Mean forest volume estimation by high-resolution aerial RGB imagery and digital surface model with Trestima as validation technique

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Abstract

Forests typically cover large areas and are hard to access, which is why it is critical to have reliable and cheap means for their surveying. The more accurate the data is and the cheaper its acquisition is, the higher the efficiency of the surveys (i.e. forest inventories) performed is. Potentially also the efficiency of future forest management operations could be higher. This study considers a remote sensing technique for the mean volume estimation based on a very high-resolution (VHR) aerial RGB imagery obtained using a small-sized unmanned aerial vehicle (sUAV) and a high-resolution photogrammetric digital surface model (DSM) as well as an innovative technology for field measurements Trestima as a validation tool. The study area covers approx. 220 ha of forest land in the municipality of Raseborg, Finland. The work concerns the entire process from remote sensing and field data acquisition to statistical analysis and the forest volume wall-to-wall mapping. The study showed that the VHR aerial imagery and the high-resolution DSM produced based on the application of the sUAV have good prospects for forest inventory. At the estimation of forest variables such as Height, Basal Area and mean Volume (V, m^3/ha), Root Mean Square Error constituted 6.61%, 22.63% and 28.48%, respectively. The application of Trestima showed stunning performance at all the selected forest compartments with very little difference over existing Forest Management Plan. Simultaneously, the results of the study confirmed that the technologies and the tools applied at this work could be the reliable and cheap means of forest data acquisition with high potential of operational use.

Language: English

Key words: forestry, remote sensing, unmanned aerial vehicle, Trestima, GIS, inventory, forest management, digital surface model, mean forest volume, RGB

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Abbreviations

2D – two-dimensional;

3D – three-dimensional;

AGL – above ground level;

ALS – airborne laser scanning;

AOI – area of interest;

ASL – above sea level;

BA – basal area (also could be referred to as G);

DBH – diameter breast height;

DSM – digital surface model (in some cases can also be referred to as DEM – digital elevation model);

DTM – digital terrain model;

f **– form factor;**

FMP – forest management plan;

H – tree height;

GCP – ground control point;

GNSS/RTK – Global Navigation Satellite System/Real Time Kinematic;

LiDAR – Light Detection and Ranging;

NFI – National Forest Inventory;

NLS – National Land Survey of Finland (Lantmäteriverket/Maanmittauslaitos);

RGB – red, green and blue;

SFFS – Sequential Forward Feature Selection;

sUAV – small unmanned aerial vehicle;

V – volume;

VHR – very high resolution;

XYZ – X, Y and Z coordinate of a projected coordinate system, respectively.

1. Introduction

Accurate enough data about forest resources is a crucial element of decision making for different stakeholders such as governmental institutions, forest owners, forest lease-holders, forest engineers and other entities involved in forestry. Considering a narrower scope of forestry - the industrial forestry - the data is usually derived from forest inventories. The data gives significant benefits for forest policy development and management, i.e. area planning, forest growth planning, harvesting methods and tools planning, final products planning and reafforestation strategy.

Typically, forests cover large areas and it is hard to survey them entirely at least in a reasonable time frame. That poses a question about efficient tools to perform assessment of large areas with ever-limited resources. In that respect, forest inventory based on remote sensing has been quite well established around the globe, which helps solving the problem. Generally speaking, the above mentioned forest inventories are based on statistical analysis of features extracted from different auxiliary data such as e.g. aerial imagery or satellite imagery, which is relatively cheap to acquire for large area. There are several methods existing.

For example, 2D aerial photography has been employed in Finnish forest inventory since 1946 (Koivuniemi, 2006, p.272). The first application of aerial imagery refers to its simple visual interpretation. A more advanced technology of aerial imagery interpretation is so called stereoscopy, which employs a pair of images to enable visual extraction of 3D forest attributes (Husch, 1971). However, these two methods are quite labor-intensive and that is why they are not widely used anymore.

The most recent development of the new generation of forest inventory tools refers to airborne laser scanning (ALS). ALS has been extensively used in Finland for many different purposes including forest management, volumetric applications and terrain modeling (Maltamo et al., 2014). The major advantage of ALS in forestry is a three-dimensional product, which allows extremely accurate estimation of 3D forest features as e.g. canopy height above ground level. ALS requires an application of heavy duty conventional aerial vehicles/platforms and complex LiDAR equipment, which makes the technology rather expensive.

There is yet one more tool, which is based on aerial imagery as well. This method is known as photogrammetry. Remarkably, that results of photogrammetric modeling are capable of deriving almost the same 3D features similar to those produced by ALS (Järnstedt et al., 2012; Tuominen et al., 2014).

As mentioned above, there is one distinct difference between ALS and photogrammetry. In simple words, ALS possesses a specific feature to penetrate vegetation and reach (in other words - measure) ground level, whereas photogrammetry uses regular photographs and cannot "see" under the canopy surface. The feature indeed makes ALS more comprehensive. On the other hand, this also means that photogrammetry, to be applicable at forest applications, requires an accurate terrain model. It is believed that photogrammetry could be less expensive (Tuominen et al., 2014, p. 3-4), as it does not require both complex laser equipment and manned aerial platforms. Simultaneously, the photogrammetry delivers a very high-resolution aerial imagery (VHR) as a default product, whereas at ALS some parallel efforts are needed to acquire the same data (Järnstedt et al., 2012). Finally, over time accurate enough terrain data becomes more and more available for different territories (as, for example, in Finland), which makes using historical data about ground level possible, as it does not tend to change dramatically in a short and even long-term perspective. That is why the method of forest inventory based on photogrammetry sounds quite promising for operational purposes in the future.

It is important to mention that both methods, i.e. airborne laser scanning and photogrammetry, require equal field data (ground truth) acquisition efforts. This data is later used for estimation of relevant forest variables, e.g. species distribution, median tree height, and stem diameter distribution, basal area and forest volume stock (e.g. Järnstedt et al., 2012). That is why the problem of minimization of field work efforts stays actual and needs to be addressed, too.

Previously, the problem of a digital surface model (DSM) application for forest variable estimation purposes has been studied e.g. by Järnstedt et al. (2012) and Tuominen et al. (2014). They obtained positive results towards a potential use of high-resolution DSM for forest inventory purposes. When it comes to new tools for field inventory, there were no similar studies available. This thesis focuses on the practical application of photogrammetry for forest inventory taking into consideration all the stages of the process, from remote sensing, field data acquisition and its processing to statistical analysis and maps production.

The objective of this particular thesis is to estimate the forest volume based on a high-resolution DSM and VHR aerial RGB (red, green and blue) imagery derived by application of a small unmanned aerial vehicle (sUAV) with a regular RGB digital camera. The work also includes a unique part related to an application of an innovative tool for field data acqusition known as Trestima (e.g. Mobiilisovellukset selvittävät metsän arvon ja puumäärän, 2013 and Rouvinen, 2014a). Trestima is a tool for forest inventory, which has been developing since 2012 by the Finnish company Trestima Oy, which employs smartphones for data collection via regular terrestrial photographing of a forest. Data acquired using Trestima has been used to compare with the results obtained at statistical modeling and the existing forest management plan.

The practical interest of this work is to evaluate possible operational use of the technologies applied in the project for forestry needs.

2. Background

2.1. General overview

In 2012 Novia University of Applied Sciences obtained a sUAV (model QuestUAV Q200, produced by QuestUAV Ltd. U.K.) for the purpose of application at a Geodesign project and its branch – the project Aeria. The sUAV was successfully applied during 2012 and 2013 at different sites to produce remote sensing data such as VHR aerial RGB imagery and high-resolution digital surface models (DSM) (Rybakov, 2015). A number of applications were assessed from the point of view of a prospective operational use of the sUAV. Later in 2013 the team of Geodesign and Aeria project started investigation of the sUAV potential at forestry applications.

2.2. Research area and initial material

For the purpose of the study the forest area Falkgölen (approx. 60° 0'50.78"N, 23°24'35.29"E) was selected (see Fig.1), which is located in the municipality of Raseborg of South-Western Finland.

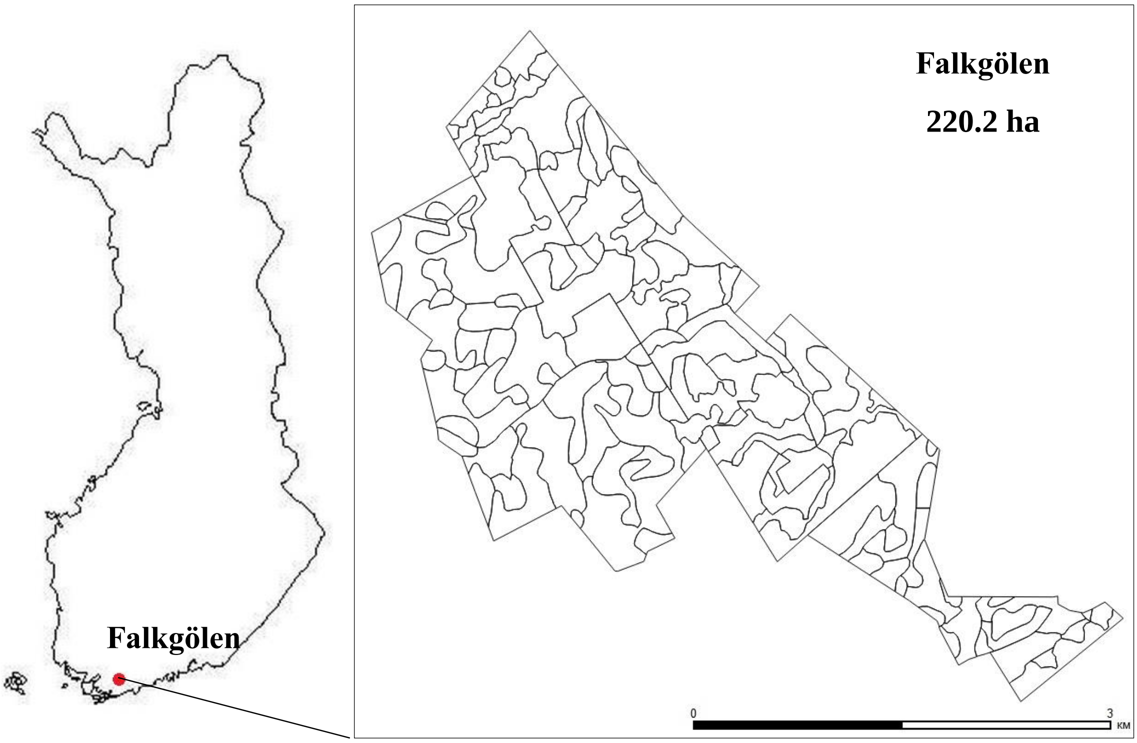


Fig. 1. Area of interest location (left) and area boundaries (incl. compartments) (right)

Falkgölen forests have been managed by Novia University of Applied Sciences for educational as well as forest management purposes for many years. In total, the study area covers approximately 220 hectares and is represented by pine and spruce dominated forest of different age classes as well as few compartments with dominance of birch and/or larch. The choice of the area was justified by its large enough size, distance from the campus area and variety of forests.

The available Forest Management Plan (FMP) for 2014-2023 (in Swedish: Skogsbruksplan) (updated in 2014) has been used as a very initial material of the project work as well as a reference at data comparison. The FMP, in general case, corresponds to the state of the forest at the moment of field work and data acquisition. However, due to the reason of possible active forest management operations in the study area, some unpredictable deviations are possible. Based on the FMP a forest compartment database was created using standard tools of ESRI™ ArcGIS and qgis software package.

Additionally, the following datasets produced by National Land Survey of Finland (NLS) were also applied at different stages of the work:

- basic map raster (NLS block K3444R);
- topographic database, containing roads, wetlands, bedrock and other relevant vector data about natural objects (NLS block K3444R); and
- laser scanning data (NLS block K3444E4), which was used to derive digital terrain model (DTM) of 0.15 m Z value accuracy (Laser scanning data, 2015).

3. Tools and methods

The work consisted of several consecutive stages described below.

Remote sensing data acquisition, i.e. very high resolution (VHR) aerial RGB (red, green and blue) imagery, has been performed by the application of the sUAV.

The raw remote sensing data were processed into an operational remote sensing datasets i.e. VHR aerial RGB aerial orthophoto (orthomosaic) as well as a high-resolution digital surface model represented by an elevation raster (also referred to as DEM or DSM) and a dense point cloud. At all further stages the remote sensing data obtained were used "as it is".

In order to support further statistical analysis and delivery of the major study results a forest inventory (field campaign) and forest data acquisition was performed. The field campaign was performed based on deep elaboration of existing auxiliary data about the study area local environment.

Combined together the remote sensing datasets and the data derived from field campaign resulted into a statistical analysis and mean forest volume wall-to-wall mapping, which constituted the most important part of the entire project.

Finally, a validation based on data acquired using Trestima – the innovative field data acquisition technique, was performed as well as an overall data comparison.

3.1. Data acquisition using sUAV

Aerial data acquisition was performed using sUAV, model QuestUAV Q200. The vehicle is featured by fully autonomous performance with assisted launch and landing functionality. Tested flight endurance of the sUAV constitutes approximately 20-25 minutes depending on local weather conditions (Rybakov, 2015). Wingspan of the sUAV is approximately 2.3 meters. At normal weather conditions the sUAV cruises at ground speed of approx. 55 km/h. This particular sUAV was tailored to be used along with a payload - Panasonic Lumix LX-5 digital RGB camera, which was employed as a sensor to collect aerial images. The camera had been modified by the sUAV producer to be triggered by sUAV autopilot. At this mission the trigger was programmed to produce images with a speed of one shot per 2.5 sec.

All in all, six flights covering the entire area were both planned and performed (see Fig. 2). The flight altitude varied from approximately 150 to 180 meters above ground level (AGL). The variation of flight altitude is explained by uneven terrain, which according to NLS data deviates from approx. 0 to 70 meters above sea level at the area of interest (AOI).

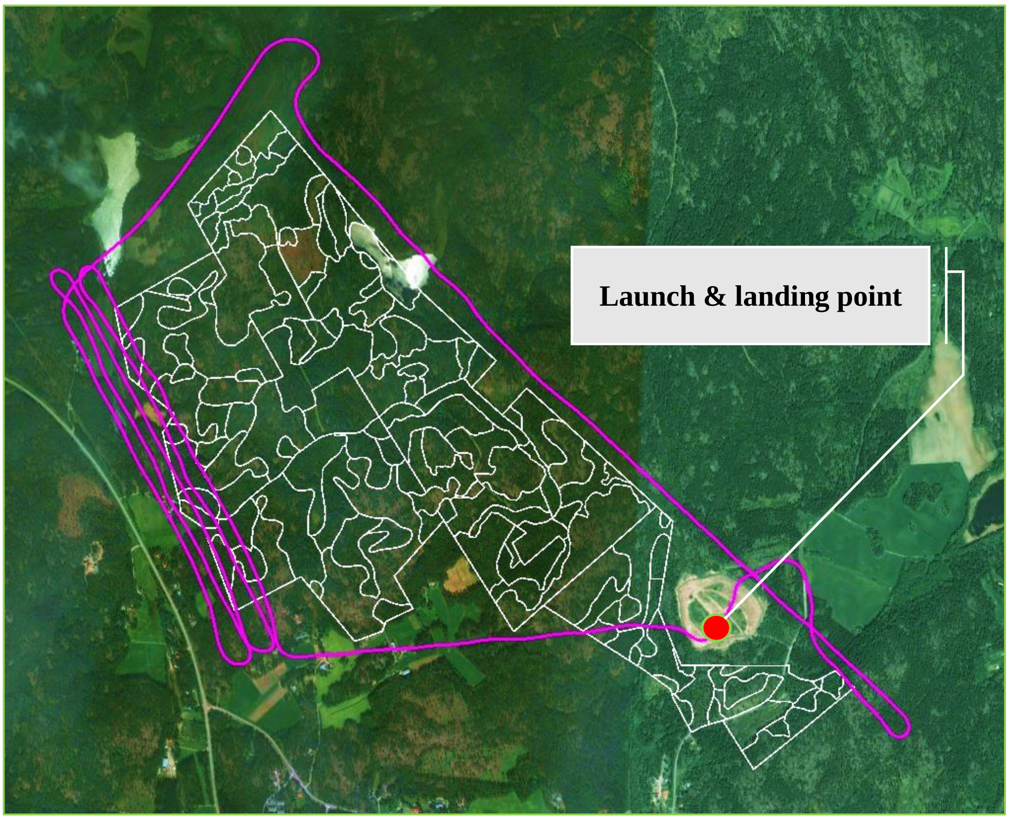


Fig. 2. Flight plan (flight #1 – realized flightlog) over AOI and launch/landing point

Flight operations were carried out during daytime between 12.00 and 16.00 EET on August, 21st 2013.

Before flight occasion a network of twelve ground control points (GCP) was established, which were evenly distributed throughout the AOI (see Fig. 3). Coordinates of GCPs were measured with GNSS/RTK Topcon equipment with an accuracy of 1-2 cm XY (plane) and 2-3 cm Z (vertical). The GCPs were later used as a georeference at photogrammetric modelling.

All in all, during flight mission 2 539 images (featured red (R), green (G) and blue (B) channels) were captured with an average overlap exceeding 60% along and 80% across (an estimation) (see Annex 1).

More in detail principles and general process of data acquisition using sUAVs as well as principles of photogrammetry have been quite well described by Åkerholm (2012), Lisein et al. (2013) and Rybakov (2015), which were thoroughly applied at this work. Although the sector of UAV applications and equipment is being developed and various UAV platforms, one better and cheaper than another, every day change each other on the market, the principles remain just the same.

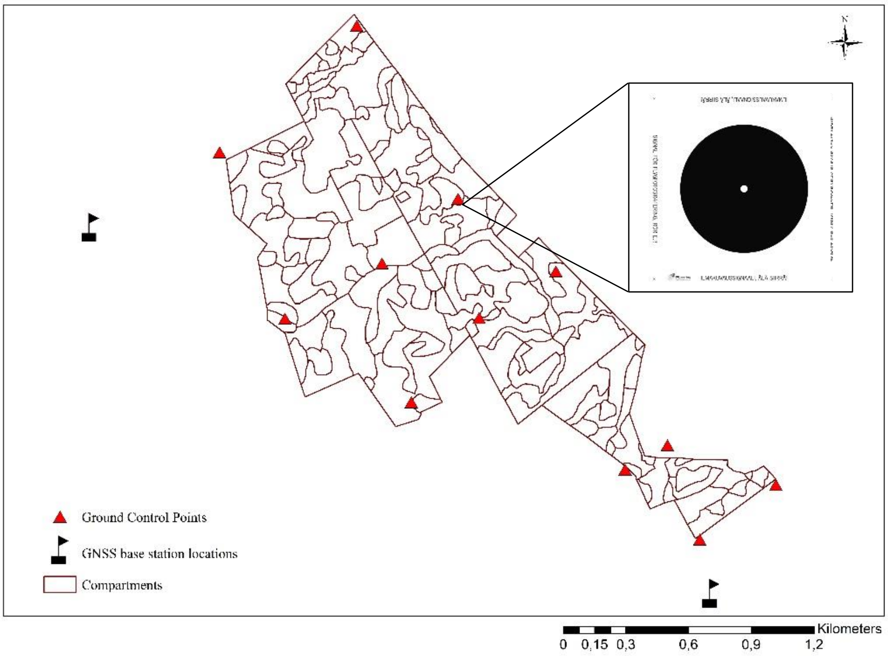


Fig. 3. AOI boarders and GCPs arrangement

3.2. Production of remote sensing data – data processing: high resolution digital surface model and VHR aerial imagery

The aerial images acquired were processed using a photogrammetric software Agisoft Photoscan Professional Edition version 1.0.0 build 1768 (64 bit), an educational license (developer - Agisoft LLC, Russia). As a result of photogrammetric modelling two basic products were produced:

- the VHR aerial image-orthophoto (see Fig. 4) with the resolution of 0.061 m/pix; and
- a dense point cloud with point density of 9 points per square meter (see Fig. 5), containing the following point classes: 1 (unclassified), 2 (ground), 3 (low vegetation) and 7 (noise) (Agisoft Features Professional Edition, 2014).

