New Technologies to Optimize the Wood Information Basis for Forest Industries – Developing an Integrated Resource Information System (WW-IRIS)

FINAL REPORT

Title of the research project	**New Technologies to Optimize the Wood Information Basis for Forest Industries – Developing an Integrated Resource Information System (WW-IRIS)**
Coordinator of the project	Prof. Erik Næsset

BASIC PROJECT DATA

Project period	01.01.2008 - 31.12.2010
Contact information of the coordinator (institute/unit, address, telephone, fax, e-mail)	Norwegian University of Life Sciences (UMB) Høgskoleveien 12 1430 Ås Tel. +47 64 96 57 34 Fax. +47 64 96 58 01 E-mail Erik.Naesset@umb.no
URL of the project	http://www.umb.no/lidar/ww-iris

FUNDING

Total budget in EUR	2.180.976 EUR
Public funding from WoodWisdom-Net Research Programme:	Total funding granted in EUR by source:
<u>Finland</u>	
Tekes - Finnish Funding Agency for Technology and Innovation	178.000 EUR
Ministry of Agriculture and Forestry (MMM)	120.000 EUR
Academy of Finland (AKA)	-

Denmark	
Danish Forest and Nature Agency (DFNA)	-
Danish Research Council for Production and Technology Sciences (FTP)	-
Germany	
Federal Ministry of Education and Research (BMBF)/	379.552 EUR
Project Management Agency Jülich (PtJ)	-
Norway	
The Research Council of Norway (RCN)	381.292 EUR
Innovation Norway (INVANOR)	-
Sweden	
The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas)	251.900 EUR
Swedish Governmental Agency for Innovation Systems (VINNOVA)	-
France	
Ministry of Agriculture, General Direction for Forest and Rural Affairs (DGPAAT)	-
Technical Centre for Wood and Furniture (CTBA)	-
National Institute of Agronomical Research (INRA)	-
United Kingdom	
Forestry Commission (FC)	-
Nordic Forest Research Co-operation Committee (SNS)	150.000 EUR

Other public funding:

Norwegian University of Life Sciences (UMB)	107.500 EUR
The Norwegian Forest and Landscape Institute	8.750 EUR
The Forest Research Institute of Sweden (Skogforsk)	33.000 EUR
Sveaskog, Sweden	79.750 EUR
The Swedish Forest Agency	25.630 EUR
Swedish University of Agricultural Sciences (SLU)	96.800 EUR
University of Eastern Finland	102.500 EUR
Albert-Ludwigs University of Freiburg (ALU), Germany	17.952 EUR
Forest Research Institute of Baden-Württemberg (FVA), Germany	30.000 EUR

Other funding:

Forest Trust Fund, Norway	121.250 EUR
Viken Skog, Norway	10.000 EUR
Arbonaut, Finland	6.000 EUR

Stora-Enso, Finland	18.000 EUR
Kempestiftelserna, Sweden	23.100 EUR
TreeMetrics, Ireland	40.000 EUR

PROJECT TEAM (main participants)

Erik Næsset, PhD, Professor	M	Norwegian University of Life Sciences	RCN, UMB, SNS
Johannes Breidenbach, Dr. rer. nat., Post Doc	M	Norwegian University of Life Sciences	RCN, UMB, SNS, BMBF
Terje Gobakken, PhD, Associate Professor	M	Norwegian University of Life Sciences	RCN, UMB, SNS
Vegard Lien, M.Sc., PhD Student	M	Norwegian University of Life Sciences	RCN, UMB, SNS
Matti Maltamo, PhD, Professor	M	University of Eastern Finland	UEF
Petteri Packalén, PhD, Senior Assistant	M	University of Eastern Finland	UEF
Timo Tokola, PhD, Professor	M	University of Eastern Finland	UEF
Timo Pukkala, PhD, Professor	M	University of Eastern Finland	UEF
Lauri Mehtätalo, PhD, Senior Assistant	M	University of Eastern Finland	UEF
Jari Vauhkonen, PhD, Post Doc	M	University of Eastern Finland	TEKES, MMM, SNS
Anne Seppänen, PhD, PhD Student	F	University of Eastern Finland	TEKES, MMM, SNS

Tero Heinonen, PhD, Researcher	M	University of Eastern Finland	TEKES, MMM, SNS
Håkan Olsson, PhD, Professor	M	Swedish University of Agricultural Sciences	SLU
Johan Holmgren, PhD, Assistant Professor	M	Swedish University of Agricultural Sciences	SLU
Eva Lindberg, M.Sc., PhD Student	F	Swedish University of Agricultural Sciences	Formas, SLU, SNS
Kenneth Olofsson, PhD, Researcher	M	Swedish University of Agricultural Sciences	Formas, SLU, SNS
Andreas Barth, PhD, Researcher	M	Forestry Research Institute of Sweden	Formas, Skogforsk
Garret Mullooly, Operations Director	M	TreeMetrics	TreeMetrics
Ljusk-Ola Eriksson, PhD, Professor	M	Swedish University of Agricultural Sciences	SLU
Malin Nilsson, M.Sc., PhD Student	M	Swedish University of Agricultural Sciences	Sveaskog
Barbara Koch, PhD, Professor	F	Albert-Ludwigs University of Freiburg	ALU
Holger Weinacker, PhD,	M	Albert-Ludwigs University	BMBF

