns were conducted: at the beginning (May), during (July) and at the end of vegetative period (September). During the campaigns spectral reflectance curves were collected on 8 homogenous polygons for the following tree species - deciduous: hornbeam *(Carpinus betulus)*, oak *(Quercus robur)*, alder *(Alnus glutinosa)*, birch (*Betula pubescens)* and coniferous: spruce *(Picea abies)* and pine *(Pinus sylvestris)*.

Spectral reflectance curves were used to calculate vegetation indices while chlorophyll content was applied to verify accuracy of collected data. Calculated vegetation indices were: general condition indices, narrowband condition indices, red edge/chlorophyll content, carotenoids and anthocyans content, water content, use of light in the process of photosynthesis as well as senescence/ripening index. The data were statistically analyzed using ANOVA and and Kruskal-Wallis ANOVA. The results showed which wavelengths and vegetation indices showed statistically significant changes. On the basis of this information, an assessment of forest phenological changes was made indicating that changes observed in case of deciduous species are more dynamic while in case of coniferous more stable. Remote sensing vegetation indices which reflected the best those changes were selected for further research.

The research was conducted as a part of the Polish-Norwegian Research Programme of National Centre for Research and Development (NCBiR), project No.: POL-NOR/198571/83/2013: Ecosystem stress from the combined effects of winter climate change and air pollution – how do the impacts differ between biomes? (WICLAP).

ID: 23 / TAS_1_A: 9

Tree species classification in Norway from airborne hyperspectral and airborne laser scanning data

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Keywords: Airborne laser scanning, imaging spectrometer, automatic processing, forest inventory

This paper presents a research collaboration to develop more automated methods for forest inventory in Norway and Scandinavia.

The current situation in the forest industry in Norway is difficult due to reduced timber prices and high labor cost. Currently forest inventory methods combine airborne laser scanning (ALS) data and manual photointerpretation using multispectral imagery (broad visual and near-infrared channels), but extensive field work is needed in addition. This makes forest inventory very expensive for large areas.

In this perspective, more automated methods for forest inventory are needed. Specifically, we will focus on methods which combine data from simultaneously acquired airborne laser scanning and imaging spectrometer. The ALS data already provides information on vegetation height. The hyperspectral data may provide information on biophysical and biochemical parameters, and species composition. Combined, the two types of data have the potential of more accurate forest inventory with less fieldwork.

Hyperspectral and ALS data were acquired simultaneously for a forest area in Våler municipality, Østfold County, Norway. Field work was conducted to identify examples of individual trees and small clusters of trees of one single species. Approximately 169 tree polygons were delineated using ALS data.

A set of sample spectra based on in situ data was prepared for each of the three species pine, spruce and birch. The mean spectra were found for each tree species, by averaging over all the samples. From these data we identified three regions where the tree species may be differentiated: 544 nm (green), 674 nm (red) and 710 nm (red edge). We used the three bands from these regions to create two indices in order to separate the different tree species. Firstly, ALS data was used to create a mask, removing areas where the vegetation was lower than 1 meter. Secondly, thresholds on the green 544 nm band and on broadband NDVI were applied to remove shadows and areas without live vegetation. Finally, the two proposed indices were used to differentiate the tree species. The resulting tree species classification map has clusters of homogeneously classified pixels, corresponding to individual trees or groups of trees of the same species. Close inspection reveals some occasional misclassified pixels and/or pixels of a different class than the majority within a cluster. The pixel-based accuracies for each species are in the range 83-86%. In photointerpretation of broadband multispectral images, it is a well-known problem that young spruce may be confused spectrally with birch, and old spruce with young pine. This indicates a potential to reduce the confusion between birch and spruce and between spruce and pine, by also considering the tree height in the classification method. The tree height, which is possible to derive from the ALS data, is a good proxy for tree age.

ID: 74 / TAS_1_A: 11

Tree species classification of Karkonoski National Park using artificial neural networks in R

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Keywords: Classification, Artificial Neural Networks, Hyperspectral data

APEX 288 band hyperspectral airborne images and artificial neural networks were used to classify six dominant tree species of Karkonoski National Park, south-western Poland. Classified tree species were beech, spruce, pine, larch, alder and birch. APEX processing and correcting of data consisted of geometric, radiometric and atmospheric correction of raw image using DSM of KPN and MODTRAN 4 radiative transfer model. Corrected data were then delivered for further processing. APEX images were corrected by VITO.

After initial inspection of band quality we decided to remove noisy bands and bands located in water vapor absorption range. After removal of unwanted spectral bands our dataset consisted of 222 bands. One of the important topics in remote sensing is information extraction. Rarely one would like to use whole available dataset for classification or other analysis. Oftentimes it is more sensible to select a subset of data for analysis which results in shorter classification times and faster workflow. In this work we attempted to select spectral bands that will give us highest classification accuracies but still allow our classification times to be relatively short. 222 spectral bands went thought PCA analysis to find out bands with highest information load. Each band had its information load assessed and was later sorted based on amount of information it held. Finally 40 most informative bands were selected for final classification.

It this work we used feed forward multi-layered-perceptron with single hidden layer. To simulate such network we used R statistical program and one of R software “packages” called *nnet*, developed at Oxford University. This package is dedicated tool for simulation and development of ANN in R software. In this work we present methods to determine best artificial neural network architecture (number of neurons in hidden layer) and impact of number of neurons in hidden layer on classification results. Because of the fact that supervised classifiers are sensitive to input data we decided to perform iterative accuracy assessment to verify our classification results and further strengthen our belief in final classification map. Final classification covering whole area of KPN achieved overall accuracy above 80% with all classes having producer accuracy no less than 70%.

ID: 50 / TAS_1_A: 12

Bridging Scale Leaps in Hyperspectral Remote Sensing: From Field to Airborne Imaging Spectroscopy

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Keywords: Scales, Spectroscopy, Hyperspectral

Collecting reference samples from tree crowns is a very demanding and laborious task. Especially when professional tree climbers are necessary for gathering leaves, only a very limited amount of trees can be sampled in a given time or with a given budget. These may suffice to roughly validate a remote sensing-based map, but a robust regression model cannot be established on these data. In addition, the sampled trees will not necessarily display a large variation in the property of interest (e.g., leaf chlorophyll or water content). One possible solution is using transferable models established on larger datasets based on reference data from controlled environments, which allow an easier sampling compared to field studies conducted in full-grown forest trees.

We planted 4 year old beech (*Fagus sylvatica*) seedlings into pots (60 trees in total, 3 trees per pot) and conducted drought stress experiments on them over a three year period (2011-2013). Half of the pots were not watered over several weeks in summer while a control group was kept watered all the time. Regular reference measurements of leaf water content, leaf chlorophyll content and leaf reflectivity were conducted, and field imaging spectroscopy data was collected from a 3.8 m high platform using HySpex hyperspectral cameras.

A field campaign with tree climbers was conducted in the late summer of 2015 during a dry phase in a forest area prone to drought stress, the Donnersberg forest in Southwestern Germany. Leaf samples from the tops of the tree crowns were analysed comparably to the seedling samples. Airborne hyperspectral data was recorded at the same time as the field campaign.

This study analyses transferability of regression models for leaf water and chlorophyll content from the seedlings to full-grown trees and from leaf level to canopy level. Index-based and partial least squares regression models were trained on spectra from the potted small trees and applied to leaf and airborne spectra from the Donnersberg region. Leaf spectra were up-scaled to canopy level using the geometric-optical radiative transfer model Inform in order to bridge the scale from leaf to airborne measurements.

TAS_1_B: Thematic Abstract Session 1 - ALS_1

Time: **Thursday, 15/Sep/2016: 10:30am - 11:30am**
Location: **Lecture room 2 - "B"**

Session Chair: **Erik Næsset**
Norwegian University of Life Sciences, Norway
Session Chair: **Martin Isenburg**
rapidlasso GmbH, Germany

ID: 62 / TAS_1_B: 1

Exploiting full waveform LiDAR metrics for reliable terrain characterization and reconstruction in dense forests

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Keywords: ALS, lidar, waveform, DTM, reconstruction, uncertainty

Extracting reliable digital terrain models is an essential task for utilizing airborne laser scanning (ALS) data in various applications. The most widely utilized ground filtering algorithms only consider the spatial and structural information from geometric perspective of ALS data and perform with significant uncertainty in densely forested areas where not all laser shots can penetrate thick canopy to detect the true ground. In such circumstances, sparse ground returns are easily to be discarded as noise and, moreover, the fitted ground trend surface would be somewhere between the ground and main story or low vegetation layer. This reduces indirectly the accuracy of tree height estimation in forestry applications. The open question is, what should be the best practice to perform a reasonable ground filtering, when the true ground surface is under-sampled as a result of a very dense canopy? In the past decade, small footprint full waveform (FWF) ALS systems have been introduced to the market and are believed to provide more physical properties of the target surface. To gain accurate object separation, an appropriate relative/absolute radiometric calibration should be thus performed to mitigate influences from target-independent factors (range, incidence angle, multiple returns, etc.), based on robust geometric preprocessing strategies.

This contribution explores a FWF information optimized detection approach of introducing contributions from radiometry of ALS data in recognizing vegetation and ground signals to complement a spatial metric based filtering approach. The comprehensive metrics, based on “waveform functions”, are proposed with a robust relative radiometric correction and extended by various mathematical formulations. The most contributive indicators are selected as operational parameters for further processing. To fuse the waveform metrics into the conventional filtering progress, geometrically based algorithms are implemented. They involve the metrics as auxiliary features for determining echo types and estimate their uncertainty as well. A quantitative uncertainty map is therefore generated as part of the terrain reconstruction. The results are verified and validated with manual interpretation and digital terrain models from manual filtering.

ID: 68 / TAS_1_B: 2

Characteristic tree assemblages classification in a complex karst region (Aggtelek, Hungary) using low point density ALS data

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Keywords: low point density ALS, classification, geometrical features, ecology

Currently the application of high density LiDAR data in forestry mostly concentrates on biomass calculation or classification of the forest into single tree species. However, in ecological point of view the LiDAR data can be a suitable dataset to analyse the forest at community level. In this study we investigated how to extract ecological information from low point density ALS data based on biological field measurement survey.

The study area is located in the Aggtelek karst region (Northeast Hungary) that is characterized with a complex topography and relief. The ecological field survey has been carried out in a 100 m regular grid. At each survey point (point of interest, POI) the surrounding circular area of 500 m² (area of interest, AOI) has been observed by ecologists: among others the dominant tree species and additionally forest physiognomy is described

The workflow was the following: firstly a combined database has been created based on the ecological observations and the LiDAR data. For the AOIs the point cloud was extracted and within the AOIs the forest segment object is described by 5*5 m resolution cells. For each LiDAR data cell within the object, point distribution and vertical distribution based geometrical features are calculated and the 5 most important features were selected by Wilk's Lambda coefficient. After that Combined Cluster Discriminant Analysis method (CCDA, Kovács et al., 2014) has been applied in order to determine the optimal number of groups and to handle the joint classes. Finally, Random Forest classification has been used to classify the dense forest region into characteristic tree assemblages classes.

We conclude that with CCDA method it is possible to classify the dense forest region into forest segments using the derived geometrical features. According to the analysis of optimal number of the groups firstly pre classification based on forest physiognomic parameters is required. After that in the similar forest physiognomic segments with CCDA determined labels can be classified by Random Forest algorithm. This case study is successfully separated oak, downey oak, sessile oak and hornbeam dominant forest species region.

Our study shows the potential of characteristic tree assemblages classification based on low point density data that allows reducing the amount of biological field work and able to extract more quantity-based ecological information concerning to the forest pattern.

ID: 78 / TAS_1_B: 3

Adaptive Stopping Criterion for Normalized Cut Segmentation of Single Trees in ALS Point Clouds of Temperate Coniferous Forests

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Keywords: Over/under-segmentation, Normalized Cut, ALS point clouds, Single tree, Classification

Normalized Cut segmentation is an established approach for 3D delineation of single trees in ALS point clouds. However, overlapping crowns and branches of many close-by trees may cause over- and under-segmentation due to the difficulty of defining a single criterion for stopping the partitioning process. Normally, this criterion is based on an appropriate numerical value (Ncut threshold) without physical interpretation which depends to some extent on the plot characteristics and hence it is disadvantageous for diversified forest types. In this work, we investigate the stopping criterion based on the visual appearance of trees within the point clouds. The main idea is to detect tree crowns by fitting local quadric surfaces to candidate tree tops, and using this information to determine whether the currently processed point cluster represents a single tree or multiple trees. In the former case, the segmentation is stopped, otherwise the current cluster is split and the partitioning process continues iteratively.In our approach, we use the local maxima detection approach to find candidate peaks of trees. Then we apply the random sample consensus method to estimate the best fitting quadratic surface parameters for points around each local maximum. The signed distances between the fitted surface and local points are binned to form histogram features. These features provide a basis for classifying the neighborhood of each local maximum either as a true tree top or a false positive. After classification in a probabilistic manner, the spatial overlap ratios (proportion of shared volumes) between all pairs of positively classified candidate tree tops are calculated. Since it is difficult to analytically derive this quantity for general quadric surfaces, we apply Monte Carlo simulation. If a pair of fitted surfaces has an overlap below a threshold value rth, then it is decided that the current cluster contains more than one tree and the segmentation has to proceed. If no such pair is found, the stopping criterion is activated and the segmentation of the current cluster is terminated. In our tests we first focus on coniferous trees due to the well-defined crown shapes compared to deciduous trees. We prepared 100 point cloud clusters covering two scenarios of a single tree vs. multiple trees within the scene (with the proportion of 50%-50%). The multiple tree clusters are chosen from the erroneous results of normalized cut segmentation with the Ncut threshold stopping criterion, i.e. where the partitioning was stopped although the scene contained more than one tree. We utilized 40 of the 100 clusters for training an SVM as the tree top classifier by manually labeling the surfaces fitted to a subset of extracted local maxima. The remaining 60 clusters were processed according to the described pipeline, yielding 'stop' or 'continue' decisions for every test case. The overall accuracy of the proposed adaptive stopping criterion was 0.8, with a weighted Cohen's κ of 0.59. This suggests that the surface fitting approach shows promising results in the role of a graph cut stopping criterion. Ongoing experiments will be extended to deciduous trees as well.

ID: 46 / TAS_1_B: 4

Uncertainty quantification in ALS-based species-specific growing stock volume estimation

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Keywords: airborne laser scanning, area based approach, Bayesian inference, uncertainty quantification, MCMC

With the constant increase of available airborne laser scanning (ALS) data from forests, it is becoming more and more important to quantify the uncertainty of the forest attributes estimated based on remote sensed data. The current approaches to the estimation of stand attributes using the so-called area-based approach (ABA) lack the means to do this. We propose a Bayesian approach to estimate stand attributes from ALS and aerial image data in the ABA framework. The solution of a Bayesian inference problem is a posterior probability density that describes the uncertainty in the estimate of the parameter of interest at plot level. From this probability density, various uncertainty statistics, such as posterior variances or credible intervals (CI) for the stand attributes on the plot can be readily computed. Application of the proposed approach is demonstrated in the example case of species-specific stem volume estimation.

The data used in this study consist of 493 field measured sample plots located in Juuka, Finland. The study area contains typical managed Finnish boreal forest dominated by Scots pine (*Pinus sylvestris L.*) and Norway spruce (*Picea abies (L.) Karst.*), with a minority of deciduous trees, mainly *Betula spp*. The LiDAR data has a sampling density of 0.6 echoes per square meter and a footprint of 60 cm at ground level. In addition, orthorectified multispectral aerial images were captured. From the ALS and aerial image data, a total of 82 different metrics were computed to be used in the ABA.

To evaluate the feasibility of the Bayesian approach to estimating the species-specific stem volumes, leave-one-out cross-validation was used. As a reference, k-nearest neighbors (kNN) method was used. The accuracies of the Bayesian maximum a posteriori (MAP) estimates for the species-specific and total volumes were close to those of the kNN estimates: The relative root mean square error (RMSE%) of the Bayesian MAP estimates was 37.94% for pine, 34.25% for spruce, 15.33% for the lumped deciduous species, and 31.17% for the total volume, while the respective RMSE%s for the kNN method were 34.95%, 31.26%, 12.53% and 40.52%. Most importantly, the Bayesian approach produced feasible uncertainty estimates for the volumes: The 95% credible intervals covered the field-measured value in 92.70% – 96.55% of the cases, depending on the species.

The Bayesian approach is flexible and allows for straightforward inclusion of prior and auxiliary information, for example from earlier forest inventories or from other remote sensing modalities. The information on the estimate uncertainties produced by the approach could be used, for example, for assessing risks in the operational decision making and for optimizing data collection strategies. Such information could also be used for estimating the uncertainty of the forest biomass and carbon stocks.

ID: 57 / TAS_1_B: 5

Lidar-based single tree detection in mountain forests using local maxima corrected with a national forest inventory based minimum tree distance model

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Keywords: ALS, laserscanning, protection forest structure, National Forest Inventory

The assessment of the state of the Swiss protection forests at national level is based on Swiss National Forest Inventory (NFI) data. Individual sample points of the NFI represent 2 km2 of forest, but rarely recognise more than two adjacent phases in the small scale patch mosaics of forest development phases, which occur frequently in mountain forests. NFI data can be used to statistically determine what proportion of the Swiss protection forest area complies with the national protection forest management guidelines NaiS, but information on the spatial distribution of forest structures is missing. Airborne laserscanning can provide data to obtain this type of information.We tested a tree detection tool, named FINT (Find INdividual Trees), which calculates positions of dominant and co-dominant trees in a rasterised Normalised Surface Model (NSM). FINT evaluates for each NSM cell with a height value larger than the defined minimum tree height, whether it is a local maximum (LM). Each cell is initially evaluated using a 3×3 cell mask. If the evaluated cell is a LM, the mask radius is enlarged with one cell, maintaining a circle-shaped form. Then, the evaluation is repeated as long as either one of the neighbouring cells is higher than the centre cell in the mask, or the maximum mask radius of 15 cells is reached, or more than half of the analysed cells in the mask has heights below 1 m.The accuracy of tree detection is highly influenced by the smoothness of the input NSM, either determined by its resolution, or the applied smoothing filters, or a combination of the two. FINT has a tendency of high commission errors. Therefore, we tested if the use of a minimum tree distance model, based on sample trees from 2'643 NFI sample plots, in combination with different gaussian filtered input NSMs improved the detection rates. In total, 27 validation plots of 25m x 25m from the eastern part of Switzerland (Graubünden) were available, in which 386 trees with a stem diameter at breast height (DBH) larger than 12 cm were mapped, measured and described (x- and y-coordinates, species, DBH, tree height, height of the crown base). Mainly coniferous trees occupy these plots (87%; Picea abies, Pinus sylvestris, Abies alba and Larix decidua). The remaining 13% of broadleaved trees are mainly Fagus sylvatica. Aerial LiDAR data were obtained in August 2015 with a RIEGL LMS-Q 780 scanner and had a point density of approximately 12 points/m2. The minimum tree distance model uses mean stand height as input variable and differentiates between coniferous (CF) and broadleaved (BL) trees. The required data for tree type detection (CF / BL) in our study area had a resolution of 3 m and was obtained from automated analysis of remote sensing data using aerial photographs.

The results show a significant decrease of the commission error. The RMSE between observed and detected stem numbers for all validation plots decreased from 1015 to 178 stems per ha. Detailed statistical results of all analysis will be presented in Krakau.

ID: 81 / TAS_1_B: 6

Forest Attributes Estimation in Coniferous Stands by Combining Airborne Laser Scanning Data and Regional Allometric Models

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Keywords: ALS, Allometry, Individual Tree Detection, Area-based Approach, Forest Attributes

Remote Sensing has the potential to provide key information for biomass/carbon stock evaluation, biodiversity preservation and forest management. Airborne Laser Scanning (ALS) can be efficiently used in forestry, providing 3-D information to get insight of forest structure. The aim of this study is to examine the use of ALS data combined with allometric relationships to assess Top Height, Stem Number, Basal Area and Volume of coniferous stands (Norway spruce and Douglas-fir) in the South of Belgium. Our approach is based on an Area-Based Approach (ABA), combined with an Individual Tree Approach (ITA), requiring a Local Maxima Detection (LMD) on the Canopy Height Model (CHM). The CHM is derived from a high density ALS dataset. Several metrics were computed from the CHM, the raw point cloud and the LMD to describe the density, the vertical and horizontal forest structure. 61 plots were measured within the ALS area to collect reference data for the models adjustment. Allometric relationships were developed with data of the Region Forest Inventory (RFI, 2892 coniferous plots). Stand-level models were fitted to estimate directly the Dominant Diameter, the Basal Area, the Volume for the whole plot, based on the Top height and the stem number assessed from the LMD or by ABA. A tree level allometric model was developed to assess the individual diameter at breast height. Following the LMD, the tree-level allometric model is used to compute the diameter of each tree based on its height, the top height and the number of stems of the plot. Stand Basal area and volume can be then computed by aggregation of the tree level data. The forest attributes estimations are refined by combining the ITA and ABA metrics for the top height and number of stems and by combining ABA metrics and Basal Area and Volume computed with individual local maxima. The quality of the fitted models was analyzed by a K-fold cross-validation (Root Mean Square Error (RMSE) and adjusted R^2 (adj-R^2)). The combination of the ITA and the ABA gave the best results (top height RMSE = 1.0 m, R^2-adj = 95 %; number of stems RMSE = 67, R^2-adj = 87 % ; basal area RMSE = 4.2 m²/ha, R^2-adj = 75 %), except for the volume (best results with ABA, RMSE = 51 m³/ha, R^2-adj = 85 %). The stand-level allometries for Volume and Basal Area gave similar adj-R^2 but worse RMSE. The continuity of this work is the achievement of the continuous mapping of the forest attributes for each stand by applying the workflow to the whole area. As perspective, a similar approach could be implemented with other data sources as low density ALS data or photogrammetric CHM, more readily available at larger-scale.

ID: 42 / TAS_1_B: 7

Multivariate imputation of stand structure attributes using back-projected ALS and optical sensor metrics

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Keywords: LIDAR, data fusion, forest structure, multispectral image, red edge index.

Deeper knowledge of stand structure can be detailed by back-projecting aerial pictures onto airborne laser scans (ALS), which is the most accurate technique for fusing high-resolution datasets (Valbuena et al. 2011). It usually assists in improving forest estimations by adding spectral information from optical sensors, especially when the spatial resolution of the imagery is high (Packalén et al. 2009). Our results show that the integration of both datasets improves the estimation of forest structure attributes, such as the relative stem density, as the multispectral signal may incorporate canopy closure-related shadowing conditions at plot-level. Also, wood volume and biomass prediction may be improved, including detailed components of the total biomass. Multivariate analysis of the relationships among stand structural variables and remotely sensed attributes (Lefsky et al. 2005), combined with non-parametric imputation methods (Hudak et al. 2008) may provide a deeper insight of those important ecological indicators and help in environmental management. We carried out a Canonical Correlation Analysis (CCA) to relate both multivariate data sets measured in a Scots pine forest. We found pairs of canonical variables providing statistically significant amounts of explained variance. As expected, indicators of stand development, i.e. height and volume, were associated with LIDAR elevation metrics. Also of high significance were tree size and stand density, representing the maturity of the stand. Interestingly, some LIDAR height metrics and red edge index-based multispectral metrics were related to Lorenz curve-derived attributes, which represent size heterogeneity within the stand. This association may be interpreted as an indicator of size variability, discriminating even-sized from uneven-sized stands, which also benefited from the multispectral information. We also found that the inclusion of aerial camera information may be beneficial for predicting certain components of the total biomass more than others. Thus, several red edge index metrics significantly explained the heterogeneity of the stand. Furthermore, CCA also may be used for predictive purposes, as it has become possible to model the relationships between the LiDAR remote sensing metrics and forest attributes with the most similar neighbor method. We may conclude that metrics from the optical sensor complemented information of LIDAR, and succeeded in describing the heterogeneous structure of the stand.

ID: 122 / TAS_1_B: 8

Using LiDAR to Detect and Predict Shrub Locations

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Keywords: LiDAR, Understory, Shrub, RandomForest, Model

Shrubs are an important component of forested ecosystems around the globe. Fulfilling many ecological niches, shrubs act as anything from a source of food and habitat for wildlife, to an understory fuel in wildfire. Shrubs add vital carbon and nutrients to forests, and can be an indicator of forest health. Despite their importance, true shrub distributions are widely unknown across landscapes. In addition, mapping shrub locations in the field is arduous and virtually impossible to implement across entire landscapes. Thus, in order to protect and manage for shrubs, it is important that a method for mapping and quantifying shrubs across the landscape is developed. LiDAR has been proven to accurately measure upper canopy features when compared with field measurements, but has not been proven to be a viable method of measuring below-canopy features such as shrubs, despite it's ability to penetrate the forest canopy. This study will develop and evaluate a method for detection and prediction of shrub locations across a landscape using LiDAR-derived metrics as predictors in a RandomForest classification model.

This study was performed on the 25.6 ha Yosemite Forest Dynamics Plot in Yosemite National Park. Medium-resolution (>25 points per square-meter) discrete-return LiDAR data was acquired in 2010; in 2011 field crews mapped and identified the species of all shrub patches >2 m^2. The LiDAR data was analyzed using FUSION, a LiDAR analysis toolkit developed by Robert J McGaughey of the US Forest Service, to 400+ metrics, including topographic metrics, from the LiDAR data. These metrics were input as predictors into a RandomForest model and used to detect and predict shrub locations; field measurements were used as training data for the model. With this method, we were able to achieve ~84% accuracy for prediction of shrub locations using topography metrics, ~75% accuracy for detection of shrub locations using LiDAR metrics, and ~79% accuracy using a combination of prediction and detection with LiDAR and Topography metrics.

ID: 132 / TAS_1_B: 9

Estimating site productivity and projecting growth and yield using ALS data

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Keywords: forest site productivity, airborne laser scanning, growth and yield, remote sensing

Sustainable forest management requires accurate information on a range of forest stand attributes. This information, collected during forest inventories, is crucial for evaluating current and projected conditions of a forest, as well as being critical for assessing the consequences of management decisions. Herein we demonstrate methods of using ALS data to derive site productivity as well as methods to incorporate ALS-derived cell-level predictions of current stand attributes into existing growth and yield models. Predictions of site productivity require information on stand age. The presented methods incorporate two different sources of stand origin. In the first approach, existing forest inventory layers are used as auxiliary data, and then productivity models are used to derive revised site productivity metric. In the second approach, we demonstrate how a productivity model can be developed with time series of satellite images used to estimate stand age. Building upon enhanced forest productivity derived with ALS data, we show how point clouds can be used in projections of forest stand attributes. We demonstrate a novel approach to utilizing ALS-derived forest stand attributes to determine future growth and yield of six key attributes at a sub-stand (25 m grid cell) level of detail: dominant height, Lorey's mean height, quadratic mean diameter, basal area, whole stem volume, and trees per hectare. To do so, we utilize an existing forest growth model to generate a comprehensive database of yield curves (templates) for all possible combinations of dominant species, site index, age, and canopy cover. Then, for each of our six attributes, we demonstrate an approach to find the most appropriate matching yield curves from all possible templates, and subsequently demonstrate the projection of these six attributes at 80 years of age. Results showed that ALS data can be used to augment site index estimation, especially in complex, heterogeneous forest stands, as it is able to accurately characterize stand heights. In areas that lack forest inventory data, estimates of forest productivity can be developed based on remote sensing data only, with stand age derived from time series of satellite images. The application of ALS data in growth and yield modeling allowed to increase the level of detail (cell instead of stand) and optimize the yield curve selection.

TAS_1_C: Thematic Abstract Session 1 – UAV

Time: **Thursday, 15/Sep/2016: 10:30am - 11:30am**
Location: **Lecture room 3 - "C"**

Session Chair: **Krzysztof Stereńczak**
Forest Research Institute, Poland
Session Chair: **Géza Király**
University of West Hungary, Hungary

ID: 40 / TAS_1_C: 1

Retrieval of Stem Curve Using UAV LiDAR

Di Wang, Markus Hollaus, Martin Wieser, Gottfried Mandlburger, Norbert Pfeifer

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Keywords: UAV-LiDAR, Stem curve, Cylinder inscribing

The tree stem curve describes the diameter and position at any height along a tree stem. It plays a vital role in many forest related studies and management applications, such as harvest operation or the estimation of biomass components. Field stem curve measurements are time and labor comsuming and often need to fell down the tree, thus exposes the stem to damage. Allometric curve functions, on the other hand, give the diameter at arbitrary height by species specific functions that were built based on the tree height and the diameter at breast height (DBH). However, the applicability of such functions is often limited, because they were developed from specific local morphological or climate conditions, and do not provide the position at any height along the tree stem. Terrestrial Laser scanning (TLS) has been proven to be an appropriate approach for automated stem curve retrieval [1]. It acquires accurate and dense 3D point cloud which provides the potential of reconstructing forest structures. The deficiencies of the employment of TLS in forests include limited terrain accessibility, area coverage, and visibility in top canopy layer. The Airborne Laser Scanning (ALS) well complements such deficiencies, whereas it only generates sparse points at individual tree level, thus is unsuitable for stem curve retrieval.

Newly developed UAV-borne Laser Scanning (ULS) provides a unique opportunity for forest studies. The high density and accuracy of ULS data enable the modeling of individual tree with fine details up to branch level. In addition to its plot level coverage, it achieves a high level of completeness with respect to the top canopy layer. Therefore, it generates a high potential especially in exhaustive forest attributes estimations.

This contribution explores the potential of automatically retrieving the stem curve from ULS data. The objective is to demonstrate the applicability of ULS data for automatic stem curve retrieval. An automatic point cloud processing chain will be presented. Stems are recognized from their spatial characteristics. A robust and self-adaptive cylinder inscribing and growing routine is employed. The achievable accurateness and completeness of the results will be shown and discussed for a concrete ULS data acquisition of an alluvial forest area (Neubacher Au, 48.2°N, 15.4°E). The study area is located at the lower course of the Pielach River (Lower Austria) near the confluence with the Danube River. The dominant trees are deciduous with heights up to 35 m. The ULS data were acquired in February 2015 under leaf-off conditions with the RIEGL VUX1-UAV compact laser scanner system mounted on a RiCopter X8-array UAV platform. The mission parameters (flying altitude: 50 m a.g.l., flying speed: 8 m/s, measurement rate: 350 kHz, large strip overlaps) not only led to an overall laser pulse density of approx. 4000 points/m^2 but also to a full 3D coverage of the captured trees with an almost constant linear 3D point spacing of appox. 5 cm from the stem to the canopy level.

ID: 117 / TAS_1_C: 2

Estimation of some dendrometrical characteristics of trees and forest stands by images taken by drone

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Keywords: diameter, the height of trees, volume, oak (Quercus petraea), stands visualisation

In the absence of satellite images obtained by techniques more efficient, records obtained with drones have become increasingly used in forestry, as performed precise measurements with low cost and a high spectral resolution. Using drones have many advantages in terms of knowledge of the dynamics of health and development of forest ecosystems to achieve sustainable management of forests. This study has tried to elaborate a simplified method for the determination of biometric characteristics of individual trees and stands of oak using images recorded on forests drone of Brasov in Romania. After analyzing images and data processing, the results on the heights of trees and their crowns diameter were analyzed in comparison with those obtained in the field by full inventory conducted in the same stands. Field measurements were carried out in the areas of constant sample placed in stands with different structures. Biometric characteristics determined on the ground have been integrated into regression models to estimate the diameter and volume of trees by their canopy crown diameter, measured on the images. The accuracy of measurements is directly influenced by the position of the trees in stands and their dimensions, by composition and density of stands. Also was created models of regression wich leads to determinations on images obtained with an accuracy of 79-93%, differentiated in relation to the structure stands.

ID: 84 / TAS_1_C: 3

Monitoring forest disaster from high precision UAV-SfM and TLS technologies

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Keywords: Laser, forest fire, UAV, monitoring, 3D data fusion

High technology using portable Terrestrial Laser Scanner (TLS) and Unmanned Aerial Vehicle (UAV) based photogrammetry (Structure from Motion, SfM) provides much faster and cheaper way to acquire 3D data in forestry field. Precision forestry expects faster data acquisition, high frequent data archive, and good measurement accuracy. High technologies using TLS and UAV-SfM can fit their expectation. Our research especially focuses on forest disaster such as forest fire. The research site is located in Fort Smith in Canada and the targeted species is boreal forest. We took two different times of 3D data before and after the forest fire. Quick and accurate monitoring system is achieved by these technologies to detect the changes caused by forest fire. In the past study, rapid monitoring system using high resolution satellite radar images has been used to monitor tree structure change. But field validation technique has not been established well to prove the result of satellite based monitoring. We developed a new portable TLS (SICK LMS511) and used a cheap UAV system using DJI phantom quad copter to take the data efficiently and analyze 3D data automatically. The limited 3D data coverage from TLS was compensated by the data taken from the sky using UAV system with GPS. Automatic fusion process has been developed and applied to match between two different coordinates. In this way, no coordinates of TLS 3D data were transferred to fit to the GPS coordinate of UAV-SfM data. After the data is matched, vertical data coverage between TLS and UAV-SfM was compared to see how detail structure of tree is captured by different 3D acquisition techniques and quantify the structural and biomass loss of forest fire between before and after forest fire. We demonstrate the technical capability of TLS and UAV-SfM to capture the form of trees and show the applicability to provide field validation data for high resolution satellite radar images (PALSAR 2 radar images).

