International scientific conference

KNOWLEDGE BASED FOREST SECTOR

November 4–6, 2015, Riga, Latvia

BOOK OF ABSTRACTS

EFI ASSOCIATED EVENT

Book of Abstracts of international scientific conference of the forest sector
KNOWLEDGE BASED FOREST SECTOR

Scientific editor: Zane Libiete, Latvian State Forest Research Institute *Silava*

SCIENTIFIC COMMITTEE

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Janis Krumins, Latvia University of Agriculture, Latvia

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Dagnis Dubrovskis, Latvia University of Agriculture, Latvia
Ugis Cabulis, Latvian State Institute of Wood Chemistry, Latvia
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PREFACE

Conference attracted participants from 7 countries (Latvia, Lithuania, Estonia, Sweden, Finland, Spain, Czech Republic), representing scientific community, including Latvian Academy of Agricultural and Forestry Sciences and Latvian Academy of Sciences as well as policy makers from ministries linked to forestry sector – Ministry of Agriculture, Ministry of Education and Science, Ministry of Environmental Protection and Regional Development, Ministry of Economics – and companies partnering with scientific institutions in the development of innovative solutions and technologies. This EFI Associated event was jointly organized by Latvian State Forest Research Institute «Silava», Latvian State Institute of Wood Chemistry, Forest and Wood Products Research and Development Institute and Latvia University of Agriculture, Forest Sector Competence Centre and JSC «Latvia's State Forests». The main goal of the conference was to share and discuss in a broader context the experiences and results achieved in the research program «Methods and technologies for increasing forest capital value», implemented from 2011 to 2015.

In the first day, the main topics were mainly related to science-policy interaction, discussing strengths and weaknesses of different types of scientific studies – from large joint research programs at sectorial level to small bi-lateral (scientific institution-enterprise) initiatives – from the perspective of different stakeholders and comparing experiences in Latvia, Finland and Sweden in this respect. Stakeholders reflected on major applicable achievements of forest sector research during last five years.

The second day of the conference was dedicated to on-site experience: presentations were covering the growth cycle of trees starting from the selection of seed source. Results of coniferous and broadleaved tree breeding were presented, demonstrating significant gain from use of selected material not only in productivity, but also in quality (including natural pruning). Applicability of spot-mounding and mechanized planting in Latvia's forests was discussed based on time studies, concluding that these methods can be justifiable only in sites where they can significantly improve the survival of planted trees. Results of afforestation and application of agroforestry systems using *Salicea* species and hybrids were shown, providing sufficient information on the length of rotation period, potential yield and uses of the raw material both for pellet production and solid-wood. Broad range of subjects related to carbon sequestration were presented – from impact of forest fires to development of biomass and decay (of dead-wood) equations and concluding that improvement in the stand productivity is reflected in both higher rate of carbon sequestration and higher share of carbon stored in materials with a long life cycle. Importance of improved soil aeration to enhance the growth of trees was demonstrated: on peat soils the mean annual increment of Norway spruce can

be event tripled using this measure. Ecological consequences of amelioration and possibilities to minimize leaching of nutrients to water ecosystems were discussed and solutions demonstrated. Ecological aspects of forest management were covered not only at stand scale (e.g. a minimal effect of large-scale clear-cuts over a long time period), but also at landscape scale, showing the long-term recovery of forest cover after large storms and reflecting on the potential impact of increased storm frequency, linked to climatic changes. Climatic changes and necessity to adapt the forest management were discussed mostly in a strategic planning level, noting that regional differences in risks (and opportunities – e.g. planting of tree species with current distribution areal slightly south of particular site) need to be considered. One of the greatest threats to forest vitality – pathogens – were extensively discussed, covering both particular aspects of widely studied fungi as well as newest findings on relative recent epidemics, like ash dieback and reflecting on solution to minimize the problems at stand and landscape (mixture of stands) scale. Extensive discussion on the use of wood from fibres to large-scale solid wood constructions for different purposes took place.

The third day of the conference was spent visiting experimental sites to elaborate on the topics initiated in the indoor sessions. Two conference field trips were organized: mainly dedicated to wood processing and forestry. In the first field trip, innovative solution scaled up to industrial application was demonstrated: factory of outsized wooden constructions and results of its work – long pedestrian crossing in nature recreation site in Tervete Nature Park. Also infrastructure for scientific experiments for the development of solutions of constructions of innovative wooden buildings was demonstrated, including project of low-energy consumption façade. Forestry field trip was organized to Forest Research Station in Kalsnava forest district. Mechanization of forestry operations in specific conditions often observed in the region – relatively large, dense young stands with delayed pre-commercial thinning – was demonstrated and discussed in the context of long-term results on further development of such stands, as well as bioenergy use. Both long term results and new technical solution of forest fertilization – its impact on tree growth and forest ecosystem as a whole – was shown. Biotic (pathogens) and abiotic (waterlogging) risks reducing tree growth were discussed and possible solutions, including removal of infected trees and their residues form the stands, use of biotic control agents, as well as amelioration, were presented. Large-scale use of forest tree breeding and its practical achievements in terms of improved forest growth and stem quality, as well as sustained sufficient genetic diversity to ensure stability of stands were demonstrated.

Dr. silv. Aris Jansons
Head of Scientific Committee
Latvian State Forest Research Institute «Silava»

PROGRAMME

November 4, 2015

8:30   Registration

9:00   *Opening of the conference*
            Janis Duklavs, Minister of Agriculture of the Republic of Latvia
            Baiba Rivza, President of Latvian Academy of Agricultural and Forestry Sciences

1st session
Chair: Valdis Egle, *Forest Sector Competence Centre* Ltd.

9:00   *Forest Sector Competence Centre*
            Valdis Egle, member of the Board of *Forest Sector Competence Centre* Ltd

9:20   *Programme of the Forest Industry Competence Centre according to the
            Ministry of Economics of the Republic of Latvia*
            Gatis Silovs, Ministry of Economics of the Republic of Latvia, Department of EU
            Funds Implementation

9:40   *Future funding for the science in Latvia and share of the research for Latvia
            state development in it*
            Agrita Kiopa, Deputy State Secretary Director for Higher Education and Research
            Ministry of Education and Science of Latvia

10:00   *Partnership of scientific institution of forestry sector in the responsibilities of
            of the Ministry of Environmental Protection and Regional Development of the
            Republic of Latvia*
            Daiga Vilkaste, Director of Department of Nature Protection of the Ministry
            of Environmental Protection and Regional Development of the Republic of
            Latvia, and Ilze Pruse, Director of Climate Change Department of the Ministry of
            Environmental Protection and Regional Development of the Republic of Latvia

10:20   *Role of the forest scientists in the implementation of priorities of the forest-
            based sector*
            Arvids Ozols, Director of Forest Department of the Ministry of Agriculture of the
            Republic of Latvia

11:00   *Forests 2050 – an insider's view on forest research programme in Finland*
            Pertti Pulkkinen, Senior Researcher of the Natural Resources Institute Finland
            (LUKE)

11:30   *Wood Centre North. How transform research to industrial application?*
            Dick Sandberg, Professor in Wood Science and Engineering, Lulea University of
            Technologies

12:00   *Necessity of applied scientific researches in forestry in future*
            Arnis Muiznieks, Executive Director of the Latvian Forest Owner Association

12:15   *Necessity of applied scientific researches in combined utilization of wood in future*
Representative of the Latvian Forest Industry Federation

12:30   Panel discussion

2nd session
Chair: Ainars Grinvalds, JSC *Latvia's State Forests*

14:00   *Results of forest research from forestry practice*
Ilga Berzkalna, Head of Development of JSC Latvia's State Forests

14:20   *Results of forestry realted scientific research from Latvian timber industry*
Juris Matvejs, Member of the Board of JSC *Latvijas Finieris*

14:40   *Implementation of results of the Forest Industry Competence Centre in practice*
Andrejs Domkins, Director of *Forest and Wood Products Research and Development Institute* Ltd.