Reseacher		of Freiburg	
Yunsheng Wang, M.Sc., PhD Student	F	Albert-Ludwigs University of Freiburg	BMBF
Sandeep Gupta, M.Sc., PhD Student	M	Albert-Ludwigs University of Freiburg	BMBF
Gero Becker, PhD, Professor	M	Albert-Ludwigs University of Freiburg	ALU
Thomas Smaltschinski, PhD, Researcher (PD)	M	Albert-Ludwigs University of Freiburg	BMBF
Bernd Becker, M.Sc., PhD Student	M	Albert-Ludwigs University of Freiburg	BMBF
Gerald Kändler, PhD, Head of Department	M	Forest Research Institute of Baden-Württemberg	FVA
Sonia Ortiz, M.Sc., Researcher	F	Forest Research Institute of Baden-Württemberg	BMBF

DEGREES
Degrees earned or to be earned within this project.

2011	PhD	M	Vegard Lien, 1981, M.Sc. 2007	UMB	Terje Gobakken, Erik Næsset, UMB
2010	PhD	M	Jari Vauhkonen, 1983 M.Sc. 2007	UEF	Timo Tokola, Matti Maltamo, UEF

2010	M.Sc.	F	Anni Virolainen, 1985 B.Sc. 2010	UEF	Lauri Mehtätalo, UEF
2012	PhD	F	Anne Seppänen, 1978, M.Sc. 2003	UEF	Timo Tokola, UEF
2012	PhD	F	Eva Lindberg, 1974, M.Sc. 2000	SLU	Håkan Olsson, SLU
2013	PhD	F	Malin Nilsson, 1968, M.Sc. 2003	SLU	Ljusk-Ola Eriksson, SLU
2008	PhD	F	Yunsheng Wang, 1980, M.Sc. 2002	ALU	Barbara Koch, ALU
2010	PhD	M	Sandeep Gupta, 1971, M.Sc. 1999	ALU	Barbara Koch, ALU

Figure 1: Part of the project team at the final project board meeting and seminar in Freiburg, Germany.

ABSTRACT

A summary of the project.

An optimized forest management can result in cost benefits and increased values for forest owners and the wood processing industries. In order to optimize management decisions in forest enterprises, information on the forest resources with high spatial and temporal resolution is essential. Further, new types of information, such as attributes characterizing the quality of the timber resources for different types of utilization in the wood processing industries rather than quantities only may also enhance management and thus increase revenues. While conventional forest inventories generally provide some of this information, they are highly restricted regarding spatial and temporal resolution. The WW-IRIS project aimed at resolving many of these restrictions by improving forest inventories with airborne laser scanner (ALS) data complemented with data from high-resolution airborne digital cameras.

The basic problem that was addressed in the project is apparent in basically all countries with a well-regulated forestry sector. The work of our international project team of 16 partners from five different European countries resulted in 14 articles in international scientific journals (several more are under preparation or still in review) and more than 20 publications in other kinds of media. Team members also contributed to numerous dissemination activities at national and international conferences and workshops for scientists as well as end users. The education of eight PhD students was completely or in considerable extend funded within the project. The participating industry partners were able to launch new services and improve their internal procedures. The project resulted in new achievements with respect to single tree segmentation algorithms, their use in forest inventories and the prediction of tree species and other timber quality-related parameters.

1.1 Introduction

1.1.1 Background

Describe the background of the project and the basic problem that it sought to address.

Sustainable forest management and wood industries profit from forest resource information with high spatial and temporal resolution. This information is especially important to make correct planning decisions under changing market conditions. Conventional sample plot forest inventories commonly provide this information but are highly restricted regarding spatial and temporal resolution. Other forest inventory methods may provide complete wall-to-wall information which may cover the need for a fine geographical resolution, yet they miss the details when it comes to completeness of the attributes describing the qualities of the resources. The WW-IRIS project aimed at resolving these restrictions by improving forest inventories with airborne laser scanner data.