ID: 26 / TAS_1_C: 4

Forest cut detection using time series of digital surface models (nDSM) from 2003 – 2015

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Keywords: NFI, aerial, nDSM, clearcuts, OBIA

In the Czech National Forest inventory (NFI2), remote sensing is utilised as a crucial support for field survey and to create the wall-to-wall maps which are then used to enhance the precision of selected NFI2 parameters. Forest Management Institute (FMI) receive the aerial imagery acquired in National imaging campaigns by the State Administration of Land Surveying and Cadastre (ČÚZK). In the past, the campaigns covered 1/3 of the Czech territory every year. Since 2012 one half of the territory is covered every year. The imagery processed by image matching technique provide normalised digital surface model (nDSM) updated in 2 years period. The aim of the paper is to describe the nDSM processing in time series of 2003 - 2015 and show possible application in the Czech NFI.

The automated extraction of forest stand heights from the aerial image stereo-pairs had been intensively tested at FMI from 2012, and became operational in 2013. The image matching is done in Czech software PhotopoL CORR. The point clouds are further processed (filtration, masking), normalised by subtracting elevation from the LIDAR-based DTM, rasterised to target resolution of 2m/pixel and mosaicked into large blocks. The workflow initially developed for digital UltraCam data was recently applied also for archive analogue imagery from 2003 – 2009.

The time series of nDSM from 2003 – 2015 represents the unique dataset with the range of forest change application, but requiring sophisticated and complex analysis approach in the same time. The classification of the nDSM change images enable to detect forest cut between the imaging dates. In this task, object-based image analysis procedure was developed using the height difference, spectral information from infrared ortophoto, contextual rules and morphological enhancement of output vector files. Clearcuts and thinning areas are thus identified and extracted in good spatial and thematic precision every 2 years. The results are primarily used to refine the timber cut estimates in NFI2. Furthermore, the output is utilised in the control system of wood on EU market (EUTR).

ID: 32 / TAS_1_C: 5

Assessment of horizontal stand structure by dense point clouds from UAV sensed optical imagery.

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Keywords: UAV, 3D point clouds, forest horizontal structure

The close range and high resolution imagery from unmanned aerial vehicles (UAVs) or more precisely from unmanned aerial system (when the drone is controlled by the ground control station) represents interesting and challenging technology to be studied nowadays. The state-of-the-art results appear to be promising for many forestry related applications including stock estimation, species classification, health monitoring, disaster mapping and so on…

In this work we evaluate possibility of assessment of horizontal structure of forest stands using a low altitude flying UAV with common optical camera acquiring photos to be processed by Structure From Motion algorithms for creation of 3D point clouds. These dense 3D point clouds are geo referenced by ground control points with known positions. The horizontal structure of the stand is assessed using known algorithms for individual tree delineation and compared with the structure measured in the ground. The technical solution its advantages and disadvantages are described together with the ergonomy of the ground versus remote sensing measurements.

ID: 14 / TAS_1_C: 6

Use of High Resolution Airborne UAV Imagery to Determine Height and Crown Diameter on A Tree Level

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Keywords: unmanned aerial vehicle (UAV), photogrammetry, individual tree based analysis, canopy height model (CHM), inverse watershed segmentation (IWS)

The latest advances in computer systems and the parallel development of unmanned aerial vehicles (UAVs) enhanced the potential of direct measurements of crown architecture and in general their extensive use in forest inventory. In this work we used a method for the estimation of tree height and crown diameter, by using UAV high resolution imagery throughout photogrammetry and “structure from motion”. We reconstructed three-dimensional structures from two-dimensional image sequences by using two circular study areas, 25 meters of radius. The involved workflow, used canopy height models (CHMs) for the extraction of height, through smoothing processing of raster images, using local maxima approach at the positions of ground truth data and inverse watershed segmentation (IWS), for estimation of the crown diameters with the help of geographical information system analyses. Finally, we validate the accuracies of the two methods by testing their significance, which was also the aim of our work. For purpose of modelling we used linear regression approach. Results showed higher agreement between field and remote sensing data for height comparing to crown diameter, based on RMSE % ranging from (11.42 – 12.62%) for height variable and (14.29 - 18.56%) for crown diameter.

ID: 33 / TAS_1_C: 7

Forest road mapping and condition monitoring within Mediterranean areas using a low-cost UAV system and VHR satellite imagery

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Keywords: uav, geobia, high spatial resolution, dsm, photogrammetry

Within the field of forestry, forest road mapping and inventory plays an important role in management activities related to wood harvesting industry, sentiment and water run-off modelling, biodiversity distribution and ecological connectivity, recreation activities, future planning of forest road networks and wildfire protection and fire-fighting.

Especially in countries of the Mediterranean Rim, knowledge at regional and national scales regarding the distribution and the characteristics of rural and forest road network is essential in order to ensure an effective emergency management and rapid response of the fire-fighting mechanism. Yet, the absence of accurate and updated geodatabases and the drawbacks related to the use of traditional cartographic methods arising from the forest environment settings, and the cost and efforts needed, as thousands of meters need to be surveyed per site, trigger the need for new data sources and innovative mapping approaches.

Monitoring the condition of unpaved forest roads with unmanned aerial vehicle technology is an attractive option for substituting objective, laboursome surveys.

The aim of our study was to develop a method for, and test the suitability of, the use of a low cost UAV system in monitoring forest road conditions and estimating road deficiencies that could induce constrains and delays in forest fighting vehicles mobilization.

Although photogrammetric processing of UAV imagery can achieve accuracy of 1-2 centimeters and dense point clouds, needs the establishment of control points. In the case of forest road networks, which are a linear features, there is a need for a great number of control points. On the other hand VHR satellite imagery can produce maps of large areas with minimal usage of control points, achieving accuracies of 25-50 centimeters.

Our aim is to use orthoimages produced either by VHR satellite or aerial imagery as control information for the photogrammetric processing of UAV imagery. In that way we can achieve highly accurate 3d models (1-2 cm) of the roads with a geo-registration accuracy of 20-25 cm. Originally, through the use of a GEographic Object Based Image Analysis (GEOBIA) and very-high spatial resolution satellite imagery, the forest transportation network was identified over a forested area in Northern Greece. Sample road transects were identified and through photogrammetric procedures digital 3D road surface models and orthoimages were produced from UAV imagery in order to identify the distress properties of ruts and depressions. Field based measurements were also used for calibrating and assessing the accuracy of the remote sensing measurements (depth and size of the elements).The proposed approach is cost efficient and has the potential to be operationally applied for forest managers and civil protection agencies, in order to monitor forest road condition during the fire-season and prioritize maintenance activities. The acquired UAV orthoimagery, together with the derived 3D models and condition measurements can be directly integrated into forest road geodatabases.

ID: 135 / TAS_1_C: 8

Assessment of spatio-temporal patterns of autumn phenology within Sessile oak (Quercus petraea Liebl.) stands using UAV-based images

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Keywords: UAV, sessile oak, phenology

In the face of a changing climatic conditions, genetically predetermined plant processes such as phenology are no exemption to the strong influence of climate change. Consequently, the 'how' and the 'when' autumn tree crown phenology occur is believed to have been altered over the years. Besides, despite the increasing suitability and application of relatively cost-effective UAV-based remote sensing in many fields of scientific study, there is currently a paucity of literature and application of UAV-based remotely sensed imagery for spatial and temporal stand-level phonological studies. The goal of this study was to assess the spatio-temporal patterns of autumn phenology within Sessile oak stands using UAV based images. There were four circular (R = 35 m) sample plots located in a 90 year old Sessile oak stand. Every tree was then classified into one of three phenological phases, according to the dominating crown colour – green, yellow or brown. A total of 450 trees were classified. The study reveals that: (1) the autumn phenology of sessile oak observed from grouped phenological phases of green, yellow and brown tree crown colours have received a significant delay-shift in 2012 than in 2011 as most tree crowns in 2012 were still green as at mid-autumn. (2) While all crowns with yellow phenological phase possessed a high tendency towards a spatially regular distribution pattern both in 2011 and 2012, the brown phenological phase showed a rather random spatial distribution pattern, with green crowns characterized by random spatial pattern in 2011 but not completely random in 2012. Finally, (3) the manual classification of tree crowns into phenological phases was a good tool to recognize autumn phenology properties as the results obtained by different observers have had big agreement in 2011 and 2012 respectively. Further studies is however obviously necessary to confirm its suitability for extensive temporal study.

ID: 143 / TAS_1_C: 9

The use of Unmanned Aircraft Vehicle with RedEdge (MicaSense) camera for the monitoring and management of the forest nursery with special emphasis on the automatic analyses of the condition and species recognition of planting material

Piotr Wężyk[1], Przemyslaw Tymkow[2], Monika Moskal[3], Marta Szostak[1], Mateusz Karpina[2], Paweł Hawryło[1], Bernadeta Rossa[2]

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Keywords: UAV, multi-spectral camera, image matching, NDVI, RedEdge, NIR

In the last few years we observe a very dynamic development of the market for close range remote sensing data acquisition which include Unmanned Aerial Vehicles sector (UAV) called drones. They are often used for acquiring of geometric information for photogrammetry purposes or LULC changes based on radiometric information about the objects. On the drones can be assembled various types of sensors including the most popular digital cameras. To ensure the possibility of photogrammetric studies drones are equipped in good quality GNSS receivers and an IMU (Inertial Measurement Unit) consisting of high-precision gyroscopes and accelerometers. All these devices together form a system of INS (Inertial Navigation System) responsible for the registration of the trajectory of flight and navigation path planned strip. Outside RGB camera, another devices like: multispectral, hyper-spectral cameras, laser scanners and even probes for the measurement of pollutants can be set. Poster presented a pilot project using high-end copter Ibotix X6 (Ibot) equipped with a multispectral camera RedEdge (MicaSence; USA), together with its hardware (GPS and radiance meter) and software (ATLAS). Test area was a forest nursery in Nędza (Forest District Rudy Raciborskie, RDLP Katowice). Tests were carried out on 27.05.2016 in good weather on the exposed areas of the seedlings with closed root system: pine, oak, beech and spruce differing in origin and date of sowing. MicaSense camera recorded the seedlings from about 30.0 m high at a speed of 2.0 m/sec and GSD 2 cm. The multi-spectral camera in addition to standard RGB have two important band responsible for the condition of the plant; RedEdge (717 nm) and NIR (840 nm). The pictures were taken at intervals of 1 sec with 12 bit radiometric resolution. On the basis of the ATLAS system they will be subjected to atmospheric correction and geometric along with generating orthomosaick's in different band compositions. On the basis of the signal value of each channel some vegetation indices' will be calculated (eg. NDVI) describing the condition of the plant. In the later part of the research the new method of DSM generation will be used based on image stereo-matching algorithms. The final step of research will be the GEOBIA classification of multispectral images supported by DSM model for the search for plants in a bad condition and distribution of different tree species. Repeated flights can provide detailed monitoring of the material over a large area with an indication of the diversity which may be affected by substrate soil, growing conditions and even the tree ecotype or nutrients.

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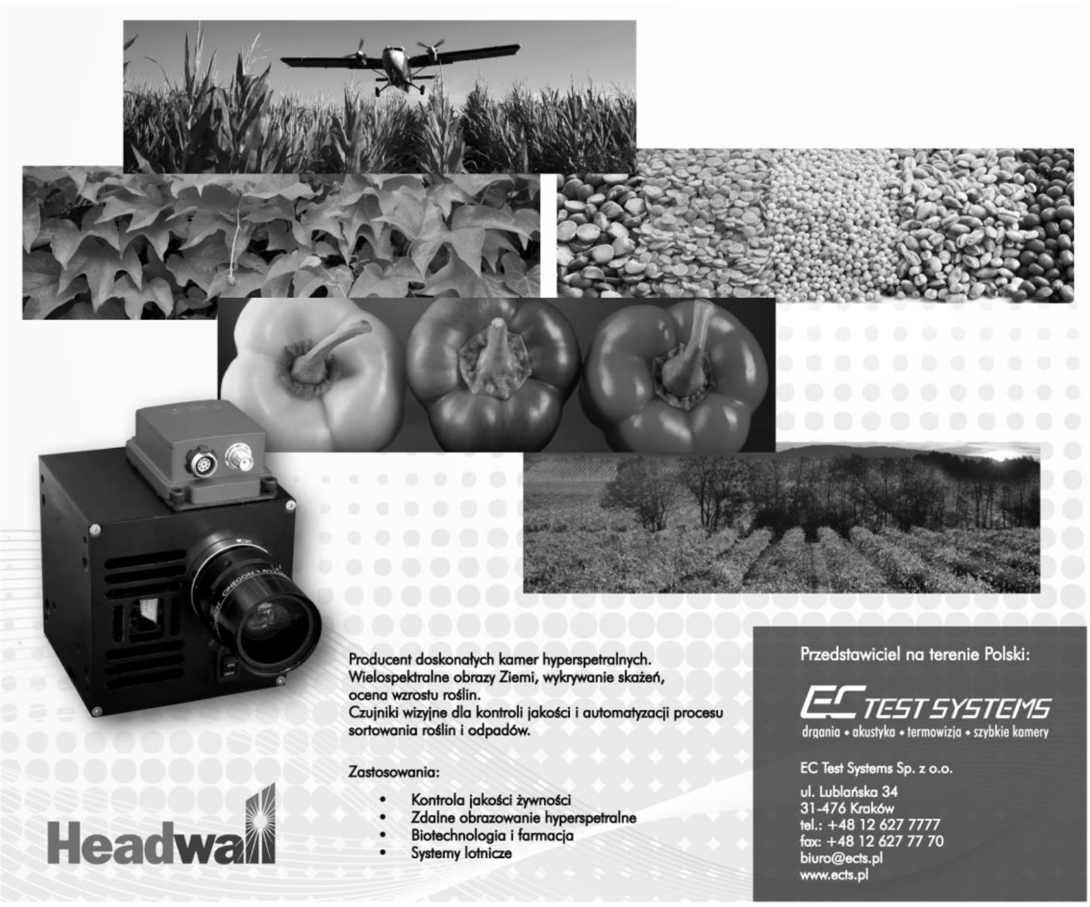

PLS-2: Plenary session Nº 2

***Time:* Thursday, 15/Sep/2016: 1:00pm - 1:30pm**

Location: Main AULA - "A"

Session Chair: Thomas Schneider

Technische Universität München, Germany

Session Chair: Piotr Wezyk

University of Agriculture in Krakow, Poland

ID: 147/ PLS-2: 1

On the potential of ALOS PALSAR backscatter and InSAR coherence for forest growing stock volume estimation in Central Siberia

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Keywords: Forest Research by Remote Sensing

So far, the full potential of ALOS PALSAR L-band interferometric (InSAR) coherence data for the estimation of forest growing stock volume (*GSV*) in the boreal forest has rarely been investigated. Moreover, ALOS PALSAR backscatter and InSAR coherence were not yet jointly used to delineate *GSV*. Due to the observation strategy and the high acquisition success rate over Eurasia, a large amount of high quality ALOS PALSAR L-band data is available over Siberia. Consequently, this paper investigates the capability of ALOS PALSAR backscatter and InSAR coherence for the estimation of *GSV* in Central Siberia, Russia. The potential of backscatter and coherence are directly compared using the same inventory data. Altogether, 87 PALSAR images are used and eleven forest inventory sites are investigated.

Based on this large dataset it was observed that InSAR coherence acquired at frozen conditions offers the highest potential for *GSV* estimation. For single coherence images the saturation occurs in average at 230 m^3/ha, the average correlation (R^2) between coherence and *GSV* is 0.58. PALSAR backscatter acquired at unfrozen conditions is also sensitive for *GSV*. However, saturation occurs at lower *GSV* levels (75-100 m^3/ha) and the average R^2 is lower (0.42 - 0.48). HV backscatter offers a slightly greater potential then HH backscatter.

Based on the multitemporal SAR data a simple inversion approach aiming at the delineation of forest *GSV* maps was developed and applied to five forest inventory sites. This approach jointly uses HV backscatter data acquired at unfrozen conditions and InSAR coherence data acquired at frozen conditions. In general, the produced maps feature a corrected relative $RMSE_{corr}$ of < 30% which is close to the accuracy of the forest inventory data. The correlation (R^2) between inventory data and SAR data based maps varies between 0.54 and 0.83.

TAS_2_A: Thematic Abstract Session 2 - Hyperspectral_2 & Monitoring_1

Time: **Thursday, 15/Sep/2016: 1:30pm - 2:30pm**
Location: **Main AULA - "A"**

Session Chair: **Joachim Hill**
Trier University, Germany
Session Chair: **Olga Brovkina**
Global Change Research Institute, Czech Republic

ID: 34/ TAS_2_A: 3

Operational Forest Vitality & Change Monitoring in Practical Use

Alexander Marx

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Keywords: forest health, windstorms, illegal logging

The paper shall provide an overview about Planet Labs operational Forest Vitality and Change Monitoring Service which is based on RapidEye satellite imagery and will also soon include also PlanetScope imagery. Examples from different kinds of forest disturbances will be shown.The Forest Vitality & Change Monitoring service (FV&CM) enables the assessment of the general forest vitality condition and the detection and detailed mapping of forest disturbances and other changes. A prerequisite for the detection of disturbances are symptoms visible in the forest canopy. Forest vitality can be compromised by mass outbreaks of defoliating insects or bark beetles, by tornados, by drought, though man-made, extreme sulfur dioxide emissions and other causes. Logging can be considered a disturbance if it is illegal or if it occurs in a non-sustainable manner. The digital maps delivered through the service help foresters and other users locate areas affected by insect or storm damage more quickly. The maps show the magnitude of the damaged areas and depict the damage in intensity categories with appropriate color schemes. Using the maps, good planning of forest sanitary measures - for example the precise application of ecologically sound insecticides in the right locations - is facilitated. After natural disasters such as severe windstorms, the maps help plan the quick salvage logging of the damaged areas to prevent the damaged timber from a further degradation and to keep associated losses to a minimum. Moreover the maps help foresters fulfil their general reporting duties with regard to the health condition of the forest. In areas at risk for illegal activities such as timber theft, locations where illegal logging has taken place can be identified easily and precisely.

ID: 48/ TAS_2_A: 4

Mapping forest changes and processes using aerial photography during the period 1945-2010 in Greece: Signs of socio-economic drivers.

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Keywords: Land use/land cover change processes, Land abandonment, Vegetation densification

In the present study we record and map the temporal changes of forest vegetation to understand the spatial processes and pressures that contribute to land use change and formulate reliable conclusions and recommendations regarding the management and protection of forests and woodlands. The mapping of land use / cover was based on aerial photographs acquired in 1945, 1985-1986, 1960 and 2007-2009. Object-based image analysis allowed for the classification of the land use/land cover of the region and, consecutively, the assessment of processes of changes in land use / land cover for each period. The results indicated that agricultural land increased during the first post-war years while agricultural land abandonment took place during the last decades, especially after the period 1960-1985. The observed land abandonment is combined with a simultaneous densification of forests and –mainly- shrublads. Radical socio-economic changes took place in the 60's: rural population was migrated towards big cities and touristic industry begins to develop. We argue that these socio-economic changes play an important role in forcing the observed changes in land use / land cover.

ID: 30/ TAS_2_A: 6

Potential of WorldView-2 imagery to map forest structure in old-growth beech forests

Nataliia Rehush, Lars T. Waser

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Keywords: beech forests, forest structure types, canopy gap fraction, WorldView-2, Ukrainian Carpathians

Beech forests are a potential natural vegetation in the European temperate forests, as well as one of the dominant forest ecosystems in the Carpathian Mountains. Assessing forest structure is essential to understand forest dynamics and crucial for a sustainable forest management planning.

In the present study a highly automated approach for assessing the structure of potential primeval and managed beech (Fagus sylvatica L.) forests in the Ukrainian Carpathians was developed. The approach consists on several steps and is carried out on landscape level in a study area located in the upper part of Borzhava river. Besides the multispectral WorldView-2 data, reference data from field surveys, forest stand maps and descriptions from Ukrainian State Forest Planning Organization were used.

Variability of forest structure in the beech forests was assessed using delineation of canopy gaps and determination of forest structure types. In a first step, delineation of canopy gaps was performed based on spectral image information and validated using data from the field survey. Canopy gap fraction in the study area varied from less than 1% in the middle-aged beech forests to 14% in the potential primeval beech forests, and was found to be highly correlated with several of the main forest stand parameters, especially with mean stand age.

In a second step, spatial pattern of canopy gaps was analysed using a regular grid with a cell size of 50 × 50 m. Based on frequency distribution analysis of the grid cells in the canopy covers, four forest structures types (high to low density) were determined. These structure types represent the conditions of the canopy cover of the beech forests and enable to be implemented by forest management planning. Then, semi-automatic classification and predictive mapping of the forest structure types were performed using multinomial logistic regression models. Predictor variables included textural features derived from the original spectral bands of WorldView-2 imagery and two vegetation indices using second order statistics.

10-fold cross-validation revealed overall accuracy of 87% and kappa of 81% for the fourth structure types. The highest agreement was achieved for the structure types with a high density (91%), the lowest for the medium density (81%). The main constraints are related to multispectral VHR imagery and pre-processing in difficult accessible mountainous regions without existing accurate digital elevation data.

Nevertheless, forest structure type maps open new possibilities for complementing tasks of the Ukrainian State Forest Planning Organization. Spatial pattern (size, distribution) of the four forest structure types in the old-growth and potential primeval beech forests can be used as essential information for planning of management measures in even-aged managed beech forests. The presented approach can be easily adapted, e.g. using Landsat or Sentinel, and has a great potential for detecting large areas of old-growth beech forests.

ID: 47/ TAS_2_A: 7

Spatial explicit reconstruction of recent fire history using USGS and ESA Landsat archives in Attica, Greece from 1984 to 2015

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Keywords: Landsat, fire history, Greece, burned areas, fire regime

The aim of this study is to enrich the fire history reconstruction in Attica, Greece after the release of the European Space Agency (ESA) Landsat archive that made available to public at no cost. In previous studies using only the Landsat archives from United States Geological Survey (USGS) to a series of USGS Landsat TM and ETM+ archived satellite images covering the periods 1984-1991 and 1999-2009, a total of 1773 fires were identified and mapped from six different scenes that covered Attica and the Peloponnese in Greece. The majority of not-captured burned areas corresponded to fires with size classes of 0-1 ha and 1-5 ha, where the loss in capturing fire scars is generally significant. This was expected since it is possible that small fires, identified and recorded by forest authorities, may not have been captured by satellite data due to limitations arising either from the spatial resolution of the sensor or imposed by the temporal series that do not systematically cover the full period.

Maps depicting the spatially explicit fire history of an area, including variables such as fire frequency and fire return interval, are important tools promoting the better understanding of processes associated with wildfires (fire ignition and spread), the assessment of the impacts of wildland fires on landscape dynamics, and decisions on appropriate management practices. Remote sensing is a cost- and time-effective alternative to automatically assess a vast amount of spatial information and produce various thematic maps.

The aim of this study was to reconstruct the recent fire history of Attica region (Greece), in a spatially explicit mode by means of remote sensing techniques and basic GIS routines using a series of Landsat images taken from 1984 to 2015. The results showed that the fire scar perimeters were captured with considerably high accuracy and fire regimes could be well identified.

ID: 43/ TAS_2_A: 8

Fast Response: Windthrow detection with satellite data

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Keywords: windthrow, change detection, active/passive remote sensing, object-based image analysis

With climate change, extreme weather events like storms are likely to intensify their occurrence. These storms can cause severe forest cover damage and inflict economic loss to forestry. To assess the destruction and to minimize subsequent biotic damage (e.g. bark beetle infestation), windthrow areas need to be detected accurately and fast. The project ‘Fast Response’ - development of a remote sensing based fast response system for handling calamities in forests - developed a concept supporting the crisis management for areas in Bavaria and Austria affected by windthrow on a remotely sensed basis, integrating optical and microwave data.

Storm ‘Niklas’, one of the strongest March storms in the last 30 years, hit Southern Germany in spring 2015 and caused severe forest damage. In course of the ‘Fast Response’ project, a bi-temporal change detection was carried out with both very high resolution (VHR) optical and SAR spaceborne data to detect the forest damage on two test sites in Bavaria, severely hit by the storm. For an initial localization of highly damaged regions, TerraSAR-X data were applied as microwaves are independent from illumination and weather conditions. For a more detailed analysis specifying the size and location of the storm’s impact, optical RapidEye data were used, providing improved capability for vegetation identification. Utilizing the VHR optical data, first an object-based bi-temporal change detection was applied to detect windthrow areas larger than 0.5 hectare. A semi-automatic feature selection and classification was applied using supervised Random Forests (RF). Several input features were assessed in terms of discrimination power for forest damage detection, such as spectral features, texture, vegetation indices, layer combinations and transformations. The most important features were identified using RF’s feature ranking procedure. Secondly, a pixel-based, hybrid-change detection approach was developed to detect small(er) groups of fallen trees on pixel-level, combining the most suitable features. The change detection results for the first test site were validated with in-situ measurements and aerial image interpretation. They reveal a high accuracy (> 90%). The validation of the second test site is still under work.

ID: 86/ TAS_2_A: 9

Assessment of hyperspectral vegetation indices for heavy metal contaminations of leaves

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Keywords: Hyperspectral measurements, remote sensing indices, heavy metal contamination, forest, health conditio

Hyperspectral remote sensing techniques allow to detect physiological and chemical properties of plants. Narrow-band techniques register detailed biophysical properties, which have direct impact on spectral responses of plants in different wavelengths (350-2500 nm). The proposed researches were conducted along the Polish part of the Karkonosze National Park. It is characterized by beech-fir forest intermixed with Norway spruce. Field campaigns were undertaken in May, June and September 2014 at 24 sites along an environmental gradient dominated by spruce (*Picea abies*) and beech (*Fagus sylvatica*). The following data were acquired from these two species:

-hyperspectral leaf characteristics (using ASD FieldSpec 3 hyperspectral spectrometer with a direct contact ASD PlantProbe + ASD LeafClip),

-bioradiometric data: surface and air temperatures (IRtec MiniRay pyrometer); content of chlorophyll, protective pigments (anthocyanins), flavonoids and nitrogencontent (Dualex Scientific+™) and chlorophyll fluorescence values (OS1p OptiSciences),

-leaves samples for measurements of heavy metals. The collected samples were cleaned and dried in laboratory conditions, then homogenized and mineralized in a microwave mineralizer (Speedwave Four Berghof, DE). Concentrations of Mn, Ni, Cu, Zn, Cd and Pb were determined.Spectral characteristics were used to analyze spectral response curves and to calculate selected vegetation indices ($mNDVI_{705}$, VOG1, SIPI, NDLI, ARI1, NDWI, NDII). Bioradiometric data and content of heavy metal were used as a reference data. In case of both species significant differences were observed in spectral characteristics of the near-infrared spectral region and in the short-wave infrared region, which is due to differences in coniferous and deciduous cell structures and water content. Overall, the measurements clearly suggest that both species were in a good condition at all sites, and there were no indications of water stress. The applied hyperspectral remote sensing tools and methods proved to be appropriate for analysis of forest tree conditions at a detailed level; the acquired data precisely depicted vegetation phenology. Detailed results will be presented during the conference.

Acknowledgements

Research has been carried out under the Polish-Norwegian Research Programme of National Centre for Research and Development (NCBiR), project No.: POL-NOR/198571/83/2013: *Ecosystem stress from the combined effects of winter climate change and air pollution – how do the impacts differ between biomes*? (WICLAP).

ID: 54/ TAS_2_A: 10

Upscaling two-sided leaf optical properties in forest reflectance model

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Keywords: leaf optical properties; forest reflectance; radiative transfer; leaf structure

Forest reflectance models are valuable tools for theoretical studies on radiative transfer in vegetation and the effects of canopy structure and optical properties on top-of-canopy reflectance. Importantly, inversion of the model against remote sensing observation may be used for quantitative retrieval of model input parameters. This allows the global retrieval of vegetation quantitative parameters without the use of in-situ data for model calibration. Contemporary remote sensing algorithms typically utilizes radiative transfer model inversion for the retrieval of forest chlorophyll content, leaf area index and fraction of photosynthetically active radiation absorbed by canopies. To achieve good retrieval accuracy, forest reflectance model simulations must be in close agreement with remotely observed reflectances. This can be achieved by careful selection of suitable forest reflectance model and its input parameters.

Leaf optical properties are the key input parameters in forward simulations of forest reflectance. They hold an information on leaf biochemical (chlorophyll and carotenoid content, water content) and structural (leaf thickness, distribution of pigments in palisade) properties. Whereas leaf biochemical properties typically absorb radiation in specific wavelengths, leaf internal structure is a driving factor of differences in leaf adaxial (upper-side) and abaxial (lower-side) leaf optical properties. Leaf biochemistry effects are well understood and can be modelled in leaf-level radiative transfer models like PROSPECT. However, up to now, leaf internal structure and the two-sided leaf reflectance has been largely neglected in current remote sensing applications, assuming equal leaf optical properties on both leaf sides. This is however great simplification which may lead to significant discrepancies between modelled and observed forest reflectance, and ultimately, in decreased performance of the inversion of forest parameters. In this study, we test the performance of Dorsiventral Leaf Radiative Transfer Model (DLM) for the simulations of two sided leaf optical properties. Model performance is tested on leaf samples (*Populus tremula*, *Salix caprea*) with measured two-sided leaf optical properties and detailed laboratory analyses of internal leaf structures (fraction of air spaces, thickness palisade and spongy parenchyma). By coupling leaf two-sided optical properties with internal leaf structure, we are able to test model assumptions on the effect of leaf structure on two-sided optical properties. In the next step, two-sided leaf optical properties (DLM model simulations) are further upscaled to canopy level using Discrete Anisotropic Radiative Transfer model (DART). We run a series of sensitivity analyses to quantify the effect of leaf optical properties parameterization (i.e. equal optical properties on both sides, double-sided optical properties) on forest reflectance, both in nadir and off-nadir observation geometry. By doing this, we are finally able to quantify the influence of (neglecting) two-sided leaf optical properties on forest reflectance simulations and quantitative parameter inversion.

TAS_2_B: Thematic Abstract Session 2 - ALS_2 & TLS

Time: **Thursday, 15/Sep/2016: 1:30pm - 2:30pm**
Location: **Lecture room 2 - "B"**

Session Chair: **Juha Hyyppä**
Finnish Geospatial Research Institute, Finland
Session Chair: **Norbert Pfeifer**
TU Wien, Austria

ID: 71/ TAS_2_B: 1

ALS for terrain mapping in forest environments: an analysis of Lidar classification algorithms

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Keywords: Airborne LiDAR Scanning, point cloud classification, geomorphology, for estry

Modern remote sensing tehnology enables the recording of accurate geomorphological data with the capability to efficiently cover large areas. However, the presence of vegetation makes the use of remote methods for terrain mapping difficult or even impossible. LiDAR can be a solution for forestry projects, as the laser pulses can cross the entire forest canopy to reach the soil underneath. In order to obtain an accurate terrain model the resulting data must be processed, so as to determine which returns are at ground level. Various algorithms have been developed for this purpose, of academic or commercial interest, open-source or proprietary.

This paper aims to provide a performance analysis of multiple algorithms for raw LiDAR data classification. By classification we refer only to the labelling of points as GROUND and NON-GROUND, since the purpose of this research is estimating the accuracy of the resulting geomorphological data. Algorithm performance is reviewed for the case of mountainous terrain, characterised by moderate and steep slopes and forest vegetation of a generally high consistency. Emphasis is placed on open-source and/or free solutions.The study area is located in the Lotru valley of the Southern Carpathian Mountains in Romania, where ALS data was recorded in 2011 with an airflown RIEGL LMS-Q560 sensor. In this area test plots with variable terrain conditions were chosen. To estimate algorithm performance, the effect of point classification accuracy on the products that are of interest in a forestry workflow (such as Digital Elevation Model and products derived from it: slope and aspect maps, landform classification) is analysed. The following methodology is applied: a DEM is generated from the classified point cloud and compared with a model generated from data recorded by total station survey. The Root Mean Square Error (RMSE) of the elevation values is then calculated for every test area. Since numerous parameter values for the algorithm are tested, their effect on the accuracy of the resulting data is evaluated, and the combination of values that leads to the smallest RMSE is determined. The best result for each algorithm is further analysed. The spatial distribution of errors and the effect of using different interpolation methods are assesed, and the correlation of the RMSE with factors such as terrain slope, relief fragmentation or vegetation cover. Furthermore, for scenarios where lower resolution data is sufficient, the degree to which the accuracy is improved (or not) when the DEM is interpolated at coarser resolutions is investigated. Analysis of this kind is also applied to the derived products previously mentioned. We also consider algorithm robustness, or the capability to produce results of a similar accuracy in different terrain conditions.

To conclude, an estimation of the performance of LiDAR classification algorithms is made for conditions specific to forest environments (very few or no buildings, moderate or steep slopes, fragmentary relief and a low density of ground level pulse returns due to vegetation). Finally, some recommendations regarding ALS data classification for forestry purposes are given, and further improvements for our research are considered.

ID: 119/ TAS_2_B: 2

Airborne Laser Scanning Data Processing as a Method to Determine Agricultural Land Abandonment

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Keywords: kernel functions, GIS, agricultural land abandonment, ALS

Agricultural land abandonment is an important challenge in sustainable development of modern European landscapes. Highly fragmented landscapes are particularly prone to agricultural land abandonment (Terres et al. 2013), However the phenomenon is usually investigated on a large scale of one satellite scene rather than a local one (Prishchepov et al. 2012) or it is analysed with low resolution data like: Corine Land Cover Data (Pazúr et al. 2014) or MODIS data (Alcantara et al. 2012).

Low resolution does not allow to identify agricultural land abandonment in highly fragmented land such as the region of Małopolska. An attempt to design a more accurate field work approach (Czesak et al. in review) shows that even though field work guarantees accurate information on the spatial extent of land abandonment, it is labour-intensive and time-consuming so difficult to conduct on larger research objects.

Therefore, there is a need to design an effective, semi-automated or fully automated method of agricultural land abandonment identification in highly fragmented areas. Few attempts to determine plant succession at local scale showed that both airborne laser scanning and GIS may be effective tools for identification of agricultural land abandonment (Szostak et al. 2013).