Fig. 4. Orthophoto (0.25 m/pix) and two patches of original resolution 0.06 m/pix

For the purpose of further post-processing the VHR orthophoto was resampled to 0.25 m/pix using ESRI™ ArcMap standard tools (see Fig. 4). Such a resolution of the aerial image raster was selected as according to Tuominen et al. (2014, p. 5) as it is normally used for forest surveys in Finland.

Next, the dense point cloud dataset was rendered into a digital surface model (DSM) also of a pixel size of 0.25 m. At this stage points classified as noise were filtered out and respectively their elevations were not included into the resulting DSM. As all elevation values of the DSM by default are given above sea level (ASL), which makes impossible to detect true height of a surface judging by DSM along, the DSM was transformed into DSM above ground level (AGL) (also could be referred to as a canopy height model (CHM)) by normalization procedure applying simple mathematical extraction of the ground level from DSM via raster calculation using ESRI™ ArcMap (Eq. 1) (see Fig. 6).

$$DSM_{AGL} = DSM_{ASL} - DTM \qquad \text{(Eq. 1)}$$

where DSM_{AGL} is a digital surface model above ground level, DSM_{ASL} is a digital surface model above sea level and DTM is a digital terrain model. Prior to the calculations DTM was also resampled into raster resolution of 0.25 m/pix.

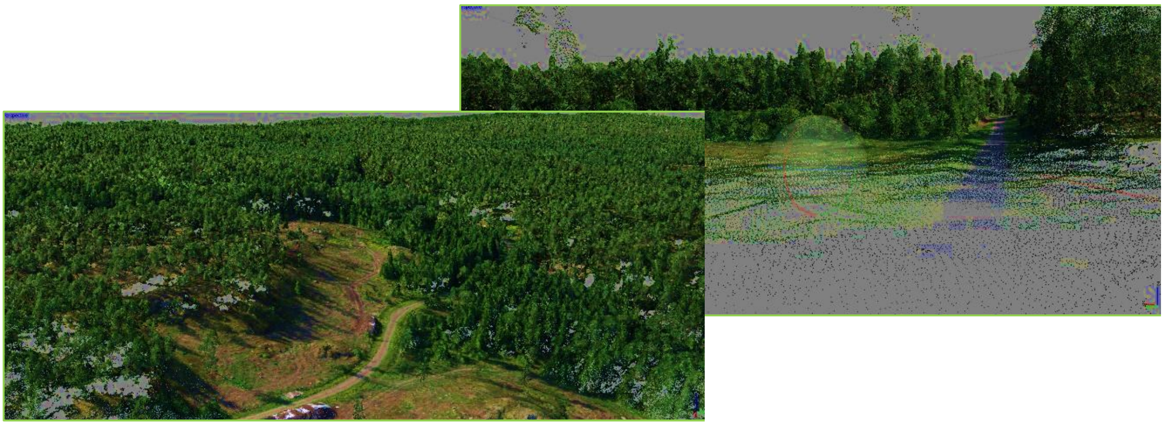


Fig. 5. Photogrammetric dense point cloud
(visualization at Agisoft Photoscan screen)

At the final stage of remote sensing data production and preparations few manipulations were given to the dense point cloud array rendered from photogrammetric modelling. As the photogrammetric dense point cloud represents DSM, i.e. does not contain terrain data under the canopy, it was amended by points of class 2 (ground) from the NLS laser scanning dataset. Simultaneously, all points of class 7 (noise) were filtered out. Therefore, the resulting point cloud contained only necessary points (classes 1, 2 and 3) and the modified point cloud was further applied at 3D feature extraction (see Fig. 7).

Fig. 6. Normalized DSM – DSM_{AGL}

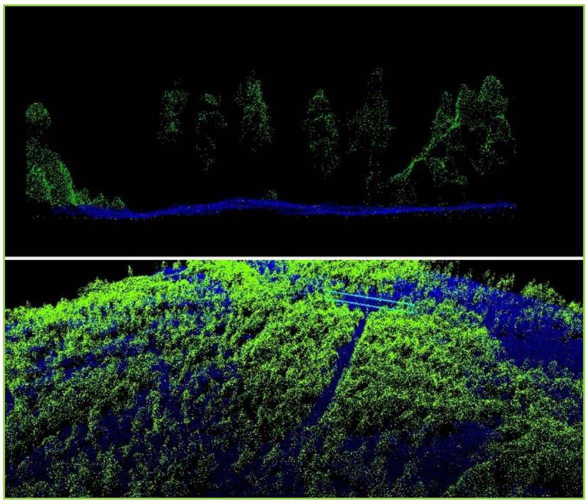


Fig. 7. Dense point cloud (merge of photogrammetric and LiDAR data), profile section (top) and 3D view (bottom) (canopy – green, ground - blue)

All data were georeferenced to EUREF-TM35FIN (EPSG code: 3067) – the projected coordinate system.

3.3. Organization of forest inventory (field campaign) and forest data gathering

Field data acquisition is a crucial part of any forest inventory. In general, the final result of the entire project fully depends on the quality of this particular part of the work. This project however was even more sensitive at this part due to extremely limited resources. Respectively, the field campaign design should have taken into consideration these obstacles. On the one hand, it was important to minimize the field work efforts as much as possible and, on the other hand, it was equally important to acquire data representing the forest over the entire 220 ha.

In general case, i.e. at long-term monitoring inventories or in the situation when auxiliary data is not available, a systematic sampling is applied as a sampling technique (Tuominen et al., 2006). At this project, however, two-phase sampling was selected a major technique (Tuominen et al., 2006). This technique also known as double sampling was offered in 1938 by Neyman (Tuominen et al., 2006) and since then turns to stay one of the best choices for forest inventories (Tuominen et al., 2006). The technique implies several steps to undertake (Tuominen et al., 2006):

- at first to generate first-phase sample plots homogeneously covering the entire area;

- stratification of the first-phase sample plots based on auxiliary data acquired, which could be, for example, data containing former or present forest management information, data about forest types, forest age, species, land use/land cover, terrain data, soils, administrative division, slopes, climatic zones etc. The stratification plays crucial role as it helps to define the most specific zones (strata) of an area (Tuominen et al., 2006).
- planning of second-phase sample plots, which are the actual field plots to visit for ground truth acqusition.

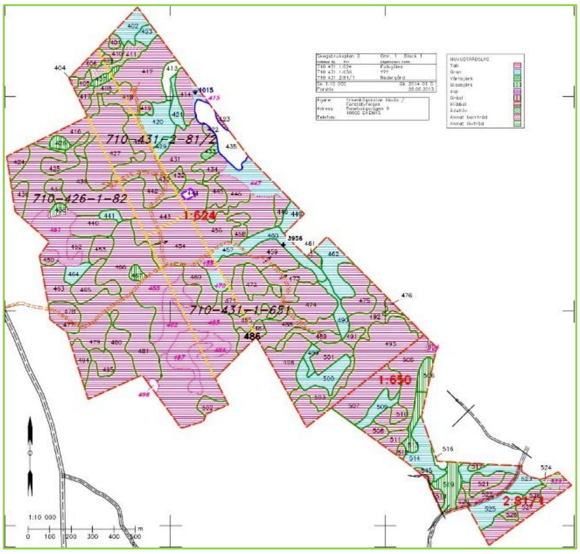
The AOI has been covered by a grid (fishnet) of approx. 299.98 m^2 (17.32 m x 17.32 m) cell. This solution bases on the decision to employ fixed radius of 9.77 m plots as second-phase sampling, which corresponds the area of approx. 299.87 m^2 i.e. as a result areas of both first-phase sample plots and second-phase sample plots are considered equal.

Stratification (Tuominen et al., 2006) was conducted based on the following auxiliary data. First of all, existing forest management plan (FMP) information including forest compartment boarders and dominant species over compartments (see Fig. 8.1) as well as stages of the forest development at compartments (see Fig. 8.2) were taken into consideration.

According to the FMP, the area is presented by the following tree species: pine, spruce, birch and larch. Different forest compartments may appear in the following development stages:

- clear cut (excluded from stratification);
- seeds trees (excluded from stratification);
- recently planted forest with seeds trees standing (excluded from stratification);
- young forest H < 1,3 m (excluded from stratification);
- young forest H > 1,3 m;
- young forest that can be harvested by thinning;
- older forest to be thinned;
- older forest to clear cut;
- forest prepared for final cut by thinning;
- non-productive forest (excluded from stratification); and
- no class assigned (excluded from stratification).

The decision about exclusion from stratification of some development stages was justified by their low value for the forest inventory purposes. For example, compartments of recent clear cuts or seed trees standing along were not considered of a large value in terms of future estimations.



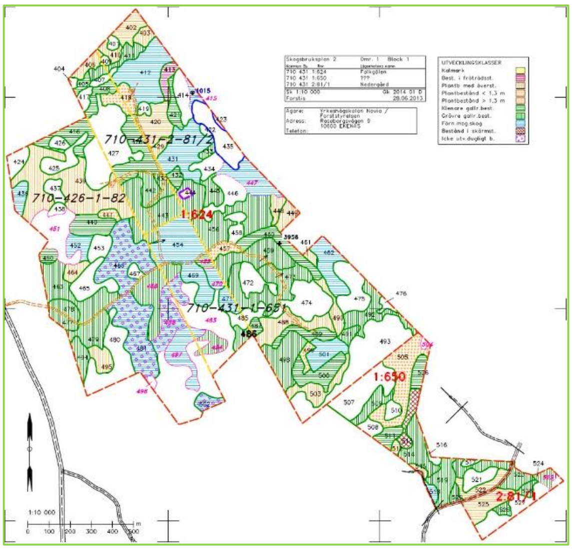


Fig. 8.1. Compartments and species **Fig. 8.2.** Development stages

Secondly, soil types were included into stratification based on available NLS data, i.e. based on basic map raster and topographic database (see Fig. 8.3).

Using the above mentioned data the AOI was divided into several strata. Theoretical number of strata calculated as a combination of species (4 classes), stages of forest development (11 classes) and soil types (3 types, excluding water bodies) resulted in 132 strata. After GIS analysis, the number of present strata dropped to 56. Filtering out strata, which are insignificant due to their area, the realized number of strata turned to be 43. All the relevant data were recorded into a GIS database and final maps of strata produced (see. Fig. 8.4).

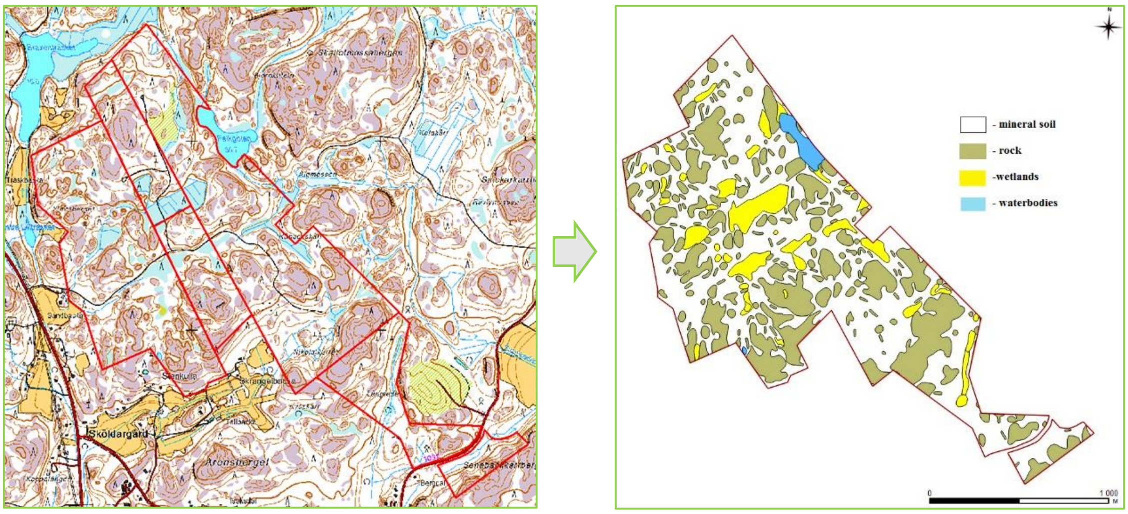


Fig. 8.3. Soil types (from base map raster to a classified vector file)

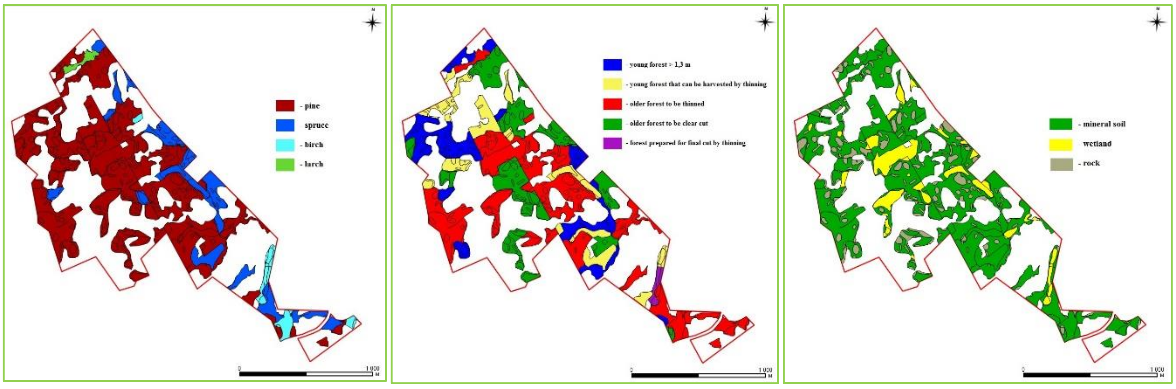


Fig. 8.4. Stratification of the AOI
(from left to right: species, development stages and soils)

Next, second-phase sample plots were assigned. Due to the size of the area, the potential number of second-phase plots could have constituted a relatively large number, which, unfortunately, could make the task of field data acquisition absolutely daunting in the framework of this particular work. Consequently, it was decided to assign only one sample plot per stratum also applying a criteria of a field plot proximity to a road network not farther than 250 meters (this has been done in order to make work of field crew as efficient and intensive as possible). All in all, 44 plots were allocated (see Fig. 9).

This approach in allocating the field measurements resembles the grouping method (e.g. Tuominen et al., 2006), which employs one field plot per stratum. The number of field plots employed in this study was small and thus, the estimation of forest variables was not carried out stratum-wise. Instead, the forest variables were estimated by regression modeling using all 44 field plots.

At each second-phase sample plot a standard number of attributes were measured, i.e. a diameter breast height (DBH) of each tally tree > 5 cm DBH and a height (H) for a basal median tree per species. All in all, at 44 field sample plots individual metrics of 944 trees of different species were measured including DBH of each tally tree as well as H for 109 basal median trees.

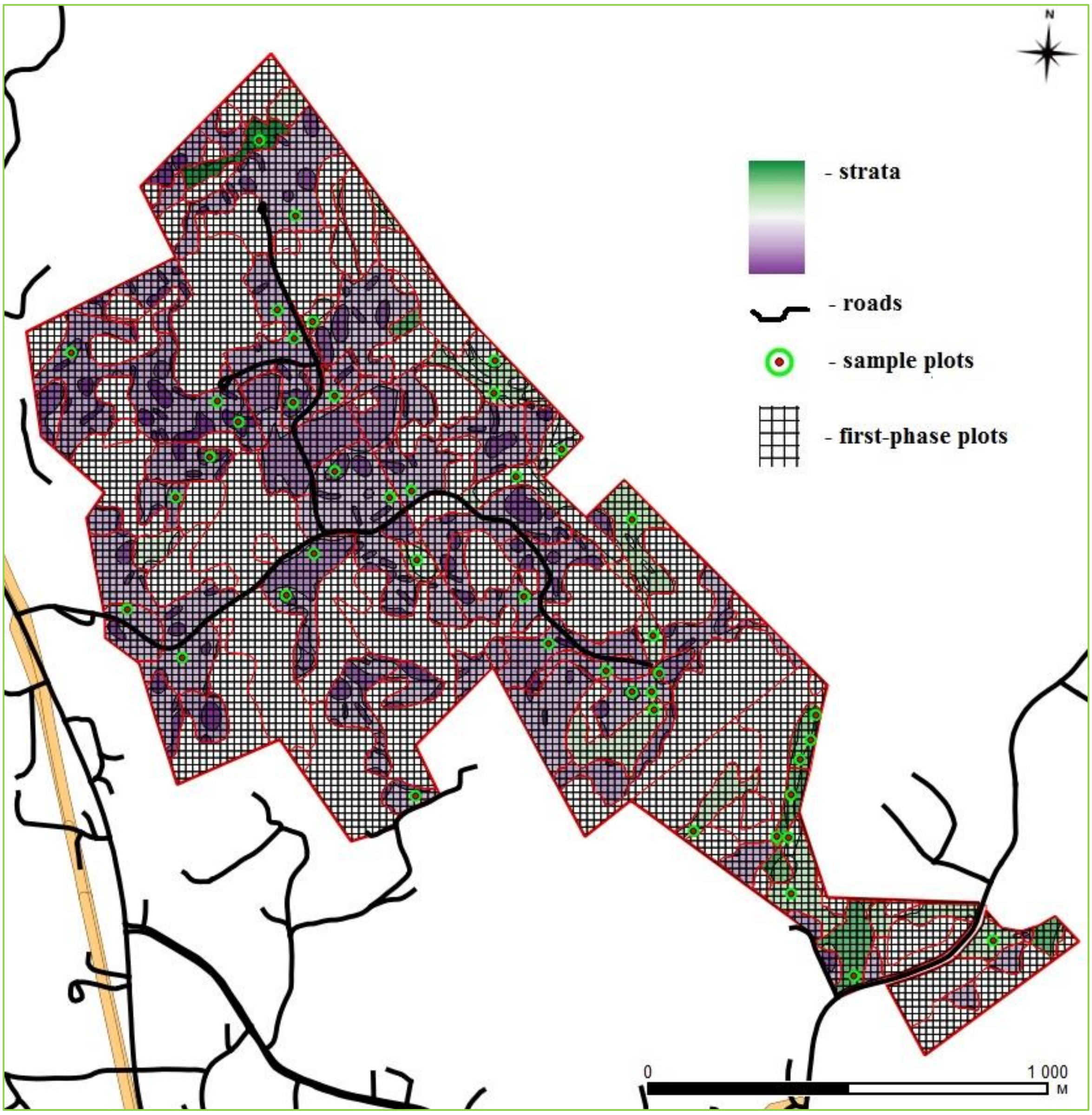


Fig. 9. Sample plots and strata

At the next stage forest variables were calculated: the tree height (H) was estimated based on the model of Eerikäinen (2009) as well as volume per each tree (and volume for field plot respectively) was calculated based on model of Laasasenaho (1982) using the tree heights measured. Respective models of pine were used for tree species "larch" and "other". The resulting statistics of the field plots is presented in Table 1. Total net time of field campaign accounted for approx. 1 day. The job was performed by three teams of two individuals each. The raw field data and respective H model and V calculated for each tally tree is gathered in Annex 2.1 Resulting data for the second phase sample plots is gathered in Annex 2.2.

Table 1. Field plots statistics

	Average	Min	Max	Standard deviation
Volume, m^3/ha	177,2	10,2	472,2	112,2
Volume of pine, m^3/ha	80,1	0,0	248,8	71,4
Volume of spruce, m^3/ha	61,2	0,0	307,9	83,2
Volume of broad-leaved trees, m^3/ha	35,9	0,0	215,1	43,2
DBH, cm	24,3	8,9	37,2	6,1
H, m	17,2	7,9	26,0	4,0
BA, m^2/ha	21,0	1,6	49,5	10,9

3.4. Statistical analysis and forest volumes wall-to-wall mapping

3.4.1. Theoretical background for estimation of forest variables

As it has been explained by, for example, Tuominen (2006) auxiliary data/features derived from such auxiliary sources as DSM or an aerial imagery may well correlate to different forest variables, e.g. mean volume, basal area, average height or DBH. There are several techniques for estimation of the variables based on the remote sensing data, for example, k-nn (k-nearest neighbour) estimation or linear regression analysis (Tuominen et al., 2006). In case of this project, linear regression was chosen for estimation of forest variables over AOI.