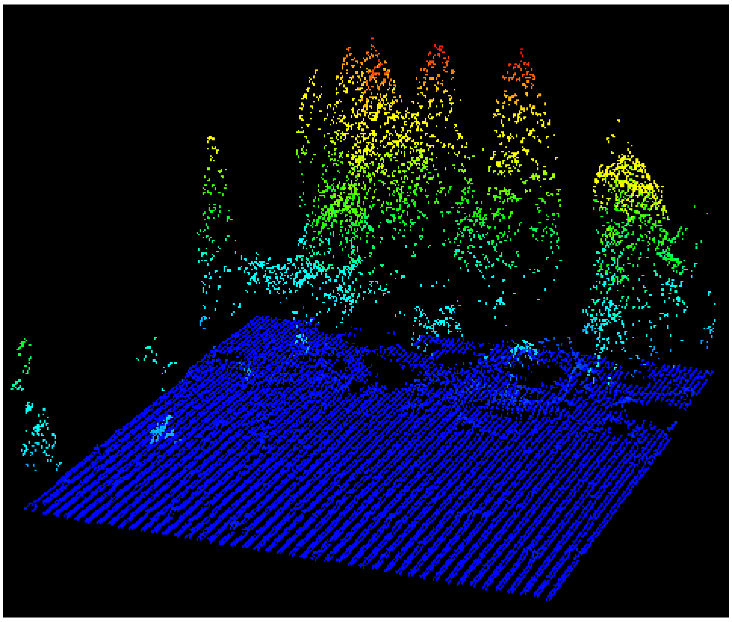

Figure 2: Single trees are clearly visible in airborne laser scanning data.

The emerging and rapidly evolving sensor and information technologies, primarily airborne laser scanning (ALS, Figure 2) and terrestrial laser scanning (TLS, Figure 3), allow for the development of new forestry-relevant applications. They can provide timely and accurate information about wood properties that can be used to better allocate the forest's raw material to the timber industries. A better utilization of the wood resources will add values along the entire forest/wood-products chain and benefit the forest owners as well as the forest and timber industries.

Figure 3: Intensity image derived from terrestrial laser scanning data.

The basic problem that was addressed in the project is apparent in basically all countries with a well-regulated forestry sector. The international project team of 16 partners from 5 different

European countries, working on datasets from Norway, Sweden, Finland, Germany and Brazil, allowed approaching the problem in a great variety of possible application areas.

The research in each country was conducted in forest environments that were considered important to national wood-based industries like conifer forest typical for the Nordic countries, deciduous and other forests typical for Central Europe, and plantation forest in South America. The latter is of significant importance to forest industries in Europe by serving as a major resource base.

1.1.2 Objectives

Describe the project objectives.

The major research objectives of the WW-IRIS project, which were developed on the basis of the identified needs of the forest industries, were:

1) Development and optimization of laser scanner methods for assessment of wood qualities and quantities at high spatial resolution and validation of these methods across countries.
2) Further improvement of the information flow regarding wood resources along the forest/wood-products chain by adapting forest information and planning systems to utilize improved information from laser scanner aided inventories.

To produce valuable results, the research objectives were transposed into solid tasks in close cooperation with forest stakeholders represented in the advisory board of the project.

1.2 Results and discussion

Main achievements of the project, quality, innovativeness, industrial relevance and contribution to competitiveness, environmental and societal impact.

The 3D structural information of the forest derived from ALS data can be used to detect and measure trees. Several teams within the project worked on the development of algorithms for segmentation of individual trees. These algorithms were evaluated on data sets from different participating countries in a joint work package (Vauhkonen et al. 2010b). Gupta et al. (2010a,b) achieved good detection rates for conifers in a mixed species study area in Germany. The natural merging of broadleaf crowns, both in the upper and especially in the under-story, was found to be the main reason for considerably lower detection rates for deciduous trees.

This means, not all trees in the forest can be detected, even with the most advanced algorithms (Figure 4). Therefore, methods were developed that account for segmentation errors and resulted in model-unbiased estimates. These methods either predict the missing trees (Lindberg et al. 2010a) or impute crown segments comprising none, one or several trees (Breidenbach et al. 2010a). Single tree forest inventories using the latter correction method proved to be unbiased and of higher precision than area-based methods utilizing ALS data in Norway. The simultaneous use of high and low resolution ALS data allowed a reduction of field work when combined with semi-supervised methods (Breidenbach et al. under preparation).