The paper presents a method of agricultural land abandonment identification based on Airborne Laser Scanning (ALS) data. The ALS differential model was analysed with chosen kernel functions: triweight and Epanechnikov. Heat maps were generated and then isolines were created which were the subject of further analyses. An isoline of the effective probability of farmland abandonment was determined on the basis of a radius, kernel function, and weight.

The research showed that the identified area of agricultural land abandonment depends on the kernel function chosen for modelling. Higher accuracy (up to 80%) was obtained with triweight function.

The research shows that using ALS data is a good method for semi-automated identification of agricultural land abandonment in highly fragmented land.

ID: 75/ TAS_2_B: 3;

Generating Better Digital Surface Models from LiDAR points

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Keywords: LiDAR, DSM, spike-free, CHM, pit-free

A Digital Surface Model (DSM) that represents the elevation of the landscape including vegetation and manmade objects is typically generated by Delaunay triangulating all of the first LiDAR returns into a Triangular Irregular Network (TIN) that is then rasterised onto a grid at a user-specified resolution. A Canopy Height Model (CHM) is often generated in the same manner except that the elevations are height-normalised either before or after the rasterisation step. This way of DSM and CHM generation has two drawbacks: 1) Using ‘only’ first returns means not all LiDAR information is used and some detail is missing. This is particularly the case for off-nadir scan angles in traditional airborne surveys. It becomes especially pronounced with new scanning systems such as UAV or hand-held LiDAR where laser beams no longer come "from above". 2) Using ‘all’ first returns practically guarantees the formation of needle-shaped triangles in vegetated areas and along building roofs that appear as spikes in the TIN. These spikes result in “pits” in the resulting raster that not only look ugly but impact the utility of the DSM or CHM in subsequent analysis, for example, in forestry applications when attempting to extract individual trees. Our presentation will describe a novel algorithm that uses ‘all relevant’ LiDAR returns to construct a ‘spike-free’ TIN from which it can rasterise ‘pit-free’ DSMs or CHMs and will demonstrate its superiority with different examples. A working prototype of the spike-free TIN algorithm is available and is now integral part of the LAStools software.

ID: 107/ TAS_2_B: 4

Forest Plantation Characterization Using LiDAR System in the Philippines

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Keywords: LiDAR, ALS, forest plantation, CHM, inventory

The Philippines, thru the Department of Science and Technology (DOST) embarked on a nationwide mapping effort using airborne Light Detection and Ranging (LiDAR) technology. The two main purposes of which are for disaster management and natural resources assessment to complement programs of other government agencies. DOST tapped fifteen Higher Educational Institutions (HEIs) from all over the country, including Central Mindanao University (CMU), to facilitate the program and conduct remote sensing activities. While other selected institutions evaluated various forest types such as mangrove and natural forest, CMU was tasked to analyze a forest plantation with LiDAR datasets. The plantation is managed by the Bukidnon Forest, Inc. (BFI), a government-owned corporation originally established in cooperation with the New Zealand government. It is just befitting for the program to introduce this kind of technology to BFI considering that their management is still using the tedious and time-consuming manual inventory.

Taking optimum advantage of the technology, it is expected to deliver estimates of forest biophysical parameters such as volume, biomass and carbon stock. Techniques, algorithms and workflows are being developed to extract key features both from point cloud and LiDAR derivatives. This paper however, presents an initial analysis taken from the generated pit-free canopy height model (CHM) using GIS-based software to compare which one is the most accurate to use. This is something BFI management urgently needed first with essential data of heights and number of trees. Using a 2-hectare *Pinus carribean* plantation as a sample, both the watershed segmentation module of ArcGIS 10.2 and the open source software SAGA 2.0.8 performed almost similarly in terms of mean stand height (2-3% underestimation) and number of standing trees (98%). USDA's Fusion 3.42 meanwhile produced tighter distribution but showed poorest in tree counts. The algorithm's performance is yet to be tested with other species as BFI's total area of 39,000 hectares is also planted with broadleaf-type *Acacia mangium* and *Eucalyptus deglupta*.

ID: 69/ TAS_2_B: 5

International benchmarking on TLS methods for forest inventories

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Keywords: terrestrial laser scanning, TLS, benchmarking, forest inventories.

The last two decades have witnessed a rapid popularity of the use of terrestrial laser scanning (TLS) in forest inventories. TLS automatically records millions to billions of three-dimensional (3D) points with a high accuracy (e.g., millimetre-level) in a short period of time. Tremendous efforts have been put into research trying to find out what is the best practices of applying TLS in silviculture and forest industry. Many tree attributes have been correlated with measurements from TLS data, and the accuracy of tree-attribute estimates was shown to be similar to, or even better than, national allometric models. There is, at this moment, still a lack of proper understanding on the performance of TLS, especially in forests with varying structures. The variances among results obtained from TLS data for plot-wise tree attributes estimation have been significant.

The international benchmarking on TLS methods for forest inventories was launched in 2014. The study was advertised actively to potential participants, reached through research networks, during conferences and via the study webpage. Results from all the partners are evaluated using the same reference data and methods. The plotwise parameters studied in this project include tree location, tree height, the Diameter-at-the-Breast-Height (DBH), stem curve (stem diameter as function of height) and Digital Terrain Model (DTM). The main objective of this benchmarking study is to understand the recent developments of TLS methodologies in plot inventories by evaluating the quality, accuracy and feasibility of the automatic and semi-automatic tree extraction methods based on TLS data.

How much variation is caused in the tree parameter estimation by the processing methods to derive the tree measurements?

How much variation is caused in the tree parameter estimation by the input TLS data, such as single- and multi-scan TLS data?

What is the impact of forest conditions, e.g., density, species and ground vegetation?

The test forest is a southern Boreal Forest in Finland. 24 sample plots, 32-by-32m each, were measured in the summer 2014. These forest plots have varying species, growth stages and management activities, and included both homogenous and less-managed forests. Five scans were made at the plot center and northeast, southeast, southwest and northwest directions, where the centre scan represents the single-scan approach and the merged five scans represent the multi-scan approach.

ID: 28/ TAS_2_B: 7

Impact LiDAR: A Software Package for Automatic Derivation of Forest Parameters from LiDAR data

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Keywords: LiDAR, software, forest segmentation, forest parameters, timber volume

In the frame of the EUFODOS project we investigated the potential of LiDAR data for deriving a set of important forest parameters. A modular remote sensing software package was developed which can process ALS data for large areas. The software first segments the input data to homogeneous forest stands and then automatically derives forest parameters for each segment. The major forest parameters are the mean height of the dominant layer, the total number of trees per hectar or polygon, the crown cover density and the number of layers. In combination with ground sampling and satellite data also the timber volume and the broadleaf/coniferous percentage can be derived for each forest stand. This powerful software package was then used to exploit the LiDAR data sets for the entire Austrian province of Styria (16.400 km²) and to produce a forest map of unprecedented spatial resolution and thematic detail. Overall, more than 6 million forest segments were derived and forest parameters and timber volume were calculated for each segment. The resulting forest parameter map is a shapefile that can easily be used in GIS software to detect past or future forest cover changes from storm damage, forest fires, insect infestations or logging activities. The forest parameters derived from LiDAR data can be used for a variety of applications such as for administrative planning activities, natural hazard management (protective forests), environmental management (biological corridor or habitat delimitation) and to support forest owners with timber volume estimations.

ID: 25/ TAS_2_B: 8

3D Forest – Tool for TLS forest data processing

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Keywords: lidar, tree, crown, parameters, application

Terrestrial laser scanning (TLS) is a powerful technology for capturing the three-dimensional structure of forests with a high level of detail and accuracy. Over the last decade many algorithms have been developed to extract various tree parameters from TLS data.

Here we present 3D Forest, an open-source non platform specific software application with an easy-to-use GUI with compilation of such algorithms. Collection starts with automatic terrain extraction and filtering for precise terrain morphology analysis following by tree parameters extraction. The current version extracts important parameters of forest structure from TLS data, such as stem positions (X, Y, Z), tree heights, diameters at breast height (DBH), as well as more advanced parameters such as tree planar projections, stem profiles or detailed crown parameters including convex and concave crown surface and volume. Moreover, 3D Forest provides quantitative measures of between-crown interactions and their real arrangement in 3D space. More can be find at www.3dforest.eu.

ID: 90/ TAS_2_B: 9

Forest lacunarity studies in the Great Hungarian Plain using LiDAR point clouds

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Keywords: Airborne Laser Scanning, Great Hungarian Plain, lacunarity, canopy structure, voxelization

Quantifying forest structure became a primary issue in the last years: ecological and habitat research, but also forestry recognized the importance of the spatial pattern of the canopy (tree crown levels, understorey vegetation, shrub layers, etc.). Gaps in forests, mosaic-like structures are essential to biodiversity. For three-dimensional (3D) mapping of these structures, full-waveform or dense multiecho LiDAR data can provide the necessary resolution and accuracy. However, for the evaluation of the distribution of gaps in the vegetation, being a multi-scale phenomenon, scale-independent characterization is needed.

Lacunarity technique, introduced in 1983 and widely used in various disciplines since the 1990ies, has already been considered for structural mapping of forests two decades ago. However, due to the lack of high-density data, and partly because of the high amount of resulting data, there has been only slow development in its application in vegetation science. The last years has seen a rapid increase in this sense, as Airborne Laser Scanning (ALS) point clouds are found to be appropriate as input data for lacunarity calculations.

Our study areas are situated in a very low relief area, in the Great Hungarian Plain. The flat topographic relief ensured that the tree growth is independent of the topographic effects. Some areas of interest (AOIs) are situated in forest plantation crops, providing various quasi-regular and irregular patterns, whereas other AOIs are in natural forest in wetland areas, showing natural gaps in the forest.

Points of interest (POIs) were defined within the AOIs as centers of the lacunarity calculations. The ALS point clouds around POIs have been voxelized and converted to 2D images for input. Series of lacunarity curves have been computed to reveal the vertical variations; these stacks of lacunarity curves were converted to images for visualization. This way we get a high-resolution lacunarity-derived image for each AOI.

Analysis of these images reveals that the spatial variation can be related to forest properties and ecology-specific aspects. The lacunarity distributions of plantations differ from many lacunarity distributions of POIs in wetlands. Wetland patterns show interesting variations, too. However, there are some instrumentation-specific properties that are rather due to the data acquisition technique, especially to the data density and number of echoes in the original input data.

BSz contributed as an Alexander von Humboldt Research Fellow. The laser scanning data used here has been measured within the framework of the ChangeHabitats[2] project (FP7-PEOPLE-2009-IAPP grant No. 251234), an IAPP of Marie Curie Actions of the European Commission.

ID: 142/ TAS_2_B: 11

New methods of city greenness inventory based on ALS, MLS, TLS and VHRS fusion

Piotr Wężyk[1], Artur Warchoł[2], Roeland de Kok[2], Katarzyna Bajorek[2]

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Keywords: city greenness inventory, MLS, TLS, ALS

The inventory of city greenness require a lot of field work spend mainly on the tree and shrub directly measurements. This part of ground truth collection based on gathering of the geometry of individual objects (location and 3D dimensions) can be today effectively exchanged by usage of state-of-the-art technologies such as: LiDAR 3D point clouds and remote sensing (VHRS) imageries. Laser scanning performed from various platform (ground based and airborne) allows the acquisition of data with different characteristics and accuracy (from mm-TLS, trough cm-MLS to dm ALS) but still complementary. The data fusion of 3D point clouds with spectral information (like 8 bands WolrdView-2 satellite image) is therefore a proper way to minimize the drawbacks of each data set and highlight its advantages. The 3D point cloud fused from ALS, MLS and TLS platform can deliver precise information about the location, height, diameter on the breast height, crown perimeter or volume . The paper present some preliminary results from running project (Monit-Air; EEA grants) in the Krakow Municipality, like the generation of the new LULC map (over 25 classes) of Krakow based on GEOBIA analysis of the WV-2 imagery (DigitalGlobe; GSD 0.5m PAN / 2.0 MS bands) additionally powered by the 3D information (relative heights of vegetation, echo ratios, p95 and other statistics) derived from ALS campaign (ISOK project). Using the MLS point cloud integrated with ALS data many thousands of precise tree locations and some chooses tree parameters were performed. The TLS data were match together with the ALS&MLS point cloud for some special areas and playgrounds were was not possible to drive by mobile LiDAR platform (MLS). The fused LiDAR technology, if properly performed for the greenness inventory, can offer a quite economic solution for the municipality. The 3D LiDAR point cloud can be also used for the monitoring of the trees (like VTA; Visual Tree Assessment) or stem stability and much more else new parameters like the crown volumes and e.g. the C02 sequestration or shadowing effect and mapping of the the 3D CAD data about the pavements surface, lawns, garbage bins, benches, lanterns and other infrastructure as well.

TAS_2_C: Thematic Abstract Session 2 – Biomass

***Time:* Thursday, 15/Sep/2016: 1:30pm - 2:30pm**
***Location:* Lecture room 3 - "C"**

***Session Chair:* Jaan Praks**
Aalto University, Finland
***Session Chair:* Christian Joachim Thiel**
Friedrich Schiller University, Germany

ID: 113/ TAS_2_C: 1

Integration of various data sources to assess above-ground biomass in the carpathian region

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Keywords: Forest Cover, Biomass, Segmentation, LiDAR

Increase of forest cover has been observed for many decades in Europe. In Poland, the process accelerated after the political and economic breakthrough in 1989. The forest regrowth following the agricultural land abandonment affected primarily marginal mountain areas, as, for instance the Polish Carpathians. Here, the contemporary forest cover is about 47%. Approximately half of the area belongs to the State Forests National Forest Holding (SF NFH), and the other half belongs to other owners. Apart from that, there are also tree- and shrub-covered areas formally under agricultural land use, yet turning slowly into forests due to secondary forest succession. These specific areas are not included in the official statistics.

The accurate quantification of forest and non-forest above-ground biomass (AGB) helps to understand carbon cycling dynamics. The AGB is assessed from stand-based inventories, in particular from stem volume that is related to the height of forest stands. But while the detailed statistics are collected for the entire state forests, private forests are surveyed with lower resolution and accuracy, and the areas undergoing secondary succession are monitored only exceptionally. In this study, we investigated vegetation height as a potential indicator of AGB, for the three classes forest/shrub vegetation, namely: state forests, other forests and secondary succession areas, in one of the Carpathian communes (Szczawnica). We used LiDAR-derived digital terrain model (DTM) and digital surface model (DSM), the national topographic data (Baza Danych Obiektów Topograficznych 10k; BDOT10k), inventory data from State Forests IT System (SILP), Forest Data Bank (Bank Danych o Lasach; BDoL) and Land Parcel Identification System (LPIS) - GIS data managed by Agency for Restructuring and Modernisation of Agriculture. First, we eliminated from analysis specific land use types such as water bodies, industrial and residential land, built-up agricultural land, and orchards using BDOT10k. Second, canopy height model (CHM) was calculated from DTM and DSM. Finally, we investigated distribution of canopy height for the three classes of forest/shrub vegetation. Our results illustrate the potential of LiDAR-derived elevation models to quantify AGB.

ID: 103/ TAS_2_C: 2

Estimating biomass losses and CO2 emissions using low point density ALS data in a Mediterranean wildfire

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Keywords: ALS, biomass losses, CO2 emissions; wildfire; Aleppo pine

Wildfires are a socio-environmental hazard in Mediterranean ecosystems, acting as a source of greenhouse gas emissions to the atmosphere. Consequently, fires are able to alter the carbon cycle at regional or even global scales, as well as to decrease the effect of carbon sequestration by forests.

In the Mediterranean basin, an average of 45,000 fires is recorded yearly, increasing the albedo and modifying the landscape. These natural or anthropogenic disturbances might be enhanced by climate change, increasing fire risk particularly in summer months. In this sense, scientists, fire managers and decision makers require the most accurate information available related with fire emissions and its impact on the environment and population.

The availability of ALS data of low spatial resolution (0.5 points/m^2) provided by the Spanish National Plan for Aerial Orthophotography (PNOA) previous to the occurrence on July 4th 2015 of a wildfire in Luna mountain range (Northeast of Spain), as well as the suitability of those data to estimate total biomass (TB), determined the main objective of this research. Accordingly, this study focuses on the estimation of biomass losses and carbon dioxide (CO^2) emissions produced by combustion of Pinus halepensis Mill. stands in “Luna” wildfire. In this regard, pre-fire TB was calculated using a model obtained in a close area by applying a multivariate linear regression analysis between the TB estimated in 46 field plots and several independent variables extracted from the ALS point cloud. The model included the percentage of first returns above 2 m AGL (above ground level) and 40th percentile of height. A leave-one-out cross-validation technique was performed to validate the model, obtaining a high coefficient of determination (0.89). The implementation of the model in a GIS allowed pre-fire TB mapping in a raster format.

Biomass losses were estimated in a three phase approach: i) wildfire severity was obtained using dNBR spectral index using Landsat images, ii) Aleppo pine forest was located using the Spanish National Forest Map and ALS data, and iii) three burning efficiency factors, related with pre-fire vegetation, were applied considering low, moderate and high severity levels. Afterwards, post-fire biomass was transformed into CO^2 emissions applying the conversion factors, summing up a total of 426,754.84 tons for the whole burned area.

Finally, given the direct effect of point density on ALS data acquisition costs and accuracy of the derived models, our study demonstrates the usefulness of low density PNOA-ALS data to accurately estimate pre-fire TB, wildfire biomass losses and CO^2 emissions. Therefore, low-density ALS data is suitable for forest management. However, further research should focus on the estimation of CO^2 emissions generated by combustion of other species.

ID: 44/ TAS_2_C: 4

The first forest biomass map over Poland derived from a synergy of optical and SAR data

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Keywords: aboveground biomass, radar, carbon, stock volume

Forest above-ground woody biomass is a fundamental biophysical variable describing the amount of woody matter within a forest. The authors present the first forest biomass map over Poland, which was obtained in the framework of the ESA GlobBiomass project. The main purpose of the ESA GlobBiomass project is to better characterize and to reduce uncertainties of above ground biomass (AGB) estimates by developing an innovative synergistic mapping approach in five regional sites (Sweden, Poland, Borneo, Mexico, South Africa) for the epochs 2005, 2010 and 2015 and one global map for the year 2010. The forest biomass map for 2010 over Poland was developed based on a synergy of radar ALOS PALSAR (L-band, HH and HV polarization) and optical Landsat missions data. The National Inventory of Forest Condition (WISL) has been used as the reference data for the biomass retrieval. The growing stock volume was converted into woody biomass. The method used for biomass estimation in Poland was based on a machine-learning Random Forest regression. The Random Forest model was calibrated using a set of training plots located over the entire forested area except steep slopes in the mountains.

ID: 93/ TAS_2_C: 5

Integrating field sampling and RapidEye spectral response signals in a tropical secondary peat-swamp forest of Borneo, Indonesia

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Keywords: Peat-swamp forest, above-ground biomass, RapidEye, Borneo, stepwise regression

Tropical peat-swamp forest is a unique ecosystem which holds an important role for the sequestration of above- and below-ground carbon. Indonesia hosts the largest parts of this forest in South-East Asia, where the most extensive part of tropical peat-swamp forests are located. However, the areas of Indonesia's peat-swamp forest keep decreasing and degrading due to timber logging, conversion to other land uses (e.g for agriculture use), continuous drainage, and forest fire which emitted a huge amount of carbon to the atmosphere. Therefore, it is necessary to develop a monitoring system specifically for this type of forest. Remote sensing plays an important role in these activities for the forest is often not easy to access and extended on vast areas. Optical remote sensing data, with its advantages and disadvantages, have been reported as one of the main data sources used by the country for these activities. This study investigates the potential of 5 m spatial resolution of RapidEye imagery to estimate biomass of a tropical secondary peat-swamp forest of Borneo, Indonesia, and to relate it to other forest stand attributes. We integrated field data, based on systematic sampling using nested sub-plots, with RapidEye imagery to model biomass. The reference biomass estimation per plot is calculated using a specific allometric model developed by a previous study which conducted in Indonesian peat swamp forests. The integration approach relies on the use of the spectral information of the pixels over the field plots and the corresponding estimated biomass. The standard method assumes that these response signals within a plot are normally distributed. However, previous studies often showed poor relationships between the two variables, especially in forests with complex structures. Therefore, in this study we derived the variable metrics (e.g.original band, vegetation indices) of RapidEye imagery based on two assumptions, the normal distribution and non-normal distribution using Weibull coefficients. We applied a stepwise regression to select any predictor variables that can be used to estimate biomass and to relate with other forest stand attributes. We further study the method by comparing the application of this approach in a different forest type (non-complex structures; e.g a forest in Germany). The results will contribute to the research on forest monitoring activities based on remote sensing and field data specifically for tropical secondary peat-swamp forest in Indonesia.

ID: 94/ TAS_2_C: 6

Uncertainty in the estimation of aboveground forest biomass: A working proposal using information from national forest inventory in Mexico

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Keywords: Aboveground biomass, accuracy, uncertainty, NDVI

Aboveground forest biomass (AFB) is one of the most important variables in the context of quantifying greenhouse gases. Recent studies have emphasized the necessity of developing equipment and methodologies which can estimated more accurately variables that allow the calculation of the AFB. The use of estimates of AFB (plot level) and its combination with remote sensing allows to present the information obtained on a regional level, as proposed in this case study. The objective of this work is to estimate the uncertainty associated with the use of satellite images to calculate aerial forest biomass, with special emphasis on the estimation of the parameters associated with NDVI. The study area is the state of Durango, specifically with data from over 1500 plots in two stages of inventories conducted, 2004-2007 and 2009-2013. Satellite images processed for this study correspond to scenes of 2007 (Landsat 4/5) and 2013 (Landsat 8). The results are in a preliminary stage, in this regard errors related to NDVI estimation will be calculated based on the spread of the variance associated with the sources of uncertainty for calculating the NDVI. With the results, maps showing the different scenarios in estimating AFB and its association with the uncertainty of the calculation will be generated.

ID: 79/ TAS_2_C: 8

Estimating Mediterranean forest parameters using dense time series multispectral data and a machine learning classifier

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Keywords: forest parameters, landsat, random forests, time series

Forest inventory information and reliable monitoring system has become increasingly important in recent decades, in particular to support requirements related to sustainable forest management, carbon accounting and issues related to global climate change. Forest structural parameters, such as number of trees per unit area and basal area, are key forest inventory attributes and important data sources for the assessment of wood volume and many modelling tasks such as: carbon sink evaluation, animal habitat suitability assessment and landscape biodiversity estimation.

Satellite remote sensing has been shown to be an appropriate tool to assess and monitor large-area forest attributes with reasonable accuracy levels, however many challenges exist over high complex and spatially heterogeneous Mediterranean forest environments.

This study is an attempt i) to evaluate the use of seasonal time-series Landsat 8 OLI satellite imagery in estimating forest stand parameters, including density (N), basal area (G) and volume (V), in a Mediterranean environment and ii) to investigate the preferable time for satellite data acquisition considering multi-temporal datasets using a Random Forest regression algorithm.

The study area is located in North Eastern Greece and characterized by oak-pine, oak-beech mixed woodland. The field collected data contain measurements of a total of 112 square field plots (0.1 ha) and the remote sensing data are nine Landsat 8 OLI images acquired in different growing seasons. Images were atmospherically and topographically normalized. The Random Forest regression algorithm (RF) was used in order to model the relationship between spectral information and forest attributes namely density (N), basal area (G) and volume (V). Spectral information was extracted from spectral bands 1 to 7 of each Landsat 8 image and was feed as the predictor variables to RF model. RF models based on multi-temporal (May to December), single season (May to September) and single date imagery were compared. Moreover the effect of most important variables and minimal depth variables on the RF predictions was also investigated. The multi-temporal and single season models imagery were much more accurate than single date imagery models. The performance of the models using most important variable selection for multi-temporal imagery were slightly better than these of the models using most important variable selection of single season. The coefficient of determination of predicted versus observed values was for density (N) R2=0.49, for basal area (G) R2=0.66 and for volume (V) R2=0.61. However, the effect of minimal depth variables selection improved the single season model more than the multi-temporal image model. And the models using minimal depth variables selection of single season were assessed as better accurate models, for all three attributes. In this case, the coefficient of determination of predicted versus observed values was for density (N) R2=0.52, for basal area (G) R2=0.68 and for volume (V) R2=0.63.

The study demonstrates the utility of freely available Landsat 8 data and the possible advantages of multi-temporal datasets and random forest regression for more accurately estimating forest attributes. It points to a cost-effective methodological framework for forest inventory and forest parameters estimation in Mediterranean mix forests.

ID: 125/ TAS_2_C: 9

Area-based estimation of growing stock volume in Scots pine stands based on point clouds derived from aerial photos and Airborne Laser Scanning. The case study in Lasy Janowskie, South-East Poland

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Keywords: AIC; ALS; Akaike weights; forest inventory; linear regression; Poland; structure from motion; timber volume

The Airborne Laser Scanning (ALS) for many years has been treated as a main technology being the information source (3D point clouds) of forest vertical structure. However, since last few years there is growing interest in using point clouds generated from high resolution digital aerial photographs (images) as an alternative for ALS data. The aim of the presented study was to compare the growing stock volume predictive models generated from image- and ALS- derived point clouds. The study was conducted in one layer even-aged Scots pine stands in “Lasy Janowskie” forest district located in South-East Poland. The image-derived point clouds (IPC-Image Point Cloud) were generated using structure from motion approach in the Agisoft PhotoScan software. The multiple linear regression method was used to create predictive models. We evaluated the accuracy of models built using three different point cloud sources i.e.: ALS, true colour aerial photos (RGB) and colour infrared aerial photos (CIR). The performance of the models was assessed by 10-fold cross-validation with five repeats. All models predicted growing stock volume with relatively high accuracy (RMSE%): ALS: 14.55%, IPC-CIR: 15.58% and IPC-RGB: 16.16%. The following variables were found to be most robust for building predictive models: ALS - mean height of points, percentage of all returns above mean height of points, interquartile range of point heights; IPC-CIR - mean height of points, percentage of all returns above mean height of points, canopy relief ratio, surface volume; IPC-RGB - mean height of points, canopy relief ratio and surface volume. The results shows that in simple one-layer Scots pine stands it is possible to predict growing stock volume using image-based point clouds with similar accuracy as using the expensive ALS data. There are not statistically significant differences in accuracy of models built from image-based point clouds obtained from RGB colour and CIR aerial photographs. Depending on the source of point cloud different metrics are identified as most robust for building predictive models of growing stock volume.

ID: 21/ TAS_2_C: 10

Quantifying canopy fuels properties for the California Rim fire integrating airborne LiDAR and Landsat OLI data

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Keywords: LiDAR; Landsat OLI; Data integration; canopy fuel load; canopy cover; canopy bulk density; megafires

Accurate spatial information on canopy fuel properties is essential for fuel management strategies to reduce the severity and impact of megafires. Airborne LiDAR technology has demonstrated its ability to accurately map canopy fuel properties. LiDAR data are increasingly available; however, for most fire incidents a prefire LiDAR dataset that would enable characterization of fuels before the incident is not available. Therefore, methods are required to overcome this lack of data. This paper presents a two-phase methodology for integrating airborne LiDAR and Landsat OLI data to quantify three main canopy fuel properties namely, canopy fuel load (CFL), canopy cover (CC) and canopy bulk density (CBD), before the occurrence of a megafire. First, postfire LiDAR data is used to estimate CFL, CC and CBD across a 2 km unburned buffer around the fire. Second, LiDAR estimates are extrapolated in time and space using prefire Landsat OLI data, which yielded an R2 of 0.85 and 0.72 and relative RMSE of 31.04% and 41.8% for the calibration and validations datasets of CFL at 30 m resolution. For CC the R2 and relative RMSE were 0.79 and 18.88% for the calibration dataset and 0.78 and 19.4% for the validation dataset. Finally, the accuracy for CBD was 0.66 and 36.71%, and 0.60 and 37.23% for the calibration and the validation datasets, respectively. A multi-scale analysis showed a general increase in accuracy of CFL and CBD retrievals with decreasing spatial resolution but almost no influence of scale on accuracy of CC.

ST-A: Student Award

Time: Thursday, 15/Sep/2016: 3:15pm - 3:30pm
Location: Main AULA - "A"

***Session Chair:* L. Monika Moskal**
University of Washington, United States of America
***Session Chair:* Piotr Wezyk**
University of Agriculture in Krakow, Poland

ID: 92/ ST-A: 1

Estimating forest structure attributes from full-waveform LiDAR: comparative analysis of methodological parameters in two geographic areas

Pablo Crespo-Peremarch, Luis Ángel Ruiz

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Keywords: LiDAR full-waveform parameters, voxelisation, forest structure, canopy fuel

LiDAR full-waveform sensors are promising for estimation of forest structure and canopy fuel variables, since the complete waveform that goes through the canopy is recorded, and allows to obtain a better description of the different vertical layers of the vegetation than discrete LiDAR. In this paper we analyse the effect of the modification of two methodological full-waveform processing parameters, voxel size and voxel value assigning method, on several forest structure and canopy fuel attribute prediction models, and we compare their behaviour in two different geographic and ecological areas: Pacific Northwest in North America, and a Central Mediterranean area in Spain. Four voxel sizes were therefore tested (0.25, 0.5, 1 and 2 meters), and maximum, mean, median, mode, percentiles 90 and 95 were assessed as value assignation methods. Afterwards, Aboveground Biomass (AGB), Basal Area (BA), Quadratic Mean Diameter (QMD), Standard Density Index (SDI), Canopy Height (CH), Canopy Base Height (CBH) and Canopy Fuel Load (CFL) variables were estimated generating linear regression models for each full-waveform processing parameter and each study area.

Regression model results showed that R2 value of AGB, BA and CFL variables decreases considerably when voxel size increases in the Mediterranean study area (decreasing from 0.79 to 0.71 for AGB, from 0.79 to 0.64 for BA and, from 0.80 to 0.73 for CFL). However, variables related to height such as CH and CBH were not affected by voxel size increment. Additionally, assignation of the maximum, percentile 90 and 95 amplitude of all the waveforms crossing the voxels achieved the highest R2, whereas mode had the lowest results. On the contrary, in the Pacific Northwest study area there were not result differences when voxel size and voxel value assignation were changed.

We concluded that a correct choice of the voxel size and the voxel value assignation is fundamental so as not to loss information like in our Mediterranean study area. Voxel size choice depends on the LiDAR footprint size. Regarding voxel value assignation method, we recommend to use maximum, percentile 90 or 95, according to the results of this paper. Comparing both study areas, we also detected that AGB, QMD and SDI were better estimated in the Northwest Pacific study area, whereas BA, CH, CBH and CFL had a higher R2 in the Mediterranean study area. This can be because of some variables are better estimated according to forest species, or how field data were measured.

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PLS-3: Plenary session Nº 3

Time: **Thursday, 15/Sep/2016: 4:00pm - 4:30pm**
Location: **Main AULA - "A"**

Session Chair: **L. Monika Moskal**
University of Washington, United States of America
Session Chair: **Piotr Wezyk**
University of Agriculture in Krakow, Poland

ID: 152 / PLS-3: 1

Is multispectral LiDAR the future of forest mapping?

Iain Woodhouse

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Over the last 40 years LiDAR systems have fundamentally changed the world of mapping and surveying, with airborne systems able to cover large areas and remote locations. Since the first introduction of a LiDAR system, there have been many technological developments such as multiple pulses in flight, and full waveform recording. Will the next major development within the realm of forest mapping be Multispectral LiDAR. This talk considers the next steps in this process, generating new methods for extracting key information about forests from cutting edge LiDAR technology.

Results from recent airborne studies with multispectral Lidar demonstrate that it is possible to extract spectral variation within vegetation in a three-dimensional manner. This is the first hurdle for demonstrating the potential use of Multispectral LiDAR technology for forest mapping applications. If it were not possible to identify spectral variation within the vertical forest canopy, then this technology would be unable to contribute to the range of potential applications.

There are two key areas for further development and testing, that arose from this project. The first is a more thorough validation of the results. Whilst the spectral calibration conducted was successful in this case, there are clear limitations to such an approach.

The other area of limitation for the project was the LiDAR system configuration used was not optimal for mapping vegetation as the wavelength lasers used were 532, 1064, and 1550nm. Previous work indicates that the best wavelengths for forest mapping are 531, 650, 660, and 780nm. Similarly, the data for this project was collected by flying multiple LiDAR systems on the same platform, with two instruments on a first flight, and a third on a second flight. This setup resulted in overlapping coverage of the point clouds at different wavelength, but with non-coincident points.

The next steps in the development process is to to fully evaluate Multispectral LiDAR technology for mapping understory spectral response. By demonstrating this principle we have begun to open up many new avenues for potential applications. This could include mapping of tree health, or mapping of invasive species.

Ultimately a true Multispectral LiDAR will provide a point cloud where each point is recorded at multiple wavelengths. To do this, manufacturers will have to make a system where the beams overlap exactly and the returns are measured simultaneously, and consistent calibration across the different wavelengths must be maintained. Combined with a LiDAR configuration optimised for vegetation mapping, spectral information will be available for all aspects of a forest canopy, not just the very top surface. With these exciting advances in the use of Multispectral LiDAR for mapping forest under-canopies, the future is bright for this technology.