Generally speaking, regression bases on the idea that a variable Y (dependent variable) could be explained by variable(s) X (independent variable(s)) (Sykes, 1992) assuming that their relationship is linear. In case of just one independent variable X the regression is called simple linear regression. When Y can be explained by more than one independent variable the regression is called multiple linear regression (Sykes, 1992).

Linear regression can be expressed by the following equation (Eq. 2).

$$Y = \beta X + \varepsilon \qquad \text{(Eq. 2)},$$

where:

Y is a dependent variable $y_1, y_2 \ldots y_n$ $(n = 1, \ldots)$, which in our case refers to a foret variable (either basal area (BA) or height (H));

X is an independent variable matrix, which in our case refers to a number of selected features extracted from remote sensing data such as VHR aerial imagery, high-resolution DSM normalized to the ground level as well as the dense point cloud;

β – regression coefficients $\beta_1, \beta_2 \ldots \beta_m$ *(m = 1, …)*; and

ε – a constant for regression line.

As estimations can not be 100% accurate there are several means to study their accuracy (Equations 3, 4 and 5).

$$Bias = \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)}{n} \qquad \text{(Eq. 3)}$$

which describes the an average bias of an estimation ($\hat{y}_i$) from observed values (y_i) (Tuominen et al., 2006),

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}} \qquad \text{(Eq. 4)}$$

RMSE (root mean square error) is the major measure of the estimation accuracy, which shows the probability of an estimate to deviate from its true value (Tuominen et al., 2006), and

$$RMSE_{\%} = 100 * \frac{RMSE}{\bar{y}} \qquad \text{(Eq. 5)}$$

$RMSE_{\%}$ - the same as RMSE but expressed in percent, where $\bar{y}$ is an average of observed values.

When it comes to the forest variables themselves the mean volume has been estimated using a traditional approach, which employs basal area (BA or G), tree height (H) and species specific form factor (*f*) (Eq. 6) (Wenger, 1982).

$$V = fGH \qquad \text{(Eq. 6)}$$

Since the target variable of the project was mean volume of the forest without distinguishing the tree species, it was decided to apply the form factor *f* of 0.498 to all sample plots. The value of 0.498 was obtained by averaging form factors calculated for each tally tree at the field plots. Respectively, in order to proceed with estimation of V, proper estimations of BA and H should have been done based on the features extracted from remote sensing datasets.

3.4.2. Remote sensing feature extraction, selection of features, regression modeling and accuracy testing

Prior to the estimation of the forest variables and accuracy assessment, it was required to render necessary features from the remote sensing datasets, which were the VHR aerial imagery, the high-resolution DSM and the dense point cloud. The two basic types of the features, which are Haralick textural features (Haralick et al., 1973) and 3D features (e.g., Nasset, 1997a,b, 2002, 2004), were extracted. The features were extracted by execution of programming scripts at GRASS 7.0svn - the free GIS software and at R - the free statistical software package. The Haralick features were extracted from the respective rasters of R, G, B channels of RGB orthophoto and a raster of high-resolution DSM raster (for the purpose of shortening also later referred to as "h"). The 3D features were extracted from the dense point cloud. The list of the extracted features is given in Annex 3.

As the quantity of the features turned to be relatively high (in our case it accounted for 54 features, that resulted in 93 derivative data arrays for all the remote sensing datasets altogether) a selection procedure was critical to apply to find the proper set of features, which the best way explains the each forest variable. For that purpose a Sequential Forward Feature Selection (SFFS) procedure was applied (Сенин, 2015), which works in the following way. First, the best correlating feature should be found and its significance (with the selected level of significance of 0.05) tested based on F-test explained by e.g. Сенин (2015). In case the significance is proved, a new feature is added to the model and tested the same way. The procedure continues until at the next stage the best calculated F-criteria for a feature becomes lower than F-criteria derived from a table (Table of critical values for the F distribution (for use with ANOVA), 2015). As Microsoft Excel possesses an embedded functionality for multiple linear regression analysis, it was selected the major tool for SFFS procedure.

3.4.5. Estimation of local variables based on application of Trestima system, comparison to FMP

As the final step of the forest variables estimation yet another technique called Trestima was used. Trestima is a system, which bases on an application of smartphones for estimation of local forest variables via simple terrestrial photographing of a forest. It consists of a mobile application installed on a smartphone, which is the major measurement tool in the forest, and an Internet interface for the system management, tasks assignment, forest figures geometry upload and data control/download. Trestima in its nature exploits a principle of the relascope and it has been in detail explained by Rouvinen (2014b).

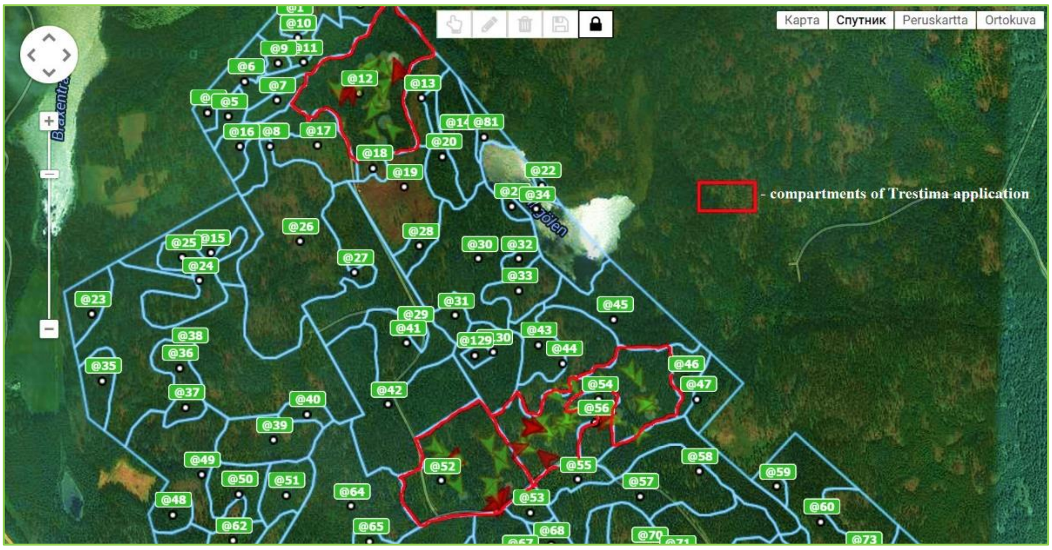


Fig. 10. Compartments where Trestima was applied

In the frame work of the project Trestima was applied at three forest compartments/figures of the study area (see Fig. 10) totaling to 65 samples (images/measurements) of BA, H and DBH. The measurements were performed in less than one hour of net time at the area of approx. 13.9 ha. The weather and forest conditions are shown/visible in the images (see Fig. 11).

Fig. 11. Trestima measurements (examples for BA, DBH and H)

The same standard set of forest variables was delivered after application of Trestima at each selected compartment i.e. mean V, BA, DBH, H as well a variable responsible for a number of stems per hectare, per tree species (see Fig. 11 and Fig. 12).

Forest inventory report: @12 TRESTIMA SEE THE WOOD FOR THE TREES

Measurement performed 14.01.2015 26.01.2015
Measured area 4.84 ha
BA sample amount 13 pcs

Specie	BA m^2/ha	Stems pcs/ha	Stems pcs	DBH cm	Height m	Vol m^3/ha	Vol m^3	Log %
pine	12.3	229	1110	27.6	22.1	129.4	627.0	72
spruce	12.9	233	1130	28.1	19.4	116.6	565.0	70
other	0.1							
Tot.	**25.3**	**462**	**2240**			**246.1**	**1191.9**	

Sample size: pine: 210, spruce: 220, other: 2, total: 433 pcs
Specie ratios: pine: 48.6 %, spruce: 50.8 %, other: 0.6 %
BA range with 95% probability 21.2-29.5. Std. error: 8.4%

Fig. 12. Variables and compartment geometry visualization at Trestima web-interface

Later, Trestima data was compared to an information stated in the forest management plan (FMP) and estimations delivered after statistical analysis. Respective reports for the three compartments and data rendered at this exercise are given in Annex 4.

4. Results

Although spatial accuracy assessment of remote sensing data (VHR aerial imagery and DEM) stayed behind the scope of the project, the data was anyway crosschecked by validation at the GIS software i.e. comparison of XY accuracy and Z accuracy using raster calculations and applying ESRI™ ArcGIS sampling tool. As a result, no significant difference was found between data produced and, for example, data by NLS.

4.1. Estimation of forest variables over area of interest

At the first stage of forest variables estimation single best correlating remote sensing features (see an explanation in Annex 3) were found for variables basal area (BA) and height (H) (see Fig. 13.1 and Fig. 13.2). These features were later used at the sequential forward feature selection (SFFS) procedure as a starting point of iterations.

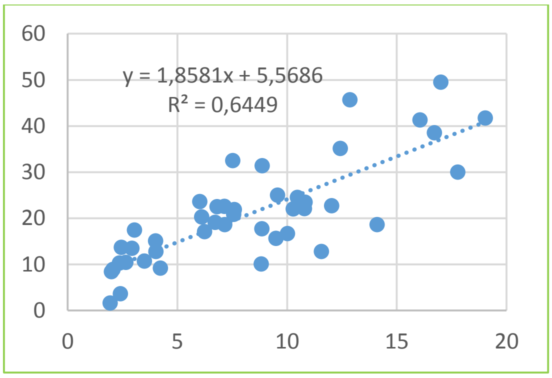


Fig. 13.1. BA (axis Y) vs h_SA (axis X)

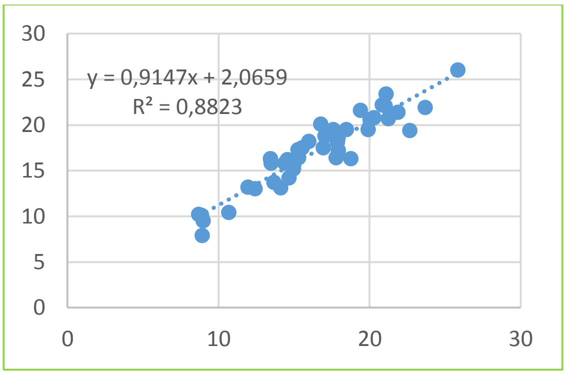


Fig. 13.2. H (axis Y) vs h_80 (axis X)

Fig.13.1 and 13.2 show that H has the best correlations with one of the 3D features (h_80, see Annex 3) extracted from high-resolution DSM, whereas BA's best correlation is at quite a low level and bases on a Haralick feature (h_SA) extracted from high-resolution DSM raster.

At the next stage, SFFS procedure was applied and as a result of multiple linear regression modeling appropriate sets of the features, which the best way explain BA, H and therefore volume (V), were selected (see Table 2).

Table 2. Selected features

Variable	Selected features
BA, m^2/ha	(1) h_SA (Haralick), (2) h0 (3D), (3) pcg (3D), (4) r_MOC-1 (Haralick), (5) d9 (3D)
H, m	(1) h80 (3D), (2) h_Contr (Haralick), (3) h95 (3D)

where, for example, for a Haralick feature h_SA first letter "h" relates to the respective raster (red (r), green (g), blue (b) or DSM (h)) and "SA" relates to the name of a Haralick feature (see Annex 3); the 3D features possess their own unique names (see Annex 3)

Consequently, a solution for regression coefficients (β) and a constant (ε) was found applying the SFFS procedure (see Table 3).

Table 3. Correlation analysis statistics

Variable	ε	β_1	β_2	β_3	β_4	β_5	R^2
BA, m^2/ha	18,6176	1,64636	1,09478	0,00412	130,23	-0,5411	**0,81**
H, m	4,311	1,274	0,106	-0,487	-	-	**0,92**

As it has been shown in Table 3 the resulting correlation (explained by coefficient of determination R^2 (Freund et al., 2010) equals 0.81 for BA and 0.92 for H, whereas R^2 for the single best correlating features found for the very same variables (shown in Fig. 13.1 and Fig. 13.2) equals 0.64 and 0.88 respectively. This result shows significant improvement of the estimation accuracy at transition from a single feature estimation to a multiple feature estimation. The improvement is especially considerable for the BA estimation. Both sets of the features equally include Haralick and 3D features. However, it is remarkable that most of the features for the both variables (BA and H) are related to the 3D model of the forest and only one feature in the set concerned with BA is related to the VHR aerial imagery.

Next, RMSE was calculated for each variable - BA, H and their derivative - V, respectively, using the averaged form factor (*f*). The estimation accuracy assessment results are presented in Table 4. From Table 4 it is visible that the best estimation concerns H, which may be explained by high initial correlation with the remote sensing data (see Fig. 13.2) and its further improvement (see Table 3). Accuracy of BA estimation is lower due to the similar reason explained above for H as well as an estimation of V demonstrates an ultimate accuracy as volume is the derivative from estimated BA and H.

Table 4. Estimation accuracy assessment

Variable	RSME	RMSE, %	Average
BA, m²/ha	4,74	**22,63**	20,97
H, m	1,14	**6,61**	17,19
V, m³/ha	50,47	**28,48**	177,19

4.2. Wall-to-wall mapping

Based on the solution for multiple linear regression the estimation of the variables was performed for the entire area of interest (AOI). Wall-to-wall mapping was executed by averaging estimates of BA, H and V obtained per each first-phase sample plot within a particular compartment over its area. Finally, relevant rasters were derived, which are displayed below in Fig. 14.1, 14.2 and Fig. 14.3, as well as a classified raster of volume estimation per compartment is given in Fig. 14.4.