15:00   Coffee break

15:20   *Results of work of the Forest Sector Competence Centre: increasing the capital value of the forest*
Jurgis Jansons, Director of Latvian State Forest Research Institute *Silava*

15:40   *Results of the Forest Sector Competence Centre: wood processing, new products and technologies*
Bruno Andersons, Chairman of the Scientific council of Latvian State Institute of Wood Chemistry

16:00   Panel discussion

November 5, 2015
SCIENTIFIC SECTIONS (presentations of topics of Forest Sector Competence Centre and international participants)

Section 1 COMBINED UTILIZATION OF WOOD
Chair: Bruno Andersons, Latvian State Institute of Wood Chemistry

Section 2 FORESTRY

  Part A – TIMBER RESOURCES
  Chair: Andis Lazdins, Latvian State Forest Research Institute *Silava*

  Part B – FOREST ECOLOGY
  Chair: Aris Jansons, Latvian State Forest Research Institute *Silava*

POSTER session

November 6, 2015

FIELD TRIPS

FORESTRY SECTION

Forest Research Station in forest district of Kalsnava – mechanization of forestry operations and bioenergy, biotic risks in forestry, improvement of forest growing conditions, forest management and water quality, forest tree breeding

SECTION OF COMBINED UTILIZATION OF WOOD

IKTK Ltd. – factory of outsized wooden constructions. Management of urban forests. Pilot project of low-energy consumption facade. Research site of solutions of constructions of innovative wooden buildings in Jelgava. Monitoring object of pedestrian crossing of outsized wooden constructions in Tērvete

ORAL PRESENTATIONS OF SCIENTIFIC SESSIONS

Section 1 COMBINED UTILIZATION OF WOOD
Chair: Bruno Andersons, Latvian State Institute of Wood Chemistry

9:00   *Research of wood materials with increased ecological value*
Uldis Spulle, *Forest and Wood Products Research and Development Institute* Ltd.

9:30   *Low energy consumption façade pilot project*
Karlis Bumanis, *Forest and Wood Products Research and Development Institute* Ltd.

10:00   *Study of wood cladding surface finishing systems performance in outdoor conditions*
Edgars Buksans, *Forest and Wood Products Research and Development Institute* Ltd.

10:45   *Research of modern and sustainable wood structures*
Andrejs Domkins, *Forest and Wood Products Research and Development Institute* Ltd.

11:15   *Modular portable composite bridge systems for forest industry applications – review of a research program*
Raitis Lacis, *Inzenierbuve* Ltd.

11:45   *Natural fibres woven structures for composites reinforcing*
Guntis Strazds, Riga Technical University

12:10   *Birch wood fibres as resources for thermal insulation material*
Uldis Grinfelds, Latvian State Institute of Wood Chemistry

13:30   *Improving of water resistance of paper from birch fibres*
Inese Sable, Latvian State Institute of Wood Chemistry

14:00   *Upgrading of plywood regarding its potential end-use*
Dace Cirule, Latvian State Institute of Wood Chemistry

14:30   *The application potentialities of woodworking by products*
Galija Sulga, Latvian State Institute of Wood Chemistry

Section 2 FORESTRY
Part A – TIMBER RESOURCES
Chair: Andis Lazdins, Latvian State Forest Research Institute *Silava*

9:00	*Key note: Challenges and possible solutions for competitive procurement of forest products* Rolf Björheden, Skogforsk, Sweden
9:30	*The alternatives of transport of wood chips in Estonian conditions – a case study* Marek Irdla, Estonian University of Life Sciences
10:00	*Results of evaluation of different methods and technologies of solid biofuel production in ditch cleaning harvesting operations* Agris Zimelis, Latvian State Forest Research Institute *Silava*
10:45	*Productivity and costs of stump extraction in forest stands heavily affected by root rot* Kristaps Makovskis, Latvian State Forest Research Institute *Silava*
11:05	*Results of research program on evaluation of impact of forest management measures on greenhouse gas emissions and CO2 removals* Andis Lazdins, Latvian State Forest Research Institute *Silava*
11:25	*Adjusted stem form equations and equation parameters for eight tree species (pine spruce, birch, aspen, black alder, oak, ash, grey alder)* Dagnis Dubrovskis, Forest Faculty of Latvia University of Agriculture
11:45	*Standwise forest growth models based on re-measured Latvia`s NFI data* Janis Donis, Latvian State Forest Research Institute *Silava*
13:00	*Evaluation of accuracy of piece by piece measurement methods used for pine sawlogs* Leonards Lipins, Forest Faculty of Latvia University of Agriculture
13:20	*Analysis of microorganisms in discoloured Betula pendula wood* Dainis Rungis, Latvian State Forest Research Institute *Silava*
13:40	*Mapping of tree crown coverage using satellite and orto-photo images* Linda Gulbe, Ventspils University College
14:00	*The practice of urban forest management* Liga Liepa, Forest Faculty of Latvia University of Agriculture
14:15	*Methods of vegetative propagation of genetically superior silver birch and Norway spruce – gains for tree breeding and forest plantation* Dace Auzenbaha and Inga Zarina, Latvian State Forest Research Institute *Silava*
14:30	*Fast growing poplars for pellet production* Silva Senhofa, Latvian State Forest Research Institute *Silava*

14:45   *Wood moisture and density content changes in conifer (Pinus sylvestris L., Picea abies (L.) H. Karst.) trunk depending on heartwood proportion*
Janis Magaznieks, Forest Faculty of Latvia University of Agriculture

16:00   *Results of soil analyses and remote sensing methods in determination of CO2 emissions from drained organic soils*
Ainars Lupikis, Latvian State Forest Research Institute *Silava*

16:20   *Above- and belowground biomass functions for four most common tree species in Latvia*
Janis Liepins, Latvian State Forest Research Institute *Silava*

16:40   *Preliminary data on productivity and costs of wood ash spreading in forest*
Modris Okmanis, Latvian State Forest Research Institute *Silava*

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Section 2 FORESTRY
Part B – FOREST ECOLOGY
Chair: Aris Jansons, Latvian State Forest Research Institute *Silava*

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9:00   *Key note: Management of forest genetic resources – an important part of knowledge based forestry*
Tiit Maaten, Estonian University of Life Sciences

9:30   *Key note: Invasive alien pests as the major threat to European woodland ecosystems: ash and elm as the examples*
Rimvydas Vasaitis, Swedish University of Agricultural Sciences

10:00   *Diurnal and seasonal dynamics of sap flow and whole tree macrostructure (crowns with foliage and conducting plus absorprive roots) via field applicable instrumental methods*
Jan Čermák, Institute of Forest Botany, Dendrology and Geobiocenology, Mendel University in Brno

10:45   *Forest tree breeding to rise the value of future forest stands*
Arnis Gailis, Latvian State Forest Research Institute *Silava*

11:05   *The destruction and transformation of Fraxinus excelsior L. forest stands in Latvia*
Ilze Puspure, Latvian State Forest Research Institute *Silava*