TAS_3 _A: Thematic Abstract Session 3 - Monitoring_2

Time: Thursday, 15/Sep/2016: 4:30pm - 5:30pm
Location: Main AULA - "A"

Session Chair: **L. Monika Moskal**
University of Washington, United States of America
Session Chair: **Iain Woodhouse**
The University of Edinburgh, United Kingdom

ID: 18 / TAS_3_A: 1

Monitoring of forest biodiversity and climatic impact on forest environment with the use of high-resolution satellite images

Zbigniew Tomasz Bochenek[1], Dariusz Ziolkowski[1], Maciej Bartold[2,1], Karolina Orłowska[2], Bogdan Zagajewski[2]

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Keywords: forest biodiversity, high-resolution satellite data, vegetation index, forest monitoring

The main goal of the research work was to assess usefulness of high-resolution optical satellite images for monitoring forest stands characterized by diversified environmental conditions, affected with various climatic impacts. Three types of high-resolution satellite data were considered in the analysis: Landsat 5 TM, Landsat 8 OLI and SPOT 5 images. Three forest areas located in northeastern Poland – Bialowieska Forest, Knyszynska Forest and Borecka Forest, characterized by different environmental conditions have been selected as the study areas. Satellite images were collected for three vegetation seasons – 2006, 2014 and 2015, differing in climatic conditions, as described by meteorological parameters – temperature and precipitation. Various vegetation indices describing complementary aspects of plant condition and vegetation structure were derived from satellite images and their values were analyzed in a temporal profile throughout vegetation season. Variability of particular vegetation indices was analyzed in conjunction with changeable meteorological parameters. Results of the research work led to the conclusion, that dedicated vegetation indices derived from Landsat / SPOT data, which characterize water stress in plants - Disease Water Stress Index (DSWI) and Normalized Difference Infrared Index (NDII) are useful for deriving information on forest environment. In particular, they can differentiate three types of forest site: dry, fresh and humid forest sites, three levels of stand mixture and some tree species. Changes of vegetation indices in temporal profile are related to information on drought appearance, as derived from meteorological data.

The conclusions on applicability of vegetation indices derived from high-resolution satellite data for forest monitoring were supported with the results of analysis of vegetation parameters measured in the course of ground campaigns: pigment content, fluorescence level and spectral characteristics obtained with the use of hyperspectral instrument. However, the detailed study of vegetation indices derived from spectroradiometric measurements revealed that narrowband indices, especially derived from red-edge spectral range can give additional possibilities for differentiating forest status and environment. That option will be further studied by application of Sentinel-2 data, which offer information in this part of electromagnetic spectrum.

ID: 65 / TAS_3_A: 3

Comparison of different definitions for wooded land using high resolution remote sensing techniques - a cross-country case study

Katja Oehmichen[1], Christoph Bauerhansl[2], Christian Ginzler[3], Franz Kroiher[1], Christoph Straub[4], Lars T. Waser[3]

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Keywords: forest, trees outside forest, other wooded land, national forest inventories, high resolution remote sensing techniques

National forest inventories are delivering precise and up-to-date information on wooded land and wood resources. This information is essential for a sustainable management of forest and for decision makers in policy, economy and administration. Moreover, the data is used for fulfilling national and international reporting obligations like the Forest Resources Assessment, where the area of forest, other wooded land (OWL), and trees outside forest (TOF) has to be reported. However, countries are applying slightly different definitions mostly based on their NFIs. Unfortunately, these definitions do not provide an explicit and complete classification of land covered by trees. The study presents a method for classifying areas according to the definitions of forest, OWL and TOF for Austria, Germany and Switzerland by remote sensing.

The test site is located at the borders of the three countries and covers an area of approximately 250km². It is characterized by mixed forests, rural and urban areas with woodland embedded in a pre-alpine topography. To derive areas covered by trees a semi-automatic method was developed based on digital stereo imagery, digital terrain models (DTM) from airborne laser scanning, CORINE 2006 land cover and terrestrial NFI data. The different image data sets were merged to a 1 m spatial resolution orthoimage using a common coordinate and reference system. The stereo-images were used to process a 1 m resolution digital surface model (DSM) by image matching techniques. Finally, a canopy height model (CHM) was calculated by subtracting the combined DTM from the DSM for the entire study area. The wooded area masks were extracted from a normalized difference vegetation index image in combination with the CHM using the height criteria of the different forest definitions. Then the criteria 'minimum height`, 'minimum crown coverage', 'minimum width' and 'minimum area' according to the countries definitions were applied to classify forests. In order to differentiate between forest, TOF and OWL the CORINE 2006 land cover data was used. Finally all maps were validated by visual image interpretation using independent reference data sets and NFI data. The validation process resulted in correspondence rates from 70% to 95% for the different classes covered by trees.The case study revealed that the estimation of forest and land covered by trees in a cross-country approach is feasible – independent on the NFI forest definition used - with a high degree of automation. However, there are given limits of remote sensing techniques, as information on land use according to a specific forest definition cannot be obtained directly. For example, a temporarily unstocked area (e.g. wind throw, clearcut) in the forest will be detected as non-forest in the imagery although its use still remains forest. Thus, combining remote sensing techniques to harmonise and compare NFI results for estimating wooded land is a very effective and promising approach supporting the international harmonization process.

ID: 123 / TAS_3_A: 4

Measurement and Monitoring of Forest Ecosystem Services: Case Studies from the Pacific Northwest, USA

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Keywords: ecosystem services, riparian, lidar, phodar, UAS

Ecosystem services can be categorized into: provision, regulating, supporting, preserving and cultural services. All of these amenities can be attributed to forested environments and are becoming a targetable issue for sustainable management of these resources. Because field studies represent only a snapshot in the spatiotemporal continuum of a landscape, remote sensing can assist with spatially explicit modeling at a site, watershed and landscape levels. Although, a wide array of remote sensing approaches for ecosystem assessment has been developed over decades, these are applicable to imaging satellite datasets, and come with limitations related to the resolution and lack of spatial (and three dimensional in the case of forests) detail. It is with the onset of lidar and our ability to capture the detailed and even leaf level structure of the forested landscape that remote sensing of ecosystem services has become feasible. This talk will focus on providing examples of provision services mapping, such as biomass and cellulosic biofuels estimation. Regulatory services will be explored through examples of detailed modeling of forests in the Pacific Northwest applied to a variety of purposes, including the close study of the riparian forest/water interface and function for the suitability and sustainability of salmon habitat. Preserving services related to biodiversity, habitat and accounting for uncertainty will also be addressed through examples of monitoring forested wetlands on Mt. Rainier, Washington. The study extends beyond the suitability of habitat toward the ecosystem services of the forest for quality drinking water. Finally, discussion on how supporting and cultural services, such as pest/disease control and recreational opportunities, can also be addressed with lidar remote sensing will be provided.

ID: 131 / TAS_3_A: 6

Experiences on GAEC control using Sentinel 2 in mapping "trees outside the forest"

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Keywords: Sentinel, GAEC, forest succession.

The new Sentinel program (ESA Copernicus) offers a variety of opportunities to remote sensing in forestry. In the last months a constant stream of new Sentinel-2A imagery becomes available for download.

The ScienceHub offers Level 1C products for Sentinel-2A imagery. For Forest applications, the Level 1C might not be the best product for deriving parameters and calibrate for multi- temporal classifications. Especially the transferability and stability of Object Based classification processes might require instead the Level 2A product as input for multi- temporal forest analysis.

In this study an overview of the effects of going from DN values to Radiance (in watts/(meter squared * µm) and further to Reflectance at Level 2A products mainly using SEN2COR and it's effect on the stability and transferability of the GEOBIA classification protocols for forest will be analysed.

A special category in forest detection is the category "trees outside the forest" This considers the amount of trees in the agricultural environment close related to the GAEC rules of cross compliance of the European Union. Detections and quality assessment is possible with the Sentinel 2 Level 2A imagery, which will be demonstrated.

With its 13 Bands and it's 10 meter GSD in 4 spectral bands, the Sentinel-2A imagery is capable of the continental assessment and mapping of very small forest plots inside the agricultural domain. The study will demonstrate a selection of practical applications (for GAEC and Forestry) with SENTINEL-2A sensors, that are now under development at the Geomatics Laboratory at University of Agriculture in Krakow.

ID: 29 / TAS_3_A: 7

Comparison of three in-situ optical methods for forest leaf area index assessment

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Keywords: leaf area index, floodplain forest, LaiPen, PCA-2200, hemispherical photographs

Leaf area index (LAI) is recognized as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS) and it is also one of the key products of the Copernicus Global Land Service. LAI is directly related to leaf biomass and thus to ecosystem vigour in general. Assessment of LAI from global to local spatial levels using remote sensing data is thus highly relevant for wide range of ecosystem and climate change studies. Despite its versatility, remote sensing based retrievals of LAI still require validation using in-situ measured data. Field measurement of LAI has to be reliable and rapid in order to cover larger areas and variety of vegetation types.

In this study, we cross-compared three optical-based methods for in-situ LAI assessment. LAI of a mixed broadleaf floodplain forest (Lanžhot, Czech Republic, 48°40'N, 16°56'E) was measured in the peak of growing season in 2015 using three instruments: Plant Canopy Analyzer LAI-2200 (LI-COR Biosciences Inc., Lincoln, US), LaiPen LP 100 (PSI Photon Systems Instruments, Drásov, Czech Republic) and digital hemispherical photography (Canon 450D digital camera combined with a fisheye hemispherical lens Sigma 4.5nm). Since LaiPen is a relatively new instrument for rapid LAI assessment, our main objective was to compare its performance with other well-established instruments. For this purpose we selected plots with various tree species composition, age and structure. LAI was measured in two 50 m long perpendicular transects per plot and the three instruments were operated nearly synchronously and used the same sampling scheme to ensure comparability of the measurements.

Preliminary results showed that LAI of the mixed floodplain forests varied between 3 and 8. We found good agreement between LaiPen and PCA-2200, whereas hemispherical photographs provided lower estimates than the other two instruments. From the operational point of view, LaiPen was very easy to operate from the three instruments used and was least prone to positional inaccuracies. Thanks to its narrow field of view, it can be easily used in wide range of illumination condition and it is thus potentially suitable for rapid use for forestry and ecology studies.

ID: 80 / TAS_3 _A: 9

A comparative analysis of classification trees and support vector machines approaches for reconstructing forest fuel type extent over Greece using multi-temporal Landsat imagery

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Keywords: forest fuels, fuel type changes, machine learning, Landsat imagery, Greece

Classification and mapping of forest fuels is one of the most important factors that should be taken into consideration for forest fire prevention and planning. The objective of the current study is the identification of fuel type changes over forested landscapes in Greece in a 30-year period using multi-temporal Landsat satellite data. Three scenes over North, Central and South Greece and different landscape settings but with high ecological value as demonstrated by the presence of Natura 2000 sites within, were selected for the analysis.

This research investigated two machine learning approaches – classification and regression trees (CART), and support vector machines (SVM) to identify fuel type extent change over a forested landscape in Greece in a 30-year period using multi-temporal Landsat satellite data. Evaluation of fuel type extent is essential for computing spatial fuel hazard, fire risk and simulation, fire growth and intensity and post fire effects across landscapes at national and regional scale. Accuracy assessment for the 2014 Landsat imagery was employed by using reliable ground truth measurements along with information from virtual globes, while intensity analysis is presented for fuel types at interval and category level.

Topographic and radiometric correction slightly improved the classification accuracy. Inclusion of additional features in the classification process related to elevation and aspect improved detection and characterization of fuel change.

The best models in all areas were obtained with the incorporation of texture and topo variables and bi-temporal spectral information. The accuracy of the results ranged from 43% to 79%.

Post classification comparison and transition matrices were built, considering also the results of the national inventory of Greece, based upon 1960 aerial photography. We used the framework of Intensity Analysis for a unified, multi-scale, analysis of forest change that over several time intervals in a straightforward, holistic manner. In the first period of the analysis more intense changes occurred in all studied sites, while some differences among the three sites were observed during the next periods which are attributed to natural disturbances and socioeconomic factors.

TAS_3 _B: Thematic Abstract Session 3 - ALS_GEOBIA & Forest health

***Time:* Thursday, 15/Sep/2016: 4:30pm - 5:30pm**
***Location:* Lecture room 2 - "B"**

***Session Chair:* Krzysztof Będkowski**
University of Łódź, Poland, Poland
***Session Chair:* Filip Hájek**
Forest Management Institute, Czech Republic

ID: 108 / TAS_3 _B: 2

Integration of remote sensing data for forest inventory in close-to-nature forests: An initial case study in Smolnícka Osada, Slovakia

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Keywords: uneven-aged forests; object-oriented classification; individual tree detection approach; airborne laser scanning

The initial case study is concerned to first assessment of possibilities for integration of remote sensing into forest inventory in Slovak close-to-nature forests. Based on aerial images and airborne laser scanning data were evaluated a several stand variables (i.e. number of trees, mean tree height and diameter, and growing stock). We used eCognition software for tree species classification and reFLex software for individual tree detection. The accuracy assessment was conducted in forests under ProSilva management with a complicated stand structure in Slovakia (Central Europe). The ALS data were taken with a Leica RCD30 scanner from the height of 1,034 m with a point density of 4 echoes per m^2. The ground reference data contained the measured positions and dimensions of 924 trees in 35 plots distributed across the region. We found that difference between the remote-based results and ground data was -50% for number of trees, 8% for mean height and diameter, and -28% for growing stock.

ID: 41 / TAS_3 _B: 3

Individual Tree Trunk Detection For a Positional Correction of Ground Truth Data

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Keywords: LiDAR, tree trunk detection

Referencing ground truth and high spatial resolution remote sensing data is an essential step to model forest ecosystems and to transfer the results of terrestrial forest inventories to an individual tree level. Especially in inhomogeneous forest stands, a positional shift between ground data and remote sensing data reduces the quality of the derived models (e.g. timber volume estimation, tree species classification) significantly. This problem increases with smaller spatial scales, especially on an individual tree level, where trees identified using remote sensing data (e.g. using a GEOBIA approach) shall be assigned to their corresponding reference trees. Due to systematic and unsystematic positional inaccuracies, the assignment of a detected tree to a wrong reference tree is likely or an assignment is not possible at all.

While an advanced post-processing of remote sensing data usually results in reliable positions, the absolute positional accuracy of terrestrially derived reference trees might be poor. This is caused by the practical requirement of deriving the locations with an adequate effort. Thus the tree locations are usually derived in relation to a GNSS (Global Navigation Satellite System) fixed reference position, whose positional accuracy is influenced negatively by the canopy (multiple scattering and shielding). Even differential GNNS does not always lead to the needed positional accuracy for an individual tree assignment.

A strategy to overcome the problem of a systematic positional shift between reference trees and remote sensing data will be presented. The automated approach is based on a previous remote sensing based identification of accurate tree locations and a subsequent assignment of these detected positions to the reference positions. The required positional accuracy of the detected trees (RMSE below 0.8 m) is provided by a further developed trunk detection algorithm, which uses high resolution airborne LiDAR point clouds as input data. The proposed correction algorithm optimizes the number of assigned positions by repeatedly guessing the shift and applying a modified iterative closest point method. After the identification of an appropriate translation matrix, the ground truth locations are corrected. The plausibility of the results is verified by applying a residual analysis using available control variables (e.g. measured tree height vs. LiDAR derived tree height). The preliminary application of the proposed method on ground truth data of a state forest survey in Rhineland-Palatinate (Germany) suggests that about 50% of the field plots (median: 10 trees per plot) could be correctable. The approach is mainly limited by the reachable trunk detection rate (mainly influenced by canopy closure and LiDAR point density), the number of recorded reference trees and the tree distribution. Since, after a successful correction, a positional accuracy in sub-meter range can be expected, the proposed method opens the opportunity to join forest inventory ground truth with multi sensor remote sensing data on an individual tree level. Thus the full potential of data fusion will get exploitable.

ID: 136 / TAS_3 _B: 4

The detection of windfall and windbreak in Norway spruce stands using OBIA, LiDAR and aerial photo based 3D point clouds – a case of study in Koscieliska Valley (Tatra National Park, Poland)

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Keywords: ALS -matching approach, OBIA, detecting of the wind detection; CHM

The upper heights of the forest stands gathered in automatic work-flow from Airborne Laser Scanning (ALS) point clouds has become very important and reference information in studies concerning monitoring of development of the mountain ecosystems. Besides, the 3D very detailed ALS point clouds describing the horizontal and vertical structure of the vegetation and DTM morphometry as well, the another technology – Digital Photogrammetry is offering today complementary data sets. The so called stereo-matching technology based on digital aerial photograph taking with high overlap along the strip and state-of-the-art algorithms searching for same pixel or other features in image domain (eg. SGM alghorythm). Based on this approach the DSM models for forest areas can be generated and the orthophoto as well. Serious problem to use such DSM (point clouds) or deriving the nDSM (CHM) is lack of the ground hidden by dense forest canopy. Therefore the role of ALS data sets is very important as additional information for DTM modelling. In presented study, we proved that Digital Surface Model (DSM) generated from stereo-matched very high resolution (GSD 0.05 cm) aerial images (using PhotoScan; Agisoft) from year 2014 and Digital Terrain Model (DTM) generated from ALS data (ISOK project; GUGiK 2013), could be processed in order to produce a normalized Digital Surface Model (nDSM; in case of forest areas = CHM).

The changes in forest cover after the windstorm damages happen in Koscieliska Valley (Tatra National Park, Poland) at Dec. 25, 2013 were mapped using bi-temporal upper height data from LiDAR (2013; p95) and stereo matching (2014; max. values). Besides, the positions (direction and length) of fallow tree stems were detected using Object-Based Image Analysis (OBIA) approach and generated orthophoto. The characteristics of the windstorm areas a specially wind direction were analyzed using OBIA (eCognition). The results showed that the windstorm of Dec. 25, 2013 destroyed 47,4% of 110,52 ha of Norway spruce forest in test area. The gaps located among Norway spruce stands added up to 17,4 ha, which represents the 15% of the wooded test area. Additionally aerial orthophoto from 2009 suggested that these forest gaps were previously caused by natural factors also like wind and bark beetles. Automatic detected on the high resolution aerial photos laying or hanging Norway spruce stems were overthrown pointing mostly to north (azimuth 2 degrees) without any relationship to terrain morphology. The detection of windthrow was useful for assure the northern direction of destructive foehn wind in Tatra Mountains and the nDSM models coming from different sources (LiDAR, stereomatching) may be taken into consideration for detecting similar damages in forest stands. This open the new opportunity for using low-cost technologies like drones airborne campaigns and stereo-matching approach for continuous monitoring of mountains ecosystems.

ID: 27 / TAS_3_B: 5

Applying Time-Series Analysis on Multi-Sensor SAR Data and Optical Satellite Imagery to Map Forest Disturbances and Forest Degradation in the Republic of Congo

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Keywords: time-series analysis, multi-source RS data, forest degradation, Sentinel-1

The launch of the Sentinel satellites has significantly increased the temporal density of available high resolution satellite datasets. These datasets can significantly improve forest monitoring tools, but they require new strategies for analysis. Hence, the inclusion of time-series analysis methods in forest monitoring has become one of the most challenging topics in remote sensing of forestry. At a tropical forest test site in the Republic of Congo we use multi-sensor satellite datasets of both Synthetic Aperture Radar (SAR) and optical imagery to derive forest degradation and forest disturbance maps for 15 years. The SAR datasets include data from Sentinel-1 (C-band), ALOS PALSAR (L-band) and TerraSAR-X (X-band), while optical datasets include Landsat, SPOT-4/5, ALOS AVNIR and RapidEye imagery. First, tools for automatic image co-registration and image stacking were developed and validated. Second, pre-processing operations were applied, including multi-temporal filtering of the SAR data and a radiometric calibration of the optical image stack. In a third step, time series analysis tools were investigated and applied to the image stacks. Time-series analysis for SAR data is based on backscatter changes over time at both pixel level and for image segments. Temporal trajectories of backscatter are derived at pixel and segment level. For optical time series analysis, a spectral mixture analysis is applied and temporal trajectories of reflectance are derived at pixel level. Temporal behaviour curves for degraded and non-degraded forest areas are then determined on the basis of VHR data and forest degradation and forest disturbances are mapped based on best fit models by moving over the temporal trajectory. The resulting forest degradation and disturbance maps are validated with VHR data by applying a two-stage sampling for accuracy assessment and area estimation of forest cover changes.

ID: 140 / TAS_3 _B: 6

Analysis of land cover change and deforestation in the province Ngounie (Gabon) during the period 2003-2013

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Keywords: remote sensing; land-cover analysis; deforestation; Landsat ; South-west Gabon.

The Congo basin is one of the richest world ecosystems in terms of biodiversity, extending into the territories of Gabon, as well as small portions of the both Congo, Equatorial Guinea, RCA and Cameroon. Understanding this system is very important because in order to preserve it is necessary to understand. Thus, using ETM+ and OLI Landsat images, the present work aimed to estimate the trend and the rate of changes in land covering and the occurrence of successional vegetation land cover class in the Ngounie province (South-west of Gabon) between the years 2003 and 2013, evaluating the NDVI and the NDWI indices and the capacity of these images to identify changes in land cover. The study area used was choosed around the city of Mandji in the north-west of the Ngounie province. The method used for image classification was the supervised classification. Finally, the results were compared with global forest and deforestation products (Global Forest Change University of Maryland). As a result we identified a decrease in forest vegetation and an increase in grassland areas during the studied period.

ID: 87 / TAS_3 _B: 7

Assessment of WorldView-2 images for identifiacation of the bark beetle damages in the Tatra National Park

Bogdan Zagajewski[1], Piotr Rębiś[1], Tomasz Zwijacz-Kozica[2], Marlena Kycko[1], Adrian Ochtyra[1], Adriana Marcinkowska-Ochtyra[1], Anna Jarocińska[1], Marcin Bukowski[2], Magdalena Zwijacz-Kozica[2]

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Keywords: WorldView-2, bark beetle, Tatra National Park, forest, condition

The goal of this presentation is an assessment of WorldView-2 images and Support Vector Machine algorithms for identification of bark beetle damages in the Tatra National Park.

The research method consists of following stages:

- a WorldView-2 image was atmospherically and geometrically corrected basing on the ASD FieldSpec 4 spectra of dominant calibration targets and the ALS data,
- a set of remote sensing indices (NDVI75, NDVI85, reNDVI76, reNDVI86, GNDVI73 GNDVI83 SAVI75) was calculated,
- basing on the field mapping 52 894 pixels were selected as the reference and validation patterns of healthily and damage forests,
- creation of buffer zones (0-5 m, 5-25 m, 25-50 m) surrounding the bark beetle damage polygons,
- classification of WorldView-2 images according to the forest in good, middle and damages areas,
- accuracy assessment (fusion matrix, kappa, overall, producer and user accuracies).

The results of analyses showed a high accuracy of classification and field mapping, because basing 146 127 reference pixels, the overall accuracy oscillated around 92%, and kappa coefficient: 0.89. The nearest buffer to the damaged areas scored lower values (~10%) of vegetation indices comparing other areas of healthy forests, which achieved optimal ranges of all indices. Details will be presented during the conference.

ID: 13 / TAS_3 _B: 8

Detection of changes in health state of spruce stands using airborne and satellite data

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Keywords: forest health indicators, hyperspectral data, satellite data

Monitoring of forest health and its methodologies are in the forefront of interest both to scientists and forest managers. This study aims to contribute to evaluation of the potential of airborne hyperspectral and satellite multispectral data for identifying the forest health status. It has two objectives: 1/to investigate how well the indicators of spruce forest health assessed from field inventory can also be detected using selected parameters from hyperspectral airborne and multispectral satellite data; 2/to evaluate changes in spruce forest health status based on time-series hyperspectral airborne and multispectral satellite data.

The study area is located in Beskydy Mountains, the North-East part of the Czech Republic, with dominated species of Norway spruce. Airborne hyperspectral data (range of 0.4 – 1 μm, 65 spectral bands, and spatial resolution of 5 m) were acquired in summer of 2010, 2013 and 2015 for the study area. In additional, satellite Landsat TM/ETM scenes were downloaded for the dates. Field work included a repeated assessment of several forest tree and stand health indicators for 68 spruce- dominated plots (S = 500 m^2) in 2010, 2013 and 2015. Additionally, various tree indicators were combined and used as integrated parameters of tree health status.

First, atmospheric correction of airborne and satellite data was performed. Second, selected narrow-band and broad-band VIs related to greenness, water content, leaf pigment and light use efficiency were calculated from airborne and satellite data. Third, an exergy of solar radiation parameter – a measure of changes between an equilibrium state and an actual state of the ecosystem – was estimated from satellite data for the study period. Finally, statistics were employed to analyse the relationship between parameters from RS data (VIs and exergy) and spruce forest health state indicators (and combinations) from field measurements.

Most of the tested VIs could not detect the indicators of spruce forest health with adequate accuracy. However, three VIs from airborne hyperspectral data (PRI, WBI, $NDVI_{red\_edge}$) were identified as good correlated (with r of 0.76, 0.81, 0.79) to three indicators from field (DryTreeTop, combination of 6 indicators, IndexColor), respectively. The only one VI from satellite data (PSRI) had a moderate correlation (r = 0.74) with DryTreeTop indicator from field. We found that exergy variations were strongly correlated (r = 88) with health decline of spruce forest stands estimated from the field data in 2010, 2013 and 2015. These findings could be potentially applicable to the analysis and monitoring of the forest ecosystem health.

ID: 66 / TAS_3 _B: 9

Mapping of standing dead trees with use of various remote sensing data for bark beetle management in Białowieża Forests

Krzysztof Stereńczak, Żaneta Ciarka, Małgorzata Białczak, Aneta Modzelewska, Bartłomiej Kraszewski, Miłosz Mielcarek, Rafał Sadkowski

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Keywords: outbreaks, bark beetle, dead tree detection

In Europe the most important Spruce insect, causing large outbreaks, is Bark beetle (*Ips typographus* L.). Apart from killing trees, heavy thinning caused by bark beetles resulting that in few years after attack stands are more vulnerable to damage from atmospheric factors (i.e.: wind, snow). Because of its economic importance forest management need to be able to use methods and technics supporting counteraction against bark beetle. First and most needed information is a spatial range and distribution of infected trees. Remote sensing is a technic which can support in effective way traditional field patrols or even replace them on large and difficult areas. Additionally, they can and provide detailed maps of outbreaks which help in their management. In presented study, carried out in Polish part of Białowieża Forests (about 620 km^2), we used ALS, airborne hyperspectral and high resolution satellite data for dead tree detection. The ALS dataset was acquired with an average point density of 6 pts./m^2. The flight was performed between 2-5 of July 2015 with the Riegl LMS-Q680i scanner at a flying height of 500 m above ground level. The hyperspectral data used in the research was HySpex VNIR-1800 images with 2.5 m spatial resolution collected between 1-4 of July 2015. Satellite data was collected on June 27, 2015 using Pleiades 1A satellite. Multispectral image has 4 bands (VIS and NIR) and 2 m spatial resolution. We created maps of outbreaks and evaluated data regarding to its use for single dead tree detection. From ALS data CIR raster (0.5 m) was generated (based on vegetation point class) and then Maximum Likelihood Classification was carried out. As a result of classification the four classes (1 – dead trees, 2 –coniferous trees, 3 – deciduous trees, 4 – shadows) were identified with the overall accuracy 93.7% and Kappa - 0.92. To indicate dead trees on hyperspectral data Modified Red Edge Normalized Difference Vegetation Index ($mNDVI_{705}$) was calculated. Basing on its values images were classified into two classes – vegetation and non-vegetation. Non-vegetation are mostly standing dead trees and gaps. Gaps were masked with use of ALS data. The overall accuracy reached 97% and Kappa Coefficient – 0.93. A Maximum Likelihood classification was used to analyze dead trees of the Białowieża Forest on satellite images. Image was classified into 3 classes – dead trees, coniferous and deciduous trees. Then a class of coniferous and deciduous trees were merged dividing area of research into dead and vivid trees. The overall accuracy of classification is 96%, Kappa 0.92. Depend on spectral resolution and additional data used (gap mask) discussion of disadvantages and advantages of all datasets was carried out.This work was financially supported by the Project LIFE+ ForBioSensing PL Comprehensive monitoring of stand dynamics in Białowieża Forest supported with remote sensing techniques is co-funded by Life Plus (contract number LIFE13 ENV/PL/000048) and The National Fund for Environmental Protection and Water Management in Poland (contract number 485/2014/WN10/OP-NM-LF/D).

TAS_3 _C: Thematic Abstract Session 3 - Image-Based-PointCloud & Forest inventory

Time: **Thursday, 15/Sep/2016: 4:30pm - 5:30pm**
Location: **Lecture room 3 - "C"**

Session Chair: **Piotr Tompalski**
University of British Columbia, Canada
Session Chair: **Lars T. Waser**
Swiss Federal Research Institute WSL, Switzerland

ID: 35 / TAS_3 _C: 1

Practical tools for forest height estimation from TanDEM-X coherence data

Jaan Praks[1], Aire Olesk[2], Oleg Antropov[1,4], Karlis Zalite[3], Kaupo Voormansik[3]

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Keywords: Forest height, SAR interferometry, TanDEM-X

Tree height is one of the central and most important forest variables, and significant efforts have been made to retrieve this parameter from spaceborne sensors for large areas. Typical levels of accuracy still appear not sufficient for operational forest management.

One of the most promising tool for forest mapping from space is Synthetic Aperture Radar and interferometric SAR imaging. It has been demonstrated that fully polarimetric SAR images can be used in conjunction with physical models to retrieve forest height with good accuracy. Unfortunately, fully polarimetric data is not widely available and the model inversion process is complex. It is also demonstrated that interferometric coherence has clear correlation with forest height but the correlation itself is often not sufficient for forest height retrieval without a priori information or reference data.

In this work we propose simple yet robust model based framework and associated set of tools (models) for forest tree height retrieval from TanDEM-X interferometric images even without a priori information.

Our work is based on extensive analysis of 17 TanDEM-X image pairs from years 2010, 2011, 2012, collected over hemiboreal forest sites in Estonia. Our reference data were represented by more than 3500 forest stand measurements, measured during various seasons, and extensive LiDAR dataset have been used to validate the approach.

Based on analysis we propose three simple models which could be used for forest height retrieval even without additional empirical parameter adjustment. Also additional parameterization is discussed and accuracy benefit which can be achieved is evaluated for every model in different conditions. Particular considered factors are influence of different tree species and seasonal and weather conditions during image acquisition. The models are based on Random Volume over Ground model which forms the theoretical framework for the in-depth InSAR coherence data analysis.

The work provides practical tools for evaluating achievable accuracy, gives probability distributions for model parameters and discusses the most favorable weather conditions and image acquisition scenarios for forest height retrieval from TanDEM-X interferometric images. We demonstrate that in the best conditions the stand average height can be retrieved within 1-3 m accuracy from TanDEM-X images with relatively simple algorithms.

ID: 24 / TAS_3 _C: 3

Calculation of mean forest vegetation height in Tanzania from Landsat time series and airborne laser scanning data

Øivind Due Trier[1], Terje Gobakken[2], Arnt-Børre Salberg[1], Dagrun Aarsten[3], Erik Næsset[2]

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Keywords: Tropical forest monitoring, forest change mapping, airborne laser scanning

This paper describes a new method for the automatic mapping of forest cover and forest cover change in Tanzania from Landsat 30 m resolution multispectral satellite images. The estimates are produced as yearly estimates of average vegetation height for each pixel location.

The current rate of deforestation in tropical regions needs to be reduced in order to decrease CO_2 emissions and preserve biodiversity. Advances in remote sensing methods are needed in order to accurately estimate the state of the forests and how they change over a number of years.

The proposed method consists of the following processing steps: (1) cloud masking, (2) scaling of digital numbers to top-of-the-atmosphere reflectance, (3) computation of the specific leaf area vegetation index (SLAVI), (4) estimation of vegetation height, (5) Kalman filtering to reduce the variance of the estimates, and (6) calculation of change maps between any two years.

By using airborne laser scanning (ALS) data and Landsat-8 data from 2014, a regression between average vegetation height and the SLAVI vegetation index is established. If only one Landsat image is used, then the variance is high. However, by using all available Landsat acquisitions of the same area within one year, and producing a yearly estimate of vegetation height, the variance is reduced. The variance is further reduced by applying Kalman filtering on the sequence of yearly estimates from 1985 to date.

From the smoothed time series of yearly average vegetation height at each pixel location, difference maps may be extracted to map forest change. Clear-cuts documented by repeated ALS acquisitions in 2012 and 2014 are reproduced in the forest change maps from Landsat. This indicates that the proposed method may be used to map forest change in large areas for which (repeated) ALS data acquisition cannot be afforded, and to map historical change.

The accuracy of the method is limited by the number of cloud free Landsat observation of each pixel location for each year. For the purpose of accuracy assessment, the variance of the yearly average vegetation height is produced for each pixel location. From this, variance maps may be produced also for the change maps, and may be used to mask areas in the change maps with high variance in order to detect false change events.

The method has been implemented in an automatic processing chain. The method may be modified to be used on Sentinel-2 satellite images of 10 m resolution.

All in all, we have demonstrated that estimation of mean vegetation height is possible from dense time series of optical satellite data. However, smaller variances of the calculated yearly average vegetation heights are needed. With better resolution and higher acquisition frequency, Sentinel-2 may provide exactly that.

ID: 77 / TAS_3 _C: 4

Ziyuan-3 combined multispectral and stereo data analysis to derive Forest Structure Information

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Keywords: forest monitoring, Ziyuan 3, forest structure, spectral singnature, angular signature

With focus on the strategically /tactical level of a forest enterprise Schneider et al. (2013) recently proposed a “Remote Sensing based Monitoring System” integrated in a decision support system for the “Forest-Wood Chain”. An annual update at the 1:10.000 mapping scale of the forest data bases is suggested on base of multi-seasonal high resolution satellite data. The features to be regularly updated were ranked according to the results of a user requirement project employing scientists, administrative and local level forest practitioners (Felbermeier et al., 2010). The mostly required information was on forest area, forest type (coniferous, deciduous, mixed) related to stand or property plot area, gaps, tree species, standing stock or standing volume and, of course, calamities.

In case of forest area and forest type Elatawneh et al., 2013 proved that with a multi-seasonal approach even changes of less than 0,01 ha can be detected with high accuracy. Much more difficult is the task of obtaining information on standing stock or volume, connected more to the vertical structure. For this information typically allometric functions are employed, relating age and height site specific.