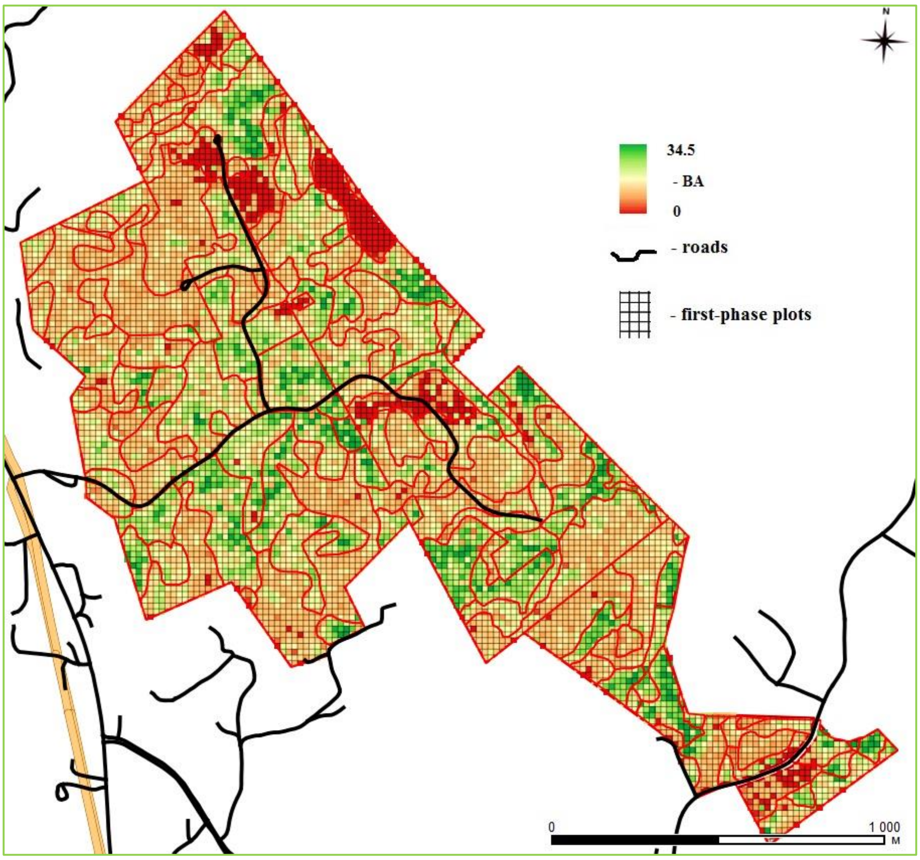


Fig. 14.1. Basal area (BA, m^2/ha) estimation raster

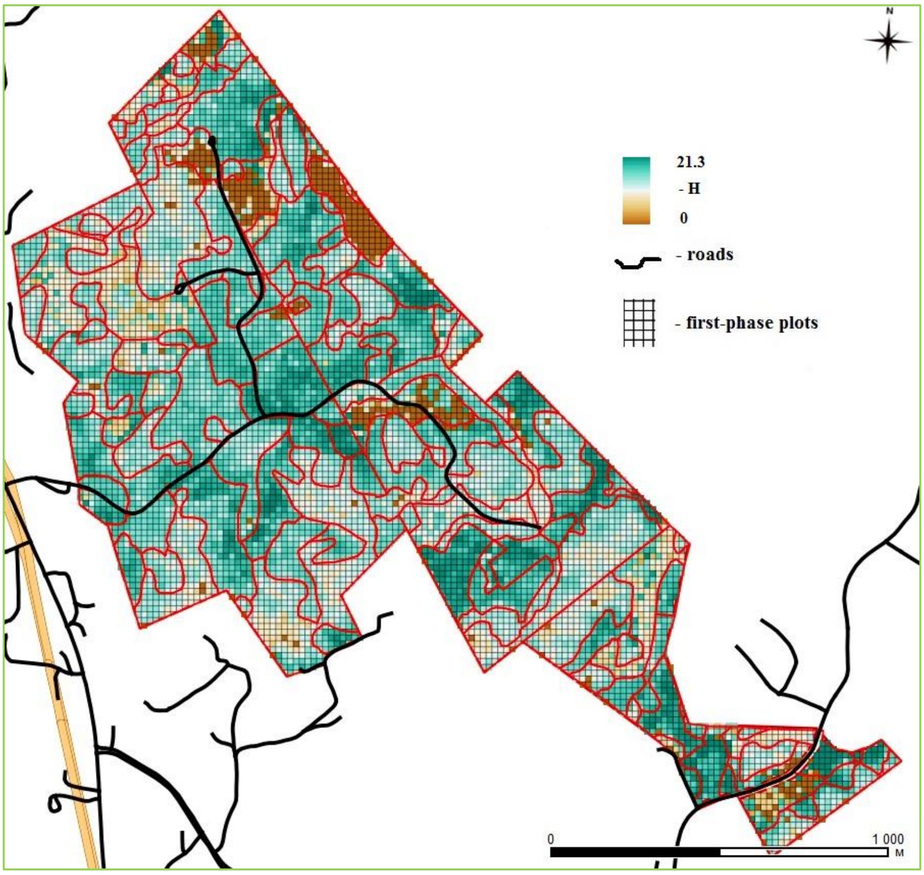


Fig. 14.2. Height (H, m) estimation raster

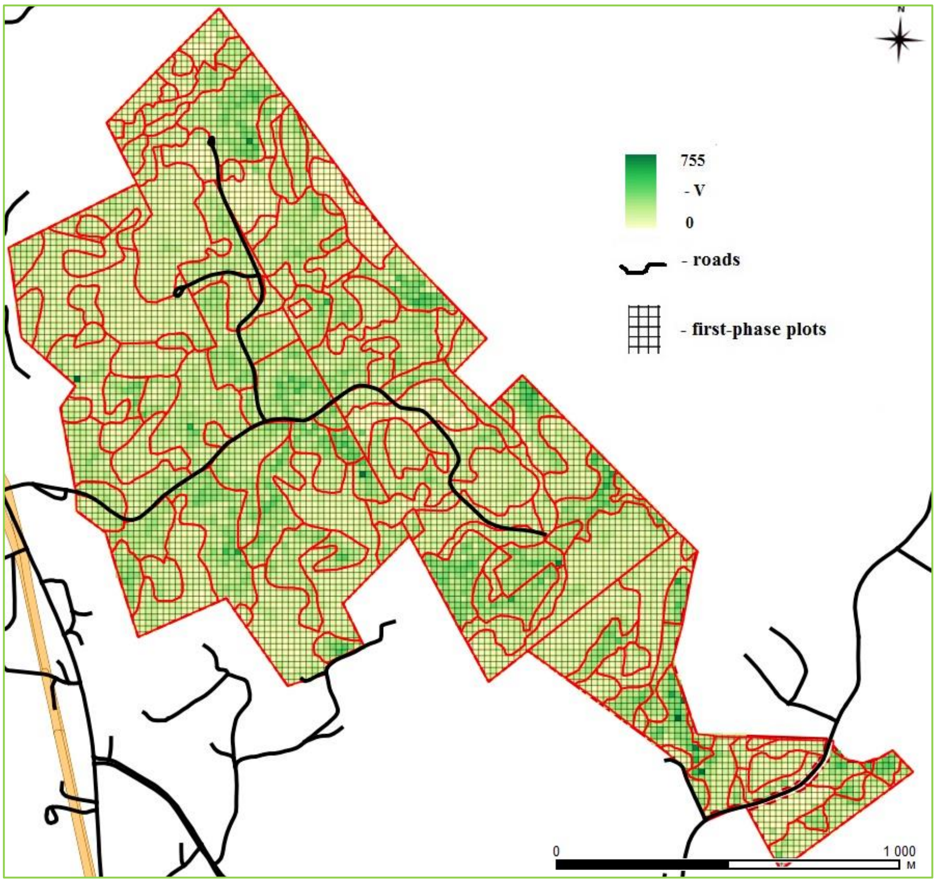


Fig. 14.3. Volume (V, m^3/ha) estimation raster

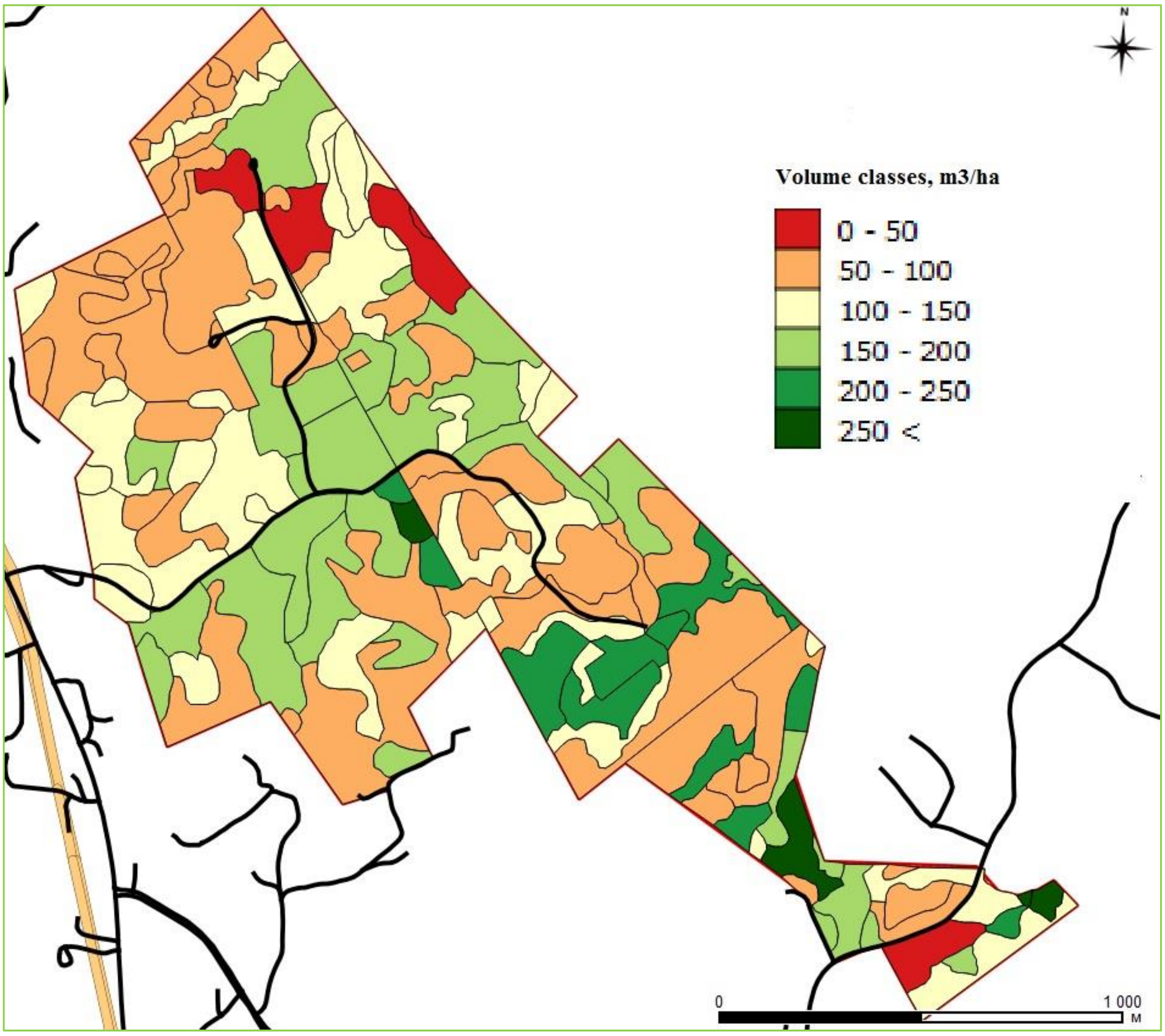


Fig. 14.4. Volume (V) classification of compartments, m^3/ha

4.3. Comparison of forest variables estimates, FMP and Trestima

At the final step all the estimates obtained within the framework of remote sensing statistical analysis and Trestima survey were directly compared over the data available from the existing Forest management plan (FMP). The following comparisons were performed:

- estimated BA (see Fig. 15.1) and H (see Fig. 15.2) were compared over respective FMP variables for all relevant compartments of the AOI;
- estimated BA, V (m^3) and V (m^3/ha) were compared for three reference compartments (number 412, 454 and 456 according to their ordinal numeration given in the FMP) over respective variables of Trestima survey and of the FMP (see Fig. 16.1, 16.2 and 16.3);

- estimated mean H was compared versus respective H given in the FMP for the three reference compartments (number 412, 454 and 456 according to their ordinal numeration given in the FMP) (see Fig. 16.4); and
- comparison of stem quantity given provided by the FMP and Trestima (see Fig. 16.5).

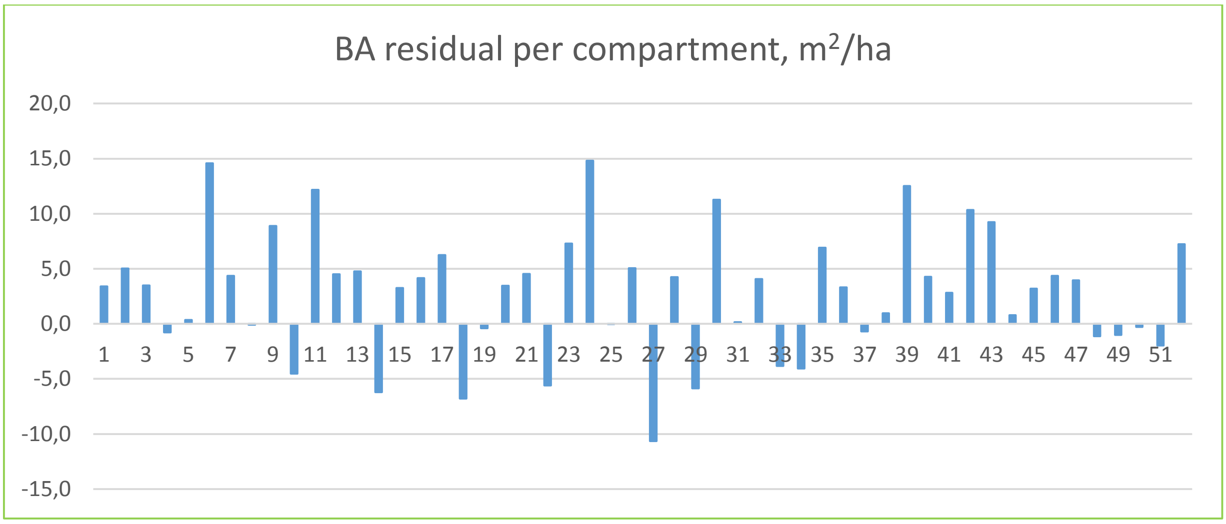


Fig. 15.1. Difference between BA by FMP and BA estimated per compartment

The comparison presented on Fig. 15.1 shows that the difference between BA stated in the FMP and estimated BA is inconsiderable at a limited number of compartments only, whereas at the most compartments BA deviates significantly – exceeding (+/-) 1 m^2. This result underlines that the estimation of BA to a very high degree did not work well locally. In other words, the estimation model for BA (see Table 2) turns out to be not the optimal for the estimation of the variable on the compartment level.

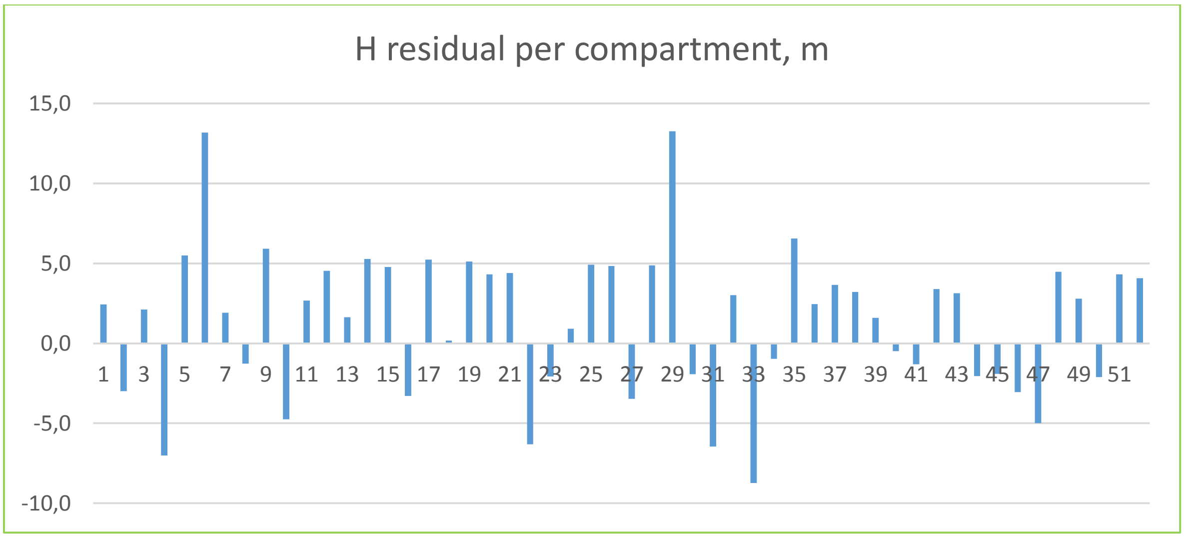


Fig. 15.2. Difference between H by FMP and H estimated per compartment

On the contrary, the comparison of H stated in the FMP and H estimated (see Fig. 15.2) shows that the H estimation worked pretty well on the local level, as the difference between the values is rather systematic. The difference ranges in the corridor of (+/-) 5 meters at the most compartments with an obvious trend of H by the FMP to surpass H estimated. The systematic difference (or better to say systematic underperformance of H estimated) may be explained by either general H estimation accuracy (see Table 4), possible systematic inaccuracies of the FMP itself, quality of the DSM and/or by the specifics of the 3D/Haralick features extraction from the dense point cloud and the DSM raster.

In the following Fig. 16.1-16.5, the compartments numbers 412, 452 and 456 (numeration according to the FMP) are numbered 1, 2 and 3, respectively.

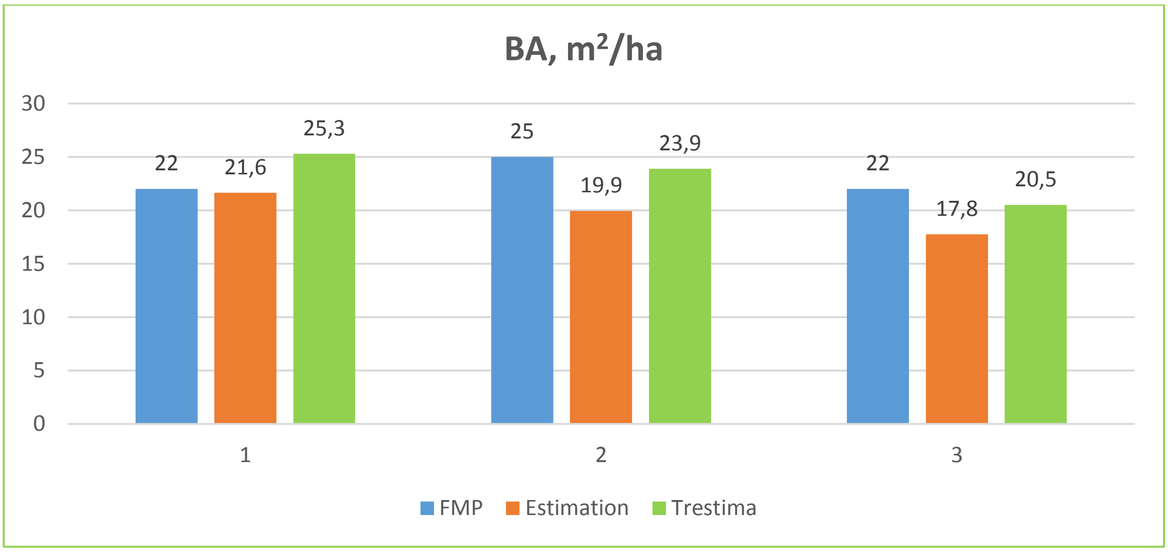


Fig. 16.1. Comparison of BA (m^2/ha)

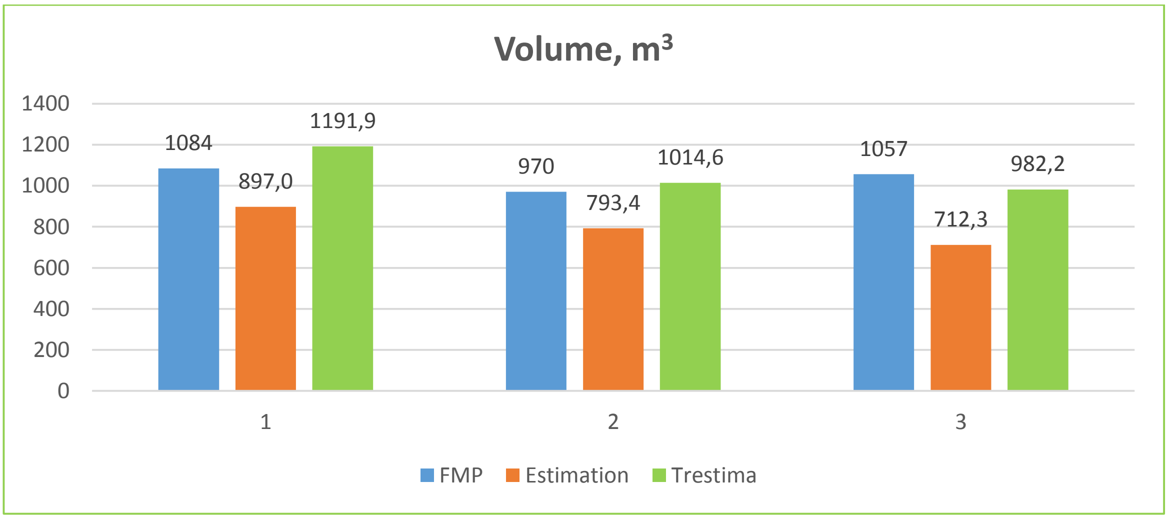


Fig. 16.2. Comparison of total volume (m^3)

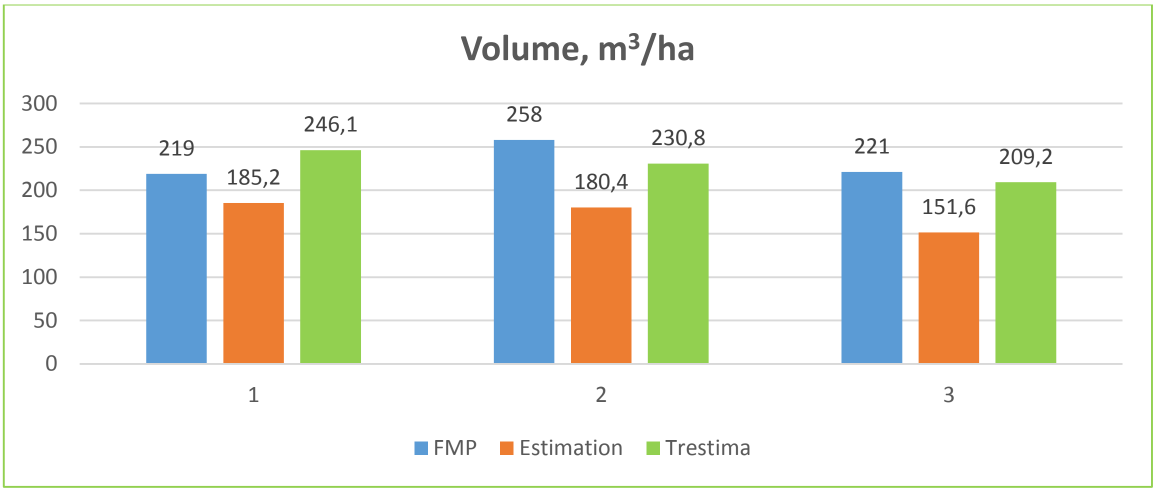


Fig. 16.3. Comparison of volume (m^3/ha)

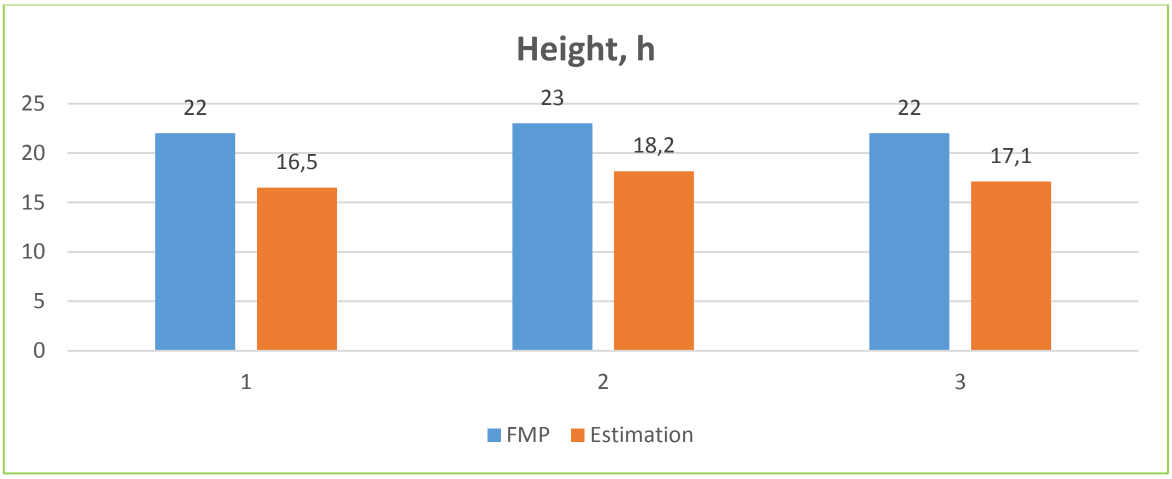


Fig. 16.4. Comparison of height (m)

The performed comparisons, which are illustrated in Fig. 16.1, 16.2, 16.3 and 16.4, show that Trestima demonstrates the best fit with the FMP data at all the compared variables with an average difference ranging from (+/-) 4-8%. This confirms potential ability of Trestima to be a reliable validation and mensuration technique.

The estimation results however show slightly low values variables BA and H (see Fig. 16.1 and 16.4) versus FMP data and, with respect to the nature of Eq.6, this leads to the respective underestimation of the volume (V, m^3 and V, m^3/ha) (see Fig. 16.2 and 16.3). This comparison partly confirms the previous conclusion about behavior of H estimated (see Fig. 15.2).

Since Trestima does not represent the same H variable, similar to the remote sensing estimation and the FMP, it was decided to exclude data given by Trestima at the comparison illustrated in Fig. 16.4. It is due to the fact Trestima renders the height for each tree species, whereas the FMP and obtained estimates operate mean H irrespective of the tree species.