11:25   *Studies on root rot causal fungus Heterobasidion annosum in Latvia*
Talis Gaitnieks, Latvian State Forest Research Institute *Silava*

11:45   *Long-term changes in forest stand and ground vegetation in historically formed large-scale cuttings*
Aris Jansons, Latvian State Forest Research Institute *Silava*

12:05   *Dendrological research in Estonia: climatic effect on tree radial growth*
Maris Hordo, Estonian University of Life Sciences

12:25	*Management potential of even-age spruce stands in Latvia – some aspects of state research programme "Forest and earth entrails resources: research and sustainable utilization – new products and technologies"*
	Jurgis Jansons, Latvian State Forest Research Institute *Silava*

12:25   *Management potential of even-age spruce stands in Latvia – some aspects of state research programme "Forest and earth entrails resources: research and sustainable utilization – new products and technologies"*
Jurgis Jansons, Latvian State Forest Research Institute *Silava*

13:50   *Potential impacts of climatic changes on forestry: major aspects in Latvia*
Aris Jansons, Latvian State Forest Research Institute *Silava*

14:15   *Efficiency of water quality protection measures after drainage system renovation in state forests of Latvia*
Zane Libiete, Latvian State Forest Research Institute *Silava*

14:40   *Assessment of carbon sequestration dynamics in old stands*
Baiba Dzerina, Latvian State Forest Research Institute *Silava*

16:00   *Reforestation with planting of silver birch: establishment and planting stock*
Kaspars Liepins, Latvian State Forest Research Institute *Silava*

16:20   *Impact of freezing rain on coniferous forest stands: a case study*
Endijs Baders, Latvian State Forest Research Institute *Silava*

16:40   *Ecological risks of forest management: assessment methods and recommendations – deer browsing*
Janis Ozolins, Latvian State Forest Research Institute *Silava*

POSTER PRESENTATIONS

1. *Woodworking wastewater treatment with aluminium-based composite coagulants and sorption properties of formed coagulates*
    Julija Brovkina, Galija Shulga, Jurijs Ozolins, Brigita Neiberte, Liga Berzina-Cimdina, Valentina Stepanova

2. *Synthesis of lignopolyol and production of polyurethane foams*
    Ugis Cabulis, Aiga Ivdre, Galina Telysheva, Aleksander Arshanitsa, Laima Vevere

3. *THE effect of functionalization of lignocellulosic microparticles on wettability of polymer composite*
    Jevgenijs Jaunslavietis, Galija Shulga, Jurijs Ozolins, Brigita Neiberte, Anrijs Verovkins, Sanita Vitolina, Sandra Livca

4. *The biorefinery based approach to the bark processing*
    Galina Telysheva, Tatiana Dizhbite, Maris Lauberts, Liga Lauberte, Anna Andersone, Laima Vevere, Alexandra Arshanitsa, Sarmite Janceva

5. *Evaluation of oxidative resistance of mayonnaise enriched with alder bark extract*
    Maris Lauberts, Liga Lauberte, Tatiana Dizhbite, Rita Kazernaviciute, Petras Rimantas Venskutonis, Galina Telysheva

6. *Scots pine growing in Latvia as a source of Pinosylvin stilbines*
   Maris Lauberts, Liga Roze, Tatiana Dizhbite, Stefan Willför, Galina Telysheva

7. *Evaluation of grey alder bark tannin as phenol substitute in the synthesis of phenol-formaldehyde resins suitable for plywood*
   Maris Lauberts, Sarmite Janceva, Electra Papadopoulou, Laimonis Kulinsh, Tatiana Dizhbite, Galina Telysheva

8. *Novel alkyd-linseed oil emulsion formulations for wood coatings*
   Errj Sansonetti, Bruno Andersons, Inga Andersone

9. *Life cycle assessment as a tool to evaluate wood products impact on environment*
   Anete Meija-Feldmane, Bruno Andersons, Henn Tuherm

10. *Financial value of Silver birch breeding*
    Arnis Gailis, Janis Donis, Aris Jansons

11. *Assessment of superiority of Scots pine plus trees*
    Una Neimane, Imants Baumanis, Liga Purina, Aris Jansons

12. *Plasticity of Scots pine, silver birch and black alder families and tree breeding*
    Virgilijus Baliuckas, Aušra Juškauskaitė

13. *The effect of tending and commercial thinning on genetic diversity of Scots pine stands*
    Vilma Kerpauskaite, Darius Danusevicius, Darius Kavaliauskas

14. *Propagation of commercially significant tree species (silver birch, Norway spruce and hybrid aspen) by tissue culture*
    Toms Kondratovics, Dace Auzenbaha, Ineta Samsone, Kristiana Sica

15. *Genetic diversity, fingerprinting and population structure of economically significant Salix species*
    Ilze Veinberga, Agnese Gailite, Vilnis Skipars, Anita Gaile, Toms Sarkanabols, Anna Skudra, Maris Laivins, Dagnija Lazdina, Dainis Rungis

16. *Suitability of hybrid poplar Populus balsamifera × P. laurifolia for forest regeneration in Latvia*
    Silva Senhofa, Aris Jansons, Dagnija Lazdina, Martins Zeps

17. *Growth and wood properties hybrid aspen clones in Latvia*
    Martins Zeps, Aris Jansons, Arnis Gailis1, Janis Smilga, Inese Sable, Uldis Grinfelds

18. *Establishing a system for genetic monitoring in wildlife populations*
    Janis Ozolins, Dainis Rungis, Agrita Zunna, Martins Lukins, Agnese Gailite, Samantha Jane Howlett, Urmas Saarma, Jurgis Suba, Alda Stepanova, Aivars Ornicans, Liga Mihailova, Gundega Done, Anita Gaile, Kriss Bitenieks, Janis Baumanis, Digna Pilate, Guna Bagrade

19. *Post-storm regeneration and stand structure of Norway spruce (Picea abies (L.) Karst.) in Oxalidosa forest type*
    Endijs Baders, Kalev Jogiste, Andis Adamovics, Aris Jansons

20. *Dormancy release and winter frost damage in Scots pine seedlings*
Linas Buzinskas, Darius Danusevicius

21. *Low density Norway spruce stands: preliminary assessment*
Juris Katrevics, Andis Bardulis, Agris Pobiarzens, Aris Jansons

22. *Influence of needlecast on growth of young Scots pine stands*
Kaspars Polmanis, Una Neimane, Darta Klavina, Imants Baumanis, Aris Jansons

23. *Influence of forest FIRE on Scots pine (Pinus sylvestris L.) age structure and regeneration pattern*
Mara Zadina, Agris Pobiarzens, Aris Jansons

24. *Impact of wind and freezing rain damages on fragmentation dynamics of forest landscape: case studies in Latvia*
Endijs Baders, Liga Purina, Zane Libiete, Aris Jansons

25. *Monitoring of Fraxinus excelsior L. forest stands in Latvia – a review of recent results*
Maris Laivins, Linda Gerra-Inohosa, Ilze Puspure

26. *The dynamic of shrub layer in Fraxinus excelsior L. forest stands in response to ash dieback in Latvia*
Ilze Puspure, Maris Laivins, Linda Gerra-Inohosa

27. *Bilberry ramet age and size structure*
Linda Robalte, Diana Jansone, Roberts Matisons, Didzis Elferts, Guntis Brumelis, Aris Jansons