The research presented is investigating the option of deriving forest structure information from satellite data of the Chinese Ziyuan 3 satelllite system. ZY-3 combines three line stereo acquisition by two pan 3,5m front- and rear-facing cameras and a pan nadir looking 2,1m resolution camera with a four spectral band module at 5,8 m spatial resolution. The pan cameras cover the spectral range from 0,5 to 0,8 µm, the ms bands the region from 0,45-0,52 µm (blue), 0,52-0,89µm (green), 0,63-0,69 µm (red) and 0,77-0,89 µm (NIR). With an inclination of 97,421 and a revisit frequency of 5 days the system offers interesting specifications even for multi-seasonal observations under the cloud conditions as prevailing in Mid Europe.

With a three line stereo data set height estimations are possible by applying three methods:

- Shade length evaluation
- Displacement of edge pixels in the image plane of the two stereo bands (and the nadir band)
- Stereo matching technique for DSM and nDSM calculation

Additionally the three line stereo data are analyzed to derive an angular signature, which is related to the anisotropy of scattering, an intrinsic property of each Earth surface. The different methods applied are ratio based:

- ANIF (forward/nadir, backward/nadir)
- AR (anisotropy ratio, forward/backward stereo band)

Finally the well-known multispectral band information is combined with the anisotropy information and the height information with the scope to derive the forest relevant parameter forest type (on stand basis), mean stand height and STD within the stand, stand age classes (<12 m, 12-24m, >24m), gaps, etc.. Verification of the results of parameter extraction is done by field survey. LIDAR and aerial photograph evaluations.

The relevance for interim forest inventories (monitoring) and forest management in general is discussed.

ID: 139 / TAS_3 _C: 5

GEOBIA approach of Scots pine crowns segmentation based on CHM generated from aerial photos and ALS point clouds

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Keywords: : structure from motion, segmentation, Cognition Network Language

The aim of the study was to analyze the usefulness of Canopy Height Models (CHM) generated from image derived and Airborne Laser Scanning (ALS) point clouds in tree crown delineation. The study was conducted in Scots pine stands in the area of “Bory Tucholskie” Nation Park in northern Poland. The investigated stands are characterized by high stem density comparing to managed forests. For creation of CHMs the color infrared (CIR) aerial images (GSD: 0.30 m) and ALS point clouds (4 points/square meter) were used. The image derived point clouds and orthophotos were generated in the Agisoft Photoscan software using structure from motion method. Canopy Height Models from image-based point clouds (CHM_IPC; GSD: 0.30 m) and ALS data (CHM_ALS; GSD: 0.75 m) were created using FUSION software. For normalization of heights to the height above ground the Digital Terrain Model (DTM) generated from ALS data was used. Tree crown delineation was performed in the eCognition Developer software. A customized segmentation algorithms for crowns delineation was created thanks to capabilities of Cognition Network Language (CNL). In case of ALS data the segmentation algorithm used only the information from CHM_ASL data whereas in case of aerial images besides height information (CHM_IPC) also the spectral information form CIR orthophoto was used. To assess the accuracy of crown delineation the data from 50 field plots were used (10 440 trees). The field plots were located in a way to represent the whole range of stands with age from 20 years to older than 180 years. Performed analysis indicated that in stands younger than 120 years, better results can be achieved using CHM_IPC whereas in very old stands (age > 120) the accuracy of crown detection is higher when using CHM_ALS. Mean percentage error of number of delineated crowns calculated from 50 field plots amounted to MPE=5.20%. Obtained results shows that CHMs generated from image derived point clouds can successfully replace the CHMs created form relatively expensive ALS data in the context of tree crown delineation of Scots pine stands.

ID: 89 / TAS_3 _C: 6

Fingerprinting Three Decades of Changes in Interior Alaska, USA (1982-2012) using Stereo Air Photos

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Keywords: Stereophoto, aerial photography, orthorectification, Agisoft, Alaska, vegetation change, climate change

The distribution and growth of vegetation is strongly controlled by climate, particularly at high northern latitudes where the strongest warming trend during the era of satellite observations (1972-present) has occurred. This trend has lead to climate driven changes in vegetation growth, mortality, and geographic distribution, in addition to increased fire and insect disturbance. Studies of vegetation at high northern latitudes using Landsat data have shown stable forest boundaries, however fine-resolution photo time series have revealed increased growth and slow expansion of trees and woody shrubs in tundra areas. We are using a multi-temporal, multi-scale approach including field plots, low-altitude aerial photography, imagery from NASA Goddard's Lidar Hyperspectral, and Thermal (G-LiHT) airborne imager, and Landsat imagery to analyze vegetation changes in the Tanana Valley of Alaska, USA. Aerial photography was collected as part of the US Forest Service Alaska Integrated Resource Inventory System (AIRIS) over 161 plot locations in color infrared photography 1982 and again in true color photography in 2012, which covers a critical period of climate warming and environmental change in this area. I will discuss how we are using Agisoft Photoscan and available satellite imagery to orthorectify both sets of aerial photos. These stereophotos will be used for interpretation and photogrammetric measurement to characterize climate driven changes, including: shrub and tree establishment, mortality, species replacement or succession, changes in surface hydrology, and the impacts of increased fire and insect activity. I will present some initial observations of environmental changes from our stereophoto dataset, discuss challenges in using historical aerial photos in Alaska, and provide an overview of how these images will be used to direct field plot measurements and other imagery (G-LiHT and Landsat) analyses over the next two years.

ID: 56 / TAS_3_C: 7

Supporting forest inventories via satellite derived height and spectral data

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Keywords: RapidEye data, Cartosat-1, forest inventory, sampling design, height information, segmentation, centre of gravity

Every ten years an inventory is recommended in the forestry sector of Bavaria, especially in the state-owned and municipality forests. The most expensive part in such inventories is the field work due to the high labour intensity. Auxiliary data especially from remote sensing systems have the potential to support forest inventories, due to the high repetition rate and large-scale area coverage. Based on a former study, using RapidEye satellite data, a new sampling design was established to locate sampling units at the centre of gravity of segments (Wallner et al. in preparation). This study triggered a further research question: Is the inventory precision of the segment-based sampling design compared to a grid-based sampling design influenced by different segment sizes. The following hypothesises were developed:

H1: Different segment sizes used for the segment-based sampling design do not have an influence on the precision of the inventory in comparison to a grid-based sampling design.

H2: Implementing height information from satellite data (e.g. Cartosat-1) within the segmentation procedure shows no improvement of the segment-based sampling design compared to the segmentation without height information.

The study is conducted within the municipality forest of the city of Traunstein in the south-eastern part of Germany. The following satellite datasets were available for this study: RapidEye data (2009) and a digital surface model based on Cartosat-1 data (2008). Grid-based estimations were available as derived from an area-based modelling of the standing timber volume. These estimations of the standing timber were generated with a parametric regression approach by selecting spectral values from the RapidEye data (Wallner et al. 2015). The main goal of this study is to analyse the influence of the segmentation with respect to the precision of the segment-based sampling design. The approach consists of three steps. Firstly, an object-based segmentation will be applied to the RapidEye data. Moreover, a surface model derived from Cartosat-1 data will be tested for the segmentation. Secondly, a statistical analysis of the different segmentation approaches will be carried out. And thirdly, a sample size simulation and a comparison of the precision between grid-based and segment-based sampling will be conducted.

For the first step an object-based segmentation will be done with the multiresolution segmentation algorithm implemented in the software package eCognition© Developer 8. Different segment sizes based on the segmentation parameters scale, shape and compactness will be tested. The second step includes the statistical analysis of spectral and height values of the used satellite systems. For the third step a Monte-Carlo-Simulation will be conducted to simulate different sample sizes. The precision is examined in terms of bias and standard error to find out the differences of the sampling designs.

ID: 19 / TAS_3_C: 8

Transferability of image-based models for timber volume estimation at plot level

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Keywords: photogrammetric point cloud, timber volume, modelling, transferability, national forest inventory

It is widely accepted that forest inventories can benefit from integrating remote sensing techniques, which is supported by results of various research projects. However, this has not yet resulted in an increased adoption of remote sensing for national forest inventories (NFIs) in Europe. Remote sensing is either not applied at all or plays a minor role only. The latter case usually comprises aerial imagery being utilised for preliminary work, such as classifying forest and non-forest areas or forest type by visual image interpretation.

Aerial imagery in particular has great potential for the extraction of information relevant to NFIs. The availability of dense image matching algorithms allows generating photogrammetric point clouds that are suitable for 3D forest attribute (e.g. height, basal area, volume) estimation, comparable to airborne laser scanning (ALS) point clouds. However, acquiring photogrammetric point clouds is more cost-efficient and additionally provides multi-spectral information. One crucial issue is the effect of image data acquisition conditions on the reliability of forest attribute estimates, which has a direct impact on the transferability of forest attribute estimation models.

The presented research is conducted within the EU Horizon2020 project DIABOLO and investigates the level of transferability of image-based timber volume estimation models. The study area covers the southern parts of the Black Forest and the Upper Rhine Plain. Stereoscopic image data of the study site was acquired during the regular aerial surveys of the Baden-Württemberg land surveying authority (LGL). Therefore, the data is divided in three lots, each lot acquired on differing days in 2012 and 2013, respectively. This provides variations in flight related (e.g. illumination, solar angle) and site related (e.g. elevation, slope, forest type) imaging conditions, allowing assessment of their effect on timber volume estimation models. Photogrammetric point clouds for each lot are derived by means of dense image matching, serving as basis for calculating canopy height models (CHMs) for the forested areas of the study site. Metrics derived from the CHM and plot-level volume data of the latest NFI in Germany (BWI3, conducted 2011/12) are combined in a regression model. Modelling is conducted for each lot separately and the resulting models are compared to each other. The models are also transferred to the respective other lots for wall-to-wall plot-level volume mapping. The achieved accuracy is assessed using enterprise inventory data and results are evaluated with respect to the various data acquisition conditions.

The results of this research will help to better understand the effects of imaging conditions on forest volume modelling and indicate the limitations of transferring models between geographic regions and image data sets. This knowledge will support NFI harmonisation efforts in Europe, which is the principal aim of DIABOLO.

ID: 129 / TAS_3_C: 9

Measuring tree diameters with close-range photogrammetry

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Keywords: Close-range photogrammetry, dbh, image optimization

Breast height and upper diameters (dbh, du) are descriptors of stem taper and allometry. Therefore, they are input parameters to estimte tree volume and biomass and their measurement is essential in forest inventories. In this study, three different approaches to measure dbh are compared with a caliper as reference for 50 trees in south eastern Norway. The measurements were done with: (1) images taken all around the tree and from bottom to top with a single reflex camera handheld (SRCH) holding a constant distance to the tree, (2) a Criterion dendrometer (CRD), (3) a handheld Gator Eye caliper (GEC).

Main processing steps for close-range photogrammetry data were automated using Python scripting in Agisoft. Afterwards, dbh was measured in the produced 3D dense point clouds using open source software and compared with the reults from the other devices.

Preliminary analysis for dbh resulted in root mean squared deviances (RMSDs) of 9.8 mm and 8.2 mm for CRD and GEC, respectively. Systematic deviances were less than 2 mm for both methods. First analysis of the close-range photogrammetry data was promising, as the level of detail of resulting point clouds is similar to data generated by terrestrial laser scanners. The photogrammetric method allows for the documentation of the trees' status and future re-processing with more advanced methods. However, the number of pictures taken would need to be optimized to save time and storage capacity in most forest inventory settings. Random and systematic deviances of the measurements based on the different methods will be compared and discussed.

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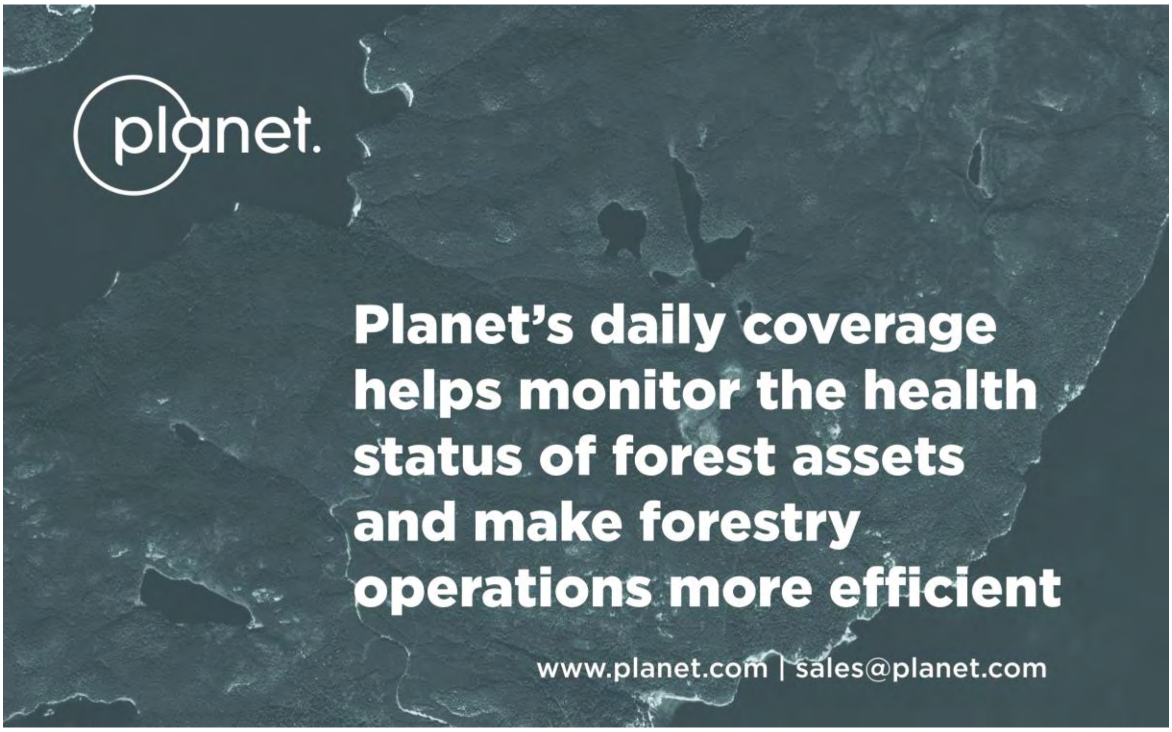

PLS-4: Plenary session Nº 4

Time: **Thursday, 15/Sep/2016: 5:30pm - 6:00pm**
Location: **Main AULA - "A"**

Session Chair: **L. Monika Moskal**
University of Washington, United States of America
Session Chair: **Piotr Wezyk**
University of Agriculture in Krakow, Poland

ID: 149 / PLS-4: 1

Taming the cloud: Creating workflows for processing large LIDAR acquisitions using FUSION

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Keywords: ALS data processing

LIDAR has emerged as a method to collect measurements useful for characterizing forest structure over large land areas. LIDAR has become an acceptable data source for forest inventory where field data can be used to model relationships between LIDAR measurements and inventory variables. However, the sheer size of data acquisitions makes the derivation of high-resolution metrics challenging from a computational and data management standpoint.

FUSION was developed as an exploratory tool to help people understand what is and is not measured by LIDAR. The FUSION suite of tools, first released in 2006, consists of an interactive data exploration system and a set of command line tools that can be linked together to perform complex analyses. The interactive tools have helped many people learn about and better understand LIDAR and the command line programs and workflow tools have made it possible to process the billions of point measurements associated with an acquisition into wall-to-wall GIS layers containing a variety of statistical metrics and other products computed from the point cloud. FUSION was first developed to meet the needs of my research group. We were frustrated by the lack of tools to work with the large data sets typical of LIDAR acquisitions and found that commercial GIS offerings could not meet our needs. FUSION has evolved over its 10 year life into a robust set of tools designed with forestry in mind and capable of processing the point and surface data associated with large acquisitions.

The latest release of FUSION includes a new workflow tool called AreaProcessor. Earlier versions of FUSION included the LTKProcessor workflow tool but it did not work well with the large data sets typical of current acquisitions. AreaProcessor is designed to produce scripts that organize and automate processing tasks to produce a standard set of canopy height models, intensity images, topographic attributes, and point cloud metrics. The scripts produced by AreaProcessor take advantage of multi-core architectures and can be restarted to complete processing tasks when something fails or an unexpected system reboot occurs. Processing status is monitored using a graphical display tool that shows the progress of all processing threads. Outputs from the workflow are organized into GIS-ready products making it relatively easy to deliver final products to end users. The tool includes utility scripts that produce a useful set of final products but users can modify these scripts and use the workflow to include any FUSION tools as well as any other LIDAR processing tools the user cares to use. The new workflow tool has been used to process several large acquisitions covering up to 100,000 ha. However, the tool should is capable of generating workflows to support processing for much larger areas. The latest release of FUSION (version 3.60) can be found here: http://forsys.sefs.uw.edu/fusion/fusionlatest.html (the old server link: http://forsys.cfr.washington.edu/fusion/fusionlatest.html also works).

PLS-5: Plenary session Nº 5

Time: **Friday, 16/Sep/2016: 9:00am - 10:00am**

Location: **Main AULA - "A"**

Session Chair: **Bogdan Zagajewski,**
University of Warsaw, Faculty of Geography and Regional **Studies, Poland**
Session Chair: **Piotr Wezyk,**
University of Agriculture in Krakow, Poland

ID: 150 / PLS-5: 1

Very high resolution laser scanning point clouds from UAV for single tree analysis

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Keywords: UAV

In recent years airborne laser scanning moved towards higher and higher point densities because of very high pulse repetition rates and multiple pulse in air techniques. Still, in complex forests single tree detection reaches its limits, even with 10 or 20 points per square meter. The "terrestrial lidar view", laser scanning from static scan positions, provides highly detailed models of trees with their individual branches, but with a limited coverage. Additionally, the point density varies by order of magnitude, depending on the distance from the scan position.

Laser scanning from unmanned, low flying platforms, fills this gap, providing highly detail point clouds because of the close range. Because of the more or less linear move of the platform, the point density is much more homogeneous and much faster than from terrestrial acquisition. Using low flying height above the canopy also side-views into the canopy are realized, providing a more homogeneous coverage from ground to top. Area coverage is still lower than laser scanning from manned flying platforms and limited because of the relatively short flying time of the unmanned platforms.

The possibility to measure, rather than empirically model, geometric attributes of individual trees in the point clouds of unmanned aerial laser scanning is demonstrated.

ID: 151 / PLS-5: 2

Characterizing Biophysical Properties of Forest Canopies with Hyperspectral Imaging Systems – Research Challenges and Perspectives

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Keywords: Hyperspectral

It is commonly agreed that, in comparison to using advanced multi-spectral imaging systems (such as Landsat-OLI or Sentinel-2) for observing forest ecosystems, the potentially largest improvements to be expected from hyperspectral imaging systems are in the field of quantifying forest canopy traits. Given the complexity of tree canopies, it is less evident what the best approach for successfully extracting information on biophysical properties of ecologically relevant parameters is. In principle, the use of geometric-optical reflectance (GORT) models is preferred in comparison to empirical approaches, primarily because of the complexity associated with collecting valid reference data in forest ecosystems and the limited transferability of such empirically derived models to other study cases.

While various GORT models are capable of simulating forest canopy reflectance to a quite satisfactory level, their successful inversion is much more complex, owing to ill-posed problems because of the relatively high number of model parameters required to account for complex tree canopies. Therefore, and because meanwhile large quantities of airborne hyperspectral image data sets with associated reference data collections have become available, research has recently focussed on the question to which extent empirical models can be generalized and thus transferred to different settings in terms of forest types and locations. In spite of the progress reported, the use of empirical relationships involves several complications, the most important of which relate to separating leaf and canopy effects.

In this presentation, we shall review these key issues with respect to extracting key biophysical parameters (such as N concentration) and indicators for water stress phenomena in forest stands, which recently have increased both by number and affected regions.

PLS-6: Plenary session Nº 6

Time: **Friday, 16/Sep/2016: 1:00pm - 3:00pm**
Location: **Main AULA - "A"**

Session Chair: **Bogdan Zagajewski**
University of Warsaw, Faculty of Geography and Regional Studies, Poland
Session Chair: **Piotr Wezyk**
University of Agriculture in Krakow, Poland

ID: 153 / PLS-6: 1

Remote Sensing Based Riparian Forest Assessments

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Keywords: ALS, riperian, ecosystem services

Rivers and the riparian forest corridor comprise a valuable freshwater ecosystem that has been altered by human activities including timber management, road building, and other land conversions. The habitats of river dependent species in the United States Pacific Northwest, in particular salmon, have often been degraded by these activities. Many salmon runs have become threatened with extinction and have been Endangered Species Act listed. New conservation planning and policies have developed around protecting freshwater habitats and restoring more natural river processes. In Washington State, timber landowners, officials from State and Federal agencies, Native tribes, and other stakeholders developed Forest Practice rules and codified a Habitat Conservation Plan with dual goals of providing regulatory surety for timber land owners and helping to recover the threatened salmon runs in forested watersheds. Conserving critical stream ecological functions and potential fish habitats throughout watersheds while managing and regulating timber harvest across the State requires accurate and up-to-date delineation and mapping of channels, tributaries, and off-channel wetlands. Moreover, the thermal loading of the streams, attenuated by forest cover shading and the large woody debris recruitment into the stream impacting water oxygen loads need to be effectively monitored. Precision forestry has turned to lidar technology for forest inventory assessments, this same technology can be further leveraged for riparian assessments. This presentation includes summary of multiple research project combining: the appraisal and delineation of off-channel and active channel water features; the assessment of leaf area index (LAI) and canopy shading, and; the quantification of large woody debris recruitment in riparian zones. Moreover, the assessment of the accuracy of the lidar is compared to other remote sensing techniques such as aerial and satellite stereo and non-stereo imagery. The work aims at assisting various agencies in monitoring effectiveness and protection efforts in both day-to-day implementation of Forest Practice rules and adaptive management.

ID: 154 / PLS-6: 2

Forest parameters with X-band SAR interferometry?

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Keywords: RADAR

Synthetic aperture radar (SAR) is increasingly used in forest remote sensing due to its ability to relate the measurement signal directly to structural parameters of the forest canopy. It has been shown long ago, that the backscattered signal amplitude is related to forest biomass. However, the relation is rather strongly dependent on imaging conditions and the relation saturates for relatively low stem volume values for shorter wavelength systems. For example, most common C- and X-band radars which have the optimal size and resolution, are not considered suitable for biomass measurement by using just the backscattered signal.

Recent advancements in SAR imaging and new techniques, such as polarimetry and interferometry, have opened new opportunities for also forest remote sensing. For example, it has been shown that polarimetric interferometry and advanced models allow model inversion which can produce also rather accurate forest height estimate. It is also shown, that this technique works for surprisingly short wavelengths and allows height estimation even for X-band high resolution SAR. Unfortunately, the technique required polarimetric data which is not widely available and also quite complicated model inversion process, which hinders the practical use.

Our latest results show, that despite the doubts, X-Band spaceborne TanDEM-X might be an excellent tool for wide are forest height mapping after all. By using a large multitemporal TanDEM-X interferometric dataset, we were able to identify the best conditions and imaging parameters for tree height extraction and showed, that when conditions are taken into account, even a simple model is sufficient for height retrieval. It his talk, we will give an overview of theoretical background of forest structure and interferometric coherence relation and describe simple tools which allow to derive height estimate from X-band interferometric coherence images.

ID: 105 / PLS-6: 4

GuidosToolbox: Quantitative image analysis of forest patch attributes

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Keywords: image analysis, forest monitoring, spatial analysis

During the past decades, human activities have imposed increasing pressure on our environment, specifically on forested landscapes. Urbanization, conversion to agriculture and large-scale monocultures, deforestation, and the increased amount of forest fires and pest outbreaks are just a few examples highlighting the urgent need for a systematic landscape monitoring scheme to support efficient mitigation measures. Current free and open data policy will have a dramatic impact on our ability to understand how biodiversity and other ecological attributes and processes are being affected by anthropogenic pressures. Space-borne observations are now widely available, providing essential and harmonized information for different thematic questions, across political boundaries, and at multiple scales. They are the most cost-efficient and consistent data source and suitable for the mapping and analysis of different land cover aspects, such as forest pattern, connectivity, degradation, fragmentation, heterogeneity, phenology, and green infrastructure. In order to address this complex task, new developments in remote sensing image analysis should focus on generic and scale-independent assessment schemes suitable to monitor and analyze any kind of digital raster data. The provision of tools for monitoring and especially quantifying the impact of human activities on forest landscapes facilitate the design of efficient and assessable forest resource policies and risk assessment studies.

Status and trends of land cover objects can be described via the quantitative assessment of their spatial attributes. This study illustrates a series of methods and tools for the description and quantitative analysis of a variety of image object attributes, publicly available in the software GuidosToolbox (http://forest.jrc.ec.europa.eu/download/ software/guidos). All concepts are based on geometric concepts only and thus applicable to any kind of raster data and at any scale, for individual analysis as well as batch-processing. The methodologies are designed to detect and quantify several aspects of image objects including, spatial pattern, connectivity, fragmentation, cost, distance, composition, configuration, naturalness, and change analysis. Further generic image processing routines allow for recoding, edge detection, noise removal, convolution, equalization, thresholding, and exporting data as GoogleEarth image overlays. The free and portable software collection is complemented by GDAL command line tools and the powerful OpenEV raster/vector data viewer. Sample applications from a variety of environmental application fields complement this overview. Reliable, generic, and quantitative assessment schemes provide an integrative and solid reference framework. In addition to detecting and highlighting hotspots of changes, the generic image analysis methodologies allow for meaningful statistical analysis. These recent developments are of particular interest for landscape planners and policy decision makers to support operational monitoring needs and to provide tools for measuring, and thus evaluating the progress in projects related to landscape dynamics and ecosystem services.

ID: 164 / PLS-6: 5

New opportunities for high-resolution wall-to-wall forest attribute mapping

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Keywords: Canopy Height Models, Image-based Point Clouds, LiDAR, NFI Plots, Forest Cover Type, Forest Cover Change, Random Forest

Remote sensing-assisted forest attribute mapping is motivated by a wide variety of applications confronting the forest management and conservation sectors. Wall-to-wall forest attribute maps are a fundamental input for the changing requirements of regional and national forest inventories (NFIs). In recent years, optical remote sensing data, and in particular digital aerial images, have been incorporated into operational NFIs and the required estimates obtained from remote sensing-based maps can now be expressed in forms similar to sample-based estimates. However, to our knowledge, there are currently no operational attempts to produce wall-to-wall forest attribute maps in the framework of a National Forest Inventory (NFI) - at least in Europe.

Two novel and highly automated approaches for countrywide forest cover and forest cover type mapping have been developed by the remote sensing group at the Swiss Federal Institute for Forest, Snow and Landscape Research. Moreover, first results of wall-to-wall forest cover change and growing stock mapping in Switzerland are shortly introduced.

The forest cover map is based on digital surface models from image-based point clouds of airborne digital sensor data and digital terrain models from LiDAR data. It fully takes into account the four key criteria of minimum tree height, crown coverage, width, and land use - and thus meets the requirements of the Swiss NFI forest definition. The forest cover map was validated using almost 10,000 terrestrial and stereo-interpreted NFI plots, which verified 97% agreement overall. The presented forest mapping approach is superior to existing products due to its national coverage, high level of detail, regular updating, and implementation of the land use criteria.

The forest cover type map is based on a random forest classification approach using RGBI airborne digital sensor data and over 50,000 digitized polygons of broad-leaved and coniferous trees as training data. The classification approach was applied for 220 subsets covering the entire country, is highly automated, and incorporates original image bands, remote sensing indices and digital surface models as predictor variables. To reduce effects of topography, illumination, and shadows, radiometric correction was initially tested and the set of predictor variables was individually adapted to the specific topography for each of the 225 subsets. 10-fold cross-validation revealed high overall model accuracies (98.6-99.8%) for distinguishing coniferous and deciduous tree species. Validation using independent sample plot data (both terrestrial and stereo-image interpreted) from the Swiss NFI revealed lower accuracies of around 5-8%. For both approaches, validation was refined and incorporates different NFI height levels and productions regions.

The great potential of repeated and routinely acquired aerial imagery and highly automated approaches for generating repeatable and objective wall-to-wall forest attribute maps is presented. These data sets will be of emerging practical relevance in the framework of a NFI, or for other applications that depend on an accurate and detailed countrywide forest attribute maps. Further applications, pros and cons of the current approaches and the used aerial images, alternative remote sensing data and future plans of implementing ensemble modelling approaches are also discussed.

Young Scientist Days on Forestry Conference

Programme of the Young Scientist Days on Forestry Conference, September 15-16, 2016
Venue: University of Agricultural in Krakow
Faculty of Forestry, al. 29 Listopada 46, Krakow

Date: Wednesday, 14/Sep/2016

4:30pm - 9:00pm Registration Desk	**REG-1: Registration 1** Session Chair: **Dr Barbara Czesak**, University of Agriculture in Krakow, Poland Session Chair: **Caileigh Shoot**, University of Washington, United States of America
7:00pm - 9:00pm GeoExpo - Main Hall	**3rd Workshop SIG on Forestry & YSDoF - Icebreaker** Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland Session Chair: **Megan Anne O'Shea**, College of the Environment, University of Washington, United States of America

Date: Thursday, 15/Sep/2016

7:30am - 8:30am Registration Desk	**REG-2: Registration 2** Session Chair: **Caileigh Shoot**, University of Washington, United States of America
8:30am - 9:00am Main AULA - "A"	**OC: Opening Ceremony** Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America
9:00am - 10:00am Main AULA - "A"	**PLS-1: Plenary session No 1** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
10:00am - 10:30am Upper Hall 1	**BR-1: Coffee break 1**
10:30am - 12:00pm Workshop room V EDU	**YSDF_O_1: Young Scientist Days on Forestry – Oral presentation 1** Session Chair: **Adrian Ochtyra,** University of Warsaw, Poland Session Chair: **Paweł Hawryło**, University of Agriculture in Krakow, Poland
12:00pm - 1:00pm Upper Hall 1	**BR-2: Lunch break**
1:00pm - 1:30pm Main AULA - "A"	**PLS-2: Plenary session No 2** Session Chair: **Dr Thomas Schneider**, Technische Universität München, Germany Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland

1:30pm - 3:15pm Workshop room V EDU	**YSDF_O_2: Young Scientist Days on Forestry – Oral presentation 2** Session Chair: **Adrian Ochtyra,** University of Warsaw, Poland Session Chair: **Dr Piotr Tompalski,** University of British Columbia Canada
3:15pm - 3:30pm Main AULA - "A"	**ST-A: Student Award** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
3:30pm - 4:00pm Upper Hall 1	**BR-3: Coffee break 3**
4:00pm - 4:30pm Main AULA - "A"	**PLS-3: Plenary session No 3** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
4:30pm - 5:30pm Workshop room 104	**YSDoF_W1: YSDoF_Workshop_1** Session Chair: **Dr Peter Vogt**, European Commission, Italy
5:30pm - 6:00pm Main AULA - "A"	**PLS-4: Plenary session No 4** Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland via Skype
8:00pm - 12:00pm	**Special Night Event of the YSDoF** Prominent Lounge Bar, Kamienna 17, Krakow

Date: Friday, 16/Sep/2016

7:30am - 8:00am Registration Desk	**REG-3: Registration 3** Session Chair: **Caileigh Shoot**, University of Washington, United States of America Session Chair: **Dr Barbara Czesak**, University of Agriculture in Krakow, Poland
8:00am - 9:00am Workshop room 104 Workshop room 106	**YSDoF_W2: YSDoF_Workshop_2** Session Chair: **Dr Peter Vogt**, European Commission, Italy Session Chair: **Dr Piotr Tompalski**, University of British Columbia, Canada Session Chair: **Jacek Mucha**, NAVIGATE, Poland
9:00am - 10:00am Main AULA - "A"	**PLS-5: Plenary session No 5** Session Chair: **Dr Bogdan Zagajewski**, University of Warsaw, Faculty of Geography and Regional Studies, Poland Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland

10:00am - 10:30am **BR-4: Coffee break 4**
Upper Hall 1

10:30am - 12:00pm **YSDF_PS: Young Scientist Days on Forestry – Poster Session**
Upper Hall 2
Session Chair: **Adrian Ochtyra,** University of Warsaw, Poland
Session Chair: **Dr Piotr Tompalski,** University of British Columbia Canada

12:00pm - 1:00pm **BR-5: Lunch break 5**
Upper Hall 1

1:00pm - 2:00pm **PLS-6: Plenary session No 6**
Main AULA - "A"
Session Chair: **Dr Bogdan Zagajewski**, University of Warsaw, Faculty of Geography and Regional Studies, Poland
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland

2:00pm - 3:00pm **YSDoF_W3: YSDoF_Workshop_3**
Workshop room 104
Workshop room 106
Session Chair: **Dr Martin Isenburg**, rapidlasso GmbH, Germany
Session Chair: **Jacek Mucha**, NAVIGATE, Poland

3:00pm - 3:30pm **BR-6: Coffee break 6**
Upper Hall 1

3:30pm - 4:15pm **DISC_P: Discussion Panel**
Main AULA - "A"
Session Chair: **Dr Martin Isenburg**, rapidlasso GmbH, Germany
Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America

4:15pm - 4:30pm **CLS: Closing Session**
Main AULA - "A"
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
Session Chair: **Prof. L. Monika Moskal**, University of Washington, United States of America

Date: Saturday, 17/Sep/2016

7:00am - 8:00pm **TV-1: Technical Visit 1: Niepolomice Primeval Forest - Royal Salt Mine Wieliczka**
Session Chair: **Dr Marta Szostak**, University of Agriculture in Krakow, Poland
Session Chair: **Karolina Zięba**, University of Agriculture in Krakow, Poland
Niepolomice Primeval Forest - Royal Salt Mine Wieliczka

7:00am - 8:00pm **TV-2: Technical Visit 2: Zakopane - Tatra National Park**
Session Chair: **Prof. Piotr Wezyk**, University of Agriculture in Krakow, Poland
Session Chair: **Adrian Ochtyra**, University of Warsaw, Poland
Zakopane - Tatra National Park

YSDF_O_1: Young Scientist Days on Forestry – Oral Presentations 1

***Time:* Thursday, 15/Sep/2016: 10:30am - 12:00pm**
***Location:* Workshop room V EDU**

***Session Chair:* Adrian Ochtyra**
University of Warsaw, Poland
***Session Chair:* Paweł Hawryło**
University of Agriculture in Krakow, Poland

ID: 88 / YSDF_O_1: 1

Using Landsat data and Decision Tree method for assessment of condition Tatra National Park forests

Adrian OchtyraBłąd! Nie zdefiniowano zakładki.[1], **Bogdan Zagajewski[1], Anna Kozłowska[2], Anna Jarocińska[1], Adriana Marcinkowska-Ochtyra[1]**

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Keywords: Landsat, forest condition, decison tree, changes

Landsat data because of the long period of acquisition are useful for environment monitoring and change detection. Vegetation is one of the sensitive component of the environment and it is an index of climate changes, especially in mountain areas. In this study Tatra mountains in Polish part of National Park were chosen to assess the forest condition based on Decision Tree (DT) method.