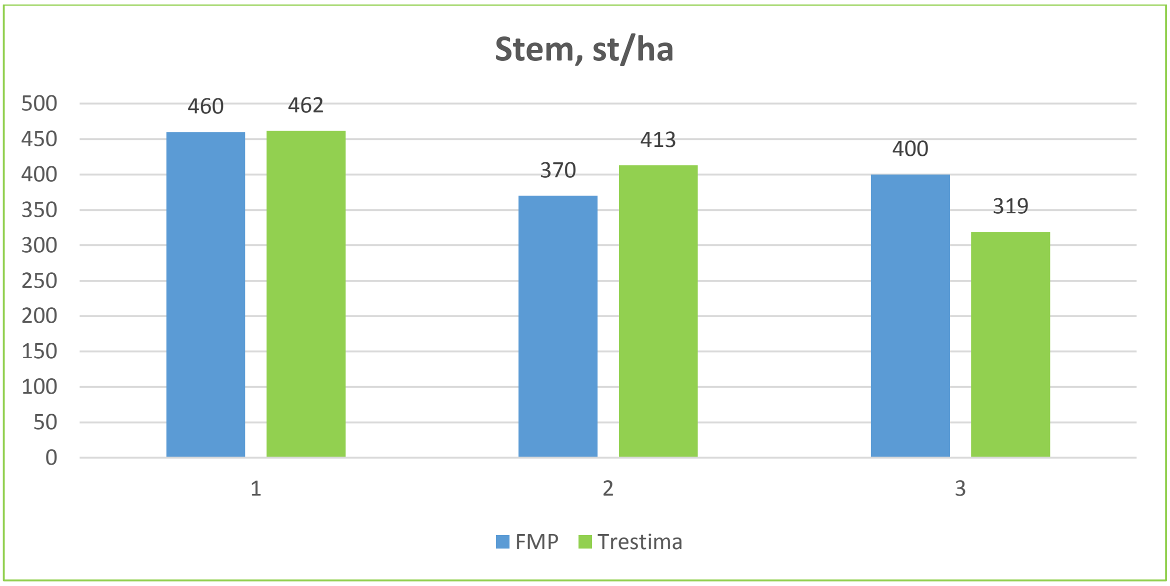


Fig. 16.5. Comparison of number of stems (units)

The final comparison was concerned stem quantity estimation (see Fig. 16.5). It shows some difference between the FMP and Trestima data. This comparison is given as it is as at this part further analysis was impossible without clear understanding of estimation approach used at both FMP and Trestima.

As stated above, it should be also taken into consideration at all the above mentioned comparisons that the FMP, although used as a reference, may contain some inaccuracies.

Notably, the speed of sampling using Trestima, which constituted 13.9 ha in less than one hour net time, was equal to a usual speed of walk in the forest.

5. Discussion

In some part this project work is a repetition of what had been done so far (e.g. Järnstedt et al., 2012 or Tuominen et al., 2014). On the other hand, a solid bunch of new ideas were realized among which, for example, the application of the UAV with the RGB digital camera for forest inventory and application of the Trestima system as a tool for field measurements (although, in the frame work of this project just a limited number of compartments were validated). At the very beginning of the project, which started in 2013 and finally turned to be a complex arrangement, despite already existing knowledge about similar research, a risk of fail was fairly high. Nevertheless, all the tools and the project programme were implemented at full scale.

First of all, in relation to the XYZ accuracy of remote sensing data and high-resolution DSM the issue indeed could be considered in a separate study. The issue deserves much higher attention, as the remote sensing data is raw for the entire process. As has been stated above, at this particular exercise the auxiliary data was taken as it was.

Meanwhile, although the present study employs quite a simple set of analytical instruments, such as linear regression and/or sequential forward feature selection, the results of statistical analysis turned out to be pretty solid. When it comes to statistical estimation of H, the achieved RMSE of 6-7% turned out to be better compared to the results of the study by Tuominen et al. (2014), where RMSE of 8-9% was obtained using airborne laser scanning (ALS) dataset (worth mentioning that ALS data in general is considered the most accurate). As well as estimation of BA (RMSE of 22-23%) also turned to be slightly better at this study versus, for example, the recent studies by Tuominen et al. (2011), where results indicate RMSE of 25-26% for ALS based estimation, and by Järnstedt (2012) where results indicate RMSE of 27-28% for ALS based estimation and 36-37% for photo based estimation, respectively.

Based on the achieved accuracy of H and BA estimation, respective estimation of V resulted in RMSE of 28-29%. This result is almost the same as the one reported by Tuominen et al. (2014), where more advanced estimation techniques were applied.

However, despite promising RMSE:s, a direct comparison of variables on the local level versus available reference data of the FMP introduces some questions to the estimation results that show quite some deviation (see Fig. 15.1 and 15.2). For example, the estimated H (see Fig. 15.2) at more than 50% of the forest compartments shows a systematic underperformance at the level of approx. 5 meters (see also Fig. 16.4). This requires special attention. A possible answer may hide behind the lack of clear knowledge about forest management activities, which, possibly, have been performed at some forest compartments since the date of remote sensing and field data acquisition and might have an effect on the local relevance of the FMP data. Simultaneously, quality of the high-resolution DSM and/or the niceties of the 3D/Haralick features extraction algorithms could be studied more in detail.

Another source of deviation, expressed in the resulting estimation of the volume variables, could originate from the application of the averaged form factor (*f*) at all the first-phase sample plots, which is not that rigorous due to the fact that different first-phase sample plots are represented by different dominated species and different species may obviously have different shapes i.e. *f*- the form factor. As a possible solution to the problem, *f* could have been selected based on the knowledge about dominating species at a particular first-phase sample plot using the estimated H. Alternatively, the estimation of V could have been performed based on the estimated DBH rather than the estimated BA.

An application of more advanced estimation techniques such as the *k-nn* method (Tuominen et al., 2006) might also have given more accurate results. However, that requires more field data. The combination of the *k-nn* estimation and more extensive field measurements, for example, with several sample plots per stratum, could have played a positive role for the accuracy.

When it comes to Trestima as a sampling tool, it shows unbeatable results versus, for example, the relascope or fixed radius sample plot method, which require more complex arrangements such as marking of a sample plot center, performing of written notes for each single measurement etc. That, along with the achieved accuracy, shows good prospects for Trestima to be applied, either as a forest inventory tool and/or as a forest data validation tool, which could be used by forest engineers or even forest owners at their regular measurements in the forest.

Overall results of the study confirmed that the technologies and the tools applied at this work could be reliable and cheap means of data acquisition for forest inventories with high potential of operational usage as well as leave a room for further development.

For example, the results indicate good prospects for the application of UAVs (or any other cheap aerial platforms) for forest inventory, which may deliver high quality data (VHR aerial imagery and high-resolution elevation model) of a quality close or even similar to ALS. The mentioned above data of photogrammetric modeling carry enough necessary features for further estimation of forest variables with potential accuracy close to performance of ALS data, provided that the terrain is well defined from other sources. In that respect, one of the possible directions for further development may lie in the field of improvement of forest variables estimation accuracy by application of other more advanced estimation techniques.

Yet another interesting field could be to study if a photogrammetric high-resolution surface model may be used to render an accurate and sufficient enough terrain model. This particular application may be of extreme interest in forestry for the areas where terrain data is missing or of low quality. For example, this is the case for almost the entire territory of Russia, Africa and Asia, to name a few. The solution for the problem of lacking reliable terrain data, if found based on photogrammetry, can significantly ease further data processing and may also let avoiding complex arrangements at remote sensing data georeferencing.

Simultaneously, as most of the features of the selected sets belong to the 3D canopy model, it would have been very useful to test Haralick features only, similar to the work performed by Tuominen et al. (2005), to check if the same accuracy is achievable. The problem originates from the fact that, as it has been stated above, accurate enough DTM is not available widely. In practice that means that in such circumstances most of the 3D features considered in this study would be impossible to derive, as the DSM could not be normalized to the ground level (see Chapter 3.4).

Trestima, however, can already be used as it is. This technique looks prospective for ground truthing. However, existing forest inventory practices around the globe employ conventional methods and tools based on the application of relascope or fixed radius based sampling, which imply manual or semi-automated measurements. In that respect, Trestima will require new developments to be integrated into approved forest inventory systems.

6. Acknowledgements

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Annexes

Annex 1.

Remote sensing data processing report incl. some flight information data

Agisoft PhotoScan

Processing Report

Survey Data

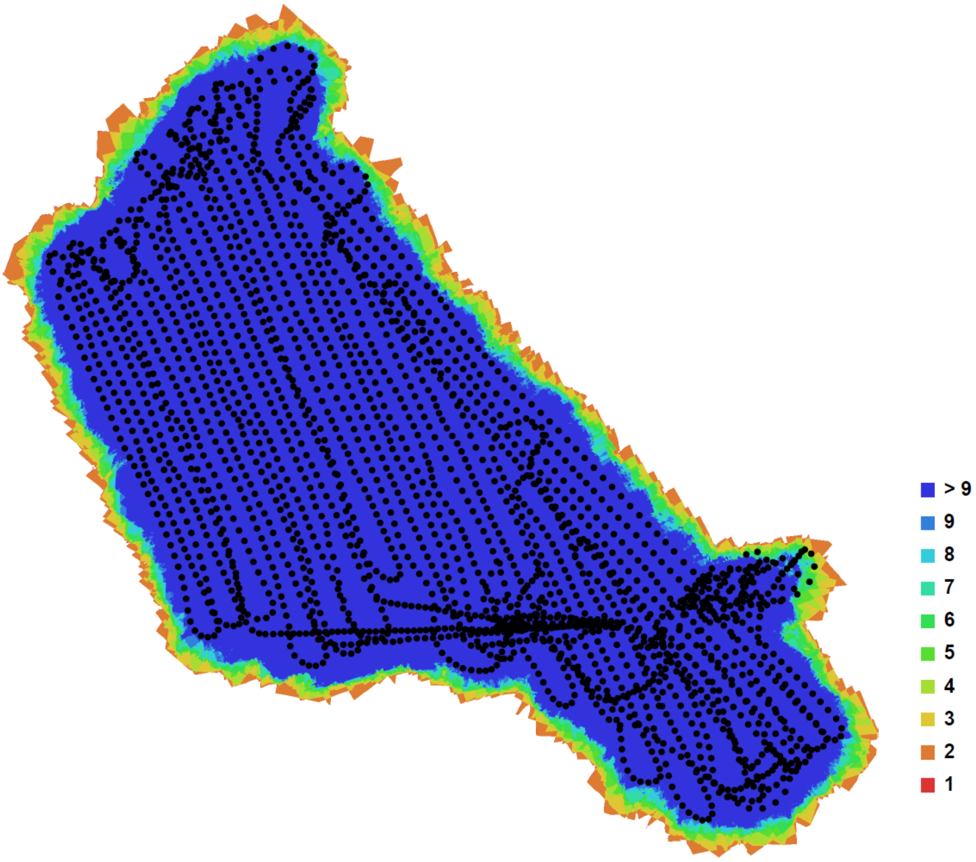

Fig. 1. Camera locations and image overlap.

Number of images:	2539	Camera stations:	2489
Flying altitude:	177.326 m	Tie-points:	6916528
Ground resolution:	0.0613318 m/pix	Projections:	21785612
Coverage area:	4.69609 sq km	Error:	0.462961 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
DMC-LX5 (5.1 mm)	3648 x 2736	5.1 mm	2.01626 x 2.01626 um	Yes
DMC-LX5 (5.1 mm)	2736 x 3648	5.1 mm	2.01626 x 2.01626 um	Yes

Table. 1. Cameras.

Ground Control Points

Fig. 2. GCP locations.

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
1	0.000398	-0.000175	-0.000039	0.000436	34	0.017989
10	-0.002456	0.002749	0.000177	0.003690	28	0.026263
11	-0.000322	-0.000548	-0.000064	0.000639	15	0.099191
12	-0.000066	0.000829	0.000166	0.000848	16	0.041712
2	-0.000469	-0.001126	0.000116	0.001225	45	0.032080
3	0.000854	0.000399	0.000050	0.000944	19	0.007122
4	0.000344	-0.000542	-0.000126	0.000654	25	0.008520
5	-0.002065	0.000884	-0.000144	0.002251	27	0.016549
6	0.000578	0.000390	0.000056	0.000700	21	0.060651
7	0.000173	-0.000530	-0.000106	0.000568	16	0.011367
8	0.000169	0.000024	0.000171	0.000242	23	0.010966

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
9	0.002836	-0.002328	-0.000318	0.003683	39	0.058933
B1	0.000000	0.000000	0.000000	0.000000		
B2	0.000000	0.000000	0.000000	0.000000		
Total	**0.001197**	**0.001100**	**0.000137**	**0.001631**	**308**	**0.039467**

Table. 2. Control points.

Digital Elevation Model

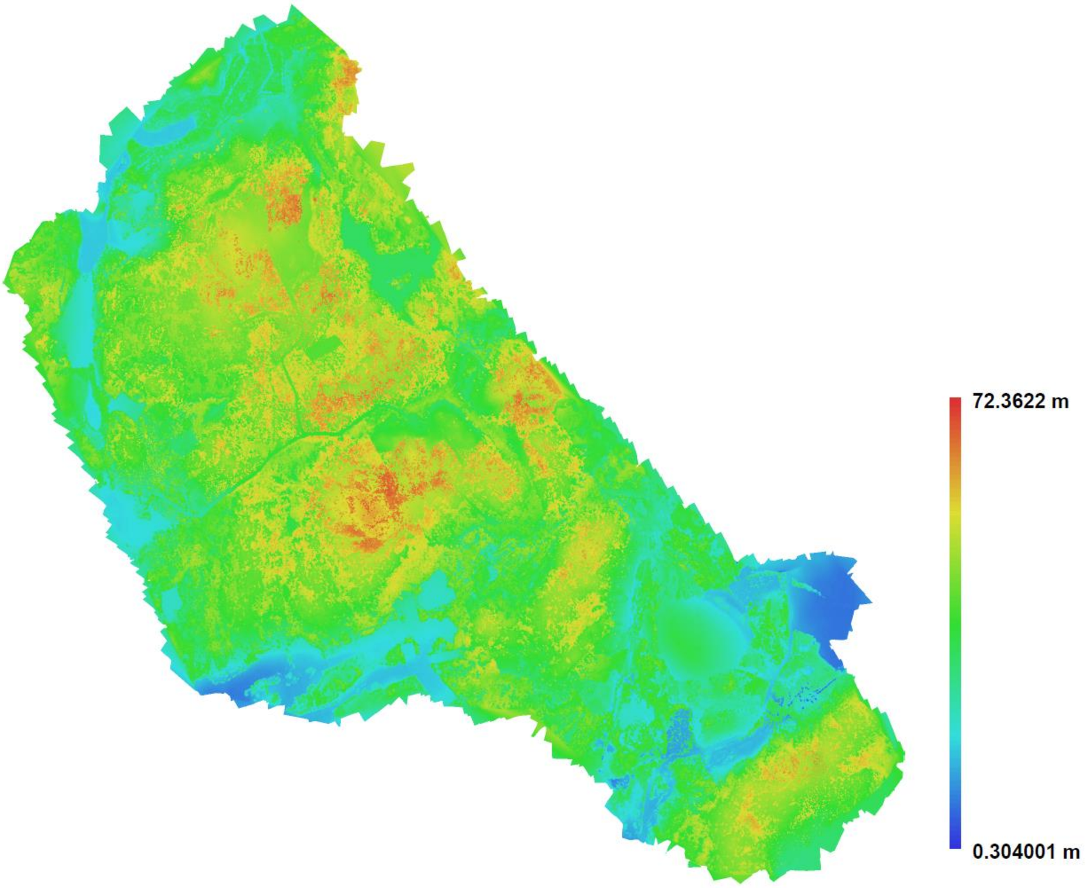

Fig. 3. Reconstructed digital elevation model.

Resolution:	0.245327 m/pix
Point density:	8.72275 points per sq m

Annex 2.1.

Raw field data and respective H model and V estimation for each tally tree

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation . m^3/ha	*f*
1	0	1	2	8,5	4,75	5,72	15,66	0,482
2	0	2	2	7,5		5	12,9	0,584
3	0	3	3	21,5		20,18	336,04	0,459
4	0	4	3	20,8		19,78	309,5	0,460
5	0	5	3	19,3		18,89	256,33	0,464
6	0	6	3	20,5		19,61	298,46	0,461
7	0	7	3	18,7		18,52	236,5	0,465
8	0	8	3	21,5	21,25	20,18	356,6	0,487
9	0	9	3	23,7		21,34	426,39	0,453
10	1	1	1	30,3		23,59	784,9	0,461
11	1	2	1	34,9	27,5	25,27	1187,39	0,491
12	1	3	1	38		26,25	1335,53	0,449
13	1	4	2	7,4	6,25	6,6	15,12	0,533
14	1	5	3	38,7	27,5	28,1	1303,46	0,394
15	1	6	3	28,7		24,78	707,33	0,441
16	2	1	1	28,4	21,25	21,09	628,88	0,471
17	2	2	2	30,4		21,5	703,55	0,451
18	2	3	2	29,7		21,25	667,47	0,453
19	2	4	2	26,8		20,13	526,98	0,464
20	2	5	2	38,1		23,89	1150,86	0,423
21	2	6	2	30,6		21,57	714,02	0,450
22	2	7	2	36,8		23,53	1069,34	0,427
23	2	8	2	31,2	21,25	21,78	724,14	0,435
24	2	9	3	19	21,5	20,02	288,72	0,509
25	3	1	1	22,6		15,44	302,09	0,488
26	3	2	1	21,4	13	15,01	233,1	0,432
27	3	3	1	28,7		17,3	531,23	0,475
28	3	4	1	11,7		10,38	58,74	0,526
29	3	5	1	20,8		14,79	247,26	0,492
30	3	6	1	13,9		11,64	91	0,515
31	3	7	1	24,9		16,21	380,66	0,482
32	3	8	1	17,2		13,29	155,12	0,502
33	3	9	1	18,1		13,69	175,96	0,500
34	3	10	1	11,4		10,2	54,97	0,528
35	3	11	1	10,3		9,51	42,39	0,535
36	3	12	1	20,6		14,71	241,52	0,493
37	3	13	1	23,7		15,82	338,47	0,485
38	3	14	2	22,8		16,73	322,23	0,472
39	3	15	2	14		13,05	102,83	0,512
40	3	16	2	14,7		13,41	115,73	0,509

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
41	3	17	2	20,9	17,25	16,08	287,26	0,521
42	3	18	2	6,2		7,83	13,45	0,569
43	3	19	2	14,4		13,26	110,1	0,510
44	3	20	2	12,9		12,45	84,2	0,517
45	3	21	3	31,8		19,79	647,15	0,412
46	3	22	3	29,9	19	19,37	557,67	0,410
47	3	23	3	10,9		12,03	53,48	0,476
48	3	24	3	14,1		13,88	101,79	0,470
49	4	1	2	14,7	10,5	11,18	88,4	0,466
50	4	2	2	15,9		11,82	115,67	0,493
51	4	3	2	12,4		9,84	60,76	0,511
52	4	4	2	6,4		5,78	10,79	0,580
53	4	5	3	7,7		9,05	20,59	0,489
54	4	6	3	15,3	14,5	14,14	124,43	0,479
55	4	7	3	11,8		12,06	62,57	0,474
56	4	8	3	6,1		7,69	11,27	0,501
57	4	9	3	6,7		8,21	14,35	0,496
58	4	10	3	14,5		13,7	105,85	0,468
59	4	11	3	8,5		9,69	26,65	0,485
60	4	12	3	5,8		7,43	9,9	0,504
61	4	13	3	7,5		8,89	19,22	0,489
62	4	14	3	13,2		12,94	83,42	0,471
63	4	15	3	11		11,53	52,18	0,476
64	4	16	3	24,5		18,04	373,49	0,439
65	4	17	3	8,9		10	30,05	0,483
66	4	18	3	5,9		7,52	10,35	0,503
67	4	19	3	7,5		8,89	19,22	0,489
68	4	20	3	7,6		8,97	19,9	0,489
69	4	21	3	18,7		15,8	198,4	0,457
70	4	22	3	15		13,97	115,27	0,467
71	4	23	3	7,8		9,13	21,29	0,488
72	4	24	3	13		12,82	80,23	0,471
73	4	25	3	7		8,47	16,07	0,493
74	4	26	3	7,3		8,72	17,92	0,491
75	4	27	3	16,2		14,61	139,65	0,464
76	5	1	1	44		23,59	1591,11	0,444
77	5	2	1	31,3		20,83	743,97	0,464
78	5	3	1	24,6		18,72	424,02	0,477
79	5	4	1	45,5		23,84	1710,85	0,441
80	5	5	1	25,1		18,9	444,74	0,476
81	5	6	1	34,2		21,58	910,31	0,459
82	5	7	1	38,5	20,5	22,55	1086,41	0,414
83	5	8	2	27		20,35	540,69	0,464
84	5	9	2	22,8		18,89	371,25	0,481