28. *Thinnings in young stands*
Aris Jansons, Andis Lazdins, Juris Katrevics, Janis Donis, Raivis Nimants

29. *Edge effect impact on additional stem volume increment after group shelterwood cutting in pine stands in Myrtillosa forest type*
Leonids Zdors, Gundars Snepsts, Janis Donis

30. *Results of hybrid aspen plantation forest fertilizing*
Toms Sarkanabols, Dagnija Lazdina, Martins Zeps, Andis Bardulis

31. *Results of private forest owners survey on forest regeneration afforestation of non-forest lands*
Dagnija Lazdina, Janis Donis, Andis Lazdins, Kristaps Makovskis

32. *Research activities of mechaniziation of the forest regeneration process*
Dagnija Lazdina, Kaspars Liepiņš, Andis Lazdins, Aris Jansons, Janis Liepins

33. *Impact of application of large amount of wood ash on Norway spruce (Picea abies (L.) H.Karst.) and Scots pine (Pinus sylvestris L.) seedlings and soil properties*
Dagnija Lazdina, Andis Lazdins, Talis Gaitnieks, Darta Kļaviņa, Modris Okmanis, Aris Jansons

34. *Wood properties and linked gene expression in Scots pine (Pinus sylvestris L.) during early and late wood formation*

Krista Kanberga-Silina, Dainis Rungis

35. *Seasonal growth dynamics of Norway spruce and black alder*
Oskars Krisans, Aris Jansons

36. *Some aspects of tree growth in Latvia*
Roberts Matisons, Mara Zadina, Aris Jansons

37. *Climate-related risks to forestry*
Aris Jansons, Janis Donis, Ingars Silins, Una Neimane

38. *Influence of climatic changes on productivity of forest stands*
Juris Rieksts-Riekstins, Oskars Krisans, Aris Jansons

39. *Regeneration and climate-growth sensitivity of European beech in Latvia*
Liga Purina, Roberts Matisons, Aris Jansons

40. *Future challenges in greenhouse gas accounting in land use, land use change and forestry sector in Latvia*
Andis Lazdins, Arta Bardule, Ainars Lupikis, Aldis Butlers

41. *Case study of Impact of forest fertilization on carbon stock in spruce stand*
Modris Okmanis, Andis Lazdins, Dagnija Lazdina, Aris Jansons

42. *Fungal communities associated to P. pinaster forests in a Mediterranean*
Pablo Vásquez-Gassibe, Juan Andrés Oria-de-Rueda, Pablo Martín-Pinto

43. *Control of Heterobasidion annosum s.l. using Phlebiopsis gigantea*
Kristine Kenigsvalde, Astra Zaluma, Anete Eberlina, Lauma Bruna, Indulis Brauners, Agrita Kenigsvalde, Kari Korhonen, Talis Gaitnieks

44. *Fine root status and mycorrhizal colonization of Norway spruce in Heterobasidion sp. infected stands on peat soils*
Darta Klavina, Rimvydas Vasaitis, Audrius Menkis, Indrikis Muiznieks, Natalija Burnevica, Kristine Kenigsvalde, Talis Gaitnieks

45. *Impact of seed origin and cultivation system on Norway spruce seedling mycorrhization*
Darta Klavina, Arnis Gailis, Imants Baumanis, Astra Zaluma, Audrius Menkis, Talis Gaitnieks

46. *Ectomycorrhizal community in conifer stands on peat soils 10 to 12 years after wood ash treatment*
Darta Klavina, Lauma Bruna, Dagnija Lazdina, Andis Lazdins, Taina Pennanen, Audrius Menkis, Talis Gaitnieks

47. *Coniferous stumps as an important source of the root rot fungi Heterobasidion spp. and Armillaria spp.*
Lauma Bruna, Natalija Burnevica, Astra Zaluma, Andis Lazdins, Talis Gaitnieks, Rimvydas Vasaitis

48. *Scots pine (Pinus sylvestris L.) resistance gene expression, regulation and efficacy in response to fungal infection*

Vilnis Skipars, Ilze Snepste, Baiba Krivmane, Viktorija Belevica, Angelika Voronova, Maris Lauberts, Liga Lauberte, Galina Teliseva, Dainis Rungis

49. *Induced resistance responses in Scots pine (Pinus sylvestris L.)*
Ilze Snepste, Vilnis Skipars, Viktorija Belevica, Baiba Krivmane, Angelika Voronova, Elza Rauda, Ilze Veinberga, Dainis Rungis

50. *Remote sensing data usage capabilities for the analysis of distribution of forest resources outside NFI sample plots*
Janis Donis, Juris Zarins, Guntis Gitendorfs, Martins Lukins

51. *LIDAR data usage capabilities for forestry and forest biological diversity evaluation*
Martins Lukins, Janis Donis, Juris Zarins

52. *Effects of FSC® forest management certification to the occupation health and safety in Latvia and Finland*
Janis Svirksts

53. *Measuring equipment for groundwater flow determination in soil and it's possible application in forestry*
Maris Eglite

ABSTRACTS OF ORAL PRESENTATIONS

SECTION 1

COMBINED UTILIZATION OF WOOD

RESEARCH OF WOOD MATERIALS WITH INCREASED ECOLOGICAL VALUE

Uldis Spulle, *Karlis Bumanis, Kristaps Ziverts, Vilnis Jakovlevs*

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Goal

Create increased ecological value (IEV) with innovative solutions in a time of production and exploitation of wood and wood-based materials used in the timber construction and living environment.

Main results

Innovative solutions of wood application for construction implemented in close to the real size building objects to monitor their performance in longer run and exposed to the real conditions. Several Latvian wood industry companies like *Amber Furniture* Ltd., *Dores Fabrika* Ltd., *Rothoblaas Baltic* Ltd., *Dendrolight Latvia* Ltd., *Arbo Windows* Ltd., *Jaunzeltiņi* Ltd., *Latvāņi* Ltd. were involved. As practical results built it up and carried out monitoring data (air humidity and temperature material temperature and moisture contents) by one year of 5 real research monitoring objects at real time:

1) Prefabricated Log house – log middle isolated with thermo sawdust's (outputs: knowledge about material economy and efficiency at time of production, real time investigation system and data base).

2) Wood cellular material building system house – first in Latvia, Europe (outputs: knowledge how to use wood cellular material called Dendrolight® as building structural elements, real time investigation system and data base).

3) Surface coating systems (outputs: knowledge of using mainly used coating materials and combination with fire retardants, and data base).

4) Panel insulations systems for facades (outputs: knowledge of designing, production and positioning such systems, real time investigation system and data base).

5) Six corner house called 3E (output 2 patentable units, knowledge of designing, production and building such systems, real time investigation system and data base).

Keywords: *wood materials, high ecological value, monitoring objects*

LOW ENERGY CONSUMPTION FACADE PILOT PROJECT

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Goal

Create pilot research object based on experiences acquired from international project «TES (Timber Element System) Energy Facade» which studied timber based element system for improving energy efficiency of building envelope mainly for renovation projects to monitor its performance in longer run and exposure to the real service conditions.

Main results

Project designed as a systematical process of planning, construction and maintenance of the building stock using prefabricated large sized insulated timber frame elements. Research outputs are knowledge of design and structural solutions, production and installation practices, real time performance monitoring system and acquired data for later performance analysis.

Energy efficiency calculations of the designed timber element facade insulation system showed thermal conductivity U-value between 0.123 to 0.125 W/m² K depending on facade finish.