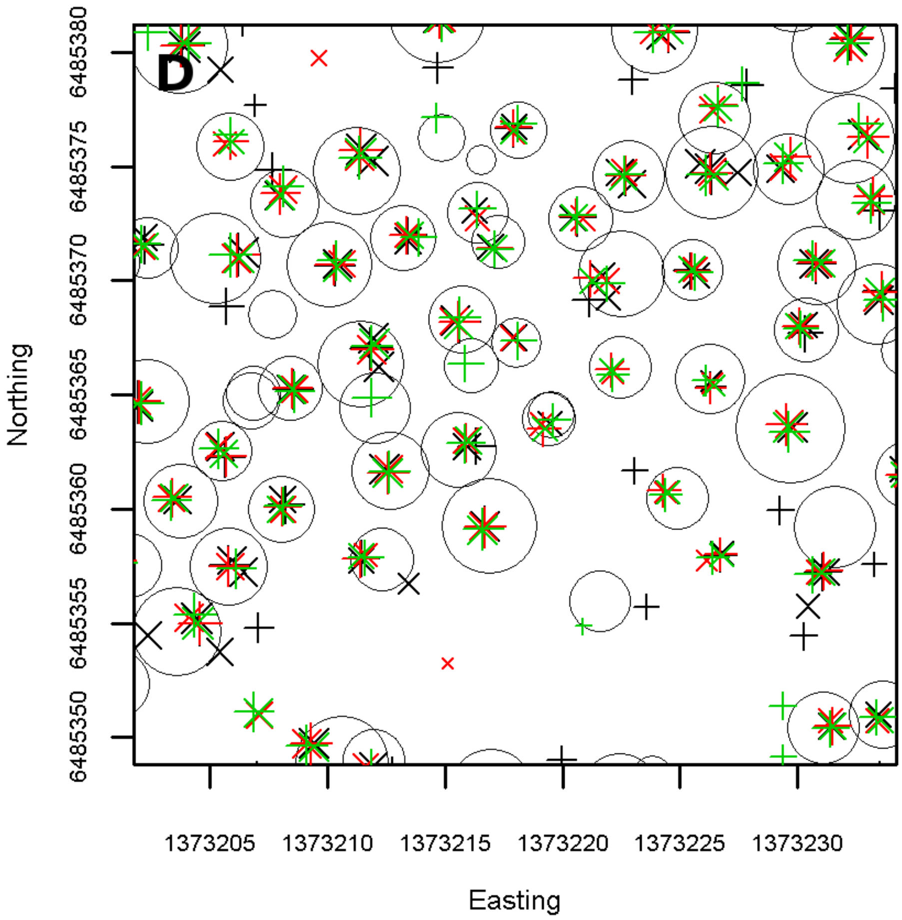

Figure 4: Field measured trees (circles) and tree detection results by different algorithms (crosses).

One of the most important timber-quality related parameters in a forest inventory based on remote sensing data was found to be tree species, since all timber quality norms are tree species-specific. Methods for the classification of tree species as such (Ørka et al. 2009) or the prediction of tree species-specific variables such as canopy base height (Breidenbach et al. 2010e, Vauhkonen 2010a, Breidenbach et al. submitted) and timber volume (Breidenbach et al. 2010b) were therefore developed in several work packages. Smaltschinski et al. (2010) developed a method to grade coniferous stems into quality levels based on ALS-derived crown diameter and length.

The possibilities to efficiently obtain wood quality related variables using existing manual field methods are limited. Therefore, methods for the estimation of stem attributes using terrestrial laser scanning (TLS) by measuring the diameter for all visible stem parts have been developed. A complete method for combining TLS measurements of tree stems and crown segments from ALS data for estimations of stem diameters was compared with conventional methods (Lindgren et al. 2008; Lindgren et al. 2010b). This included the automatic linking of ALS and TLS data at an individual tree level (Olofsson et al. 2008). The stem measurements obtained from TLS were also compared with measurements from harvesters. Harvester data were imputed to areas without reference data using ALS-derived crown segments. The prediction results of stem volume, mean tree height, and stem diameter distributions were validated at sub-stand level (Holmgren et al. 2010).

A new ALS based forest inventory and planning concept was developed for industrial eucalyptus plantations in Brazil. The use of dynamic treatment units in forest planning increased the total volume production, i.e., the sum of harvested and remaining timber volume. Spatially optimized cutting areas often deviated from compartment boundaries (Packalén et al. submitted). Stand attributes and site index were modelled by Zonate et al. (2010) and Packalén et al. (submitted). The accuracies were considerably better than what is typically attainable in boreal forests. In industrial plantations it was also possible to utilize clone information in the statistical models. With respect to stem volume, clone information improved the accuracy over 30%. Additionally, a theoretical-model for ALS based forest inventories was developed and validated on data from Brazilian eucalyptus plantations (Mehtätalo et al. submitted).

Forest information systems were therefore developed and improved to enhance the information flow within the forest enterprises. To go one step further and provide this information to the end users, e.g., the wood processing industry, a software prototype was developed that includes a logistics interface on the base of Google Maps^{TM} (Figure 5). In the interface the users can select the forests that best meet industry demands by assigning specific log demands to each forest. It provides a tactical harvest planning system that allows the user to extract the maximum forest value given the constraints of demands and logistics. The web based platform also allows an efficient means to transfer information throughout an organisation. It improves the collaboration between colleagues through the easier sharing and viewing of information in real time.