Landsat data since 1987 to 2011 from similar phenological period (June – September) were selected. Images were corrected atmospherically in ATCOR 2/3 software. Dominant land cover types were classified using Maximum Likelihood method which allowed to select forested areas and to mask other classes. Vegetation indices as Normalized Difference Vegetation Index and Moisture Stress Index were calculated for all images and used in Decision Tree classifier. The condition of forest stands was divided into 4 classes: poor, medium, good and very good and each class was differentiated onto subclasses based on the canopy moisture leading to distinguish finally 9 classes of condition.

The results are presenting the maps of distribution of forest condition and the statistics showing the condition classes of forest stands in Tatra National Park in selected dates. The analysis shows general improvement of forest condition and for the most recent images a big parts of dead forests caused by bark beetle. The worst condition was observed for the 1987, where 133.6 km^2 was covered by forest stands where about 21% were in the worst condition and 87% in medium condition. The best one was for the 2005, where 152.4 km^2 was covered by forest stands where about 75.51% were in good condition and 11% were in the best condition. This research shows the potential of using Landsat multitemporal data and Decision Tree method in forest condition and change detection analysis.

ID: 104 / YSDF_O_1: 2

Automatic detection of coniferous tree genera based on aerial images

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Keywords: tree species classification, forest inventory, aerial photographs, remote sensing (RS), support vector machine (SVM)

In recent years, several studies have explored the identification of tree species using remote sensing data. Until now, the application of remote sensing data in German forestry is limited to the differentiation between coniferous and broad-leaved trees.

The objective of this thesis is the automatic detection of the coniferous tree genera spruce *(Picea spec.)*, fir *(Abies spec.)*, pine *(Pinus spec.)*, Douglas fir *(Pseudotsuga spec.)* and larch *(Larix spec.)* based on high resolution and highly overlapping aerial images. Various experiments were conducted aiming to increase detection accuracy, taking into consideration: 1) the usefulness of an additional class 'mixed pixels', 2) the separation of the natural age classes 'pole wood' and 'old forest', 3) the combination of two datasets of aerial images acquired on different days.

Normalized digital surface models and orthophotos were derived from aerial images captured in July 2014 and April 2015. Spectral, geometric and texture variables were calculated. In a raster-based approach these variables were aggregated to 2x2 m – cells. The classification was performed with support vector machine considering different kernels. After variable selection and model selection the accuracy of different combinations of training samples and variables was calculated. Furthermore, the model was simplified by decreasing the number of variables. Accuracy assessment was done via Kappa value and confusion matrices with a k-fold cross validation.

The different combinations, with exception of the aerial images of July 2014, achieved very good results with overall accuracies (OA) between 85.2% and 94.3%. Both the additional class 'mixed pixels' and the model without mixed pixels yielded an OA of more than 90%. The model without mixed pixels achieved an OA that was 4.3 percentage point higher than the 'mixed pixels' model. Consequently, the class 'mixed pixels' could not increase accuracy. The separate model for the natural age class 'old forest' gained the statistically best model with an OA of 94.3%. The separation of the two natural age classes could only increase accuracy for the class 'old forest'. While the classification of April variables yielded very good results with a Kappa value of 0.93, the classification of July variables achieved only fair results with a Kappa value of 0.35. The use of two aerial data sets did not improve accuracy. The substantial difference between the aerial data sets can be explained by seasonal variations and different image quality. The classification could be simplified successfully. 14 variables were sufficient for reaching about 90% of the maximum accuracy.

As a final product, a thematic map was produced, showing the distribution of coniferous tree genera. The thematic map was validated with data from forest inventories. The accuracy of the thematic map could be increased by 7.5 percentage points through filtering. Consequently, post-processing of the map is very important for increasing accuracy. The agreement of the thematic map with the reference data achieved 75% OA and a Kappa value of 0.60. In future studies the transferability of the developed methods to other areas has to be tested. Also the applicability must be validated in practice.

ID: 99 / YSDF_O_1: 3

Effect of the Syrian war on forest degradation – Al Bassit area study case

Maria Al Kayed[1], Chadi Abdallah[2], Ghaleb Faour[2], Mahmoud Ibrahim[3], Hassan Makhlouf[1]

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Keywords: Forest fire, Syria, Landsat, fire indices, NBR, NDVI

Forest fires are an important cause of disturbance in worldwide ecosystems. They represent an extremely serious environmental issue in the Mediterranean region where human-induced fires – mostly due to deliberate lighting of forest fires and negligence – represent the vast majority of forest fires (> 95%). Satellite remote sensing has emerged in the recent years as an important tool to study forest fires. Studies have demonstrated the utility of platforms (Landsat, MODIS, etc.) for mapping fire severity, using either one image acquired after the fire, or two images, acquired before and after the fire.

Since 2011, Syria has been suffering from the devastating effects of the civil war in the country, which include forest fires, caused by human activities. Forest fires constitute a permanent threat to forest resources. Forests in Syria occupy around 2328.4 Km^2 (approximately 1.26 % of the total surface of the country). The Lattakia governorate, located in the northern Syrian coastal area has the highest concentration of forests in the country (29%). These forests are mainly found in "Bayer" and "Al Bassit" regions with species that vary, mainly *Pinus brutia* and *Quercus pseudocerris.* One of the main natural reserves in the area is the Frounlok of Bayer region to the north of Lattakia, its altitude ranges from 550 to 620 m, and is occupied mostly by *Quercus*.

The normalized burn ratio (NBR) is one of the widely used spectral indices for measuring fire severity. This index isolates burnt areas from unburnt ones and provides a quantitative measure of absolute change in green biomass. It can be precise in dense forest areas, where the difference in vegetation type and in density are negligible.

Our aim is to assess forest fires caused by the Syrian war in this region during the last few years, from 2012 to 2015. For that purpose, Landsat 7 ETM+ and Landsat 8 OLI/TRS images were studied. Surface reflectance images, surface reflectance temperature (derived from thermal bands), and indices – mainly NBR and NDVI were downloaded from ERS platform. The high level data indices range from -10,000 to 10,000; the preliminary assessment of the extent and locations of fires was done via the manual classification of the dNBR.

The preliminary results show that the total estimated burned area in the fire season of 2012, is around 205 Km^2 (approximately 49% of the selected study area). The fires were concentrated mostly in the areas of Frounlok forest, and in the region of Kassab near the Turkish borders. Burn severity in different areas ranges from low (31.5%), to medium (67.41%) to high (1.09%). An early conclusion suggests that the Syrian war laid its impact on forest degradation in the area. More analysis for the period of war is being conducted as to be presented in the conference.

ID: 31 / YSDF_O_1: 4

An application of radiative transfer model to simulate forest reflectance – Bialowieza Forest case study

Alicja Elżbieta Rynkiewicz[1], Anna Jarocińska[1], Bogdan Zagajewski[1], Adrian Ochtyra[1,2], Adriana Marcinkowska-Ochtyra[1], Krzysztof Stereńczak[3], Aneta Modzelewska[3]

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Keywords: PROSAIL, trees, Radiative Transfer Model, HySpex, Bialowieza *Forest*

Monitoring of vegetation cover, especially on protected areas, is an important indicator of local and global changes, because it shows interactions of different abiotical components, which shouldn't be interrupted by anthropopressure. Bialowieza forest is partly protected natural forest and holds Bialowieza National Park (BNP) which is Biosphere Reserve and World Heritage Site since 1979. This area is the last remnant lowland primeval forest of mixed temperate deciduous and coniferous ecosystem.This case study presents an application of radiative transfer model (RTM) to simulate top of canopy reflectances of trees in Bialowieza forest. RTMs are physically-based models, which help to understand light interception by plant in optical remote sensing. On the basis of biophysical and biochemical variables RTMs can simulate vegetation reflectance in forward mode. If forward modelling gives good results, then model can be inverted to retrieve canopy variables from measured signal. After model parametrisation, retrieval of vegetation biophysical properties from hyperspectral data and canopy monitoring are possible.The aim of the study was to check the possibility to use Radiative Transfer Model to simulate the reflectance of different tree species from Bialowieza Forest in Eastern Poland. In the study were analysed trees from 10 species: birch, oak, hornbeam, ash, maple, alder, linden, elm, pine and spruce. The analysis were conducted within project: ForBioSensing LIFE+ "Comprehensive monitoring of stand dynamics in Białowieża Forest supported with remote sensing techniques" co-funded by the European Commission under European Union financial instrument LIFE+ and by the National Fund for Environmental Protection and Water Management. During field measurements gathered from 1st till 5th July 2015 were identified tree species and measured chlorophyll content using CCM-300 Chlorophyll Content Meter as an input parameter to the PROSAIL model. Also was acquired reference spectrum using ASD FieldSpec 4 for objects spectrally stable and flat like concrete, asphalt, sand and water. The HySpex images were acquired on 2nd and 4th July 2015 with spatial resolution 2.5 m for VNIR image and 5 m for SWIR image. The images have 451 bands spectral reflectance in range from 400 to 2500 nm. On HySpex images radiometric, geometric and atmospheric correction was done, the images were resampled to 5 meters resolution. The correction was verified using spectral reflectance from field measurements.Each tree or group of trees from field measurements were identified on the image and the spectrum was collected. Then, PROSAIL model was used to simulate the spectrum for each polygon. The version in Python – PyProSAIL, was used. Parametrization was done based on acquired biophysical parameters and literature. Then simulated spectral reflectance were compared with HySpex spectrum. To check the accuracy were calculated RMSE na dnRMSE values for whole spectrum 400-2500 nm and at specific ranges: 400-600, 400-800, 800-1500 and 1500-2500 nm. Based on results we claimed that PROSAIL model allow to successfully simulate trees reflectances. Furthermore, elaborated parameters can help to perform next step – inverse modelling, which allow to remote retrieval of forest variables. It would be advantageous in researches of protected area like Bialowieza forest.

ID: 110 / YSDF_O_1: 5

Accuracy Assessment of Digital Surface Models from Aerial Images for Forest Data

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Keywords: Digital surface model, Image matching, Aerial imagery, Tree height

In Saxony, a federal state in the east of Germany, the public forest enterprise Sachsenforst is responsible for, among others, the consultancy and assistance of private and corporate forests as well as it is an experimental and research institution. Sachsenforst and in particular its Department of Cartography, Forestry GIS and Surveying has to face the constantly increasing demand for up-to-date high quality geodata.

In this context the forest enterprise has started a project with the objective to develop an efficient and effective acquisition methodology. An important tree population data which has to be determined frequently in this context is the height of trees. Previously airborne laser scanning was used for this purpose. But at present the Saxon ordnance survey has no up-to-date and area-wide laser scanner data at its command. For this reason it is necessary to look for a satisfying alternative like the creation of digital surface models based on image matching of aerial images. From this results the aim of this study at hand to compare several algorithms and to analyze their results with regard to Sachsenforst's demand of accuracy. Furthermore, the measurements shall identify parameters influencing the correctness of the digital surface models.

This research has led to the conclusion that digital tree height models from aerial images are not just a cost-efficient alternative to airborne laser scanning but moreover providing results with an accuracy which is acceptable for Sachsenforst under certain conditions. The usage of a correction value is vital to reduce the arithmetic mean difference to a satisfying level of approximately one meter. Furthermore, it is necessary to resort to images with an overlap rate of not less than 80%/40%. If these conditions are met, the workflow will result in a model displaying tree heights of desired quality and independent to tree species and terrain slope.

ID: 109 / YSDF_O_1: 6

Application of hyperspectral technique for an evaluation of spruce's condition (Picea abies) in the NE and SW Poland.

Marlena Kycko[1], Karolina Orłowska[1,2], Adrian Ochtyra[1,2], Zbigniew Bochenek[3], Bogdan Zagajewski[1], Dariusz Ziółkowski[3], Martyna Wietecha[1], Jakub Czos[1], Karolina Olszanka[1]

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Keywords: spruce, remote sensing vegetation indices, spectrometer

Hyperspectral techniques based on narrow bands of electromagnetic radiation allow for analysis and assessment of the condition of plant species as well as to determine the precise parameters such as chlorophyll and water content in the plant. These methods can be used for non-invasive, comprehensive and at the same time continuous monitoring of the environment which has a great significance in case of protected areas, where the aim is to preserve natural biodiversity of plant communities.

The aim of the study was to analyze the variability of spruce (*Picea abies*) condition in the areas of NE and SW Poland. The occurrence of this species is strongly dependent on presence of snow cover and climatic conditions, and for this reason the concentrations can be observed mainly in the north-east of the country and in mountainous areas. The research areas were: Knyszynska Forest, Borecka Forest, Bialowieza National Park (NE Poland, lowlands), Beskid Mountains and Karkonosze National Park (SW Poland, mountainous areas).

During the research were performed measurements of spectral characteristics of spruce using the spectrometer Field Spec ASD 3 and 4. The study was conducted in months of May to September of the year 2014-2015. Spectral reflection curves Obtained from the field measurements were used to analyze the spectral differentiation of spruce from both regions and to assessment their condition during two measurement years. Specific ranges of the electromagnetic spectrum that show statistically significant differences between spruces in both years were selected Using a statistical analysis. These ranges may indicate the wavelengths which depicting spruce features that are the most vulnerable to damage. Remote sensing indicators of the condition of vegetation groups were calculated: Broadband Greenness, Narrowband Greenness, Light Use Efficiency, Canopy Nitrogen, Dry or Senescent Carbon, Leaf Pigments and Canopy Water Content, which were statistically analysed. The indicators were used to assess the overall the condition of spruce, identify potential stressors and to compare the condition of species between different research areas in individual years. The study showed that for the areas studied, the higher the condition index value are for areas SW than NE Poland.

The research was conducted as a part of the WICLAP Project - "Ecosystem stress from the combined effects of winter climate change and air pollution - how do the impacts differ between biomes?", funded from Polish-Norwegian Research Programme of National Centre for Research and Development (NCBiR), project No. POL-NOR/198571/83/2013.

ID: 72 / YSDF_O_1: 7

Monitoring vegetation condition under heavy metal pollution using airborne hyperspectral data

Bikram Pratap Banerjee[1], Simit Raval[1], Hao Zahi[2], PJ Cullen[3]

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Keywords: Vegetation stress, Heavy metal, Hyperspectral remote sensing, Vegetation health indices

Remote sensing enables monitoring heavy metal pollution in vegetation for management and mitigation. This paper presents an approach to utilise a set of thirteen vegetation health indices related to chlorophyll, xanthophyll, blue/green/red ratio, and structure from hyperspectral reflectance data. Airborne hyperspectral data was collected around Yerranderie, Blue Mountains National Park, Australia. The area has a total of eleven historic mine shafts and has a legacy of heavy metals and acidic leachates in a pristine ecosystem now recognised as Great Blue Mountain World Heritage Area. The forest is predominantly comprised of different species of Eucalyptus trees. In addition to the airborne hyperspectral survey, soil samples and field spectra of tree leaves were collected along two leaching pathways. In our study, we firstly analysed the soil samples to measure the level of pollution and computed the correlation coefficient (R) with measured values of vegetation indices. Secondly, we explored the patterns of vegetation health indices along the polluted streams. Thirdly, we classified the stream network order and then compared the responses of the vegetation health indices between the first-order-near-mine and first-order-away-mine streams. We observed high levels of Ag, As, Cd, Cu, Fe, Hg, Pb and Zn along the two leaching pathways. Few vegetation indices have shown a negative correlated response to the increase in heavy metal concentration. For example, Transformed Chlorophyll Absorption in Reflectance Index/Optimized Soil-Adjusted Vegetation Index (TCARI/OSAVI) produced a correlation of -0.41 with the level of Cu concentration. Measured values of the vegetation indices increased marginally with the downstream path flow distance from the nearest mine shaft. Inter-stream analysis between first-order-near-mine and first-order-away-mine streams have shown similar responses of vegetation health indices. Based on the inter-stream analysis of the vegetation health indices it was not possible to derive the significant level of stress on the forest vegetation. The observed effect could be a product of numerous factors including the vegetation to be immune or have developed immunity towards high levels of heavy metal pollution over a century of mining.

ID: 70 / YSDF_O_1: 8

Scale-dependent mapping of stand structural heterogeneity from airborne LiDAR data

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Keywords: Scaling problems, Forest structure, Mixed effects models, LiDAR

Heterogeneity in forest structure, naturally occurring or induced by disturbance, is continuous in space and time. In practice, heterogeneity in structure is quantified from ecological or forest inventory data; often bound to observations made on sample plots. For any given location, the plot-based quantities of structure are known to vary for different plot sizes due to differences in unobserved neighborhoods at plot boundaries. This scale dependence may confound relationships between the forest structural indices and their predictors in regressions affecting the resulting map accuracies. In this study, we first investigated for plot size effects on variability in forest structure described by forest structural indices. We thereafter explored the relationship between the indices of structure and heterogeneity and the plot sizes in forest stands with varying degrees of structural complexity. Finally, the observed plot size effects were modeled statistically and multiple regressions used to map structural complexity and heterogeneity over unobserved parts of the study area from airborne LiDAR data. Three forest structural indices were considered: the aggregation index of Clark and Evans, the Structural Complexity Index and the Enhanced Structural Complexity Index. We used inventory data from one fully mapped 28.5 ha plot in a semi-natural mature deciduous forest stand and 23 fully mapped one-hectare inventory plots spread in different temperate forest types in central Germany. To study the plot size effects, the structural indices were quantified on the basis of 18 plot sizes from 0.1 to 9.8 ha simulated on the 28.5 ha plot and 10 plot sizes from 0.1 to 1 ha simulated on the 23 one-hectare inventory plots. A fixed effects analysis was used to model plot size effects across levels of stand complexity. In addition, a structural equation model was used to explain the effect of differences in the plot sizes on multiple regressions between LiDAR derived canopy metrics and the forest structural indices. Resultant map accuracies were assessed using the Root Mean Square Error (RMSE) and the True Skills Statistic (TSS) in a leave-one-out cross validation procedures for larger plot sizes and an independent set of data collected on 500 m^2 inventory plots. Preliminary results show that all structural indices were influenced by the plot size and LiDAR data is a good predictor of forest structural complexity and heterogeneity (RMSE $\approx$ 20%). The highest map accuracy so far (TSS $\approx$ 0.71) has been obtained at the scale shown by the structural equation model to have minimal effects of spatial cofounding. These findings are relevant to optimize plot sizes for efficient inventory of components of forest structure as well as for the design of natural resource inventories. The structural complexity and heterogeneity map produced for the study area will be relevant for guiding further ecological and forest management planning.

YSDF_O_2: Young Scientist Days on Forestry – Oral Presentations 2

***Time:* Thursday, 15/Sep/2016: 1:30pm - 3:15pm**
***Location:* Workshop room V EDU**

***Session Chair:* Adrian Ochtyra**
University of Warsaw, Poland
***Session Chair:* Piotr Tompalski**
University of British Columbia, Canada

ID: 22/ YSDF_O_2: 1

Template matching as a tool for Araucaria angustifolia (Bertol) Kuntze recognition using ALS data

João Paulo Pereira[1], Veraldo Liesenberg[2], Marcos Benedito Schimalski[2], Holger Weinacker[1], Barbara Koch[1]

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Keywords: Template matching, Araucaria angustifolia, LiDAR ALS, normalized fast correlation, CHM

Araucaria angustifolia, also known as Paraná's pine or araucaria, is an important and endangered southern Brazilian tree species from the Araucariaceae family. There is a lack of information about its ecology and sustainable management tools. In addition, the natural occurrence area of this species is around 7.700 km2. Araucaria has high quality wood and edible seed production. However, due to prohibitive legislation that restricts forest management, most landowners avoid araucaria's regeneration. In an attempt to solve this issue, recent remote sensing technologies, such as airborne laser scanning (ALS), have been important assets to this cause. The ALS system is assembled in an airplane, helicopter or UAV (Unmanned Aircraft Vehicle) having four main components: i) LASER system (responsible to emit and receive LASER pulses); ii) inertial measurement unit (to monitor the three axes oscillations of the aircraft during flight); iii) a GNSS system (to provide the location of the aircraft during the flight); and iv) a computer system to store the collected data. This system is capable of mapping large areas with the outcome being a three-dimensional point cloud that can provide several different variables (e.g. tree count, tree measurements, species classification, forest structure, etc). Therefore, this study aims to use the advantages of the ALS to provide the Araucaria angustifolia trees location, both in dense forest and open field, and to assist in the elaboration of a scientific based sustainable management plan. The null hypothesis is that ALS data is capable to provide enough information to the point where A. angustifolia trees in dense forest areas can be counted with sufficient precision. To test this hypothesis a template matching algorithm is being implemented. Template matching is a high-level machine vision technique, which identifies parts of an image (base image) that match a predefined template (sample images). In this study, the base image consists of a 0,30m geometric resolution canopy height model (CHM) derived from ALS point cloud with average density of 7 points.m-2. In total, 30 araucaria templates were selected and compared to the base image. To compare the templates with the base image, normalized fast correlation was employed in order to detect trees that could be A. angustifolia. Initial tests have shown that normalized fast correlation is efficient in A. angustifolia detection, where 78% of the trees were correctly recognized. However, there are still several omission errors, which indicates the need of further improvements, complementary analysis and the algorithm calibration. The next step is to find a better calibration for the algorithm to increase the hit rate and to reduce both omission and commission errors. If this algorithm proves to be efficient it will allow a better knowledge of the amount of araucarias in a certain area and their respective location.

ID: 95/ YSDF_O_2: 2

3D GIS tool for visualization and analyze of detailed forest inventory data

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Keywords: 3D GIS; Remote Sensing; Forest modeling; Forest visualization

The basic of forest management is to know the exact amount of forest resource. Methods for modeling the forest were started develop since the presence of foresters. During the forest modeling process, the goal is to create an accurate and comprehensible dataset with the minimum of manual field work to be efficient. Most of the traditional methods are using forest compartment based inventory which could provide only rough estimations of the real forest parameters from manual sampling methods. Since economy came into view more in forest sector the need of detailed forest inventory is necessary. Various automated terrestrial and aerial remote sensing methods have been developed to collect data over forests. The level of detail in the extracted forest parameters with these methods are ranging between individual trees and forest compartment level. These datasets are containing spatial information about the position of stems and canopy dimensions. But the raw dataset of forest parameters itself does not satisfy all of our needs. Several forest visualization systems exist with various functions for forest modeling. People recognize spatial patterns better in realistic visualizations than in raw data. Individual tree based models in a realistic environment are helping the user to get more information about the structure of the modeled forest. For this purpose, we planned and created a modeling tool to aid the forest inventory data by visualization with computer vision. During the research we used existing methods to get forest parameters from remote sensed data. These derived datasets were used for the modeling as an input as well as traditional field surveyed data. We developed a 3D GIS tool which allows the user to create visualization from the preprocessed remote sensed data with lower level of visualization detail directly. It is generating the stem and the canopy objects for individual trees with information about the objects attributes. The tool also provides 3 dimensional data analysis function for the tree models. Growing space indexes could be derived using the generated canopy and stem models within the tool. In case of artificial plantations where the stem positions are known from the planting scheme the tool itself could derivate parameters by using height surface model and field reference data automatically. Thematic output options are available to get more details about the investigated forest parameter like height or tree species. Uneven aged natural forest, artificial plantation, short rotation coppice and ice damaged natural forest types were used during the development as a training site in Hungary. These training sites were surveyed with different type of modern geomatic methods. Stem positions and canopy projections were derived from ALS, image based 3D point clouds and field surveyed data inputs. The outputs of the used tree surveying methods were integrated into the tool. During the design the goal was to create an easy to use tool to aid the forest inventory for more detailed data visualization.

ID: 120/ YSDF_O_2: 3

Quantifying the impact of lianas on the vertical forest structure with terrestrial LiDAR

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Keywords: lianas, tropical forests, forest vertical structure, LAI, TLS

Lianas are an important component of tropical forests, commonly constituting up to 40% of the woody stems and about 35% of the woody species. Lianas competing strongly with trees for both above- and belowground resources. Tropical forests are currently experiencing large-scale structural changes, including an increase in liana abundance and biomass. Despite the large amount of data currently available on lianas, there are no quantitative studies on the influence of lianas on the vertical structure of the forest.

The main objective of this study was to evaluate the contribution of lianas to forest structure using a terrestrial laser scanner before and after liana removal. We used Riegl VZ-400, which is a full waveform LiDAR scanner that has been successfully used in the recent years for studying different forest structure parameters such as biomass, tree height, etc. We established two small plots of 10 by 10 m each (one removal plot and one non-manipulated control plot) in a lowland tropical seasonally moist secondary forest on the Barro Colorado Natural Monument, Panama.

We manipulated lianas by cutting them at the base in the removal plot, leaving the control plot untouched so that we could account for the effect of natural phenological variation over time. We scanned both plots 2 weeks and 4 weeks after liana cutting to quantify the effects of lianas on forest structure.

We compared the laser-derived vertical distribution of the vegetation elements and Plant Area Index (PAI) after cutting to the pre-cut scans in removal and control plots. The laser-derived data provided an accurate representation of the vertical profile of the forest and the results indicate that lianas contributed a substantial amount to the vertical structure of the forest.

ID: 51/ YSDF_O_2: 4

Automatic branch measurement using Terrestrial Laser Scanning

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Keywords: Lidar, Wood quality, Terrestrial laser scanning, Branch detection

Introduction. An accurate method to automatically detect branches and measure their diameters using point clouds is required to introduce practical solutions for wood quality assessment of standing trees by means of Terrestrial laser scanning (TLS). Information about wood quality is needed to enhance the value and sustainability of wood procurement processes.

Method and material. The automatic branch detection method developed for this paper included 1) detection and modelling of the stem, 2) detection of branch points, and 3) modelling of the branches. The accuracy of the method was tested with two mature Scots pine trees (Pinus sylvestris L.) using a data acquisition method used in practical forest field measurements. The trees were scanned with TLS on two sides at distances of 4-6m. The trees were felled and every branch's diameter was measured manually with callipers for reference. Branch diameters were also measured manually using the point clouds.

Results. The detection rates were 79% and 68% and diameter accuracies 79.5% and 54% using the manual and automatic methods, respectively. Branch diameters measured using TLS point clouds were underestimations in general.

Discussion. The detection rate expectably decreased towards the tree top. The factors impacting the detection and estimation accuracy, e.g., scanning settings, are discussed. For example, beam divergence is identified as one of the main reasons of the inaccurateness in the branch diameter measurements.

Conclusion. The results indicate that the method described in this paper can be used to estimate the main branch structure of single trees. The automatic method was fast and yielded similar accuracies compared to the manual point cloud measurements. In collection of TLS data for branch modelling purposes, dense point clouds with coverage on all sides of the trees are required – closer distance than that used in this study would probably improve the results. In further studies, it should be tested whether the method can be used for generalizing tree-level branch structure models over larger areas in area-based-approach (ABA) with airborne laser scanning (ALS), and whether it would yield sufficient accuracies in wood quality assessment applications.

ID: 67/ YSDF_O_2: 5

The Study on Estimation of Forest stock Volume in Hong Kong

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Keywords: forest stock volume;regression model;remote sensing monitoring

Forest stock volume is an important property of forest resources, is an important symbol of forest biomass and carbon sequestration, and is an important part of forest resources monitoring. Based on remote sensing technology for forest resources, particularly forest volume monitor, give full play to its advantages such as macroscopic, fast, time saving ,labor saving and other advantages, has very important significance and great potential. The purpose of this study is to timely, accurately grasp the current status and trends of forest resources, dynamic monitoring of forest resources to achieve, especially to provide monitoring volume scientific means for the forest. My research select TM remote sensing images, topographic maps and forest inventory data with Hong Kong administrative region. By using remote sensing software ERDAS IMAGINE and ENVI, Geographic information system software ARCGIS, and statistics analysis tools SPSS and Matlab. With the remote sensing technology as the foundation, TM image preprocessing, remote sensing variables extraction, forest types, vegetation index and forest volume extraction. Based on geographic information system technology is secondary for vector data acquisition and processing, using GIS Spatial analysis methods to extract topographical factors such as slope, aspect. Supplemented by the GPS navigation technology, conduct field investigations on the ground. By using the theory of mathematical statistics, regression analysis method is adopted. Analysis the various factors of remote sensing which affecting the forest. Using multiple collinearity diagnosis and principal component analysis methods for model variables filtering and the least square method of stepwise for regression model. The classification error matrix precision for evaluating. The average accuracy of the forest stock volume is 84.3%, can be used as a county-level administrative units of forest resources survey of regional volume using the statistical data.

ID: 16/ YSDF_O_2: 6

Bare-ground surface extraction from Fused UAV images and Terrestrial laser scanner

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Keywords: UAV, TLS, Bare ground, DTM, Filtering

We present the workflow to extract ground surface from low-cost Unmanned Aerial Vehicle (UAV) images and Terrestrial Laser Scanner (TLS) point clouds. UAV systems with camera sensors provide a trustfully high resolution spatial datasets. However, the image-based 3D points are not sufficient to generate point cloud under density forest areas and often contains only maximum altitude value of tree in point cloud. Due to the lack of ground surface point under density forest, detailed digital terrain model (DTM)'s generation is not possible. Hence the point cloud has to include points from ground; we propose the ground based laser scanning technology to combine from image based point clouds with this technique. Not only to combine point clouds are important, but also filtering the point cloud from the tree or non-ground object points.

In this study, we had performed UAV flight and acquired images from the multirotor platform which includes conventional Canon Power shot camera. TLS point cloud gathered from single station and 360 degree with field of interested area. Further analysis is ongoing to detect landslide monitoring from integrated and filtered point cloud data with multi-temporal data.

Digital terrain models differencing and three-dimensional point cloud comparison will be able to perform after integrated point clouds.

The developed method accurately integrates the point cloud from georeferenced UAV image-based and georeferenced TLS point clouds.

The experimental results show that TLS derived point clouds georeferenced with Ground control points (GCPs), the accuracy of global positioning of UAV imagery can be improved with alignment methods. Simultaneously, the accuracy of GCPs which acquired from GNSS surveys were used to geo-referencing of TLS have the same to point clouds accuracy under ± 2 cm.

ID: 85/ YSDF_O_2: 7

Objected based image aanalyssis of coastal zone using LiDAR derivatives in Gloria, Oriental Mindoro

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Keywords: object based image analysis, LiDAR, coastal zone, support vector machine

Monitoring the coastal ecosystem is important in environmental management and protection. However, there is a challenge in producing a high-accuracy and high spatial resolution map in coastal zone. The existing coastal zone map of Gloria, Oriental Mindoro has a coarse scale that needs an update and improvement. Obtaining a good coastal habitat map is an input in the coastal resource management plan for resource conservation and habitat protection. Nowadays, the use of remote sensing and geographic information system in environmental management is growing in number. Object based image analysis (OBIA) is state-of-the-art process in classifying high resolution images. Additionally, Light Detection and Ranging (LiDAR) is a remote sensing method that generates precise three-dimensional information of the earth's surface. OBIA using LiDAR derivatives was used in this study. LiDAR derivatives used for segmentation and classification were intensity, canopy height model, digital surface model, digital terrain model, hill shade, entropy, normalized digital surface model, number of returns, slope and slope of slope. Segmentation used were (1) multi-threshold for the delineation of water vs land and ground vs non-ground (2) multiresolution to minimize the heterogeneity of the image object. In classifying the segmented objects, support vector machine (SVM) was used with the use of collected training points obtained from the field, and visual inspection from LiDAR derived data and google earth. The classes produced in the map were mangrove, aroma, nipa, coconut, non-ground vegetation, fishpond, building, road, ground vegetation and water. LiDAR derived map generated high accuracy with 90%. The coastal zone of Gloria is covered with beach forest species such as mangrove, aroma, and nipa that makes an additional layer of protection in the coastal communities from strong waves and storm surge. Through the produced map, users can determine effectively and efficiently possible areas for further rehabilitation and reforestation of mangroves.

YSDF_PS: Young Scientist Days on Forestry – Poster Session

Time: **Friday, 16/Sep/2016: 10:30am - 12:00pm**
Location: **Upper Hall 2**

Session Chair: **Adrian Ochtyra**
University of Warsaw, Poland
Session Chair: **Piotr Tompalski**
University of British Columbia, Canada

ID: 121 / YSDF_PS: 1

Automatic determination of the number of trees in tree stands, on the basis of point cloud processing of the Airborne Laser Scanning

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Keywords: airborne Laser Scanning (ALS), analyses of point clouds, number of trees, canopy cover.