Figure 1. Pilot demonstration.

Keywords: *facade, energy efficiency, renovation, timber based element system*

STUDY OF WOOD CLADDING SURFACE FINISHING SYSTEMS PERFORMANCE IN OUTDOOR CONDITIONS

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Goal

Create wood cladding surface finishing systems study field to monitor their performance in longer run and exposed to the real outdoor conditions.

Main results

Different wood cladding surface finishing systems were applied to the several field study objects. Realistic service conditions were simulated to monitor performance of wood cladding finishing durability against weathering (moisture, radiation etc.) and serviceability of combined surface finishing (antiseptic, fire retardant etc.) systems and assembling elements.

During the first year of study starting from the installation of wood cladding objects in spring 2014 there are several observations made regarding specific finishing systems and their performance. Long term evaluation requires further monitoring to draw relevant conclusions regarding wood cladding surface finishing systems performance in outdoor conditions.

Figure 1. Open air study field for wood cladding surface finishing efficiency monitoring.

Keywords: *wood cladding, surface finishing system, monitoring*

RESEARCH OF MODERN AND SUSTAINABLE WOOD STRUCTURES

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Goal

Create research platform for development of innovative solutions for modern and sustainable large wood structures in Latvia to avoid undeveloped situation in comparison to countries with similar importance of forest sector.

Main results

Industrial research involved partners from industry (*CBS Igate* Ltd., *IKTK* Ltd., *Inženierbūve* Ltd.) and academia (Riga Technical University, Forest and Wood Products R&D Institute) to consolidate knowledge and skills in wood science and technology, building science and technology as well as internationally recognized researcher capacity. As result research platform created for development of modern and sustainable large wood structures based on infrastructure developed during the project implementation. This will be used for industrial research and long term monitoring of wood application for infrastructure and study of performance, safety and durability issues.

Figure 1. Modern large scale wood structure performance monitoring.

First study within this project is commenced on modern wood structure pedestrian bridge which serves like real laboratory for continuous measurements and monitoring of structure performance and service properties.

Keywords: *modern wood structures, monitoring*

MODULAR PORTABLE COMPOSITE BRIDGE SYSTEMS FOR FOREST INDUSTRY APPLICATIONS – REVIEW OF A RESEARCH PROGRAM

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This article presents latest research initiative in a field of forest industry infrastructure. Core of the research program is a development and testing of modular portable bridge system which is able to carry typical forest truck loads and characterized by relatively fast construction methods, reusability in multiple logging spots and would be considered as an economically viable alternative to permanent bridge structures.

Proposed bridge system utilizes concrete and wood composite elements, which size and weight are designed for portability and modularity as a prerequisite. Use of glulam material adds for lightweight character of the bridge system as well as to some extent it demonstrates sustainability awareness and ambition to expand usage of renewable materials in forest infrastructure applications.

The experimental bridge in focus covers a nominal span of 6m and is intended for one lane heavy vehicle traffic with overall width of 3,86 m. The bridge consists of two panels each having a concrete deck that is supported by three glulam beams with diaphragms.

In order to examine structural and functional effectiveness of the bridge system a number of static and dynamic load tests were carried out at different seasons encompassing diverse environmental conditions, which were monitored by permanent moisture measurement system.

NATURAL FIBRES WOVEN STRUCTURES FOR COMPOSITES REINFORCING

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The increase in production of natural fibres woven structures for reinforced composites can be noticed in different sectors of economy. That can be explained in relation to limited sources of raw materials and different environmental issues, as well as European Union (EU) guidelines to the car manufacturers.

Woven structures of flax yarns (382 Tex, 582 Tex, 670 Tex and 68/2 Tex) and hemp yarns (100 Tex, 1186 Tex) were produced. The density fabrics was from 83 g/m^2 for 100 Tex hemp yarns reinforcement in play weaving technique to 1353 g/m^2 for 670 Tex flax yarns reinforcement in multi layers overlaid weave technique. The technical textiles based composites are the rapidly developing light-weight engineering materials. The fabrics used in composites manufacture have to be especially engineered as a single-fabric system could impart reliability and performance of composite material. Investigation of woven fabric structures from natural fibres in different types of weaves show strong impact on fabrics investigated mechanical properties – tensile strength, tensile extension and elastic module.

The hybrid reinforcements of hemp and flax yarns and polypropylene yarns or polyethylene yarns were produced. The research focuses on production of reinforcement of natural yarns and thermoplastic yarns as a matrix in one woven product for the production of composites of industrial application. Composite tensile extension (3.5–5.1 %) and tensile strength (814.9 N–1809.6 N) depend on the reinforcement used, matrix properties as well as the method of composite production method. The composites of natural yarns and thermoplastic yarns are applicable for wall covering panels, because this is a stable and low weight material with predictable fibre and matrix proportions in reinforcement and changeable composite design as well as properties.

Keywords: *flax fibres, hemp fibres, woven reinforcement, mechanical properties and composites*

BIRCH WOOD FIBRES AS RESOURCES FOR THERMAL INSULATION MATERIAL

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Adequate heat is one of the prerequisites for human survival; therefor building insulation is required in places where the outside temperature is not suitable for living. For thousands of years people have used nature materials for that purpose – moss, clay, straw, wool, herbs etc. In the last century, however, a lot of synthetic materials have taken place in this application area, but considering the global tendency to reduce CO_2 emissions, humanity comes again to green-thinking. In addition to this reason, natural materials in the construction create a pleasant microclimate for living. Modern thermal insulation material should have air permeability together with good thermal insulation properties and easy handling. Thermal insulation boards from soft wood fibres are part of global market nowadays. The climate change with its rising temperatures and longer dry periods enlarges the regions with conditions more convenient for hardwood species than for softwood species (de Borst & Bader, 2014). Manufacturers can change the focus on hardwood products. Birch is the most common hardwood species in Latvia – its stock was 160 million m³ in 2014 and that is 24 % of total wood stock of our country.

Fibres were obtained from birch chips in thermo – mechanical pulping process. Board formation and production was done in the presence of water; natural binder, fire retardant and fungicide was added in different concentrations. Board properties were investigated: density, transportability or resistance to particulate loss, thermal conductivity, reaction to fire and surface – water contact angle.

This study includes thermal insulation boards with density 60–120 kg/m3, strong correlation between density and binder amount was found. Transportability also improved with addition of binder and other additives and 0.1–0.5 % of binder was the most appropriate amount for this purpose. Measured thermal conductivity was in range 0.040–0.043 W/(m·K) and a good correlation with density of fibre-board was found. Birch fibres from thermo-mechanical process are applicable to thermal insulation board production. It is possible to diversify board properties, changing amount of different additives. It is a good opportunity to obtain a product of high added value from wood residues instead of burning them to produce only energy.

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IMPROVING OF WATER RESISTANCE OF PAPER FROM BIRCH FIBRES

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Wood is a natural, renewable and available source for widespread paper products. The birch (*Betula pendula*) is the most common hardwood species in Latvia; its stock was 160 million m^3 in 2014 or 24 % of the total wood stock of country. Birch wood can be used for furniture, plywood or as building material, as well as its liberated fibres for specific products. The modification of the fibre pulp quality to improve paper features is significant scientific challenge in the paper industry, and fibre deformations are proven to have an effect on the fibre strength and paper sheet properties. External fibrillation, internal fibrillation (swelling), fines formation, fibre shortening, and fibre straightening are the properties that are changing in the refining process. Fibrillation is explained as a peeling-off mechanism – the primary wall and secondary S1-layer of fibre are peeled off, and the secondary S2-layer is exposed to inter-fibre bond. This delamination is caused by the cyclic compression action of the forces inside the refiner and that mechanical treatment increases the inter-fibre bonding that affects properties of fibre product.