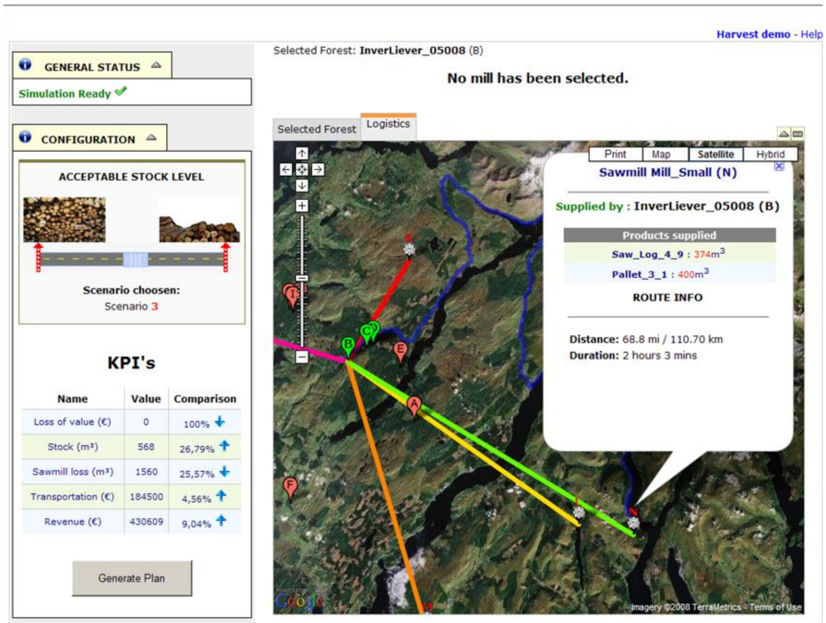

Figure 5: The logistics interface of a forest information system developed within the project.

A XML-based forest plantation simulator was developed to model the wood flow (Seppänen et al. under preparation). The simulator was also used as a benchmarking system for actual harvests in Brazilian eucalyptus plantations. The digital road network, digital elevation models, and tree data need to be utilized in planning of harvesting operations. A co-operation with the University of Lavras (Brazil) was established to fulfill this task. Field data were collected from forest roads and methods for predicting the road quality using ALS data were developed.

1.3 Conclusions

The most important contributions to the state-of-the-art, derived from the results and discussion.

The developed tree crown segmentation algorithms revealed their up and downsides in the different study areas. Especially the heterogeneous mixed forests in Germany resulted in considerable segmentation errors. The developed segmentation error correction methods proved to be helpful under comparatively homogenous forest conditions, but are assumed to be even more important under heterogeneous conditions. The very dense eucalyptus plantation forests in Brazil demonstrated the limits for current segmentation algorithms. The segmentation algorithms were for this specific task reconfigured, so they detect tree rows instead of single trees. Together with correction methods for segmentation errors developed in this project, single tree forest inventories resulted in unbiased predictions and are thus finally ready for operational use.

The calibration of ALS intensity and the fusion of ALS with multispectral image data were found essential for predicting tree species-specific forest attributes and thus also very important for the derivation of timber quality-related parameters.

TLS data as training sets for ALS based inventory procedures resulted in predictions with accuracies similar to traditional field methods. In addition, however, more detailed information especially with respect to timber quality related parameters were obtained with TLS data compared with traditional field methods. Stem measurements were also automatically obtained from harvester machines. The prediction of wood products measured by harvesters with explanatory variables extracted from ALS derived tree crowns underlined the large information potential in combining such data sets.

1.4a Capabilities generated by the project

Knowledge generated in the project / outcomes of the project, such as unpublished doctoral theses, patents and patent applications, computer programs, prototypes, new processes and practices; established new businesses; potential to create new business opportunities in the sector.

Eight PhD students were completely or in considerable parts funded by the WW-IRIS project (see section DEGREES).

More information about the software shown in Figure 5 can be obtained from www.treemetrics.com.

A software system for optimizing stand delineations was developed. It is constructed to receive data from different data sources, for instance from the recently developed forest management planning system (www.slu.se/heureka). The software was tested on data from industrial eucalyptus plantations in Brazil to form dynamic treatment units.

1.4b Utilisation of results

Give a brief description of how the results of the research and development have been used and/or what is the exploitation plan or plans for transferring the results into practice.

While most of methods developed at the academic institutions were published and consequently made available for any market actor through the public domain, the participating companies had obviously a time and knowledge advance over others. Especially, forest planning service providers are expected to profit from the developed methods. Specific meetings and seminars were held between some of the scientific partners and industry partners where opportunities and relevance for improvement of current products (forest resource information, forest planning products) and data production facilities and tools were pointed at on the basis of findings made in the project.

1.5 Publications and communication

a) Scientific publications

For publications indicate a complete literature reference with all authors and for articles a complete name. Indicate the current stage of the publishing process when mentioning texts accepted for publication or in print. Abstracts are not reported. Indicate the five most important publications with an asterisk.