The purpose of the study was to compare traditional methods used in the forestry, in order to determine the number of trees and the parameter of horizontal canopy cover in timber tree stands – with modern automated geoinformatics solutions, using the original algorithm to process point clouds of the Airborne Laser Scanning. Research were conducted in the Tuchola Forest, in the area of the Przymuszewo Forest District (RDLP Torun). A total of 6 transects was established in one-storey and single-species pine tree stands Scots Pine (*Pinus silvestris L.*). The size of transects ranged from 0.52 ha to 3.69 ha, and their locations were determined using the receiver GNSS ProMark (Spectra). In the field of transects were calculated all the standing trees, which crowns could be seen from the aircraft. The point cloud from the Airborne Laser Scanning used in research, was characterized by an average density of 4 points/m2 (Standard I; ISOK; GUGiK). When using the algorithm Cover (FUSION; McGaughey 2016) and the original program OMEGA, the horizontal canopy cover was determined with an error (RMSE), equal to 4.79%. The program FUSION allowed to obtain slightly better results at the level (RMSE), of only 2.93%. The number of trees on the basis of the point cloud ALS was determined using both the program CanopyMaxima (FUSION; McGaughey 2016), as well as algorithms implemented in the program OMEGA. The average number of trees per 1 ha, determined on the basis of the analysis of the point cloud ALS, contained errors (RMSE), respectively 59.23 % (FISION) and 12.36%, in the case of the most suitable variant of the algorithm OMEGA. The slightest error (RMSE) in the case of the program OMEGA, amounted to only 3.43%. The number of trees determined in the area, amounted to 4817, while the program Omega detected 4753 trees. The time of the analysis of point clouds ALS for the personal computer (PC AMD Phenom II X4 B50 3,1 GHz, 8 GB RAM, AMD Radeon HD 6800) when determining the canopy cover, took an average of 1.06 sec, and 2.11 sec, when determining the number of trees. The results of research conducted authorize to draw the conclusions about the need for further development of algorithms OMEGA, useful at the stage of determining the reference (stratification) surfaces for the inventory process and forest management on large forest areas.

ID: 96 / YSDF_PS: 2

The influence of the spatial structure and phenological phases of the Ojcowski National Park forest stands on the quality of elevation models gathered from ALS point clouds

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Keywords: Airborne Laser Scanning, height models, Ojcow NP, ALS point cloud statistics, 3D forest stand structure

The study area was located in the southern part of the Ojców National Park (ONP), which is characterized by varied terrain morphology. The aim of this study was to analyze the differences between elevation models, generated for sample plots, which were designated according to tree species. The ALS data, coming from ISOK project - the leafless condition (Leaf-OFF) and the data owned by ONP growing season (Leaf-ON) were used. The mean difference between DTM ALS_ONP (Leaf-ON) and DTM ALS_ISOK (Leaf-OFF) on the analyzed plots was -0.02 m, while on whole area of research the difference was -0.04 m.

It was found that the dominant species, canopy cover and understory in the growing season hinders the penetration of the laser beams to the ground, what consequently decreases the quality of Digital Terrain Models (DTM). As a result, the analysis also showed the incorrect classification of the ground (especially rocks), which caused the difference DTM_ONP (Leaf-ON) – DTM_ISOK (Leaf-OFF) ranging from -42.97 m to 33.19 m.

In the study the possibilities of using data from airborne laser scanning (ALS) as an alternative to traditional forest inventory were also analyzed. As a result of ALS point cloud analysis (average density of 20 pts/m^2, from 06.2012) for the Ojcowski National Park (2146 ha) selected characteristics were determined and compared with reference data (SILP) such as: upper height of stands (correlation coefficient of R^2 = 0.83), canopy closure (full compliance only for 22.7% of stands, the undervaluation of 1st class: 48.7%, undervaluation by 2 classes: 21.9%, +1 or +2 overstating the class: 5.6%), vertical structure (stands without lower layers was confirmed for 45% of the stands, in other cases a clear compliance was not found). The results, in spite of some limitations in the detection of lower layers of the forest stand (underbrush, the lower floors) resulting from a smaller number of reflections of the laser beam (the influence of assimilation apparatus during full vegetation; Leaf- ON) confirmed the very high utility of ALS to determine the spatial 3D structure of stands.

ID: 58 / YSDF_PS: 3

Vegetation condition of forests in Gorczanski National Park

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Keywords: Gorczanski National Park, Landsat OLI, supervised classification, vegetation indices

The slow, natural process of death and rebirth of the forest is observed in many national parks. However, changes in the forests can be also caused by insects and strong winds. The aim of the project was to analyze the current forests condition in the Gorczanski National Park using Landsat satellite images and ground-based spectrometric measurements. The presentation was basing on project *Health condition of forests, analysis of the condition - Gorczanski National Park* made as part of the Summer School of Geoinformation "GeoGorce 2015" by the University of Warsaw Geoinformatics and Remote Sensing Students' Association's team.

On the two satellite images acquired from Landsat OLI (July 2015) was conducted radiometric and atmospheric correction (Dark Object Subtration). Then the images were joined into a mosaic (because a single image does not cover the whole park) and area of interest - Gorczanski National Park was subset from the images. After preprocessing was done supervised classification using Maximum Likelihood algorithm. The land cover classes were: roads, buildings and uncovered ground, mid-forest glades, meadows and pastures, beech forests, spruce forests, renewal and withering trees. The verification was made based on ground truth polygons.

Using Landsat image were calculated remote sensing vegetation indices:

- NDVI (Normalized Difference Vegetation Index) – to estimate the vegetation condition,
- MSI (Moisture Stress Index) – to analyze water content in plant cover and water stress,
- PSRI (Plant Senescence Reflectance Index) – to analyze the aging process of plants and to estimate amount of carbon based on analysis of lignin and cellulose in dry matter.

In addition, to assess the overall condition of vegetation the transformation Tasseled Cap was calculated. The values of vegetation indices and transformation Tasseled Cap were estimated in each class. The differences were analyzed using statistical analysis.

Also, to compare the results of processing satellite data to field measurements, measurements from high resolution spectroradiometer ASD FieldSpec 4 were analyzed. Using spectral reflectance were calculated vegetation indices (NDVI, SR, EVI, ARVI, NDVI 705, mSR 705, mNDVI 705, VOG 1, VOG 2, PRI, SIPI, NDNI, NDLI, CAI, PSRI, CRI 1, CRI 2, ARI 1, ARI 2, WBI, MSI, NDII) and were analyze the differences between two classes: beech and spruce. Fusion of satellite and field indices showed similarity.

In summary, the remote sensing methods used in the project, make possible assessment of forests condition and correct classification of land cover. Research has shown spatially varied but generally good condition of forests in Gorczanski National Park.

ID: 124 / YSDF_PS: 4

Application of LiDAR data in modelling of spatial rockfall activity on forested slopes in Kościeliska Valley (Tatra Mts.)

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Keywords: LiDAR, spatial modelling, rockfall, Tatra Mts.

Rockfall is one of the major morphogenetic process in mountainous regions. There are some interactions between rockfall activity and forested slopes in mountains. This observations were achieved in Kościeliska Valley in Tatra Mts. This kind of natural hazards need to have observations and modeling for spatial distribution of rocks. In this areas computer modelling should become a standard tool for detecting rockfall activity. It should be used in designing of protective measures (Stoffel et al. 2005). Airborne LiDAR (Light Detection and Ranging) data have been shown to have the potential to quantify rockfall process activity. Spatial distribution of rockfall have been mapped with sufficiently high accuracy in some LiDAR-based studies. This method was used first time in Polish Tatra Mts.

ALS data allowed to analyze rockfall trajectories, velocity, energy and height. This kind of analysis were taken into account on two forested slopes near Raptawicka Grań and Czarna Turnia (two rock walls). The main aim of this study was to point out zones of concentration of rocks on forested slopes. LiDAR point clouds were acquired within the national project (ISOK – Informatyczny System Osłony Kraju) at a minimum density of 4 points/m^2. The processed LiDAR data were received from CODGiK (Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej) in a series of 92 1:2500 scale map sheets in LAS format.

In detecting rockfall activity there are needed field observations and measuring rocks received from rock walls. Next steps were concerned about GIS data analysis. It was calculated in Rockfall Analyst which is an extension of ArcGIS (Lan et al. 2007). Rockfall Analyst allow to simulate trajectories based on geostatistical functions built in GIS environment. Using DEM generated from LiDAR data as input was possible to quantify the characteristics of rockfall in Kościeliska Valley. Location of trees was set in ENVI LiDAR with 3, 4, 5 class from ALS according to the American Society for Photogrammetry and Remote Sensing standards. On forested slopes it was necessary to calculate the trajectory, bouncing and final deposition of rocks in aspect of measuring injuries in trees. There are some studies which show that rockfall has negative impact on trees and can lead to impairment of forest (Stoffel i in. 2005).

Results from Kościeliska Valley show that rockfall has substantial impact on trees in underlying slopes. LiDAR data received from ALS allow to simulate rockfall physical parameters with high precision. According to this we are able to define trees with possible injuries as a result of rockfall. This kind of analysis should mark areas with present rockfall process. In forestry this results can aid to avoid destroyed trees by rocks impact.

ID: 15 / YSDF_PS: 5

Spatial Prediction of Forest Trees and Shrubs Species Group Using Combination of Spectral and Non-Spectral Data and Data Mining Algorithms

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Keywords: Spatial distribution, Topography, Climate, Soil, Quickbird, Data mining algorithms

Identifying features of vegetation is one of the most important ways to manage and protect plant communities. Modeling the spatial distribution of plants is one of the indirect methods for predicting the properties of plants and can be define based on the relationship between the spatial distribution of vegetation and environmental variables. The purpose of this study was the prediction of the spatial distribution of tree species by the combination of environmental data (topography, soil and climate) and Quickbird satellite spectral data. Tree and shrub's attributes were obtained from 518 sample plots of series one of Dr. Bahramnia forestry plan at Gorgan city in Iran and tree species groups were determined in each plot based on frequency of basal area of species. Primary and secondary characteristics of topographic map were produced by digital elevation model. Climate data were determined by the relationship between climatic factors and elevation. Pixel value at the location of samples was extracted after had been done geometric correction based on orthorectification method and processing on multi-spectral and panchromatic bands. Random forest (RF) and support vector machine (SVM) were used with any of the group variables and combined them and 80 % from sample plots for modeling spatial distribution of species groups. Results showed that physiographic factors, especially altitude combination with soil and climate factors were the most important variables on distribution of species and the best model in this study was created by integration of them (overall accuracy = 63.85%). Also Results showed that the combination of non-spectral data with spectral data could improve overall accuracy of classification. Random forest and support vector machine created the best results respectively using spectral data, spectral and non-spectral data.

ID: 97 / YSDF_PS: 6

Influence of forest and woodland area on fortified landscape based on visibility analysis with Airborne Laser Scanning (ALS) of fortress in Wolski Forest in Krakow

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Keywords: Airborne Laser Scanning, fortified landscape, Wolski Forest, visibility analysis

The landscape is a key resource of a fortified area, with camouflage greenery, especially forest and woodland area, being an important element. An understanding of a historic fortification system in its entirety and the associated cultural and environmental heritage is the main argument calling for the necessity of having an interdisciplinary approach to the research of landscape and greenery of historic fortification, the remains of which have amazingly survived to the present. An analysis of the topographical landscape and the enormous area of the sites demonstrate the advanced level of military engineering that went into designing them, changing the landscape and creating this structured greenery.

Fortress greenery arrangements are a valuable part of the natural environment. They guarantee that endangered species of flora and fauna are preserved in the environment. Additional role of fortress greenery is to aid consolidation or renovation of areas on the outskirts of the city that were part of the former fortification landscape.

With Airborne Laser Scanning data this study identifies forms of fortifications, visualizes data and analyses visibility to project recomposition of landscape of III Fortified Sector of Cracow Fortress in Wolski Forest. ALS data are new form of geospatial data useful for landscape architects. These data give new means to protect and revitalize cultural landscape. Study discuses possibilities of adaptation and modernization of fortification based on landscape conservation theory and project practice.

Possibility of using III Fortified Sector of Cracow Fortress for recreational and didactic purposes is proposed. Project based on visibility analysis and historical materials shows way to restore compositional values of landscape with fortifications.

3D GIS analysis showed high usefulness to identify fortification, visualize of these objects without vegetation and perform visibility analysis. In contrast to traditional methods (inventories and historical documentation), data from laser scanning are the new generation of geospatial data. They offer an opportunity to develop a new, faster technology to use in the restoration, preservation and inventory of military architecture.

ID: 115 / YSDF_PS: 7

Airborne Laser Scanning point cloud comparison with UAV image-based point cloud in forest inventory issue

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Keywords: LiDAR, UAV, Forest inventory, image-based point cloud, steromatching

The most important thing in forest inventory are geometric features of the trees. To acquire this information field works are carried out but usually that is a very expensive and time-consuming method. The another way to get information about three-dimensional characterization of vertical forest structure is utilization of remote sensing techniques. Airborne Laser Scanning also known as the Light Detection and Ranging (LiDAR) is an active remote sensing technique which enables to estimate a range of forest inventory attributes including volume, dominant height and basal area. This technology was tested and developed in the last 20 years in forest inventory case, so some countries use this data to get information about forest resources. Recently, there has been increasing interest in utilization of image-based point cloud. It is cheaper to acquire than ALS point cloud and the properties of these data are similar. To generate the most detailed image-based point cloud it is advisable to use high spatial resolution digital airborne imagery so the use of Unmanned Aerial Vehicle (UAV) is considered by researchers.

The aim of this study was to compare ALS point cloud with UAV image-based point cloud in forest inventory issue. The area of interest is located in Drewnica forest district, Masovian district in Poland. This area is dominated by Scots pine (Pinus sylvestris) and birch (Betula pendula) stands. LiDAR data set with 4 pts/m2 point cloud density was obtained in 2012 for national ISOK project. UAV photogrametric mission (GSD= 5 cm) was carried out in 2014 by MSP company. To create image-base point cloud, Agisoft software was used. Two data sets were normalized by ALS ground points and analyzed.

First results of comparison of point cloud statistics show differences between ALS (all returns) and UAV point clouds for all stands: maximal height (hmax): mean = -0,04 [m] (SD =0,62[m]), 80th height percentile (p80): -2,80 (1,29), p90: -1,98 (0,67), p95: -1,42 (0,55), p99: -0,72 (0,40); ALS (first returns) and UAV point clouds: -0,04 (0,62), -0,94 (0,84), -0,77 (0,5), -0,57 (0,43) and -0,24 (0,34) respectively. For pine stands: ALS (first returns) and UAV point clouds: 0,26 (0,44), -0,23 (0,45), -0,56 (0,26), -0,53 (0,42), -0,26 (0,41); for birch stands: -0,36 (0,62), -1,65 (0,44), -0,98 (0,59), -0,61 (0,43), -0,22 (0,23) respectively. This work is a part of master thesis supervised by Piotr Wężyk, Assoc. Prof on University of Agriculture in Cracow, Forestry Faculty, Institute of Forest Resources Management, Department of Forest Management, Geomatics and Forest Economics.

ID: 60 / YSDF_PS: 8

Vegetation condition of trees based on HySpex hyperspectral images on urban areas - Bialystok city case study

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Keywords: vegetation indices, hyperspectral images, HySpex, defoliation, discoloration, trees, urban

Trees on urban areas are an important part of the city, but also they are exposed to many stress factors. Therefore, it is important to constantly monitor their condition. Apart from traditional methods it is possible to monitor the trees condition using remote sensing methods. The aim of the research is to determine the utility of hyperspectral images to analyse the condition of the trees in the city. The research was performed in the area of Bialystok.

Two images were acquired using HySpex scanners: July 3rd and August 27th 2015. At the same time were conducted field measurements – location, species and the discoloration and defoliation values were collected for 266 trees. Images were corrected radiometrically, geometrically and atmospherically. After preprocessing pixels not covering the trees were masked from the images using normalised Digital Surface Model and values of Normalised Difference Vegetation Index. On the images were calculated selected vegetation indices to analyse the overall condition, efficiency with which vegetation can use incident light for photosynthesis, pigment content and water content. Values of vegetation indices were acquired form the image and averaged for each tree measured during field measurements. Values of indices were correlated with biophysical variables – discoloration and defoliation acquired during field measurements. On the basis of the relationship regression equations were determined, which were used to make maps of biophysical variables. Next step was verification of acquired maps based on verification trees. The accuracy of the calculated variables was calculated. The last step was change detection using two images to analyse the vegetation condition changes.

Based on the conducted studies can be said that the condition of the trees is not good. Trees in the Bialystok contain a lot of carotenoid relative to the chlorophyll content, which weakens the photosynthesis process. The chlorophyll content in the leaves is moderate and water content is sufficient in July. It is also observed deterioration of vegetation condition in August. The values of discoloration are small, only on individual trees are visible significant changes. It was observed increase of defoliation values of trees. Significant changes in the condition are visible for trees growing near streets.

ID: 91 / YSDF_PS: 9

The use of ALS technology and hyperspectral imaging to support the process of land consolidation

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Keywords: LIDAR, ALS, hyperspectral imaging

Nowadays, in southern Poland there are many land consolidation projects. They are based only on cadastral and topographic maps. Very often these data are not actual and can not be used direct in GIS software. Modern remote sensing technologies are a remedy for these problems. In this poster the authors present the use of ALS technology and hyperspectral imaging to support the process of land consolidation. The first technology is used to build a DTM (Digital Terrain Model), which is a source for special terrain analysis important in land consolidation works, like soil-erosion maps etc, whereas the second technology is used to update the cadastral map (land usage). The authors want to show the full process of making these maps in SAGA GIS software. In addition, they wrote scripts in Python programming language to automate this procedure. In the end, the authors show the sample maps and summarize the advantages and disadvantages of ALS technology and hyperspectral imaging in land consolidation process.

ID: 20 / YSDF_PS: 10

Monitoring tropical forests with InSAR

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Keywords: Forestry, SAR, Biodiversity, Carbon Cycle

A novel methodology for tropical forest monitoring based on InSAR is developed. The idea is to monitor forest height changes. Height decreases result from logging and represent a decrease in biomass and carbon stock. Height increases result from tree growth and increasing biomass and carbon stocks. The method is developed for monitoring in REDD+. A Reference Emission Level (REL) is derived from height changes between the SRTM in 2000 and Tandem-X around 2012. Careful error removals and corrections for wavelength specific penetration differences are included. Annual, or bi-annual, coaverages with Tandem-X or similar satellite missions in the coming years will provide the MRV data to be compared to the REL. The method is based on several research studies published in peer-reviewed journals. The company Forest Vision is established in order to set the method into operational use. By now we have processed Uganda wall-to-wall and obtained a REL. The mean height change in Uganda during 2000 - 2012 was a decrease of 31 cm, corresponding to an annual decrease of 2.6 cm. This is further recalculated to an estimated CO_2 emission estimate of 20.7 million tons.

ID: 64 / YSDF_PS: 11

Evaluation of the suitability of Sentinel-1 data for monitoring land cover changes in Jambi province, Sumatra using Google Earth Engine

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Keywords: Sentinel-1, land use/cover change, forest degradation, Google Earth Engine

The province of Jambi in Sumatra is affected by rapid and massive changes in land cover / use over the last 15 years. Detailed time series mapping of land use/cover changes due to land conversion and fires from optical remote sensing data is difficult because of constant cloud cover, smoke or haze. Based on the high spatial and temporal resolution of Sentinel-1 data, frequent land use/cover change analyses are now possible irrespective of the atmospheric conditions. In the context of an ongoing research project, training data for the classification of RapidEye imagery was collected in several ground survey campaigns between 2013 and 2016. We use this data to evaluate the suitability of Sentinel-1 radar data for the identification of changes in land cover/use from 2014 to 2016. Special emphasis is laid on the conversion of secondary forest or jungle rubber into open bushland or oil palm plantations. Open bushlands are usually an interim land cover before oil palm plantations are established. With the use of the Google Earth Engine, time series analyses of Sentinel-1 radar data will be realized to detect changes in land use/cover. Based on these analyses, we will evaluate the potential of Sentinel-1 data in comparison to high and medium resolution optical satellite imagery like RapidEye and Landsat.

ID: 112 / YSDF_PS: 12

Evaluation of Landsat data for large area prediction of forest canopy cover in boreal region

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Keywords: canopy cover, boreal forest, Landsat, global product validation

The boreal forests are highly vulnerable to global warming which increases disturbance from fire and insect outbreaks, in turn potentially contributes significant emission and halts the achievement of international climate goal reached in Paris last year. The vast size of boreal forest (21% of world's forest area) makes financial and logistical constraints for complete coverage of ground- or aircraft- based inventory. Thus, remote sensing (RS) approach with the images acquired by optical Earth observation satellites provides a critical and affordable support to timely and spatially complete mapping of boreal forest cover. Within the context of large-scale forest mapping and monitoring with RS, there is a growing motivation to shift the traditional approach of discrete forest *vs* non-forest classification towards the estimation of continuous field of tree cover (i.e., canopy cover (CC)). Classification-based forest cover estimates may render global comparison and international forestry statistics (e.g., FAO Forest Resources Assessment) unreliable as the reporting countries—which are increasingly using RS data—may inconsistently adopt different forest definitions, mainly the CC threshold above which an area is classified as forest. CC is also an important ecological indicator related to spatial heterogeneity of vegetated surface, light interception and productivity, forest microclimate, biomass/carbon, and wildlife habitat.

In this study, we evaluated the capability of Landsat multispectral satellite data for CC estimation in boreal region using a large number of high quality (unbiased vertical measurements) field reference data (250 plots, 8 sites) covering large variation in latitude (southern, central, and northern Finland), forest structure, species composition, and site type. Landsat mission is currently one of the best data source available (appropriate spatial and temporal resolution) for global forest cover mapping. Reference CC data derived from high resolution images or aerial photos may be inaccurate.

We investigated two statistical models suitable for CC data (0-1 response) namely zero-and-one inflated beta regression (ZOINBR) and random forest (RF). Landsat-based predictors utilized include individual spectral band, spectral vegetation indices (NDVI, reduced simple ratio), and the Tasseled Cap (TC) features (brightness, greenness, wetness, angle, and distance). Further, we tested spectral mixture analysis (SMA) which explicitly decouples spectral contribution from the tree canopy and understory. Previous studies have shown substantial understory spectral contribution in boreal forests. Finally, we carried out the first validation of the new global Landsat tree cover continuous (TCC) product in boreal forest. The results showed considerably good accuracy (leave-site-out cross-validated RMSE 15.4%; R^2 0.48; bias 0.8-1%) could be achieved by univariate ZOINBR with input shortwave infrared channel (TM band 5) or TC wetness. RF with all spectral predictors provided lower accuracy and larger over- (under-) estimation at low (high) CC. The regression tree-based TCC product appeared consistently overestimated at $CC<20\%$ and underestimated at $CC>60\text{-}70\%$. Including more predictors in ZOINBR did not appreciably increase prediction accuracy. The alternative SMA method did not outperform empirical models likely due to uncertainty in the estimated endmembers (pure canopy and pure understory) spectra from Landsat resolution in managed boreal forest with more open canopy.

ID: 12 / YSDF_PS: 13

Characteristic of timberline location in the Carpathian Mountains

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Keywords: timberline, the Carpathians, high resolution imageries, image interpretation

The world-wide pattern of timberline distribution on mountain ranges is related to global factors. The basic drivers are temperature and the amount of radiation, which falls with distance from the equator. This phenomenon causes the lowering of the altitudinal location of the timberline. However, this relationship is not linear and its own specific features may be found in each mountain system. Additionally, this basic relationship is overlaid by the specific features of the massif as the climate type (e.g. degree of continentality or oceanity) and the mass-elevation effect. The aim of this study was to determine major morphometric characteristics of the timberline within Carpathian arc and to identify the main environmental factors, which influence its course. The analyses were performed on the basis of image interpretation of high-resolution satellite imageries (0.5-0.6 m) taken in 2002-2012 and combined with ASTR elevation model. The average, maximum and minimum altitude of the timberline in 54 mountain ranges were studied and characterized with varies morphometrical parameters. The mass elevation effect and latitudinal location have major impact on the altitude of timberline (R^2 = 0.71 and R^2 = 0.56, respectively; $p > 0.01$). With exception of the timberline located the lowest (most probably as an effect of human intervention) the timberline altitude changes by 70 m a.s.l. (+-20 m) with each degree of latitude. The influence of the climate type e is complex and it is not clearly visible also due to past and recent human impact.

ID: 128 / YSDF_PS: 15

Usability of airborne multi-angular imaging spectroscopy data for analysis of boreal forest canopy shadow fraction

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Keywords: multi-angle, imaging spectroscopy data, airborne, shadow fraction, boreal forest

Imaging spectroscopy is a remote sensing technology which records continuous spectral data at a very high (better than 10 nm) resolution. Such spectral images can be used to monitor, for example, the photosynthetic activity of vegetation. Photosynthetic activity is dependent on varying light conditions and varies within the canopy. To measure this variation we need very high spatial resolution data with resolution better than the dominating canopy element size (e.g., tree crown in a forest canopy). This is useful, e.g., for detecting photosynthetic downregulation and thus plant stress. Canopy illumination conditions are often quantified using the shadow fraction: the fraction of visible foliage which is not sunlit. Shadow fraction is known to depend on view angle (e.g., hot spot images have very low shadow fraction). Hence, multiple observation angles potentially increase the range of shadow fraction in the imagery in high spatial resolution imaging spectroscopy data. To investigate the potential of multi-angle imaging spectroscopy in investigating canopy processes which vary with shadow fraction, we obtained a unique multiangular airborne imaging spectroscopy data for the Hyytiälä forest research station located in Finland ($61^0$50'N, $24^0$17'E) in July 2015. The main tree species are Norway spruce (*Picea abies* L. karst), Scots pine (*Pinus sylvestris* L.) and birch (*Betula pubescens* Ehrh., *Betula pendula* Roth). We used an airborne hyperspectral sensor AISA Eagle II (Specim – Spectral Imaging Ltd., Finland) mounted on a tilting platform. The tilting platform allowed us to measure at nadir and approximately 35 degrees off-nadir. The hyperspectral sensor has a 37.5 degrees field of view (FOV), 0.6m pixel size, 128 spectral bands with an average spectral bandwidth of 4.6nm and is sensitive in the 400-1000 nm spectral region. The airborne data was radiometrically, atmospherically and geometrically processed using the Parge and Atcor software (Re Se applications Schläpfer, Switzerland). However, even after meticulous geolocation, the canopy elements (needles) seen from the three view angles were different: at each overpass, different parts of the same crowns were observed. To overcome this, we selected 27 test sites with pure pine stands. We assumed that for sunlit, shaded and understory spectral signatures are independent of viewing direction to the accuracy of a constant BRDF factor. Thus, we compared the spectral signatures for sunlit and shaded canopy and understory obtained for each view direction. We selected visually six hundred of the brightest and darkest canopy pixels.

Next, we performed a minimum noise fraction (MNF) transformation, created a pixel purity index (PPI) and used Envi's n-D scatterplot to determine pure spectral signatures for the two classes. The pure endmembers for different view angles were compared to determine the BRDF factor and to analyze its spectral invariance. We demonstrate the compatibility of multi-angle data with high spatial resolution data. In principle, both carry similar information on structured (non-flat) targets thus as a vegetation canopy. Nevertheless, multiple view angles helped us to extend the range of shadow fraction in the images. Also, correct separation of shaded crown and shaded understory pixels remains a challenge.

ID: 102 / YSDF_PS: 16

Automatic delineation of individual tree crown of Araucaria angustifolia (Bertol) Kuntze using ALS data in Brazilian natural areas

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Keywords: Crown delineation, tree detection, thiessen polygons, CHM, Araucaria angustifolia

This work aimed to automatically delineate individual tree crowns of Araucaria angustifolia from an ALS 3D point cloud from a natural area in southern Brazil. Despite of been a coniferous, this endangered species presents an irregular chandelier-inverted crown shape and has as natural habitat the Mix Ombrophylous Forest. The study area is located in the city of Painel, Santa Catarina state, presenting 64 hectares formed mostly of open field and dense natural forest fragments. In this study site, an ALS flight was performed generating a point cloud with average density of 7 points.m-2. For tree detection procedure, a canopy height model (CHM) of 0,30m geometric resolution was employed. To support the analysis, field data was collected, where four crown radius oriented in each cardinal point (north, south, east and west) of 146 trees of A. angustifolia were measured. The procedure adopted for tree detection and crown delineation is called Thiessen Polygon methodology. A python script was developed employing Scikit-image (open source library), which is a collection of algorithms for image processing. To enhance treetop recognition, the CHM is smoothed (sCHM) with a Gaussian filter. Then a new operation is executed on the sCHM using a maxima filter (sCHMmax). Upon completion of the filtering, sCHM and sCHMmax are compared. In this step, all values in the neighborhood of the highest pixel are altered, except for the highest pixel. This way, pixel values that remained unchanged are registered as treetops. These treetops are then employed as seeds for Thiessen polygons calculation and smoothed to better adjust to the tree crown form. To assess the methodology, commission error, omission error and hit rate were evaluated. Also, crown diameter was calculated from the automatic tree crown delineation and then compared to the one acquired on field work (Dunett's test). According to Dunett's test results, the crown diameter obtained through automatic tree crown delineation do not differ statistically (p-value 0,817) from tree crown measured in the field. The tested methodology presented a hit rate of 91,7% and a good correlation with field data (R^2 = 0,865). No studies have focused on Araucaria angustifolia with this approach, however our results are well in agreement with those from other authors. However, an omission error of 8,3% was detected. This omission error occurred due to the search window employed during the Gaussian filter procedure. To work with Araucaria angustifolia, the filtering window must be from 8x8 to 12x12 pixels. This configuration is necessary due to the irregularity and size of the crown. Using such large filtering window, a generalization occurs in the neighborhood of a large crown tree. Therefore, small trees located in these neighborhoods may not be detected. ALS data presents great potential to be employed in the automatic calculation of tree crown delineation of Araucaria angustifolia in natural environment. In addition, Thiessen polygon methodology proved to be an effective method for tree detection and tree crown delineation, even with irregular crown shape species such as Araucaria angustifolia.