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
85	5	10	2	23,6	21	19,19	446,51	0,532
86	5	11	2	27,6		20,54	567,13	0,462
87	5	12	2	10,6		12,28	58,07	0,536
88	5	13	2	21,7		18,45	331,7	0,486
89	5	14	2	14		14,59	116,65	0,519
90	5	15	2	19,1		17,32	246,71	0,497
91	5	16	2	31,6		21,67	756,76	0,445
92	5	17	2	21,5		18,37	324,73	0,487
93	5	18	2	14,1		14,65	118,72	0,519
94	5	19	2	25,7		19,93	485,24	0,469
95	5	20	2	16		15,75	161,69	0,511
96	5	21	2	20,2		17,82	281,19	0,492
97	5	22	2	12,1		13,36	81,13	0,528
98	5	23	2	11,8		13,15	76,16	0,530
99	5	24	2	27,5		20,51	562,71	0,462
100	5	25	2	12,6		13,69	89,79	0,526
101	5	26	3	30,9	24	22,95	771,46	0,448
102	5	27	3	29,8		22,67	679,17	0,430
103	5	28	5	17,3	15,5	15,52	180	0,493
104	6	1	1	7,9		7,19	20,05	0,569
105	6	2	1	7,8		7,12	19,39	0,570
106	6	3	1	5,2		5,14	6,88	0,630
107	6	4	1	7,8		7,12	19,39	0,570
108	6	5	1	9,4		8,27	31,59	0,550
109	6	6	1	10,8		9,23	45,46	0,538
110	6	7	1	8	6,75	7,26	19,6	0,537
111	6	8	2	11,1		9,64	48,64	0,521
112	6	9	2	11,8		10,1	57,07	0,517
113	6	10	2	15		12	105,97	0,500
114	6	11	2	10,3		9,11	39,99	0,527
115	6	12	2	11,6		9,97	54,58	0,518
116	6	13	2	8		7,47	20,61	0,549
117	6	14	2	12,3	10,5	10,41	64,15	0,519
118	6	15	2	8,9		8,13	27,25	0,539
119	6	16	2	9,2		8,34	29,73	0,536
120	6	17	2	11,7		10,03	55,82	0,518
121	6	18	2	20,2		14,53	222,22	0,477
122	6	19	2	17,9		13,49	165,23	0,487
123	6	20	2	8		7,47	20,61	0,549
124	6	21	2	7,9		7,4	19,94	0,550
125	6	22	2	8,7		7,98	25,67	0,541
126	6	23	2	7,4		7,02	16,82	0,557
127	6	24	3	31,5		20,21	652,75	0,414
128	6	25	3	22,4		17,49	307,84	0,447

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
129	6	26	3	25,7	18,5	18,61	417,65	0,433
130	6	27	3	5,4		7,23	8,4	0,507
131	7	1	2	10,6		10,72	50,04	0,529
132	7	2	2	15,7		14,21	138,9	0,505
133	7	3	2	7,2		7,92	17,95	0,557
134	7	4	2	8		8,61	23,73	0,548
135	7	5	2	18,2		15,63	201,2	0,495
136	7	6	2	9,8		10,09	40,66	0,534
137	7	7	2	7,7		8,35	21,44	0,551
138	7	8	2	7,6		8,27	20,71	0,552
139	7	9	2	16		14,39	145,72	0,504
140	7	10	2	7,5		8,18	20	0,553
141	7	11	2	11,8	11,75	11,62	67,23	0,529
142	7	12	2	7,4		8,09	19,3	0,555
143	7	13	2	10,2		10,41	45,2	0,531
144	7	14	2	8,2		8,78	25,33	0,546
145	7	15	3	15,4		16,67	146,49	0,472
146	7	16	3	11		13,64	61,93	0,478
147	7	17	3	12		14,4	77,63	0,477
148	7	18	3	16,7	18	17,42	185,76	0,487
149	7	19	3	17,9		18,07	212,29	0,467
150	7	20	3	15,2		16,55	141,78	0,472
151	7	21	3	11,1		13,72	63,41	0,478
152	7	22	3	21,8		19,91	339,35	0,457
153	7	23	3	16,9		17,53	184,45	0,469
154	7	24	3	8		11,07	26,78	0,481
155	7	25	3	10,5		13,24	54,85	0,478
156	7	26	3	17		17,59	187,14	0,469
157	7	27	3	17,8		18,02	209,41	0,467
158	7	28	3	9,8		12,66	45,76	0,479
159	7	29	3	16		17,02	161,12	0,471
160	7	30	3	17,5		17,86	200,91	0,468
161	7	31	3	20		19,11	277,12	0,462
162	7	32	3	6,2		9,31	13,67	0,486
163	7	33	3	17,8		18,02	209,41	0,467
164	7	34	3	17,8		18,02	209,41	0,467
165	7	35	3	15,2		16,55	141,78	0,472
166	7	36	3	6,3		9,41	14,26	0,486
167	7	37	3	10		12,83	48,26	0,479
168	7	38	3	17,6		17,91	203,72	0,468
169	7	39	3	13,3		15,32	101,13	0,475
170	7	40	3	6,9		10,01	18,12	0,484
171	7	41	3	17,2		17,7	192,59	0,468
172	7	42	3	6		9,1	12,54	0,487

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
173	7	43	3	21,2		19,65	317,94	0,458
174	7	44	3	21,4		19,74	325,01	0,458
175	7	45	3	12,9		15,04	93,53	0,476
176	7	46	3	17,5		17,86	200,91	0,468
177	7	47	3	17,1		17,64	189,85	0,469
178	7	48	3	15,7		16,85	153,72	0,471
179	7	49	3	6		9,1	12,54	0,487
180	7	50	3	7,3		10,4	21,02	0,483
181	7	51	3	13,2		15,25	99,2	0,475
182	7	52	3	16,7		17,42	179,13	0,469
183	7	53	3	12,1		14,47	79,32	0,477
184	7	54	3	12,1		14,47	79,32	0,477
185	7	55	3	9,9		12,75	47	0,479
186	7	56	3	18,7		18,48	235,97	0,465
187	7	57	3	9		11,98	36,57	0,480
188	7	58	3	13		15,11	95,4	0,476
189	7	59	3	7,9		10,98	25,91	0,481
190	7	60	3	7,6		10,69	23,39	0,482
191	7	61	3	11,9		14,32	75,97	0,477
192	7	62	3	17		17,59	187,14	0,469
193	7	63	3	18,5		18,38	229,93	0,465
194	8	1	1	12	8	9,84	49,87	0,448
195	8	2	1	6		5,29	9,32	0,623
196	8	3	2	22		17,16	312,05	0,478
197	8	4	2	28		19,62	550,37	0,456
198	8	5	2	27	22	19,25	593,16	0,538
199	8	6	2	33		21,26	794,22	0,437
200	8	7	2	28		19,62	550,37	0,456
201	8	8	2	20		16,19	247,19	0,486
202	8	9	2	25		18,47	423,28	0,467
203	8	10	2	24		18,05	384,4	0,471
204	8	11	2	24		18,05	384,4	0,471
205	8	12	2	17		14,56	164,46	0,498
206	8	13	2	24		18,05	384,4	0,471
207	8	14	2	25		18,47	423,28	0,467
208	8	15	2	23		17,62	347,31	0,474
209	8	16	2	27		19,25	506,29	0,459
210	8	17	2	22		17,16	312,05	0,478
211	8	18	2	6		6,41	10,48	0,578
212	8	19	2	25		18,47	423,28	0,467
213	8	20	2	32		20,95	742,43	0,441
214	8	21	3	7		9,07	17,05	0,488
215	8	22	3	25		20,45	445,9	0,444
216	8	23	3	30	21,5	22,18	645,94	0,412

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
217	8	24	3	34		23,33	873,55	0,412
218	8	25	3	29		21,87	622,07	0,431
219	9	1	1	23	16	16,47	322,68	0,472
220	9	2	2	40	24	22,48	1249,99	0,442
221	9	3	2	49		24,05	1710,93	0,377
222	9	4	2	32		20,6	727,6	0,439
223	9	5	2	5		6,21	7,24	0,594
224	9	6	2	10		10,39	43,54	0,534
225	9	7	2	9		9,62	33,06	0,540
226	9	8	2	10		10,39	43,54	0,534
227	9	9	3	17		15,82	166,55	0,464
228	9	10	3	31	20	21,16	627,98	0,393
229	10	1	1	31	22	20,38	768,29	0,499
230	10	2	1	22		17,32	318,03	0,483
231	10	3	1	32		20,65	769,74	0,463
232	10	4	1	24		18,11	392,14	0,479
233	10	5	2	22		18,34	337,22	0,484
234	10	6	2	21		17,93	303	0,488
235	10	7	2	16		15,53	158,99	0,509
236	10	8	2	29	23	20,72	705,08	0,515
237	10	9	2	30		21	669,4	0,451
238	10	10	3	43	22	23,86	1177,25	0,340
239	10	11	3	33		21,83	769,86	0,412
240	10	12	3	5		7,18	7,14	0,506
241	10	13	3	6		8,14	11,41	0,496
242	11	1	1	29		14,78	470,05	0,481
243	11	2	1	9		6,43	23,9	0,584
244	11	3	1	10		7,02	31,43	0,570
245	11	4	1	14		9,19	75,57	0,534
246	11	5	1	8		5,83	17,64	0,602
247	11	6	1	9		6,43	23,9	0,584
248	11	7	1	14		9,19	75,57	0,534
249	11	8	1	10		7,02	31,43	0,570
250	11	9	1	19		11,45	165,59	0,510
251	11	10	1	16		10,15	106,75	0,523
252	11	11	1	21		12,23	213,08	0,503
253	11	12	1	10		7,02	31,43	0,570
254	11	13	1	20		11,85	188,5	0,506
255	11	14	1	14		9,19	75,57	0,534
256	11	15	1	12		8,14	50,58	0,549
257	11	16	1	18	10	11,04	132,76	0,473
258	11	17	1	16		10,15	106,75	0,523
259	11	18	1	16		10,15	106,75	0,523
260	11	19	1	10		7,02	31,43	0,570

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
261	11	20	1	14		9,19	75,57	0,534
262	11	21	1	9		6,43	23,9	0,584
263	11	22	1	17		10,61	124,74	0,518
264	11	23	1	13		8,68	62,32	0,541
265	11	24	1	12		8,14	50,58	0,549
266	11	25	1	5		3,98	5,51	0,705
267	11	26	1	21		12,23	213,08	0,503
268	11	27	1	12		8,14	50,58	0,549
269	11	28	1	21		12,23	213,08	0,503
270	11	29	1	9		6,43	23,9	0,584
271	11	30	1	11		7,59	40,3	0,559
272	11	31	2	11		8,89	43,97	0,520
273	11	32	2	10		8,29	34,43	0,529
274	11	33	2	11		8,89	43,97	0,520
275	11	34	2	13	9	10,01	60,27	0,454
276	11	35	2	11		8,89	43,97	0,520
277	11	36	2	17		11,95	131,77	0,486
278	11	37	2	15		11,03	96,61	0,496
279	11	38	2	13		10,01	67,35	0,507
280	11	39	2	8		7,02	19,42	0,550
281	11	40	2	9		7,67	26,26	0,538
282	11	41	2	11		8,89	43,97	0,520
283	11	42	3	13	8,5	10,22	54,43	0,401
284	12	1	1	34	20	19,7	838,89	0,469
285	12	2	2	28		18,76	522,15	0,452
286	12	3	2	13		11,96	81,69	0,515
287	12	4	2	12		11,31	66,46	0,520
288	12	5	2	10		9,9	41,35	0,532
289	12	6	2	16		13,74	138,31	0,501
290	12	7	2	18		14,78	185,16	0,492
291	12	8	2	21	17	16,18	284,77	0,508
292	12	9	2	12		11,31	66,46	0,520
293	12	10	2	13		11,96	81,69	0,515
294	12	11	2	12		11,31	66,46	0,520
295	12	12	2	12		11,31	66,46	0,520
296	12	13	2	8		8,37	23,06	0,548
297	12	14	2	9		9,15	31,38	0,539
298	12	15	2	8		8,37	23,06	0,548
299	12	16	2	10		9,9	41,35	0,532
300	12	17	2	14		12,58	98,73	0,510
301	12	18	2	25		17,75	404,13	0,464
302	12	19	2	19		15,27	211,29	0,488
303	12	20	2	22		16,6	300,17	0,476
304	12	21	2	31		19,66	653,24	0,440

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
305	12	22	2	22		16,6	300,17	0,476
306	12	23	3	19		16,52	214,5	0,458
307	12	24	3	17		15,54	163,32	0,463
308	12	25	3	13		13,22	82,82	0,472
309	12	26	3	19	16	16,52	207,08	0,442
310	12	27	3	23		18,21	337,55	0,446
311	12	28	3	11		11,86	53,66	0,476
312	12	29	3	12		12,56	67,32	0,474
313	13	1	1	23		16,14	325,27	0,485
314	13	2	1	26,5		17,3	455,43	0,477
315	13	3	1	21,7		15,66	282,76	0,488
316	13	4	1	23		16,14	325,27	0,485
317	13	5	1	24		16,49	360,13	0,483
318	13	6	1	21,8		15,7	285,91	0,488
319	13	7	1	14,4		12,33	102,55	0,511
320	13	8	1	23,8	15,25	16,42	330,19	0,452
321	13	9	1	24,6		16,69	381,93	0,481
322	13	10	1	26		17,14	435,44	0,478
323	13	11	1	24,2		16,56	367,33	0,482
324	13	12	1	17,4		13,85	164,65	0,500
325	13	13	1	19,1		14,62	207,22	0,495
326	13	14	1	28,6		17,91	544,41	0,473
327	13	15	1	24,2		16,56	367,33	0,482
328	13	16	1	21,5		15,59	276,49	0,489
329	13	17	3	14,7	13,5	14,17	107	0,445
330	14	1	1	11		7,7	40,76	0,557
331	14	2	1	8		5,92	17,82	0,599
332	14	3	1	16	9	10,29	96,6	0,467
333	14	4	1	14		9,32	76,45	0,533
334	14	5	1	21		12,4	215,67	0,502
335	14	6	1	19		11,61	167,59	0,509
336	14	7	1	15		9,82	91,44	0,527
337	14	8	1	16		10,29	108,01	0,522
338	14	9	1	16		10,29	108,01	0,522
339	14	10	1	14		9,32	76,45	0,533
340	14	11	1	16		10,29	108,01	0,522
341	14	12	1	15		9,82	91,44	0,527
342	14	13	1	14		9,32	76,45	0,533
343	14	14	3	8		8,48	21	0,493
344	14	15	3	8		8,48	21	0,493
345	14	16	3	8		8,48	21	0,493
346	14	17	3	8		8,48	21	0,493
347	14	18	3	10	10	9,85	37,79	0,488
348	14	19	3	11		10,48	47,6	0,478

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
349	15	1	1	15	8	9,49	77,41	0,462
350	15	2	1	6		4,15	8,09	0,689
351	15	3	1	15		9,49	88,9	0,530
352	15	4	1	8		5,38	16,71	0,618
353	15	5	1	13		8,39	60,65	0,545
354	15	6	1	9		6	22,74	0,596
355	15	7	1	11		7,22	38,78	0,565
356	15	8	1	8		5,38	16,71	0,618
357	15	9	1	9		6	22,74	0,596
358	15	10	1	8		5,38	16,71	0,618
359	15	11	1	6		4,15	8,09	0,689
360	15	12	1	8		5,38	16,71	0,618
361	15	13	1	7		4,76	11,86	0,647
362	15	14	1	21		12,37	215,06	0,502
363	15	15	1	13		8,39	60,65	0,545
364	15	16	1	11		7,22	38,78	0,565
365	15	17	1	17		10,52	123,88	0,519
366	15	18	2	16		11,08	108,95	0,489
367	15	19	2	5		4,21	5,39	0,652
368	15	20	2	7		5,56	12,34	0,577
369	15	21	2	7		5,56	12,34	0,577
370	15	22	2	8		6,24	17,44	0,556
371	15	23	2	13		9,42	63,17	0,505
372	15	24	2	13		9,42	63,17	0,505
373	15	25	2	11		8,2	40,52	0,520
374	15	26	2	7		5,56	12,34	0,577
375	15	27	2	11		8,2	40,52	0,520
376	15	28	2	10		7,56	31,44	0,530
377	15	29	2	9		6,91	23,77	0,541
378	15	30	2	15		10,55	92,09	0,494
379	15	31	2	14	9	9,99	68,87	0,448
380	15	32	2	13		9,42	63,17	0,505
381	15	33	2	9		6,91	23,77	0,541
382	15	34	2	7		5,56	12,34	0,577
383	15	35	2	11		8,2	40,52	0,520
384	15	36	2	7		5,56	12,34	0,577
385	15	37	2	5		4,21	5,39	0,652
386	15	38	2	6		4,88	8,37	0,607
387	15	39	2	15		10,55	92,09	0,494
388	15	40	2	17		11,59	127,42	0,484
389	15	41	2	22		13,85	243,95	0,463
390	15	42	2	6		4,88	8,37	0,607
391	15	43	2	11		8,2	40,52	0,520
392	15	44	2	6		4,88	8,37	0,607

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation . m^3/ha	*f*
393	15	45	2	7		5,56	12,34	0,577
394	15	46	2	12		8,82	51,08	0,512
395	15	47	3	5		5,97	6,32	0,539
396	15	48	3	17		14,16	147,9	0,460
397	15	49	3	16	14	13,65	130,42	0,475
398	15	50	3	5		5,97	6,32	0,539
399	15	51	3	6		6,82	9,96	0,517
400	16	1	1	25,2		20,11	474,72	0,473
401	16	2	1	20,5	18,5	17,97	294,48	0,496
402	16	3	1	24		19,61	421,93	0,476
403	16	4	1	22,8		19,07	372,41	0,478
404	16	5	1	23,9		19,57	417,69	0,476
405	16	6	1	16,8		15,91	174,02	0,493
406	16	7	1	20,5		17,97	286,7	0,483
407	16	8	1	15,5		15,1	141,73	0,497
408	16	9	1	19,4		17,39	249,97	0,486
409	16	10	1	18,3		16,79	215,97	0,489
410	16	11	1	17,9		16,56	204,28	0,490
411	16	12	1	22,7		19,03	368,45	0,478
412	16	13	1	19,7		17,55	259,71	0,485
413	16	14	1	25,4		20,2	483,84	0,473
414	16	15	1	13,7		13,88	103,15	0,504
415	16	16	2	21,6		17,8	315,46	0,484
416	16	17	2	29,1	22	20,92	672,43	0,483
417	17	1	1	23	14	13,98	286,29	0,493
418	17	2	1	8		6,9	19,92	0,574
419	18	1	1	27		19,41	524,75	0,472
420	18	2	1	28		19,8	573,26	0,470
421	18	3	1	31		20,89	732,24	0,464
422	18	4	1	29	21	20,18	647,5	0,486
423	18	5	2	26		19,42	480	0,466
424	18	6	2	28		20,21	570,03	0,458
425	18	7	2	5		5,57	6,6	0,603
426	18	8	2	17		14,9	168,93	0,499
427	18	9	2	22		17,63	322	0,480
428	18	10	2	23		18,11	358,64	0,477
429	18	11	2	24	19	18,56	408,23	0,486
430	18	12	2	7		7,36	15,86	0,560
431	18	13	3	24	21	20,9	427,95	0,453
432	19	1	1	26	16	17,26	409,05	0,446
433	19	2	1	17		13,03	149,03	0,504
434	19	3	1	29		18,36	571,94	0,472
435	19	4	1	17		13,03	149,03	0,504
436	19	5	1	13		10,58	73,45	0,523