1. Articles in international scientific journals with peer review

**Breidenbach, J, Næsset, E, Lien, V, Gobakken, T, Solberg, S (2010a). Prediction of species specific forest inventory attributes using a nonparametric semi-individual tree crown approach based on fused airborne laser scanning and multispectral data. Remote Sensing of Environment, 114(4), 911-924, doi: 10.1016/j.rse.2009.12.004.*

**Breidenbach, J, Nothdurft, A, Kändler, G (2010b). Comparison of nearest neighbour approaches for small area estimation of tree species-specific forest inventory attributes in central Europe using airborne laser scanner data. European Journal of Forest Research, 129(5), 833-846, doi: 10.1007/s10342-010-0384-1.*

Breidenbach, J, Ortiz, S, Reich, M (2010c). Forest monitoring with TerraSAR-X: first results. European Journal of Forest Research, 129(5), 813-823, doi: 10.1007/s10342-009-0318-y.

Breidenbach, J, Næsset, E, Gobakken, T, Solberg, S, Lien, V (submitted). Using airborne laser scanning, multispectral data and segmented tree crowns for an inventory of variables related to timber quality. Remote Sensing of Environment.

Breidenbach, J, Næsset, E, Gobakken, T, Lien, V (under preparation). Synergetic use of high and low density ALS data in forest inventories - a model-based approach.

Hawbaker, T, Gobakken, T, Lesak, A, Tromborg, E, Contrucci, K, Radeloff, V (2010). Light Detection and Ranging-Based Measures of Mixed Hardwood Forest Structure. Forest Science, 56(3), 313-326.

Korpela, I, Ørka, H, Maltamo, M, Tokola, T, Hyyppä, J (2010). Tree species classification using airborne lidar–effects of stand and tree parameters, downsizing of training set, intensity normalization, and sensor type. Silva Fennica, 44(2), 319-339.

**Lindberg, E, Holmgren, J, Olofsson, K, Wallerman, J, and Olsson, H (2010). Estimation of tree lists from airborne laser scanning by combining single-tree and area-based methods. International Journal of Remote Sensing, 31, 1175 - 1192.*

**Magnussen, S, Næsset, E, Gobakken, T (2010). Reliability of LiDAR derived predictors of forest inventory attributes: A case study with Norway spruce. Remote Sensing of Environment, 114(4), 700-712.*

Mehtätalo, L, Nyblom, J (submitted). A model-based approach for ALS inventory: application for square grid spatial pattern. Forest Science.

Packalén, P, Heinonen, T, Vauhkonen, J, Pukkala, T, Maltamo, M (submitted). Dynamic Treatment Units in Eucalyptus Plantation. Forest Science.

Packalén, P, Mehtätalo, L, Maltamo, M (submitted). ALS based estimation of plot volume and site index in a Eucalyptus plantation with a nonlinear mixed effect model that accounts for the clone effect. Annals of Forest Science.

Salas, C, Ene, L, Gregoire, T, Næsset, E, Gobakken, T (2010). Modelling tree diameter from airborne laser scanning derived variables: a comparison of spatial statistical models. Remote Sensing of Environment, 114(6), 1277-1285.

Seppänen, A, Eerikäinen, K, Tokola, T (under preparation). Using synthetic data and Monte Carlo simulation in the evaluation of forest growth and yield simulators designed for Pinus kesya plantations in southeastern Africa.

Vauhkonen, J, Tokola, T, Maltamo, M, Packalén, P (2008). Effects of pulse density on predicting characteristics of individual trees of Scandinavian commercial species using alpha shape metrics based on airborne laser scanning data. Canadian Journal of Remote Sensing, 34, 441-459.

Vauhkonen, J, Tokola, T, Packalén, P, Maltamo, M (2009). Identification of Scandinavian commercial species of individual trees from airborne laser scanning data using alpha shape metrics. Forest Science, 55(1), 37-47.

Vauhkonen, J, Korpela, I, Maltamo, M, Tokola, T (2010a). Imputation of single-tree attributes using airborne laser scanning-based height, intensity, and alpha shape metrics. Remote Sensing of Environment, 114(6), 1263-1276, doi: 10.1016/j.rse.2010.01.016

Vauhkonen, J (2010a). Estimating crown base height for Scots pine by means of the 3-D geometry of airborne laser scanning data. International Journal of Remote Sensing, 31(5), 1213-1226, doi: 10.1080/01431160903380615

Zonete, MF, Rodriguez, LCE, Packalén, P (2010). Estimação de parâmetros biométricos de plantios clonais de eucalipto no sul da Bahia: uma aplicação da tecnologia laser aerotransportada. Scientia Forestalis, 86, 225-235.

**Ørka, HO, Næsset, E, Bollandsås, OM (2009). Classifying species of individual trees by intensity and structure features derived from airborne laser scanner data. Remote Sensing of Environment, 113(6), 1163-1174.*

2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

Lindberg, E, Holmgren, J, Olofsson, K, Olsson, H, Wallerman, J (2008). Estimation of tree lists from airborne laser scanning data using a combination of analysis on single tree and raster cell level. Proceedings of the SilviLaser conference 2008, Edinburgh, Great Brittan, Sept. 17-19, 2008.