The aim of the current study was to assess effect of mechanical pre-treatment on structure and characteristics of birch Kraft pulp fibres and on water resistance properties of paper.

Tree samples of birch were grown in former agricultural lands in the central part of Latvia, fibres were made by Kraft pulping method in laboratory digester; pulp samples for testing were selected randomly, providing average sample. Mechanical treatment of the fibres was performed according to ISO 5264-2 for 5, 10, and 15 minutes. Shopper-Riegler number (°SR) of pulp was determined according to ISO 5267-1; water retention value (WRV) was obtained according to ISO 23714. Paper handsheets were prepared according to ISO 5269-2. The properties of the water resistance of paper were tested according to TAPPI T 441 om-09 (COBB test) and surface wettability according to TAPPI T 458 cm-14.

Results showed significant ($p < 0.05$) effect of mechanical treatment on all inspected properties. After 15 minutes °SR increase for 246 %, WRV for 34 %. Decreasing of COBB number for 45 % and changes in water-contact angle created conclusion about higher water resistance of paper, caused by improved fibre bonding as a result of mechanical pre-treatment of birch fibres.

Keywords: *refining, water retention, contact angle*

UPGRADING OF PLYWOOD REGARDING ITS POTENTIAL END-USE

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Preference for specific material is largely determined by the ability of the material to meet certain requirements or standards. The objective of the present study was to evaluate the possibility to upgrade plywood according to definite end-use requirements, consequently, expanding the potential application area of this material. To develop a suitable method for production of plywood which meets the requirements expected for high-quality concrete formwork material, the formation of ripples induced by water ingress through a damaged surface was studied and various techniques to restrict the formation of ripples were tested. The modification of the upper layer by an impregnation as well as application of an adequately rigid coverage were found to be the more promising treatments. Moreover, a number of commercial coatings were tested to assess their efficiency for sealing edges and thereby preventing formation of ripples when plywood is used in places with extremely high humidity or in direct contact with water. To find an appropriate type of surface treatment for plywood intended for the exterior use, a test was carried out during which a set of plywood with different surface design (coated, laminated, impregnated) was exposed outdoors for three years. Regular examinations were performed of moulds and blue stain fungi growth on the surface, changes in surface contact angle as well as discolouration used as the indicators for evaluation of surface performance. The results showed that the laminated and with multi-layered coating treated plywood were more resistant to the weathering. In its turn, a heavy blue stain fungus infestation as well as extreme discolouration was observed for impregnated plywood already within a few month of outdoor exposure, regardless of the biocide composition used for the treatment. It indicates that the impregnated plywood is unsuitable for the outdoor use. Moreover, examination of the penetration profiles of a copper containing biocide in plywood by using the atomic absorption spectroscopy showed that only the outer layers were properly impregnated and considerable decline of the biocide concentration was detected towards the plywood middle layers. It implies that the conventional process designed for solid wood impregnation does not provide adequate result when applied for plywood.

THE APPLICATION POTENTIALITIES OF WOODWORKING BY-PRODUCTS

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The aim of the P2 project «Study of the application potentialities of woodworking by-products» (Forest Sector Competence Centre, No KC/2.1.2.1.1/10/01/003) was to extend the use of the wood value chain for obtaining new value-added products from the birch wood residues (wood sanding dust, plywood squared edges, bark) of the JSC *Latvian Plywood Factory*, which are mainly used as an energy source. Wood-polymer composites (WPCs) are the biggest biomaterial group in Europe, and their forecasted production in 2020 is 450 000 t. Taking this into account, in the project, the purposeful functionalization of lignocellulosic residues – birch wood sanding dust for obtaining a wood filler as well as the targeted modification of lignosulfonates, a by-product of cellulose production, for creating a lignin-based interface tension modifier (compatibilizer), aimed to be used in the WPCs, have been developed. Waste polypropylene, a polymeric municipal solid waste, was used as a polymer matrix in the developed WPCs. The fuctionalization of lignocelluloses was carried out by two methods, namely, by their hydrolysis alone and by the hydrolysis with the followed modification. The hydrolysis was implemented with sodium hydroxide water solutions. The modification was carried out by introduction of tertiary amino groups at the birch lignocelluloses surface. In both cases, the developed lignin-based compatibilizer, representing the nanoscale particles with the pronounced ability to decrease the surface tension at the polymer/wood interface, was applied. The developed WPCs were fabricated by the polymer processing modes (extrusion and injection under pressure) and contained 10–50 mass % of the functionalized lignocellulosic filler, 1–3 mass % of the interface tension modifier and 0.5–1.0 mass % of a lubricant. The texture of the obtained composites was characterized by the good homogeneity that was resulted in the enhanced mechanical properties (tensile, bending), the high values of contact angles and the low water sorption. In the project, the following analytical and instrumental methods were applied: elemental and functional analysis, spectroscopic analysis, SEM, AFM, TEM, optical microscopy, zeta potential and nano- un microsizes measuring, surface tension and contact angles determination, TGA un DTG, mechanical tests, contact angles and water sorption measuring, etc. The patent application «Method for obtaining a lignocellulosic filler for wood-polymer composites» was prepared and submitted to the LR Patent Office.

Keywords: *birch wood residues, hydrolysis, functionalization, lignin-based compatibilizer, WPC*

SECTION 2

FORESTRY

PART A

TIMBER RESOURCES

THE ALTERNATIVES OF TRANSPORT OF WOOD CHIPS IN ESTONIAN CONDITIONS – A CASE STUDY

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Year by year, the production and transportation of wood chips have increased in Estonia. The maximum gross weight of a road train is 44 tons, hence it is not feasible to use trailers with a capacity of more than 90 m^3 because the moisture content of wood chips varies considerably and it is not recommended to exceed the weight restriction. As the majority of wood chips is cut right by the road side in Estonia, the entire process depends greatly on the weather and affects also the vehicles' fuel consumption, since high precipitation and extremely variable temperatures (–25°C…+30°C) result in changing road conditions. Consequently the goal of the case-study was defined – to analyse the price formation of wood chips in Estonian conditions. Within one year, all expenses related to a total of 9 vehicles on fuel, manpower and spare parts were examined. The vehicles were divided into 3 groups according to their transport routes. All vehicles were equipped with a GPRS tracking system that provides information on fuel consumption, working hours, driving speed and itinerary in real time and this data were later used to obtain a detailed overview. The fuel consumption varied between vehicles with different transport routes throughout the whole year. As it is very difficult to use the logistic solution of minimising the number of unloaded journeys, all costs per each travelled kilometre should be reviewed. The group of vehicles with the lowest fuel consumption included three-axle trucks and the largest item of expenditure was fuel. However, transportation of wood chips with two-axle trucks proved the most inexpensive, because, considering total expenditure, the cost of one travelled kilometre was the lowest.