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation . m^3/ha	*f*
437	19	6	1	18		13,58	172,88	0,500
438	19	7	1	19		14,11	198,79	0,497
439	19	8	1	15		11,85	107,34	0,513
440	19	9	1	7		6,19	14,1	0,592
441	19	10	1	10		8,47	36,4	0,547
442	19	11	1	16		12,45	127,19	0,508
443	19	12	1	16		12,45	127,19	0,508
444	19	13	1	12		9,9	59,32	0,530
445	19	14	1	26		17,26	438,1	0,478
446	19	15	1	25		16,86	397,65	0,480
447	19	16	1	39		21,25	1150,81	0,453
448	19	17	1	30		18,7	620,7	0,470
449	19	18	1	24		16,45	359,3	0,483
450	19	19	2	8	6	6,88	16,85	0,487
451	19	20	2	8		6,88	19,07	0,551
452	19	21	3	8	9	9,38	22,11	0,469
453	19	22	3	7		8,47	16,07	0,493
454	19	23	3	5		6,57	6,72	0,521
455	19	24	3	10		11,07	41,62	0,479
456	20	1	1	24		20,97	448,94	0,473
457	20	2	1	29		23,26	712,15	0,464
458	20	3	1	23		20,45	403,94	0,475
459	20	4	1	25		21,47	496,49	0,471
460	20	5	1	28		22,84	654,43	0,465
461	20	6	1	27	23	22,4	614,23	0,479
462	20	7	1	25		21,47	496,49	0,471
463	20	8	1	27		22,4	599,26	0,467
464	20	9	1	31		24,05	835,08	0,460
465	20	10	1	26		21,94	546,61	0,469
466	20	11	2	42		26,67	1532,48	0,415
467	20	12	2	22		18,9	349,42	0,486
468	20	13	2	28		21,87	626	0,465
469	20	14	2	8		8,41	23,17	0,548
470	20	15	2	29	23	22,3	705,08	0,479
471	20	16	2	8		8,41	23,17	0,548
472	20	17	2	20		17,74	274,92	0,493
473	20	18	2	7		7,46	16,07	0,560
474	20	19	2	24		19,97	432,96	0,479
475	20	20	2	31		23,11	792,03	0,454
476	20	21	2	27		21,42	574,63	0,469
477	20	22	2	33		23,86	912	0,447
478	20	23	2	23		19,45	390,09	0,483
479	20	24	3	6		9,91	13,55	0,484
480	20	25	3	10		14,35	54,24	0,481

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
481	20	26	3	5		8,68	8,32	0,488
482	20	27	3	19		21,43	287,59	0,473
483	20	28	3	12		16,24	88,42	0,481
484	20	29	3	15		18,71	158,58	0,480
485	20	30	3	18	22	20,8	268,4	0,507
486	20	31	3	16		19,45	187,06	0,478
487	20	32	3	24		24,11	502,61	0,461
488	21	1	2	30		19,89	627,67	0,446
489	21	2	2	9		10,82	37,46	0,544
490	21	3	2	8		10,05	27,86	0,551
491	21	4	2	17		15,54	177,24	0,502
492	21	5	2	17		15,54	177,24	0,502
493	21	6	2	19		16,41	229,63	0,494
494	21	7	2	14		14,03	111,56	0,517
495	21	8	2	14		14,03	111,56	0,517
496	21	9	2	28	21	19,39	596,53	0,500
497	21	10	2	13		13,46	93,19	0,522
498	21	11	2	12		12,86	76,6	0,527
499	21	12	2	31		20,13	671,95	0,442
500	21	13	2	10		11,54	48,75	0,538
501	21	14	2	11		12,22	61,79	0,532
502	21	15	2	16		15,06	153,6	0,507
503	21	16	2	39		21,71	1065,33	0,411
504	21	17	2	37		21,36	961,04	0,418
505	21	18	3	30		19,59	580,57	0,419
506	21	19	3	34	19	20,5	689,62	0,371
507	21	20	3	40		21,62	1033,92	0,381
508	22	1	1	27	21	19,71	564,36	0,500
509	22	2	1	29		20,36	629,09	0,468
510	22	3	1	29		20,36	629,09	0,468
511	22	4	1	26		19,37	486,9	0,473
512	22	5	1	18		15,95	199,6	0,492
513	22	6	1	32		21,23	789,73	0,463
514	22	7	1	32		21,23	789,73	0,463
515	22	8	1	24		18,63	402,47	0,478
516	22	9	1	17		15,42	173,12	0,495
517	22	10	2	9		9,59	32,97	0,540
518	22	11	2	15	14,5	13,8	131,06	0,537
519	22	12	2	14		13,18	103,98	0,512
520	22	13	2	12		11,85	69,95	0,522
521	22	14	2	20		16,46	251,98	0,487
522	22	15	2	10		10,38	43,48	0,533
523	22	16	2	13		12,53	86,01	0,517
524	22	17	2	15		13,8	123,88	0,508

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
525	22	18	2	7		7,92	17,05	0,559
526	22	19	3	22		19,25	331,93	0,454
527	22	20	3	20	18	18,39	259,05	0,448
528	22	21	3	15		15,8	131,48	0,471
529	22	22	3	15		15,8	131,48	0,471
530	22	23	3	12		13,85	74,5	0,476
531	22	24	3	17		16,93	179,33	0,467
532	22	25	3	26		20,73	484,93	0,441
533	22	26	3	25		20,38	444,33	0,444
534	22	27	3	20		18,39	265,44	0,459
535	22	28	3	6		8,75	12,12	0,490
536	22	29	3	7		9,72	18,14	0,485
537	22	30	3	10		12,34	46,36	0,478
538	22	31	3	8		10,64	25,78	0,482
539	22	32	3	6		8,75	12,12	0,490
540	22	33	3	9		11,51	35,16	0,480
541	22	34	3	10		12,34	46,36	0,478
542	22	35	3	24		20,02	405,25	0,447
543	23	1	1	25		19,26	449,04	0,475
544	23	2	1	22		17,94	328,42	0,482
545	23	3	1	44	24	24,76	1617,31	0,430
546	23	4	2	20	17	16,89	261,6	0,493
547	23	5	2	10		10,33	43,24	0,533
548	23	6	2	9		9,5	32,62	0,540
549	23	7	2	17		15,23	173,17	0,501
550	23	8	2	22		17,87	327,1	0,482
551	23	9	3	13		15,86	100,47	0,477
552	23	10	3	29		23,51	676,76	0,436
553	23	11	3	17		18,43	197,16	0,471
554	23	12	3	21	22	20,48	355,77	0,502
555	23	13	3	28		23,19	627,44	0,439
556	23	14	3	14		16,56	121,38	0,476
557	24	1	1	7		6,67	14,9	0,580
558	24	2	1	35		15,63	707,97	0,471
559	24	3	1	23		13,22	272,22	0,496
560	24	4	1	20		12,38	195,83	0,504
561	24	5	1	32		15,14	579,93	0,476
562	24	6	1	25		13,72	330,49	0,491
563	24	7	1	10		8,37	36,06	0,549
564	24	8	1	26		13,95	361,81	0,489
565	24	9	1	23		13,22	272,22	0,496
566	24	10	1	9		7,84	27,76	0,557
567	24	11	1	25		13,72	330,49	0,491
568	24	12	1	28	12	14,38	365,59	0,413

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
569	25	1	1	30		22,71	743,14	0,463
570	25	2	1	32		23,39	864,25	0,459
571	25	3	1	31		23,05	802,55	0,461
572	25	4	1	37		24,87	1206,73	0,451
573	25	5	1	34	24	24,01	993,98	0,456
574	25	6	1	35		24,31	1062,99	0,454
575	25	7	1	37		24,87	1206,73	0,451
576	25	8	1	27		21,58	578,87	0,469
577	25	9	2	25	22	20,36	520,73	0,521
578	25	10	3	8	11	11,43	26,62	0,463
579	25	11	3	6		9,28	12,76	0,486
580	25	12	3	9		12,43	37,95	0,480
581	26	1	1	19		15,65	218,09	0,492
582	26	2	1	18	16,5	15,15	205,83	0,534
583	26	3	2	19		15,63	217	0,490
584	26	4	2	16		14,06	142,04	0,502
585	26	5	2	19		15,63	217	0,490
586	26	6	2	24	18	17,79	383,13	0,476
587	26	7	2	27		18,87	494,48	0,458
588	26	8	2	20		16,1	245,66	0,486
589	26	9	2	26		18,52	454,02	0,462
590	26	10	2	26		18,52	454,02	0,462
591	26	11	2	13		12,25	83,9	0,516
592	26	12	2	28		19,2	536,46	0,454
593	26	13	3	13		14,02	88,05	0,473
594	26	14	3	22		18,69	320,98	0,452
595	26	15	3	17	16	16,38	168,58	0,453
596	26	16	3	10		11,86	44,54	0,478
597	26	17	3	23		19,08	355,78	0,449
598	26	18	3	21		18,27	287,84	0,455
599	26	19	3	6		8,35	11,65	0,493
600	26	20	3	12		13,34	71,64	0,475
601	26	21	3	9		11,05	33,77	0,480
602	27	1	1	29	17	17,68	533,24	0,457
603	27	2	1	24		16,19	354,1	0,483
604	27	3	1	13		11,34	77,97	0,518
605	27	4	1	16		12,94	131,53	0,506
606	27	5	1	12		10,75	63,61	0,523
607	27	6	1	13		11,34	77,97	0,518
608	27	7	1	8		8,08	22,51	0,554
609	27	8	1	12		10,75	63,61	0,523
610	27	9	1	8		8,08	22,51	0,554
611	27	10	1	45		20,88	1481,4	0,446
612	27	11	1	13		11,34	77,97	0,518

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
613	27	12	1	13		11,34	77,97	0,518
614	27	13	1	15		12,43	111,9	0,509
615	27	14	1	9		8,8	30,45	0,544
616	27	15	1	11		10,13	50,93	0,529
617	28	1	1	5		5,68	6,79	0,609
618	28	2	1	7		7,13	15,67	0,571
619	28	3	1	8		7,82	21,94	0,558
620	28	4	1	7		7,13	15,67	0,571
621	28	5	1	7		7,13	15,67	0,571
622	28	6	1	6		6,42	10,65	0,587
623	28	7	1	36	17	17,91	805,71	0,442
624	28	8	1	17		12,67	145,4	0,506
625	28	9	1	16		12,24	125,26	0,509
626	28	10	1	36		17,91	844,94	0,463
627	29	1	1	45		20,46	1454,04	0,447
628	29	2	1	7		5,64	13,23	0,610
629	29	3	1	6		4,95	8,93	0,638
630	29	4	1	6		4,95	8,93	0,638
631	29	5	1	12		8,98	54,71	0,539
632	29	6	1	10		7,69	33,72	0,558
633	29	7	1	6		4,95	8,93	0,638
634	29	8	1	8		6,34	18,71	0,587
635	29	9	1	6		4,95	8,93	0,638
636	29	10	1	5		4,26	5,7	0,681
637	29	11	1	11		8,35	43,43	0,547
638	29	12	1	14		10,17	82,26	0,525
639	29	13	1	14		10,17	82,26	0,525
640	29	14	1	11		8,35	43,43	0,547
641	29	15	1	14		10,17	82,26	0,525
642	29	16	1	17	11	11,8	128,68	0,480
643	29	17	1	13		9,59	67,63	0,531
644	29	18	1	7		5,64	13,23	0,610
645	29	19	1	14		10,17	82,26	0,525
646	29	20	1	7		5,64	13,23	0,610
647	29	21	1	11		8,35	43,43	0,547
648	29	22	1	9		7,02	25,51	0,571
649	29	23	1	10		7,69	33,72	0,558
650	29	24	1	14		10,17	82,26	0,525
651	29	25	1	15		10,74	98,61	0,520
652	29	26	1	12		8,98	54,71	0,539
653	29	27	1	11		8,35	43,43	0,547
654	29	28	1	14		10,17	82,26	0,525
655	29	29	1	13		9,59	67,63	0,531
656	29	30	1	7		5,64	13,23	0,610

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation . m^3/ha	*f*
657	29	31	1	11		8,35	43,43	0,547
658	29	32	2	11	7	8,16	34,74	0,448
659	30	1	1	32		17,66	666,67	0,469
660	30	2	1	5		5,31	6,49	0,622
661	30	3	1	6		6,07	10,23	0,596
662	30	4	1	9		8,22	28,83	0,551
663	30	5	1	10		8,88	37,83	0,542
664	30	6	1	31	17	17,42	605,95	0,461
665	30	7	1	31		17,42	619,7	0,471
666	30	8	1	24		15,45	339,48	0,486
667	30	9	2	6	6	6,25	9,88	0,559
668	30	10	3	10	9	10,07	34,36	0,434
669	30	11	3	7		7,89	15,16	0,499
670	31	1	1	18		14,71	185,61	0,496
671	31	2	1	21		16,08	271,65	0,488
672	31	3	1	21		16,08	271,65	0,488
673	31	4	1	31		19,51	687,29	0,467
674	31	5	1	27		18,31	497,38	0,474
675	31	6	1	25	18	17,63	422,07	0,488
676	31	7	1	23		16,89	338,96	0,483
677	31	8	1	25		17,63	414,2	0,479
678	31	9	1	22		16,5	304,3	0,485
679	32	1	1	34	23	22,37	955,19	0,470
680	32	2	2	20		17,56	271,62	0,492
681	32	3	2	9		10,34	35,69	0,543
682	32	4	2	32	23	22,1	829,73	0,467
683	32	5	2	31		21,8	738,81	0,449
684	32	6	2	32		22,1	791,05	0,445
685	32	7	2	32		22,1	791,05	0,445
686	32	8	2	13		13,44	93	0,521
687	32	9	2	35		22,92	956,1	0,434
688	32	10	2	13		13,44	93	0,521
689	32	11	2	25		19,75	457,99	0,472
690	32	12	2	9		10,34	35,69	0,543
691	32	13	2	35		22,92	956,1	0,434
692	32	14	2	13		13,44	93	0,521
693	32	15	2	26		20,13	500,69	0,468
694	32	16	2	10		11,17	47,06	0,536
695	32	17	2	22		18,49	340,57	0,485
696	32	18	2	22		18,49	340,57	0,485
697	32	19	2	49		25,78	1860,53	0,383
698	32	20	3	22		19,8	342,61	0,455
699	32	21	3	26	20	21,37	465,53	0,410
700	32	22	3	36		24,28	1003,3	0,406

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
701	33	1	1	16,4	9,75	10,44	108,32	0,491
702	33	2	1	11,2		7,55	41,58	0,559
703	33	3	1	25		14,15	339,71	0,489
704	33	4	1	13,9		9,11	73,99	0,535
705	33	5	2	6,7		4,21	9,32	0,628
706	33	6	2	10,6	5,25	6,49	25,3	0,442
707	33	7	3	6		6,1	9,26	0,537
708	33	8	3	10,6		9,51	40,46	0,482
709	33	9	3	23,2		15,96	296,26	0,439
710	33	10	3	7,4		7,19	15,77	0,510
711	33	11	3	6,7		6,65	12,22	0,521
712	33	12	3	5,7		5,86	8,16	0,546
713	33	13	3	8		7,65	19,31	0,502
714	33	14	3	6,2		6,25	10,05	0,533
715	33	15	3	9,8		8,96	32,9	0,487
716	33	16	3	12		10,44	56,11	0,475
717	33	17	3	9		8,39	26,28	0,492
718	33	18	3	7,3		7,11	15,23	0,512
719	33	19	3	8,2		7,8	20,59	0,500
720	33	20	3	9,9		9,03	33,79	0,486
721	33	21	3	8,3		7,87	21,26	0,499
722	33	22	3	6,6		6,57	11,77	0,524
723	33	23	3	6,9		6,8	13,18	0,518
724	33	24	3	6,1		6,18	9,65	0,534
725	33	25	3	6		6,1	9,26	0,537
726	33	26	3	10,1		9,17	35,62	0,485
727	33	27	3	7,6		7,34	16,9	0,508
728	33	28	3	7		6,88	13,67	0,516
729	33	29	3	6		6,1	9,26	0,537
730	33	30	3	6,5		6,49	11,32	0,526
731	33	31	3	11,7	10	10,24	51,33	0,466
732	33	32	3	10,4		9,38	38,48	0,483
733	33	33	3	8,1		7,72	19,94	0,501
734	33	34	3	10,2		9,24	36,56	0,484
735	33	35	3	10,2		9,24	36,56	0,484
736	33	36	3	6,4		6,41	10,89	0,528
737	33	37	3	7,3		7,11	15,23	0,512
738	34	1	1	9		8,11	28,52	0,553
739	34	2	1	12		10,16	60,62	0,528
740	34	3	1	16		12,51	127,7	0,508
741	34	4	1	19		14,01	197,53	0,497
742	34	5	1	20		14,47	224,65	0,494
743	34	6	1	10		8,82	37,6	0,543
744	34	7	1	23	14	15,72	286,29	0,438

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
745	34	8	1	26		16,82	427,9	0,479
746	34	9	1	23		15,72	317,56	0,486
747	34	10	1	29		17,78	555,61	0,473
748	34	11	2	15		13,02	116,03	0,504
749	34	12	2	19	15	15,04	207,01	0,485
750	34	13	2	18		14,57	182,12	0,491
751	34	14	2	11		10,55	52,62	0,525
752	34	15	2	21		15,91	263,77	0,479
753	34	16	2	20		15,49	234,88	0,483
754	34	17	2	14		12,45	97,53	0,509
755	34	18	2	10		9,85	41,11	0,531
756	34	19	2	23		16,71	326,52	0,470
757	34	20	3	18	18	16,85	213,52	0,498
758	34	21	3	16		15,87	149,21	0,468
759	34	22	3	15		15,34	127,32	0,470
760	34	23	3	31		21,21	671,75	0,420
761	34	24	3	15		15,34	127,32	0,470
762	35	1	1	17		15,46	173,53	0,495
763	35	2	1	26		19,59	492,18	0,473
764	35	3	1	26		19,59	492,18	0,473
765	35	4	1	22	19	17,97	346,21	0,507
766	35	5	1	22		17,97	328,93	0,482
767	35	6	1	22		17,97	328,93	0,482
768	35	7	1	20		17,04	260,29	0,486
769	35	8	1	22		17,97	328,93	0,482
770	35	9	1	21		17,51	293,53	0,484
771	35	10	1	24		18,82	406,24	0,477
772	35	11	1	22		17,97	328,93	0,482
773	35	12	1	17		15,46	173,53	0,495
774	35	13	1	18		16,01	200,3	0,492
775	35	14	2	26	20	18,97	496,95	0,493
776	36	1	1	19		16,09	223,59	0,490
777	36	2	1	15		13,94	123,75	0,502
778	36	3	1	25		18,62	435,29	0,476
779	36	4	1	21		17,01	285,87	0,485
780	36	5	1	21		17,01	285,87	0,485
781	36	6	1	21		17,01	285,87	0,485
782	36	7	1	23		17,85	356,43	0,481
783	36	8	1	24		18,24	394,82	0,478
784	36	9	1	21		17,01	285,87	0,485
785	36	10	1	25		18,62	435,29	0,476
786	36	11	1	22	18	17,44	329,46	0,497
787	36	12	1	21		17,01	285,87	0,485
788	36	13	1	24		18,24	394,82	0,478