Maltamo, M, Bollandsås, OM, Næsset, E, Gobakken, T, Packalén, P (2009). Different sampling strategies for field training plots in ALS inventory. Proceedings of the SilviLaser conference 2009, College Station, USA, Oct. 14-16, 2009.

Olofsson, K, Lindberg, E, Holmgren, J (2008). A method for linking field-surveyed and aerial-detected single trees using cross correlation of position images and the optimization of weighted tree list graphs. Proceedings of the SilviLaser conference 2008, Edinburgh, Great Brittan, Sept. 17-19, 2008.

Ortiz, S, Breidenbach, J, Bäuerle, H, Nothdurft, A (2009). Classifying Forest Types by Fusing Airborne LiDAR and Spaceborne SAR Data. Proceedings of the SilviLaser conference 2009, College Station, USA, Oct. 14-16, 2009..

Ørka, HO, Næsset, E, Bollandsas, OM (2009). Comparing classification strategies for tree species recognition using airborne laser scanner data. Proceedings of the SilviLaser conference 2009. College Station, Texas A&M University.

3. Articles in national scientific journals with peer review

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4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

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5. Scientific monographs

Gupta, S (2010). Single Tree Detection and Modeling Using Airborne Laser Scanner Data. PhD thesis (Dr rer. nat.), Albert-Ludwigs-University of Freiburg, 172 p.

Vauhkonen, J (2010b). Estimating single-tree attributes by airborne laser scanning: methods based on computational geometry of the 3-D point data. Itä-Suomen yliopisto, Metsätieteiden osasto. PhD thesis. Dissertationes Forestales 104, 44 p.

Wang, Y (2008). Fully Automatic Reconstruction of Virtual Environment Based on LIDAR Data, PhD thesis (Dr rer. nat.), Albert-Ludwigs-University of Freiburg, 111 p.

6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

Breidenbach, J, Kublin, E (2009). Estimating Timber Volume using Airborne Laser Scanning Data based on Bayesian Methods. Proceedings of the IUFRO Division 4 conference Extending Forest Inventories over Space and Time. Quebec City, Canada, May 19-22, 2009.

Breidenbach, J, Næsset, E, Gobakken, T (2010d). Model-based variance estimation for aggregated predictions of forest attributes to stand level based on airborne laser scanning data. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Breidenbach, J, Næsset, E, Lien, V, Gobakken, T, Solberg, S (2010e). Towards an inventory of quality attributes of individual trees using airborne laser scanning and multispectral data. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Gupta, S, Koch, B, Weinacker, H (2010a). Tree species detection using full waveform lidar data in a complex forest. In Wagner, W, Székely, B (eds.): ISPRS Technical Commission VII Symposium – 100 Years of ISPRS, Vienna, Austria, July 5-7, 2010, IAPRS, Vol. XXXVIII, Part B, pp. 249-254.

Gupta, S, Weinacker, H, Koch, B (2010b). Single tree detection using full waveform laser scanner data. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Holmgren, J, Barth, A, Larsson, H, Olsson, H (2010). Prediction of stem attributes by combining airborne laser scanning and measurements from harvesting machinery. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Lien, V, Breidenbach, J, Næsset, E, Gobakken, T (2010). Assessing laser pulse penetration in spruce canopies - combining field measured branch properties with discrete return airborne laser scanning data. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Lindberg, E, Holmgren, J, Olofsson, K, Olsson, H (2010b). Estimation of stem attributes using a combination of terrestrial and airborne laser scanning. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Mehtätalo, L, Virolainen, A, Tuomela, J, Nyblom, J (2010). A model-based approach for estimating the height distribution of eucalyptus plantations using low-density ALS data. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Nilsson, M, Wästerlund, D, Eriksson, LO (under preparation). Strategic and tactical forest planning as an implementation of knowledge management.

Nilsson, M, Eriksson, LO (under preparation). The need of forest information in tactical forest planning for market planning.

Packalén, P, Mehtätalo, L, Maltamo, M (2010c). ALS based estimation of plot volume and site index in a Eucalyptus plantation with a nonlinear mixed effect model that accounts for the clone effect. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

Salas, C, Ene, L, Gregoire, T, Næsset, E, Gobakken, T (2010). Modelling tree diameter from airborne laser scanning derived variables: a comparison of spatial statistical models. Proceedings of the IUFRO Division 4 conference Extending Forest Inventories over Space and Time. Quebec City, Canada, May 19-22, 2009.

Smaltschinski, T, Opferkuch, M, Becker, G, Weinacker, H (2010). Assessment of grades and quality of wood in forest stands via laser scanning. FORMEC 2010, Forest Engineering: Meeting the Needs of the Society and the Environment, July 11-14,2010, Padova, Italy.