Keywords: *wood chips, transport, production cost*

RESULTS OF EVALUATION OF DIFFERENT METHODS AND TECHNOLOGIES OF SOLID BIOFUEL PRODUCTION IN DITCH CLEANING HARVESTING OPERATIONS

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Within the study in 2015 conducted research on machinal ditches removal. This work is the realization of equipment used to chain base which equipped with harvester cutter head. On the basis of a technical choice ar the following indicators: manipulator jib, the maximum working capacity with full jib and technical suitability for work on soils with low load-bearing capacity. One of the tasks of the project is to develop harvesting methods for suitable machinal ditches, increasing productivity.

The most effective method of work is the standard wood assortments combining wood and small tree biofuel – forestry residues puts in heaps, but wood and small trees stowed on timber. Working with the following method: the study objects relevant ditch slopes per hour can be processed 108 trees, providing productivity 6.5 m^3 h^{-1}. However, if would increase the minimum diameter of the tree, whose processed harvesters, productivity can be increased by an average of 39.5 %.

Keywords: *ditches harvesting, biomass from ditches*

PRODUCTIVITY AND COST OF STUMP EXTRACTION IN FOREST STANDS HEAVILY AFFECTED BY ROOT ROT

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The scope of the study was to evaluate productivity and cost of stump extraction in spruce stands on mineral soils heavily affected by root rot as well as to compare productivity of 2 stump extraction buckets – CBI bucket for middle size stumps and MCR-500 bucket for stumps with diameter up to 50 cm. The study was implemented in 5 stands in central and western part of Latvia. The extracted area in each stand was at least 0.5 ha and about the same area was left as control. All stumps with diameter above 10 cm were measured (diameter, height, species, visual signs of root rot damages, location) and marked, so that time study data can be applied to a specific stump. Soil scarification in all plots was done by disc trencher next spring after stump extraction just before planting. The work was done by 1 experienced operator (with CBI bucked) and 1 less experienced operator (MCR-500 bucket), which has 3 days long training session before time studies. Komatsu PC210LC excavator was used in CBI studies and New Holland E215B in MCR-500 studies. Both machines has similar weight – 23 tonnes. The stump extraction was done in winter, 2011–2012. Forwarding was done in spring, 2012. Prime cost estimations are based on productivity data obtained in time studies and machine cost figures provided by contractors.

During the studies 82 % of the marked stumps, as well as several non-marked stumps (6 % of number of the initially marked stumps) were extracted. Stump extraction was hampered by heavy snowfall, so the stumps has to be cleaned from snow before extraction. Another factor negatively affecting productivity was high groundwater level and soil moisture. Operators spent considerably more time, in compare to earlier studies (Lazdiņš & Hofsten, 2009; Lazdiņš & Zimelis, 2012a; b; Zimelis *et al.*, 2014), to get rid of residual soil from stumps. It was concluded in the study that productivity and quality of operation might be increased on wet mineral soils if stump extraction is done when soil surface is frozen.

No statistically significant difference was found between productivity of the CBI and MCR-500 bucket (in average 0.37 productive time per 1 tonne of biomass), but the distribution of time between work elements was different. More experienced operator (CBI bucket) spent more time for manoeuvres to find better position for stump lifting; another operator spent more time for stump lifting and splitting. The MCR-500 has considerable potential to increase productivity; due to technical issue it was not possible to secure normal working pressure in a hummer line feeding cylinder of the splitting knife and moving of the knife was much slower than it should be. There are also some concerns about estimation of extracted biomass, because Swedish biomass equations (Lazdinš *et al.*, 2009) applied to the calculation are not sufficiently evaluated in Latvia.

Comparison of productivity of stump extraction depending from diameter of stumps approved earlier finding that the productivity is rapidly going down for all tree species if the diameter of stump is below 20 cm, and it would be wise to leave those stumps untouched during stump extraction. However, further research should be done to evaluate role of small stumps in distribution of the root rot. If they are contributing to distribution of root rot, then the applied extraction technique should be improved to increase efficiency of extraction of

small stumps.

No reduction of productivity was found during extraction of stumps with diameter above 50 cm, in spite both buckets used in trials are recommended for smaller stumps. One of the reasons for continuously increasing productivity while extracting large stumps is nearly 2 years delay between final felling and stump extraction – fine roots are already decomposed and stumps can pulled with less efforts.

Productivity of stump extraction increased during extraction of rotten stumps (by 14 % in average), however, it should be considered that rotten stumps have smaller bulk density and they have empty holes inside quite often; therefore the productivity might not be as high as predicted by the biomass equations. It is found also in the studies that in contrast to earlier results in trials with the MCR-500 (Lazdiņš *et al.*, 2012) productivity goes down if operator tries to extract several stumps simultaneously by cutting side roots of smaller stumps in a group and then pulling central stump of a group. The reason for the decrease of productivity is not identified in the studies; however, it might be also affected by delay between final felling and stump extraction. Contact between stumps became poorer and simultaneous pulling is not so affective as directly after final felling.

Following to results of the trials it is recommended to change work method and not to use slash roads during stump extraction, but drive in area between strip roads in a zigzag shape pattern so that the most of the work is done in a position when bucket is in front of the excavator. Extracted stumps should be piled on sides of slash roads to avoid secondary contamination with soil. No stumps should be extracted from slash roads. If necessary, they can be pulled and turned over to improve forwarding conditions. It is also recommended to cut larger roots nearby slash roads before pulling stumps.

The project also contributed to concerns about compaction of soil during stump extraction. There is no significant difference of soil penetration resistance between experimental and control plots, therefore it can be concluded that stump extraction is not compacting soil.

The prime cost of production of wood chips from stumps in the experimental was 12.3 EUR m^{-3}. Stump extraction was only 21 % of the prime cost. Considerable increase of productivity can be achieved if stumps with diameter below 20 cm are left in a stand untouched. The most efficient solution to reduce the cost of stump extraction is soil scarification simultaneously with stump lifting (e.g. with specialized bucket MCR-500) and two step comminution of biomass – first in a roadside storage producing coarse pieces of wood and then at the end use area to avoid transportation of stumps to a long distances.

Savings on soil scarification, if it is done during stump extraction can make stump biofuel production profitable in a current conditions. However, there is still no market for stump biofuel, which is one of the key issues to solve before starting of large scale commercial production. Another issue is lack of technologies for efficient transportation of stumps and lack of experienced machine operators.

Keywords: *stump extraction, MCR-500, root rot*

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RESULTS OF RESEARCH PROGRAM ON EVALUATION OF IMPACT OF FOREST MANAGEMENT MEASURES ON GREENHOUSE GAS EMISSIONS AND CO2 REMOVALS

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The scope of the research program on impact of forest management on greenhouse gas (GHG) emissions and CO2 removals was to elaborate accounting methods for the key sources of emissions and CO2 removals in forest land.

The most important task in light of the Kyoto obligations was evaluation of impact of afforestation, because this activity can compensate emissions due to deforestation. Thirty eight plots were established for monitoring of the carbon pools in afforested lands. The data that will be obtained in these plots will provide the most comprehensive information about impact of afforestation on CO2 removals due to afforestation. Parallel studies on impact of land use on soil carbon stock demonstrated that soil carbon pool is increasing in case of afforestation of cropland and is not significantly affected in case of afforestation of grassland.

The impact of forest regeneration is evaluated during literature review and using BioSoil data on pine stands. According to the BioSoil results the carbon stock changes are cyclic and heavily dependant on characteristics of growing trees; however available data are insufficient to elaborate models describing changes of soil carbon stock under different initial status and management procedures. The soil carbon pool in pine stands reach maximum before the final felling age (about 100 years) and then reduces until regenerated stand reaches 40 years age, when it increases again.