INDEX OF AUTHORS

V

W

X

Y

Z

INDEX OF AUTHORS, INSTITUTIONS AND SESSIONS

A

B

Barton, Ivan	University of West Hungary, Faculty of Forestry, Hungary	YSDF_O_2 Presenter
Bauer, Oliver	Bavarian State Institute of Forestry (LWF), Freising	TAS_2_A
Bauerhansl, Ch.	Austrian Research and Training Centre for Forests, Natural Hazards and Landscape, Austria	TAS_3 _A
Beckschäfer, Philip	Georg August Universität Göttingen, Germany	YSDF_O_1
Beko, Laszlo	Karoly Robert Univ. College, Hungary	TAS_1_A
Białczak, Małgorzata	Department of Forest Resources Management, Forest Research Institute, Poland	TAS_3 _B
Bochenek, Zbigniew Tomasz	Remote Sensing Department, Institute of Geodesy and Cartography, Warsaw, Poland	TAS_1_A, TAS_2_A, YSDF_O_1, TAS_3 _A Presenter
Bonnet, Stéphanie	Unit of Forest Management, Department of Biosystem Engineering, University of Liège, Gembloux Agro-Bio Tech, 2 Passage des déportés, 5030 Gembloux, Belgium	TAS_1_B Presenter
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Brell, Maximilian	GFZ Potsdam, Germany	TAS_1_A
Brolly, Gábor	University of West Hungary, Faculty of Forestry, Hungary	YSDF_O_2
Brovkina, Olga	Global Change Research Institute, Czech Republic	TAS_3 _B Presenter
Bucha, Tomáš	National Forest Centre, Slovak Republic	TAS_3 _B
Buddenbaum, Henning	Environmental Remote Sensing and Geoinformatics, Trier University, Germany	TAS_1_A Presenter
Bukowski, Marcin	Tatra National Park, Zakopane, Poland	TAS_3 _B
Burai, Peter	Karoly Robert Univ. College, Hungary	TAS_1_A Presenter
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C

Casas, Angeles	Center for Spatial Technologies and Remote Sensing (CSTARS), University of California Davis	TAS_2_C
Cateanu, Mihnea	Transilvania University of Brasov, Romania	TAS_2_B Presenter
Chiteculo, Vasco	Czech University of Life Sciences, Czech Republic	TAS_1_C
Chrysafis, Irene	School of Agricultural Sciences & Forestry, Democritus University of Thrace, 68200, Orestiada, Greece	TAS_2_C Presenter
Ciarka, Żaneta	Department of Forest Resources Management, Forest Research Institute, Poland	TAS_3 _B
Cicşa, Avram	Transilvania University, Romania	TAS_1_C
Cienciala, Emil	Institute of Forest Ecosystem Research	TAS_3 _B
Clasen, Anne	TU Berlin, Germany; GFZ Potsdam, Germany	TAS_1_A Presenter
Coops, Nicholas C.	University of British Columbia, Canada	TAS_1_B

Crespo-Peremarch, Pablo	Geo-Environmental Cartography and Remote Sensing Group (CGAT), Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Spain	ST-A Presenter
Cullen, PJ	School of Chemical Engineering, University of New South Wales, Australia, Kensington NSW 2052	YSDF_O_1
Czesak, Barbara	University of Agriculture in Krakow, Poland	TAS_2_B Presenter
Czimber, Kornél	University of West Hungary, Faculty of Forestry, Hungary	YSDF_O_2
Czos, Jakub	Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, University of Warsaw, Poland	YSDF_O_1

D

de Kok, Roeland	www.landconsult.de, Germany, ProGea Consulting, Krakow, Poland	TAS_3 _A, TAS_2 _B
de la Riva, Juan	University of Zaragoza, Geography Department, Spain; GOFOREST-IUCA	TAS_2 _C
Descals, Adria	University of Agriculture in Krakow, Poland	TAS_3 _B Presenter
Deutscher, Janik	Joanneum Research, Austria	TAS_2 _B Presenter TAS_3 _B Presenter
Deák, Márton	Department of Physical Geography,Eötvös Loránd University, Hungary	TAS_1 _B
di Porcia e Brugnera, Manfredo	Computational & Applied Vegetation Ecology lab, University of Ghent, Belgium	YSDF_O_2
Dimitrios, Panagiotidis	Czech University of Life Sciences, Czech Republic	TAS_1_C
Dobosz, Monika	Jagiellonian University, Poland	TAS_2 _C Presenter
Dobre, Alexandru-Claudiu	Transilvania University, Romania	TAS_1_C Presenter
Domingo, Darío	University of Zaragoza, Geography Department, Spain; GOFOREST-IUCA	TAS_2 _C Presenter
Dorren, Luuk	Bern University of Applied Sciences, Switzerland	TAS_1 _B Presenter
Dotzler, Sandra	Environmental Remote Sensing and Geoinformatics, Trier University, Germany	TAS_1_A

E

Einzmann, Kathrin	University of Natural Resources and Life Sciences, Vienna (BOKU), Austria	TAS_2_A Presenter

F

Faour, Ghaleb	National Council for Scientific Research and Remote Sensing Center (Lebanese Republic)	YSDF_O_1
Fehrmann, Lutz	University of Goettingen, Germany	YSDF_PS
Fuerst, Christoph	RIEGL Laser Measurement Systems GmbH, Austria	SPON-S Presenter

Förster, Michael	TU Berlin, Germany	TAS_1_A

G

Gaisecker, Thomas	RIEGL Laser Measurement Systems GmbH, Austria	SPON-S
Gallaun, Heinz	Joanneum Research, Austria	TAS_2 _B TAS_3 _B
Ganz, Selina	Forest Research Institute of Baden-Württemberg (FVA), Germany, Germany	YSDF_O_1 Presenter
Gao, Weixiao	Technische Universität Berlin, Germany	YSDF_O_2 Presenter
Garcia Alonso, Mariano	University of Leicester, United Kingdom; Jet Propulsion Laboratory (JPL), California Institute of Technology	TAS_2 _C Presenter
García-Abril, Antonio	Universidad Politecnica de Madrid, College of Forestry, Spain	TAS_1 _B
Georgiadis, Charalampos	School of Civil Engineering, Aristotle University of Thessaloniki (AUTH), Greece	TAS_1_C
Giagkas, Fotios	School of Rural and Surveying Engineering, Aristotle University of Thessaloniki (AUTH), Greece	TAS_1_C
Ginzler, Christian	Eidg. Forschungsanstalt WSL, Switzerland; Swiss Federal Research Institute WSL, Switzerland	TAS_1_B TAS_3 _A
Gobakken, Terje	Norwegian University of Life Sciences, Norway	TAS_1_A TAS_3 _C
Granica, Klaus	Joanneum Research, Austria	TAS_2 _B
Gutjahr, Karlheinz	Joanneum Research, Austria	TAS_3 _B
Gęca, Tomasz	University of Agriculture in Krakow, Poland	YSDF_PS

H

Hanus, Jan	Global Change Research Institute, Czech Republic	TAS_3 _B
Hass, Erik	Environmental Remote Sensing and Geoinformatics, Trier University, Germany	TAS_1_A
Hawryło, Paweł	University of Agriculture in Krakow, Poland	TAS_2 _C Presenter TAS_3 _B TAS_3_C TAS_1_C
Heilmeier, Hermann	Interdisziplinäres Ökologisches Zentrum, TU Bergakademie Freiberg, Freiberg, Germany	TAS_2 _B
Hernando, Ana	Universidad Politecnica de Madrid, College of Forestry, Spain	TAS_1 _B
Hernik, Józef	University of Agriculture in Krakow, Poland	TAS_2 _B
Hernández-Clemente, Rocio	Swansea University, United Kingdom	YSDF_PS
Heurich, Marco	Department of Conservation and Research, Bavarian Forest National Park, Grafenau, Germany	TAS_1 _B
Hill, Andreas	ETH Zurich, Switzerland	TAS_3 _B
Hill, Joachim	Trier University, Germany	DISC_P Presenter PLS-5 Presenter TAS_1_A
Hirschmugl, Manuela	Joanneum Research, Austria	TAS_2 _B TAS_3 _B
Hoffmann, Karina	Public Enterprise Sachsenforst, Department of Cartography, Forestry GIS and Surveying, Pirna, Germany	YSDF_O_1

Hollaus, Markus	Department of Geodesy and Geoinformation, Technische Universität Wien	TAS_1 _B TAS_1_C
Holopainen, Markus	University of Helsinki, Finland	YSDF_O_2
Homolová, Lucie	Global Change Research Institute, Czech Academy of Sciences, Czech Republic	TAS_2_A TAS_3 _A
Hoscilo, Agata	Remote Sensing Center, Institute of Geodesy and Cartography, Poland	TAS_2 _C Presenter
Hovi, Aarne	Aalto University, Department of Built Environment, Espoo, Finland	YSDF_PS
Hościło, Agata	Remote Sensing Center, Institute of Geodesy and Cartography in Warsaw, Poland	TAS_3 _B
Huber, Markus O.	Eidg. Forschungsanstalt WSL, Switzerland	TAS_1 _B
Hyyppä, Juha	Finnish Geospatial Research Institute, NLS, Finland	PLS-1 Presenter TAS_2 _B YSDF_O_2
Hájek, Filip	Forest Management Institute, Czech Republic	TAS_1_C Presenter

I

Ibrahim, Mahmoud	General Organization of Remote Sensing (Syrian Arab Republic)	YSDF_O_1
Immitzer, Markus	University of Natural Resources and Life Sciences, Vienna (BOKU), Austria	TAS_2_A
Isenburg, Martin	rapidlasso GmbH, Germany	DISC_P Presenter TAS_2 _B Presenter

J

Janoutová, Růžena	Global Change Research Institute, Czech Academy of Sciences, Czech Republic	TAS_2_A
Jarocińska, Anna	University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland	TAS_2_A TAS_3 _B YSDF_O_1 YSDF_O_1 YSDF_PS
Jeronimo, Sean	University of Washington, United States of America	TAS_1 _B

K

Kaartinen, Harri	Finnish Geospatial Research Institute, Finland	TAS_2 _B
Kaczka, Ryszard J.	University of Silesia in Katowice, Poland	YSDF_PS
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Kane, Jonathan	University of Washington, United States of America	TAS_1 _B
Kane, Van	University of Washington, United States of America	TAS_1 _B
Kania, Adam	Atmoterm SA, Opole, Poland	TAS_2 _B
Kankare, Ville	University of Helsinki, Finland	YSDF_O_2
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Kleinschmit, Birgit	TU Berlin, Germany	TAS_1_A
Knoke, Thomas	Technische Universität München, Germany	TAS_3 _C
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Kolecka, Natalia	Jagiellonian University, Poland	TAS_2 _C YSDF_PS
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Korhonen, Lauri	University of Eastern Finland, School of Forest Sciences, Joensuu, Finland	YSDF_PS
Koutsias, Nikos	University of Patras, Greece	TAS_1_A TAS_2_A TAS_2_A
Kovács, József	Department of Physical and Applied Geology, Eötvös Loránd University, Hungary	TAS_1 _B
Kozak, Jacek	Jagiellonian University, Poland	TAS_2 _C
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Krishna Moorthy Parvathi, Sruthi Moorthy	Computational & Applied Vegetation Ecology lab, University of Ghent, Belgium	YSDF_O_2 Presenter
Kroiher, Franz	Thünen Institute of Forest Ecosystems, Germany	TAS_3 _A
Krok, Grzegorz Aleksy	University of Agriculture in Cracow, Forestry Faculty, Poland	YSDF_PS Presenter
Krzystek, Peter	Munich University of Applied Sciences, Munich, Germany	TAS_1 _B
Kukunda, Collins Byobona	Georg-August-University Göttingen, Germany	TAS_1_A YSDF_O_1 Presenter
Kulla, Ladislav	National Forest Centre, Slovak Republic	TAS_3 _B
Kycko, Marlena	Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, University of Warsaw, Poland; University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland	TAS_1_A TAS_2_A TAS_3 _B YSDF_O_1 Presenter
Kłos, Andrzej	Opole University, Chair of Biotechnology and Molecular Biology, Opole, Poland	TAS_2_A

L

Labadan, Abigail	Central Mindanao University	TAS_2 _B
Lamelas, María Teresa	GOFOREST-IUCA; Centro Universitario de la Defensa de Zaragoza	TAS_2 _C
Lamprecht, Sebastian Martin	Trier University, Germany	TAS_3 _B Presenter
Lausch, Angela	UFZ Leipzig, Germany	TAS_1_A
Legner, Kate Anne	University of Washington, United States of America	TAS_3 _C Presenter
Lehtomäti, Matti	Finnish Geospatial Research Institute, Finland	TAS_2 _B
Lejeune, Philippe	Unit of Forest Management, Department of Biosystem Engineering, University of Liège, Gembloux Agro-Bio Tech, 2 Passage des déportés, 5030 Gembloux, Belgium	TAS_1 _B
Lenart, Csaba	Karoly Robert Univ. College, Hungary	TAS_1_A
Lewandowska, Aneta	Remote Sensing Center, Institute of Geodesy and Cartography, Poland	TAS_2 _C
Lhotáková, Zuzana	Department of Experimental Plant Biology, Charles University in Prague, Czech Republic	TAS_2_A
Li, Zengyuan	Institute of Forest Resources Information Techniques, Chinese Academy of Forestry	TAS_1 _B
Liang, Xinlian	Finnish Geospatial Research Institute, Finland	TAS_2 _B Presenter YSDF_O_2
Liesenberg, Veraldo	Department of Forest Engineering, Santa Catarina State University, Brazil	YSDF_O_2
Lu, Hao	Institute of Forest Resources Information Techniques, Chinese Academy of Forestry; Department of Geodesy and Geoinformation, Technische Universität Wien	TAS_1 _B Presenter
Lukeš, Petr	Global Change Research Institute, Czech Academy of Sciences, Czech Republic	TAS_2_A Presenter TAS_3 _A Presenter
Luna, Donald	University of the Philippines Los Baños, Philippines	YSDF_O_2
Lutz, James	Utah State University, United States of America	TAS_1 _B
Lähivaara, Timo	Department of Applied Physics, University of Eastern Finland, Finland	TAS_1 _B

M

Macandog, Damasa Magcale	University of the Philippines Los Baños, Philippines	YSDF_O_2
Magdon, Paul	Georg-August-University of Goettingen, Germany	TAS_2 _C
Makhlouf, Hassan	Lebanese University - faculty of science, Lebanon (Lebanese Republic)	YSDF_O_1
Mallinis, Giorgos Evangelos	School of Agricultural and Forestry Sciences, Democritus University of Thrace (DUTH), Greece	TAS_1_C Presenter TAS_2 _C TAS_3 _A
Maltamo, Matti	School of Forest Sciences, University of Eastern Finland, Finland	TAS_1 _B

Mandlburger, Gottfried	Department of Geodesy and Geoinformation, Vienna University of Technology, Austria	TAS_1_C
Manu, Raphael	GeoSocial Solutions Consultancy, Ghana	TAS_1_C
Manzanera, Jose Antonio	Universidad Politecnica de Madrid, College of Forestry, Spain	TAS_1 _B Presenter
Marcinkowska-Ochtyra, Adriana	University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland	TAS_3 _B YSDF_O_1 YSDF_O_1
Markiet, Vincent Robert Leon	University of Helsinki, Finland	YSDF_PS Presenter
Marx, Alexander	Planet Labs Germany GmbH, Germany	TAS_2_A Presenter
Mauro, Francisco	Oregon State University	TAS_1 _B
May, Johannes	NIBIO, Norway	YSDF_PS Presenter
McGaughey, Robert	USDA Forest Service, Pacific Northwest Research Station, Seattle, WA, USA	PLS-4 Presenter
Menk, Julia	Bern University of Applied Sciences, Switzerland	TAS_1 _B
Mielcarek, Miłosz	Department of Forest Resources Management, Forest Research Institute, Poland	TAS_3 _B
Mitsopoulos, Ioannis Dimitrios	Ministry of Environment and Energy, Greece	TAS_3 _A Presenter
Modzelewska, Aneta	Department of Forest Resources Management, Forest Research Institute, Poland; Forest Research Institute Department of Information Technology and Modelling, Sękocin Stary	TAS_3 _B YSDF_O_1
Mollatz, Michael	Joanneum Research, Austria	TAS_2 _B
Montealegre, Antonio Luis	University of Zaragoza, Geography Department, Spain; GOFOREST-IUCA	TAS_2 _C
Moskal, L. Monika	University of Washington, United States of America; RSGAL, College of the Environment, School of Environmental and Forest Sciences, University of Washington, USA	DISC_P Presenter PLS-6 Presenter TAS_1 _B TAS_3 _A Presenter TAS_1_C
Mottus, Matti	University of Helsinki, Finland	YSDF_PS
Mouketou-Tarazewicz, Dieudonne	LAGRAC, Department of Geography, University Omar Bongo of Libreville - Gabon / Department of Geoinformation, Cartography and Remote Sensing, WGiSR - University of Warsaw.	TAS_3 _B

N

Neuwirthová, Eva	Department of Experimental Plant Biology, Charles University in Prague, Czech Republic	TAS_2_A
Niedzielko, Jan	MGGP Aero Sp. z o.o.	YSDF_PS
Næsset, Erik	Norwegian University of Life Sciences, Norway	TAS_1_A TAS_3 _C
Nölke, Nils	University of Goettingen, Germany	YSDF_PS

O

Ocampo, Davies	University of the Philippines Los Baños, Philippines	YSDF_O_2
Ochtyra, Adrian	Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, University of Warsaw, Poland; College of Inter-Faculty Individual Studies in Mathematics	TAS_1_A TAS_2_A TAS_3 _B YSDF_O_1 YSDF_O_1 Presente

	and Natural Sciences, University of Warsaw, Poland; University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland	YSDF_O_1 YSDF_PS
Oehmichen, Katja	Thünen Institute of Forest Ecosystems, Germany	TAS_3 _A Presenter
Olesk, Aire	University of Tartu, Estonia	TAS_3 _C
Olpenda, Alex	Warsaw University of Life Sciences, Poland	TAS_2 _B Presenter
Olszanka, Karolina	Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, University of Warsaw, Poland	YSDF_O_1
Orłowska, Karolina	Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, Warsaw University, Poland	TAS_3 _A TAS_1_A Presenter TAS_2_A YSDF_O_1

P

Packalen, Petteri	School of Forest Sciences, University of Eastern Finland, Finland	TAS_1 _B
Panagiotidis, Dimitrios	Czech University of Life Sciences, Czech Republic	TAS_1_C Presenter
Pang, Yong	Institute of Forest Resources Information Techniques, Chinese Academy of Forestry	TAS_1 _B
Paschmionka, Barbara	Environmental Remote Sensing and Geoinformatics, Trier University, Germany	TAS_1_A
Pascual, Cristina	Universidad Politecnica de Madrid, College of Forestry, Spain	TAS_1 _B
Patias, Petros	School of Rural and Surveying Engineering, Aristotle University of Thessaloniki (AUTH), Greece	TAS_1_C
Pereira, João Paulo	Chair of Remote Sensing and Landscape Information Systems, FeLis, University of Freiburg, Germany	YSDF_O_2 Present. YSDF_PS Presenter
Perez-Cruzado, Cesar	Georg-August-University of Goettingen, Germany	TAS_2 _C
Perheentupa, Viljami	University of Helsinki, Finland	YSDF_PS
Perin, Jérôme	Unit of Forest Management, Department of Biosystem Engineering, University of Liège, Gembloux Agro-Bio Tech, 2 Passage des déportés, 5030 Gembloux, Belgium	TAS_1 _B
Perko, Roland	Joanneum Research, Austria	TAS_3 _B
Pfeifer, Norbert	TU Wien, Austria; Department of Geodesy and Geoinformation, Technische Universität Wien	PLS-5 Presenter TAS_1 _B TAS_1_C
Pfennigbauer, Martin	RIEGL Laser Measurement Systems GmbH, Austria	SPON-S
Pipkins, Kyle	TU Berlin, Germany	TAS_1_A
Pleniou, Magdalini	University of Patras, Greece	TAS_2_A Presenter
Pokorný, Radek	Global Change Research Institute CAS, Czech Republic	TAS_3 _A
Polewski, Przemyslaw	Munich University of Applied Sciences, Munich, Germany	TAS_1 _B
Posiak, Barbara	University of Agriculture in Krakow, Poland	YSDF_PS

Praks, Jaan	Aalto University, Finland	DISC_P Presenter PLS-6 Presenter TAS_3 _C Presenter
Psarras, Thomas	University of Patras, Greece	TAS_2_A
Puno, Rena Cristina	Central Mindanao University	TAS_2 _B
Pyorala, Jiri	Finnish Geospatial Research Institute, Finland	TAS_2 _B
Pyörälä, Jiri Kristian	University of Helsinki, Finland	YSDF_O_2 Presenter

Q

Quinones, S.G.	University of the Philippines Los Baños, Philippines	YSDF_O_2

R

Raczko, Edwin	University of Warsaw Faculty of Geography and Regional Studies, Poland; University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland	TAS_1_A Presenter TAS_2_A
Raggam, Johann	Joanneum Research, Austria	TAS_3 _B
Raizman, Yuri	VisionMap, Israel	DISC_P Presenter
Ramirez, Carlos	USDA Forest Service, Region 5 Remote Sensing Lab	TAS_2 _C
Ratajczak, Michał	Laboratory of Geomatics; Department of Forest Management, Geomatics and Forest Economics; Forest Research Institute; Faculty of Forestry; University of Agriculture in Krakow	YSDF_PS Presenter
Rautiainen, Miina	Aalto University, Department of Built Environment, Espoo, Finland	YSDF_PS
Raval, Simit	Australian Centre for Sustainable Mining Practices, School of Mining Engineering, University of New South Wales, Australia, Kensington NSW 2052	YSDF_O_1
Rehush, Nataliia	Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland	TAS_2_A Presenter
Riegl, Ursula	RIEGL Laser Measurement Systems GmbH, Austria	SPON-S
Rivera, Efren	University of the Philippines Los Baños, Philippines	YSDF_O_2
Robak, Anna	University of Warsaw, Faculty of Geography and Regional Studies, Poland	YSDF_PS
Robak, Anna	University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Senisng	YSDF_PS Presenter
Rossa, Bernadeta	Instıtute of Geodesy And Geoınformatıcs, Wroclaw University of Environmental and Life Sciences, Poland	TAS_1_C
Rudjord, Øystein	Norwegian Computing Center, Norway	TAS_1_A
Ruiz, Luis Ángel	Geo-Environmental Cartography and Remote Sensing Group (CGAT), Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Spain	ST-A
Rynkiewicz, Alicja Elżbieta	University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing	YSDF_O_1 Presente r
Różycka-Czas,	University of Agriculture in Krakow, Poland	TAS_2 _B

Renata		
Rönnholm, Petri	Aalto University, Department of Built Environment, Espoo, Finland	YSDF_PS
Rębiś, Piotr	University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland	TAS_3 _B

S

Saatchi, Sassan	Jet Propulsion Laboratory (JPL), California Institute of Technology	TAS_2 _C
Sabat, Anita	University of Warsaw, Faculty of Geography and Regional Studies, Poland	YSDF_PS Presenter
Sadkowski, Rafał	Department of Forest Resources Management, Forest Research Institute, Poland	TAS_3 _B
Salata, Tomasz	University of Agriculture in Krakow, Poland	TAS_2 _B
Salberg, Arnt-Børre	Norwegian Computing Center, Norway	TAS_3 _C
Sarodja, Damayanti	Georg-August-University of Goettingen, Germany	TAS_2 _C Presenter
Sačkov, Ivan	National Forest Centre, Slovak Republic	TAS_3 _B Presenter
Schardt, Mathias	Joanneum Research, Austria	TAS_2 _B TAS_3 _B
Schimalski, Marcos Benedito	Department of Forest Engineering, Santa Catarina State University, Brazil	YSDF_O_2 YSDF_PS
Schmitt, Andreas	German Aerospace Center (DLR), Oberpfaffenhofen, Germany	TAS_2_A
Schneider, Thomas	Institute of Forest Management,Technical University of Munich, Germany; Technische Universität München, Germany	TAS_3 _C TAS_3 _C Presenter
Schnitzer, Stefan	Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Ancon, Republic of Panama; Department of Biological Sciences, Marquette University, Milwaukee, WI 53201-1881	YSDF_O_2
Sedliak, Maroš	National Forest Centre, Slovak Republic	TAS_3 _B
Segl, Karl	GFZ Potsdam, Germany	TAS_1_A
Seifert, Frank Martin	ESA, Italy	DISC_P Presenter PLS-1 Presenter
Sejalbo, Charmina	University of the Philippines Los Baños, Philippines	YSDF_O_2
Seppänen, Aku	Department of Applied Physics, University of Eastern Finland, Finland	TAS_1 _B
Shataee, Shabban	Gorgan University of Agriculture and Natural Resources, Iran	YSDF_PS
Shoot, Caileigh	University of Washington, United States of America	TAS_1 _B Presenter
Skidmore, Andrew K.	Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands	TAS_1 _B
Solberg, Svein	NIBIO, Norway	YSDF_PS
Somers, Ben	KU Leuven, Belgium	TAS_1_A
Spyt, Barbara	University of Silesia in Katowice, Poland	YSDF_PS Presenter

Marta		
Stamou, Zoi	University of Patras, Greece	TAS_2_A
Standovár, Tibor	Department of Plant Systematics, Ecology and Theoretical Biology, Eötvös Loránd University, Hungary	TAS_1 _B TAS_2 _B
Steinegger, Martin	Joanneum Research, Austria	TAS_2 _B TAS_3 _B
Stereńczak, Krzysztof	Forest Research Institute, Poland	TAS_1_A TAS_2_C TAS_3 _B Presenter YSDF_O_1
Stoffels, Johannes	Environmental Remote Sensing and Geoinformatics, Trier University, Germany	TAS_1_A TAS_3 _B
Strati-Tsakiri, Maria	School of Rural & Surveying Engineering, Aristotle University, GR-541 24 Thessaloniki, Greece	TAS_2 _C
Straub, Christoph	Bavarian State Institute of Forest Research	TAS_3 _C TAS_3 _A
Surovy, Peter	Czech University of Life Sciences, Czech Republic	TAS_1_C TAS_1_C Presenter
Szmorad, Ferenc	Department of Plant Systematics, Ecology and Theoretical Biology, Eötvös Loránd University, Hungary	TAS_1 _B
Szostak, Marta	University of Agriculture in Krakow, Poland	TAS_1_C TAS_3 _C YSDF_PS
Székely, Balázs	Department of Geophysics and Space Science, Eötvös Loránd University, Hungary; Interdisziplinäres Ökologisches Zentrum, TU Bergakademie Freiberg, Germany; Department of Geodesy and Geoinformation, Vienna University of Technology, Austria	TAS_1 _B TAS_2 _B Presenter
Sławik, Łukasz	MGGP Aero Sp. z o.o.	YSDF_PS
Şanlıoğlu, İsmail	Selcuk University, Turkey	YSDF_O_2

T

Tejera, Rosario	Universidad Politecnica de Madrid, College of Forestry, Spain	TAS_1 _B
Thiel, Christian Joachim	Friedrich Schiller University, Germany	PLS-2 Presenter
Tian, Jiaojiao	Earth Observation Center, Remote Sensing Technology Institute, Photogrammetry and Image Analysis; German Aerospace Center (DLR)	TAS_3 _C TAS_3 _C
Tits, Laurent	KU Leuven, Belgium	TAS_1_A
Tokola, Timo	School of Forest Sciences, University of Eastern Finland, Finland	TAS_1 _B
Tomancak, Ondřej	Forest Management Institute, Czech Republic	TAS_1_C
Tomor, Tamas	Karoly Robert Univ. College, Hungary	TAS_1_A
Tompalski, Piotr	University of British Columbia, Canada	TAS_1 _B Presenter TAS_2_C
Trier, Øivind Due	Norwegian Computing Center, Norway	TAS_1_A Presenter TAS_3 _C Presenter
Trochta, Jan	Reseach institute for landscape and ornamental gardering, Czech Republic	TAS_2 _B Presenter

Trucíos-Caciano, Ramón	Georg-August-Universität Göttingen, Germany	TAS_2 _C Presenter
Tsioukas, Vasileios	School of Rural and Surveying Engineering, Aristotle University of Thessaloniki (AUTH), Greece	TAS_1_C
Tudoran, Gheorghe-Marian	Transilvania University, Romania	TAS_1_C
Tymkow, Przemyslaw	Instıtute of Geodesy And Geoınformatıcs, Wroclaw University of Environmental and Life Sciences, Poland	TAS_1_C

U

Udelhoven, T.	Trier University, Germany	TAS_3 _B
Urban, K.	University of Goettingen, Germany	YSDF_PS Presenter
Usień, M.	University of Agriculture in Krakow, Poland	YSDF_PS Presenter
Ustin, S.	Center for Spatial Technologies and Remote Sensing (CSTARS), University of California Davis	TAS_2 _C

V

Valbuena, R.	University of Eastern Finland	TAS_1 _B
Varga, K.	Interdisziplinäres Ökologisches Zentrum, TU Bergakademie Freiberg, Freiberg, Germany	TAS_2 _B
Varvia, P.	Department of Applied Physics, University of Eastern Finland, Finland	TAS_1 _B Presenter
Vastaranta, M.	University of Helsinki, Finland	YSDF_O_2
Verbeeck, H.	Computational & Applied Vegetation Ecology lab, University of Ghent, Belgium	YSDF_O_2
Vogt, P.	European Commission, Italy; European Commission, Joint Research Centre, Italy	DISC_P Presenter PLS-6 Presenter
Voormansik, K.	Tartu Observatory, Estonia	TAS_3 _C

W

Wakabayashi, H.	Nihon University, Japan	TAS_1_C
Wallner, A.	Institute of Forest Management,Technical University of Munich, Germany; Bavarian State Institute of Forest Research; Technische Universität München, Germany	TAS_3 _C Presenter TAS_3 _C
Wang, Di	Department of Geodesy and Geoinformation, Vienna University of Technology, Austria	TAS_1_C Presenter
Warchoł, Artur	ProGea Consulting, Krakow, Poland	TAS_2 _B
Waser, Lars T.	Swiss Federal Research Institute WSL, Switzerland	TAS_3 _A DISC_P Presenter PLS-6 Presenter TAS_2_A
Watanabe, Manbu	Tokyo Denki University, Japan	TAS_1_C
Waśniewski, Adam	Faculty of Geography and Regional Studies, University of Warsaw, Poland	TAS_3 _B Presenter
Wei, Zilin	Technische Universität München, Germany	TAS_3 _C

Weinacker, Holger	Chair of Remote Sensing and Landscape Information Systems, FeLis, University of Freiburg, Germany	YSDF_O_2
Wężyk, Piotr	University of Agriculture in Krakow, Poland	TAS_1_C Presenter TAS_2 _B Presenter DISC_P Presenter TAS_3 _B TAS_3 _C Presenter TAS_3 _A Presenter TAS_2_C YSDF_PS
White, Joanne C.	Canadian Forest Service (Pacific Forestry Centre), Natural Resources Canada	TAS_1 _B
Wieser, Martin	Department of Geodesy and Geoinformation, Vienna University of Technology, Austria	TAS_1_C
Wietecha, Martyna	Forest Research Institute, Poland	TAS_1_A Presenter
Wietecha, Martyna	University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland; Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, UW University of Warsaw, Poland	TAS_2_A YSDF_O_1
Wietecha, Martyna	University of Warsaw, Faculty of Geography and Regional Studies, Poland	YSDF_PS
Wimmer, Andreas	Joanneum Research, Austria	TAS_2 _B
Woodhouse, Iain	The University of Edinburgh, United Kingdom	PLS-3 Presenter
Woźniak, Rafał Marcin	University of Agriculture in Krakow, Poland	YSDF_PS Presenter
Wrońska-Wałach, Dominika	Jagiellonian University, Poland	YSDF_PS
Wulder, Michael A.	Canadian Forest Service (Pacific Forestry Centre), Natural Resources Canada	TAS_1 _B

X

Xystrakis, Fotios	University of Patras, Greece	TAS_2_A Presenter

Y

Yao, Wei	Munich University of Applied Sciences, Munich, Germany	TAS_1 _B

Z

Zagajewski, Bogdan	University of Warsaw Faculty of Geography and Regional Studies, Poland; University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warszawa, Poland; Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, Warsaw University, Poland	TAS_1_A TAS_2_A Presenter TAS_3 _B Presenter TAS_3 _A YSDF_O_1 YSDF_O_1 TAS_1_A YSDF_O_1 YSDF_PS
Zahi, Hao	School of Mining Engineering, University of New South Wales, Australia, Kensington NSW 2052	YSDF_O_1

Zalite, Karlis	Tartu Observatory, Estonia	TAS_3 _C
Zara, Precious Realon	University of the Philippines Los Baños, Philippines	YSDF_O_2 Presenter
Zemek, Frantisek	Global Change Research Institute, Czech Republic	TAS_3 _B
Zeybek, Mustafa	Selcuk University, Turkey	YSDF_O_2 Presenter
Zielonka, Anna Maria	Jagiellonian University, Poland	YSDF_PS Presenter
Ziembik, Zbigniew	Opole University, Chair of Biotechnology and Molecular Biology, Opole, Poland	TAS_2_A
Zimmermann, Sebastian	University of Technology Dresden, Faculty of Environmental Sciences, Dresden, Germany	YSDF_O_1 Presenter
Ziolkowski, D.	Remote Sensing Center, Institute of Geodesy and Cartography, Poland	TAS_1_A TAS_2_A YSDF_O_1
Zięba, K.	University of Agriculture in Krakow, Poland	YSDF_PS Presenter
Zwijacz-Kozica,M.	Tatra National Park, Zakopane, Poland	TAS_3 _B

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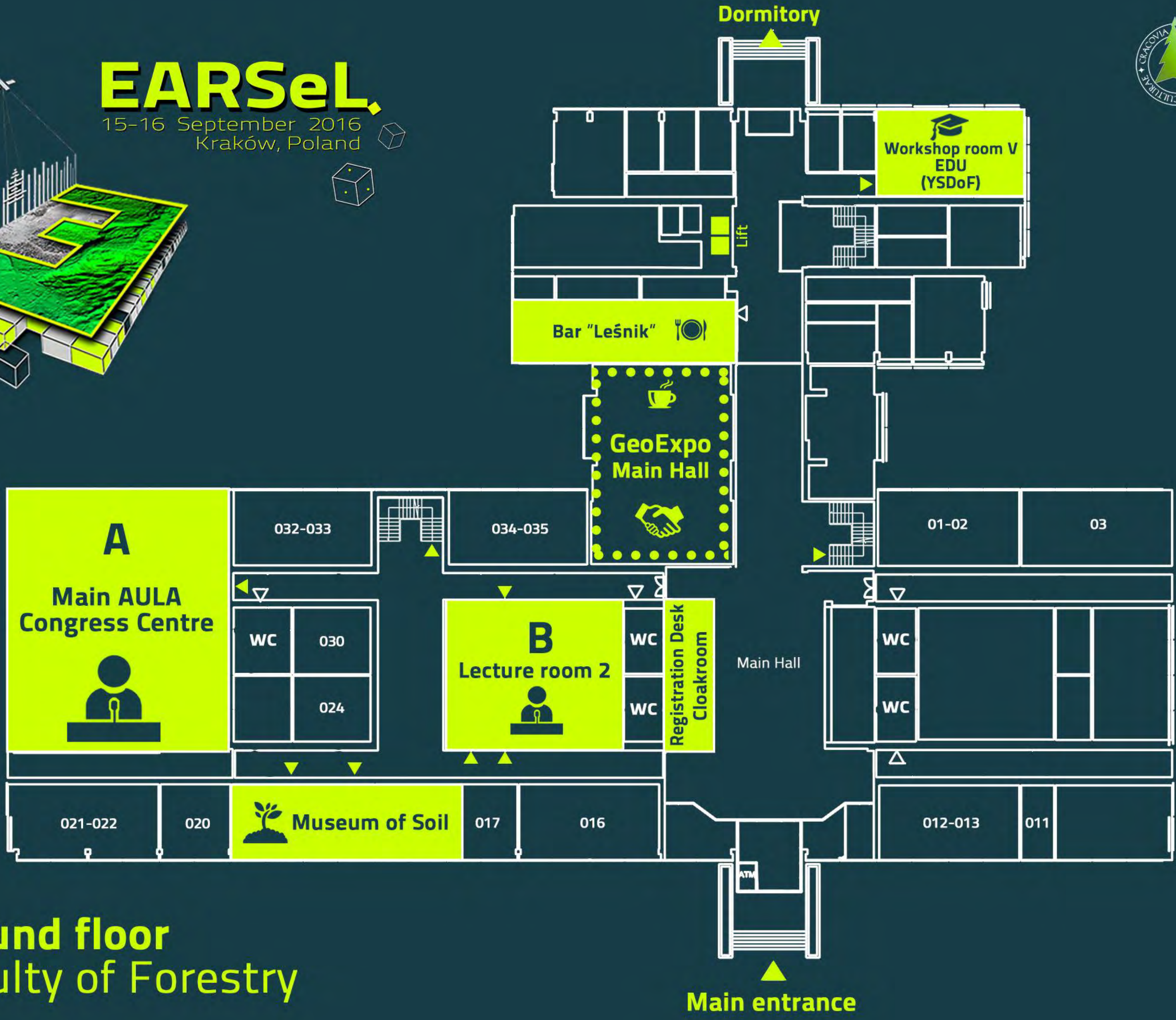

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