Vauhkonen, J, Ene, L, Gupta, S, Heinzel, J, Holmgren, J, Pitkänen, J, Solberg, S, Wang, Y, Weinacker, H, Hauglin, KM, Lien, V, Packalén, P, Gobakken, T, Koch, B, Næsset, E, Tokola, T, Maltamo, M (2010b). Comparative testing of single-tree detection algorithms. Proceedings of the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010.

b) Other dissemination

Such as text books, manuals, user guidelines, newspaper articles, TV and radio programmes, meetings and contacts for users and results.
Dissemination of results to industrial partners and industrial partners dissemination within the company.

Barth, A. Datafångst för operativ planering (Data acquisition strategies for operational planning). Presentation, 12 November 2009, Sundsvall, Sweden, meeting with industry, size of audience 35.

Barth, A. Datafångst för operativ planering (Data acquisition strategies for operational planning). Presentation, 17 November 2009, Örebro, Sweden, meeting with industry, size of audience 40.

Barth, A. Datafångst för operativ planering (Data acquisition strategies for operational planning). Presentation, 19 November 2009, Växjö, Sweden, meeting with industry, size of audience 60.

Barth, A. Strålande metoder ger bättre data (Data acquisition strategies for Swedish forestry). Presentation, 10 February 2010, Umeå, Sweden, meeting with industry, size of audience 240.

Barth, A. Strålande metoder ger bättre data (Data acquisition strategies for Swedish forestry). Presentation, 17 February 2010, Sundsvall, Sweden, meeting with industry, size of audience 200.

Barth, A. Strålande metoder ger bättre data (Data acquisition strategies for Swedish forestry). Presentation, 24 February 2010, Jönköping, Sweden, meeting with industry, size of audience 187.

Barth, A. Strålande metoder ger bättre data (Data acquisition strategies for Swedish forestry). Presentation, 3 March 2010, Västerås, Sweden, meeting with industry, size of audience 303.

Breidenbach, J (Editor) (2010). Development of an Integrated Resource Information System – WW-IRIS. Project brochure distributed at the SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010. Number of copies: 200. Online: http://www.umb.no/statisk/lidar/WW-IRIS%20flyer.pdf.

Næsset, E, Breidenbach, J, Gobakken, T, Holmgren, J, Koch, B, Maltamo, M (2010). Development of an Integrated Resource Information System – WW-IRIS; Overview of the main results. Keynote presentation, SilviLaser conference 2010, Freiburg, Germany, Sept. 14-17, 2010, size of audience 130.

Gobakken, T, Næsset, E (Organizers) (2008). WW-IRIS project board meeting and seminar. Presentation of latest results for the project partners. Edinburgh, Great Britain, Sept. 16, 2008.

Gobakken, T, Breidenbach, J, Næsset, E, Barth, A (Organizers) (2009). WW-IRIS project board meeting and seminar. Presentation of latest results for the project partners. Uppsala, Sweden, Sept. 15, 2009.

Breidenbach, J, Gobakken, T, Næsset, E, Ortiz, S (Organizers) (2010). WW-IRIS project board meeting and seminar. Presentation of latest results for the project partners. Freiburg, Germany, Sept. 13, 2010.

1.6 National and international cooperation

Give a brief description of the cooperation/ networking (partnership between the project participants and how this has developed; industrial involvement; synergies of industrial and research expertise; Has the project collaborated with similar projects in the WW-Net countries or other regions, or established new links with/ between local or international organisations involved in the respective research field? Describe how these partnerships have supported the project.
National vs. transnational aspects in the project; added value for the project and its impacts which result from transnational cooperation.

The international structure of the project allowed comparing developed algorithms on a data set that was unique with respect to its variability. Yearly one-day seminars were found very useful for disseminating new findings within the team of project partners. Many fruitful discussions during these meetings and afterwards have led to valuable ideas on how to solve the problems that motivated the project. Several researchers also took the opportunity for short visits at another research partners' institution for solving specific tasks in common work packages.

The daily coordination of the consortium was handled by the coordinator with support of what we call an informal 'core team' of partners. Members of the core team acted as local nodes in each of their countries. These nodes were the universities of the consortium. This organization has functioned excellent and eased the burden of the coordinator because the nodes knew their local national partners within the consortium better than the coordinator. The nodes helped preparing documents, progress reports, and the program for the project board meetings etc.

The academic partners coordinated the cooperation with national industry partners as most of the work packages were national packages. We believe this was a good structure for the project. However, it has still been a challenge at times to get involvement from some of the industry partners.

Some similarities with the WoodWisdom funded project WoodValue were discussed at the 2nd WoodWisdom seminar in Stockholm. A formalized cooperation between the projects was, however, not found to result in large synergies.