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation . m^3/ha	*f*
789	36	14	1	20		16,56	253,69	0,488
790	36	15	1	26		18,97	477,83	0,474
791	36	16	1	18		15,59	195,56	0,493
792	36	17	1	21		17,01	285,87	0,485
793	36	18	2	20	17	16,3	261,6	0,511
794	37	1	2	9		7,25	24,86	0,539
795	37	2	2	9		7,25	24,86	0,539
796	37	3	2	8	7	6,72	19,37	0,573
797	37	4	2	8		6,72	18,64	0,552
798	37	5	2	11		8,22	40,62	0,520
799	37	6	2	6		5,58	9,29	0,589
800	37	7	2	6		5,58	9,29	0,589
801	37	8	2	7		6,16	13,47	0,568
802	37	9	2	7		6,16	13,47	0,568
803	37	10	3	12		9,95	53,63	0,477
804	37	11	3	11		9,49	43,42	0,481
805	37	12	3	9	9	8,5	27,92	0,516
806	37	13	3	6		6,73	9,88	0,519
807	37	14	3	10		9,01	34,4	0,486
808	37	15	3	7		7,36	14,36	0,507
809	37	16	3	6		6,73	9,88	0,519
810	37	17	3	8		7,95	19,91	0,498
811	37	18	3	7		7,36	14,36	0,507
812	37	19	3	7		7,36	14,36	0,507
813	37	20	3	7		7,36	14,36	0,507
814	38	1	1	29	24	23,29	733,33	0,477
815	38	2	1	33		24,7	964,57	0,457
816	38	3	1	26		22,06	549,42	0,469
817	38	4	1	33		24,7	964,57	0,457
818	38	5	1	25		21,62	499,82	0,471
819	38	6	1	28		22,89	655,95	0,465
820	38	7	1	28		22,89	655,95	0,465
821	38	8	1	23		20,68	408,01	0,475
822	38	9	2	22		19,23	356,68	0,488
823	38	10	2	29		22,4	683,27	0,462
824	38	11	2	27		21,59	580,03	0,469
825	38	12	2	23		19,75	397,18	0,484
826	38	13	2	24	22	20,24	485,72	0,530
827	38	14	2	23		19,75	397,18	0,484
828	38	15	2	26		21,16	531,27	0,473
829	38	16	2	24		20,24	439,8	0,480
830	38	17	2	18		16,94	216,66	0,503
831	38	18	2	24		20,24	439,8	0,480
832	38	19	2	26		21,16	531,27	0,473

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
833	38	20	2	27		21,59	580,03	0,469
834	38	21	2	22		19,23	356,68	0,488
835	38	22	2	17		16,3	187,31	0,506
836	38	23	2	28		22,01	630,72	0,465
837	38	24	2	21		18,7	318,32	0,491
838	38	25	3	11	13	14,07	58,92	0,441
839	39	1	3	5	5	6,23	5,79	0,473
840	39	2	4	8		8,48	23,4	0,549
841	39	3	4	25		19,43	452,72	0,475
842	39	4	4	24		18,98	409,55	0,477
843	39	5	4	31		21,73	759,67	0,463
844	39	6	4	24		18,98	409,55	0,477
845	39	7	4	27	21	20,26	564,36	0,487
846	39	8	4	24		18,98	409,55	0,477
847	39	9	4	27		20,26	545,92	0,471
848	39	10	4	22		18,04	330,13	0,481
849	39	11	4	32		22,07	818,78	0,461
850	40	1	1	14		9,64	78,67	0,530
851	40	2	1	9		6,81	24,94	0,576
852	40	3	1	14		9,64	78,67	0,530
853	40	4	1	10		7,42	32,79	0,563
854	40	5	1	16	8	10,63	87,87	0,411
855	40	6	1	15		10,15	94	0,524
856	40	7	1	25		14,12	338,94	0,489
857	40	8	2	18	14	13,07	174,03	0,523
858	40	9	3	36		19,53	780,06	0,392
859	40	10	3	28	18	17,87	469,51	0,427
860	41	1	2	22,6	20	18,16	391,22	0,537
861	41	2	2	24,8		18,92	429,55	0,470
862	41	3	2	8,5		10,47	32,55	0,548
863	41	4	2	6,3		8,61	15,24	0,568
864	41	5	2	15,2		14,88	138,22	0,512
865	41	6	2	23,3		18,41	373,95	0,476
866	41	7	2	7		9,22	19,89	0,561
867	41	8	2	28,5		20,03	580,94	0,455
868	41	9	2	11,7		12,79	72,72	0,529
869	41	10	2	8,2		10,23	29,71	0,550
870	41	11	2	8,6		10,55	33,53	0,547
871	41	12	2	20		17,15	264,33	0,491
872	41	13	2	24,7		18,89	425,73	0,470
873	41	14	2	18		16,28	206,81	0,499
874	41	15	2	13,2		13,74	98	0,521
875	41	16	2	10,5		11,97	55,48	0,535
876	41	17	2	8		10,06	27,91	0,552

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation . m^3/ha	*f*
877	41	18	2	7,8		9,9	26,17	0,553
878	41	19	2	30,5		20,56	670,62	0,446
879	41	20	2	12,8		13,49	90,86	0,523
880	41	21	2	7,1		9,31	20,62	0,559
881	41	22	2	8,8		10,7	35,53	0,546
882	41	23	2	9,1		10,94	38,68	0,544
883	41	24	2	26,8		19,54	508,95	0,462
884	41	25	2	12,3		13,18	82,34	0,526
885	41	26	2	14,8		14,66	129,59	0,514
886	41	27	2	6,5		8,79	16,49	0,565
887	41	28	2	14,4		14,44	121,25	0,516
888	41	29	3	13,5		14,09	95,18	0,472
889	41	30	3	11,4		12,75	61,89	0,476
890	41	31	3	6,3		8,69	13,29	0,491
891	41	32	3	20,8	16	17,68	244,21	0,407
892	41	33	3	25		19,19	414,73	0,440
893	41	34	3	14,4		14,62	111,92	0,470
894	41	35	3	16,2		15,59	149,82	0,466
895	41	36	3	12,8		13,66	83,19	0,473
896	41	37	3	10,1		11,82	45,3	0,478
897	41	38	3	6,7		9,05	15,58	0,488
898	41	39	3	8,3		10,42	27,19	0,482
899	41	40	3	26,3		19,59	463,92	0,436
900	41	41	3	9,8		11,6	41,89	0,479
901	41	42	3	17,8		16,38	188,39	0,462
902	41	43	3	8,3		10,42	27,19	0,482
903	41	44	3	24,6		19,06	400,05	0,442
904	41	45	3	18,8		16,84	214,77	0,459
905	41	46	3	16,5		15,75	156,7	0,465
906	41	47	3	10,8		12,33	53,86	0,477
907	41	48	3	12,2		13,28	73,62	0,474
908	41	49	3	11,8		13,02	67,61	0,475
909	41	50	3	28,2		20,15	539,86	0,429
910	42	1	2	7,6		6,41	16,24	0,558
911	42	2	2	10,4	7,75	8,53	34,58	0,477
912	42	3	2	7,3		6,17	14,59	0,565
913	42	4	2	7,2		6,1	14,06	0,566
914	42	5	2	8		6,71	18,64	0,553
915	42	6	2	12,2		9,82	58,85	0,513
916	42	7	2	6,8		5,79	12,1	0,575
917	42	8	2	6		5,17	8,75	0,599
918	42	9	3	24,1	20,75	20,1	425,2	0,464
919	42	10	3	24,4		20,22	421,82	0,446
920	42	11	3	15,1		15,49	130,29	0,470

Tree nr	Field plot id	Tree id	Species	DBH, cm	Height, m	H model, m	V estimation. m^3/ha	*f*
921	42	12	3	19,7		18,1	253,65	0,460
922	42	13	3	11,7		13,1	66,96	0,475
923	42	14	3	18,7		17,59	223,22	0,462
924	42	15	3	16,3		16,23	158,33	0,467
925	42	16	3	12,7		13,85	83,12	0,474
926	42	17	3	30		22,2	670,49	0,427
927	42	18	3	26,9		21,17	526,91	0,438
928	43	1	1	31,3		21,58	768,63	0,463
929	43	2	1	17,1		15,7	177,94	0,494
930	43	3	1	19,8		17,13	256,53	0,486
931	43	4	1	15,2		14,56	132,06	0,500
932	43	5	1	27		20,17	543,73	0,471
933	43	6	1	21,4		17,9	310,59	0,482
934	43	7	1	22,3		18,3	343,45	0,481
935	43	8	1	23,9	20	18,98	426,23	0,501
936	43	9	1	19		16,73	231,6	0,488
937	43	10	1	20,3		17,38	272,82	0,485
938	43	11	1	9,5		10,44	39,07	0,528
939	43	12	2	29,9		20,97	664,46	0,451
940	43	13	2	24,2		18,93	412,13	0,473
941	43	14	2	17,8		15,91	197,47	0,499
942	43	15	2	26	20	19,63	496,95	0,477
943	43	16	2	27		19,99	529,42	0,463
944	43	17	3	27,3	21	21,76	535,58	0,420

Annex 2.2.

Second phase sample plots forest variables

Plot id	Dominant species	D, cm	D pine, cm	D spruce, cm	D decid, cm	H, m	H pine, m	H spruce, m	H decid, m	BA, m^2/ha	BA pine, m^2/ha	BA spruce, m^2/ha	BA decid, m^2/ha	V, m^3/ha	V pine, m^3/ha	V spruce, m^3/ha	V decid, m^3/ha
0	3	20,6	0	8,1	21,1	19,5	0	4,9	20,1	8,4	0	0,3	8	74,98	0	0,95	74,02
1	2	34,8	35	7,4	35,2	26	26	6,2	26,5	15,6	9,4	0,1	6,1	177,87	110,31	0,5	67,05
2	2	31,8	28,4	32,8	19	22,1	21,2	22,2	21,5	22	2,1	19	0,9	215,89	20,97	185,29	9,63
3	2	22,7	21,8	18,1	28,3	15,7	14,8	15,1	18,5	23,6	13,1	4,7	5,8	175,02	95,12	34,54	45,36
4	2	15	0	14,1	15,1	13,1	0	10,6	13,6	10,1	0	1,7	8,3	61,62	0	9,19	52,43
5	1	31	37,4	23,6	30,4	20,7	21,7	19	23,4	49,5	24	20,7	4,8	472,16	236,48	187,31	48,37
6	3	19,3	8,7	13,7	27,3	14,2	7,7	11	18,9	12,8	1,3	5,8	5,7	84,15	5,41	32,49	46,24
7	3	15,9	0	13	16,4	16,3	0	12,2	17	31,4	0	4,4	27	243,01	0	27,93	215,08
8	2	26,9	10,8	26,2	29,9	19,5	7,5	19	21,8	38,5	0,5	28,7	9,4	340,71	1,97	251,89	86,85
9	1	37,2	23	40,8	27,8	21,4	16	22,6	19	18,6	1,4	14	3,3	164,51	10,76	127,25	26,5
10	1	31	28,6	25,8	38,6	20,6	20,1	20,2	21,6	23,5	8	7,7	7,9	213,01	74,97	72,49	65,55
11	1	16,7	17,7	12,8	13	10,4	10,6	9,7	8,5	21,9	17,4	4,1	0,4	117	94,78	20,41	1,82
12	1	22,2	34	21,2	18,3	16,4	20	15,9	15,9	24,5	3	16,3	5,2	188,5	27,97	122,97	37,56
13	1	23,4	23,7	0	14,7	16,2	16,2	0	13,5	22,7	22,1	0	0,6	177,38	173,82	0	3,57
14	1	15,2	16,2	0	9,2	10,1	10,2	0	9,3	9,2	8	0	1,2	48,16	42,51	0	5,65
15	2	13,9	14	13,6	15	9,5	8,7	9,5	13	17,1	6	9,4	1,7	82,96	28,16	44,77	10,03
16	1	22,4	21,5	26,4	0	18,8	18,4	20,5	0	20,3	16,8	3,4	0	181,97	149,03	32,94	0
17	1	21,4	21,4	0	0	13,2	13,2	0	0	1,6	1,6	0	0	10,21	10,21	0	0
18	1	26,2	28,9	23,9	24	19,5	20,3	18,4	21	19,1	8,7	8,9	1,5	174,61	82,63	77,71	14,27
19	1	25,2	25,9	8	8,3	16,3	16,6	6,4	9,5	22,6	21,7	0,3	0,6	176,23	172,15	1,2	2,89
20	2	27,5	26,9	30,2	18,1	22,2	22,4	22,4	20,7	45,7	18,5	21,8	5,4	467,81	193,67	221,83	52,31
21	2	30,8	0	28,5	35,6	19,4	0	19	20,3	30	0	20,4	9,6	251,21	0	174,37	76,84
22	1	23,4	27,9	14,8	20,2	18,5	20	13,6	18	32,5	16,6	4,2	11,8	281,06	155,54	28,69	96,83
23	1	28,4	36,6	18,7	24,1	20,8	22,1	16	21,7	18,6	8	3,5	7,1	177,12	79,86	27,94	69,33
24	1	27,2	27,2	0	0	13,7	13,7	0	0	17,4	17,4	0	0	116,56	116,56	0	0
25	1	32,5	33,5	25	8	23,4	23,8	22	11,3	25	22,9	1,6	0,5	268,69	248,75	17,36	2,58

Plot id	Dominant species	D, cm	D pine, cm	D spruce, cm	D decid, cm	H, m	H pine, m	H spruce, m	H decid, m	BA, m^2/ha	BA pine, m^2/ha	BA spruce, m^2/ha	BA decid, m^2/ha	V, m^3/ha	V pine, m^3/ha	V spruce, m^3/ha	V decid, m^3/ha
26	2	21,9	18,5	23,8	18,9	17,3	16,1	17,6	16,9	20,8	1,8	13,1	6	167,89	14,14	107,64	46,11
27	1	29,2	29,2	0	0	16,4	16,4	0	0	13,7	13,7	0	0	105,97	105,97	0	0
28	1	30,6	30,6	0	0	15,8	15,8	0	0	8,9	8,9	0	0	66,95	66,95	0	0
29	1	23,8	24	11	0	13	13,1	7	0	15,1	14,8	0,3	0	95,96	94,8	1,16	0
30	1	27,8	28,8	6	9	16,1	16,5	6	8,6	10,3	9,9	0,1	0,4	79,19	77,21	0,33	1,65
31	1	24,8	24,8	0	0	17,5	17,5	0	0	13,5	13,5	0	0	113,15	113,15	0	0
32	2	32,5	34	32,7	30,5	21,9	23	21,8	22,2	41,7	3	32,3	6,4	400,13	31,85	307,87	60,41
33	1	14,2	19,9	9,5	11,9	10,2	11,7	5	9,9	10,4	3,2	0,4	6,8	51,87	18,79	1,15	31,92
34	2	21,6	22,6	18,8	23,3	15,8	15,1	14,8	18,7	22,5	10,3	7,1	5,2	169,23	75,5	50,74	42,99
35	1	22,6	22,2	26	0	18,2	18,1	20	0	17,7	16	1,8	0	155,09	138,51	16,57	0
36	1	22,1	22,2	20	0	17,5	17,5	17	0	22,1	21,1	1	0	186,66	177,93	8,72	0
37	2	8,9	0	8,5	9,1	7,9	0	7	8,5	3,6	0	1,5	2	14,35	0	5,8	8,55
38	1	26,3	28,9	24,7	11	21,6	23,3	20,6	13	41,3	16,8	24,2	0,3	420,92	181,13	237,83	1,96
39	4	26,7	26,8	0	5	20,1	20,1	0	5	16,7	16,6	0	0,1	157,71	157,52	0	0,19
40	2	25,7	18,1	18	33	15,2	10,9	14	19	10,7	4,4	0,8	5,4	72,01	24,54	5,8	41,67
41	3	21	0	21,7	20,2	17,2	0	17,4	16,8	35,1	0	19,7	15,4	281,02	0	164,63	116,39
42	3	21,6	0	9,2	23,2	18,1	0	7,4	19,5	12,8	0	1,5	11,3	104,64	0	5,93	98,71
43	3	24,7	23,4	26,2	27,3	19,2	18,6	19,7	21	23,5	13,1	8,4	2	211,38	116,8	76,71	17,86

Where

Species:

1 – pine, 2 – spruce, 3 – birch, 4 – larch

Annex 3.

A list of Haralick and 3D features – the remote sensing features

Haralick features	
First-order statistics in the spatial domain	
SA	Sum Average
ENT	Entropy
DE	Difference Entropy
SE	Sum Entropy
VAR	Variance
DV	Difference Variance
SV	Sum Variance
Second-order statistics in the spatial domain	
ASM	Angular Second Moment
IDM	Inverse Difference Moment
Contr	Contrast
Corr	Correlation
MOC	Information Measures of Correlation
3D features	
havg	Average value of H above ground level of vegetation pulses, first returns, meters
hstd	Standard deviation of H above ground level of vegetation pulses, first returns
h0, h5, h10, h20, h30, h40, h50, h60, h70, h80, h85, h90, h95, h100	H above ground level, where percentages of vegetation pulses (0%, 5%, 10%, 20%, …95%, 100%) were accumulated, meters
hcv	Coefficient of variation of H above ground level of vegetation pulses, first returns, %
veg	Proportion of vegetation pulses, first returns, %
d0, d1, d2, d3, d4, d5, d6, d7, d8, d9	Proportion of vegetation pulses having H above ground level above fraction 0, 1, … 9 from all points, first returns, %
p20, p40, p60, p80, p95	Proportion of vegetation pulses having H above ground level greater or equal to corresponding percentile of H, first returns, %
pcg	Ratio of number of vegetation pulses to the number of ground points, first returns, %
pgh	Proportion of ground pulses, first returns, %

Annex 4.

Trestima reports

Forest inventory report: @12

TRESTIMA
SEE THE WOOD FOR THE TREES

Measurement performed 14.01.2015 | 26.01.2015

Measured area 4.84 ha

BA sample amount 13 pcs

Specie	BA m^2/ha	Stems pcs/ha	Stems pcs	DBH cm	Height m	Vol m^3/ha	Vol m^3	Log %
pine	12.3	229	1110	27.6	22.1	129.4	627.0	72
spruce	12.9	233	1130	28.1	19.4	116.6	565.0	70
other	0.1							
Tot.	**25.3**	**462**	**2240**			**246.1**	**1191.9**	

Sample size: pine: 210, spruce: 220, other: 2, total: 433 pcs

Specie ratios: pine: 48.6 %, spruce: 50.8 %, other: 0.6 %

BA range with 95% probability 21.2-29.5. Std. error: 8.4%

Fig. 1. Compartment 412 (the FMP numeration)

Forest inventory report: @52

TRESTIMA
SEE THE WOOD FOR THE TREES

Measurement performed 14.01.2015 02.02.2015
Measured area 4.40 ha
BA sample amount 11 pcs

Specie	BA m^2/ha	Stems pcs/ha	Stems pcs	DBH cm	Height m	Vol m^3/ha	Vol m^3	Log %
pine	20.9	336	1475	30.4	21.1	210.9	927.3	75
spruce	1.9	69	304	19.4	14.2	13.5	59.3	36
birch	0.6	8	35	37.5	22.5	6.4	28.0	56
aspen	0.5							
Tot.	**23.9**	**413**	**1815**			**230.8**	**1014.6**	

Sample size: pine: 303, spruce: 27, birch: 9, aspen: 7, total: 346 pcs
Specie ratios: pine: 87.4 %, spruce: 7.9 %, birch: 2.7 %, aspen: 2.0 %
BA range with 95% probability 17.5-30.4. Std. error: 13.8%

Fig. 2. Compartment 454 (the FMP numeration)

Forest inventory report: @54

TRESTIMA
SEE THE WOOD FOR THE TREES

Measurement performed 14.01.2015 02.02.2015
Measured area 4.70 ha
BA sample amount 23 pcs

Specie	BA m^2/ha	Stems pcs/ha	Stems pcs	DBH cm	Height m	Vol m^3/ha	Vol m^3	Log %
pine	15.8	244	1144	31.4	21.5	162.2	761.6	76
spruce	3.6	62	291	29.0	24.3	38.6	181.2	75
birch	0.9	13	62	31.3	22	8.4	39.4	51
other	0.2							
Tot.	**20.5**	**319**	**1498**			**209.2**	**982.2**	

Sample size: pine: 478, spruce: 109, birch: 26, other: 7, total: 620 pcs
Specie ratios: pine: 77.1 %, spruce: 17.6 %, birch: 4.2 %, other: 1.1 %
BA range with 95% probability 17.8-23.2. Std. error: 6.6%

Fig. 3. Compartment 456 (the FMP numeration)