The net impact of forest regeneration on CO2 removals characterizes with cumulative changes of carbon stock in living and dead biomass, wood products, litter and soil comparing different forest management scenarios, respectively, scenario with no changes and implementation of certain silvicultural measures. The cumulative impact of forest breeding is about 50 tonnes CO2 ha^{-1} during the rotation cycle. Extrapolated to the whole country forest breeding can contribute to additional removals of 104 mill. tonnes CO2 during 75 years.

Thinning is one of the most common forest management measures providing contributing to CO2 removals directly and indirectly through harvested wood products (10–15 %) and replacement effect in energy sector (15–20 % of the total biofuel deliveries). Short term and long term experimental plots are established within the scope of the project to evaluate cumulative impact of different thinning methods including business as usual on CO2 removals in living biomass. According to the obtained results the additional increment after thinning in spruce stands thinned at 20–40 years age is 27 m^3 ha^{-1}; in pine stands – 15 m^3 ha^{-1}. In CO2 equivalents thinning produces additional removals of 3.17 tonnes annually in spruce stands and 1.76 tonnes – in pine stands. The additional CO2 removals due to thinning of pine and spruce forests equals to 110 Gg annually.

Elaboration of biomass equations is one of the most important precondition for successful reporting of the national GHG inventory, as well as for accurate evaluation of impact of the forest management measures. The smallest uncertainty during the whole range of tree dimensions and biomass fraction is obtained using 2 factor Gauss function using diameter at

the breast height and tree height as arguments. Calculation can be done to oven dry biomass or to carbon.

Decomposition of below-ground biomass is estimated by extraction and analyses of old stumps. According to the results stumps of coniferous trees are decomposing within 92 years and stumps of deciduous trees – within 38 years. The decomposition is characterized by logarithmic regression.

Decomposition of harvesting residues in coniferous trees stands takes about 40 years. In deciduous trees stands it is recommended to use the default decomposition period – 20 years.

The half decomposition period for above-ground coarse dead wood particles in pine stands is 67 years, in spruce stands – 51 year; however, the uncertainty rate is relatively high and more data are necessary to verify the obtained results. Decomposition of above-ground biomass is characterized by linear regressions.

Evaluation of impact of deforestation of GHG emissions is characterized by decomposition of litter layer, because the default methodology requires to apply instant oxidation to all carbon pools except soil and litter. According to the study results the half decomposition period of litter is 6 years and it can be characterized using power regression.

The project approves conclusion of other researchers that reconstruction of drainage systems in mature, growing forest normally has no impact on increment. The most critical point for reconstruction of drainage system is forest regeneration, where it determines if the stand will follow to a development curve of drained stands or will drop to a curve characteristic for naturally wet soils. It is recommended to compare growth curve of naturally wet and drained forest stands for evaluation of impact of forest drainage after final felling. In CO_2 equivalents reconstruction of drainage systems before the forest regeneration contributed to reduction of about 3.3 tonnes ha^{-1} of GHG emissions annually and on organic soils – 2.7 tonnes ha^{-1} annually. The total potential of reduction of the GHG emissions due to reconstruction of drainage systems in compare to situation without drainage in Latvia equals to about 1.5 mill. tons CO_2 annually.

Comparison of soil carbon stock in 95 forest monitoring plots in 2006 and 2012 demonstrated no significant difference, respectively, no soil carbon stock changes took place in forest land between 2006 and 2012. Average carbon stock in litter layer is 15.2 tonnes ha^{-1}, in mineral soil at 0–40 cm depth – 91.8 tonnes ha^{-1}. Soil carbon stock is not significantly affected by dominant species; however, average soil carbon stock in pine stands is smaller than in other plots. Comparing different growth conditions, the highest soil carbon stock is found in naturally wet mineral soils, comparably smaller carbon stock – in drained mineral soils. The highest carbon stock in litter layer is found in drained and naturally dry soils.

The study results approved hypothesis that harvested wood products (HWP) is one of the most important sources of CO_2 removals in Latvia; however, the project also approved reduction of CO_2 removals in HWP and a risk of turning HWP into source of CO_2 emissions in case of reduction of felling stock or increase of share of low grade timber.

Keywords: *greenhouse gas emissions, forest management, CO2 removals*

STANDWISE FOREST GROWTH MODELS BASED ON RE-MEASURED LATVIA`S NFI DATA

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For forest growth and yield modelling in Latvia`s forest sector are used models which where based mainly on temporary sample plots established in 1960–1970. Since 2004 in Latvia is carried out National Forest inventory (NFI) during which permanent sample plots are established. Objective: to provide the forest sector with adequate wood growth and increment forecast models. Task: to develop stand growth forecasting model – breast height diameter, mean height, dominant height and changes in the number of trees and basal area. We used data from 5458 re-measured NFI sample plots as well growth cores from 1249 sample plots. For height change prediction we used generalised algebraic difference approach. We tested several well-known growth functions e.g. Chapman-Richards, Hossfeld. For approximation of changes in number of trees we used two step mortality models based on logistic regression. For prediction gross and net annual increments we used non-linear regression.

Results: equation systems for forecast of volume, basal area, height and diameter increment for 6 commercially most important forest tree species in Latvia (Scots pine, Norway spruce, birch spp., European aspen, grey alder, black alder). Models allow forecasting growth of mixed stands as well stands influenced by thinning.

Keywords: *growth, NFI, modelling*

EVALUATION OF ACCURACY OF PIECE BY PIECE MEASUREMENT METHODS USED FOR PINE SAWLOGS

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For piece by piece measurement there are many methods for volume determination used, different volumetric algorithms, bark thickness and taper rates. There is no objective information available about each survey method of volume determination accuracy and the factors influencing it, depending on quantity of measured timber.

The study aims to justify the most suitable and precise piece by piece measurement technique (s) for Latvian conditions that could be applied in transactions involving roundwood and control measurements.

To assess the best individual measurement method (s) of a total of 169 analyzed pine assortments: the butt logs – 37, middle – 118 and top logs – 14. For achieving precise volume (benchmark) the Trimble FX 3D Scanner was used.

From the data collected volume over bark was calculated using the following piece by piece volume estimation methods:

For control logs:
1. section type with step 0,5 m;
2. section type with step 1 m;
3. top+middle+butt measurement;
4. top+butt measurement Latvian method;
5. top+butt measurement Swedish method.

In timber trade:
1. middle diameter measurement;
2. top measurement + Forest Faculty(LUA) taper values depending on part in the trunk;
3. top measurement + JSC Latvia's State Forests taper values.

The first image shows the data distribution in each part of the stem, which should now be seen as the most important influencing factor, because in the calculation of the average deviation compared to the benchmark method, it is impossible to objectively evaluate the accuracy and usefulness of particular method. For each measurement type in the graph there is zero line drawn – scanner measurements (benchmark), other values are shown as a percentage deviation. For each measurement technique there is marked the minimum and maximum deviation from the exact volume obtained from a scanner.

For each measurement method accuracy states the volume deviation distribution and placement around the 0 line. Analyzing the butt assortments by sectional measurement techniques there has been observed some positive deviations, which could be explained by an irregular cross-sectional shape. During piece by piece measurement cross section area is taken as the circumference area, which may be greater than the actual basal area. The smallest deviations are observed for sectional type of measurement with step 0,5 m and 1 m, and butt + middle + top end diameter measurement. By contrast, using only middle diameter measurement method and the top end + taper method, negative deviations are observed.
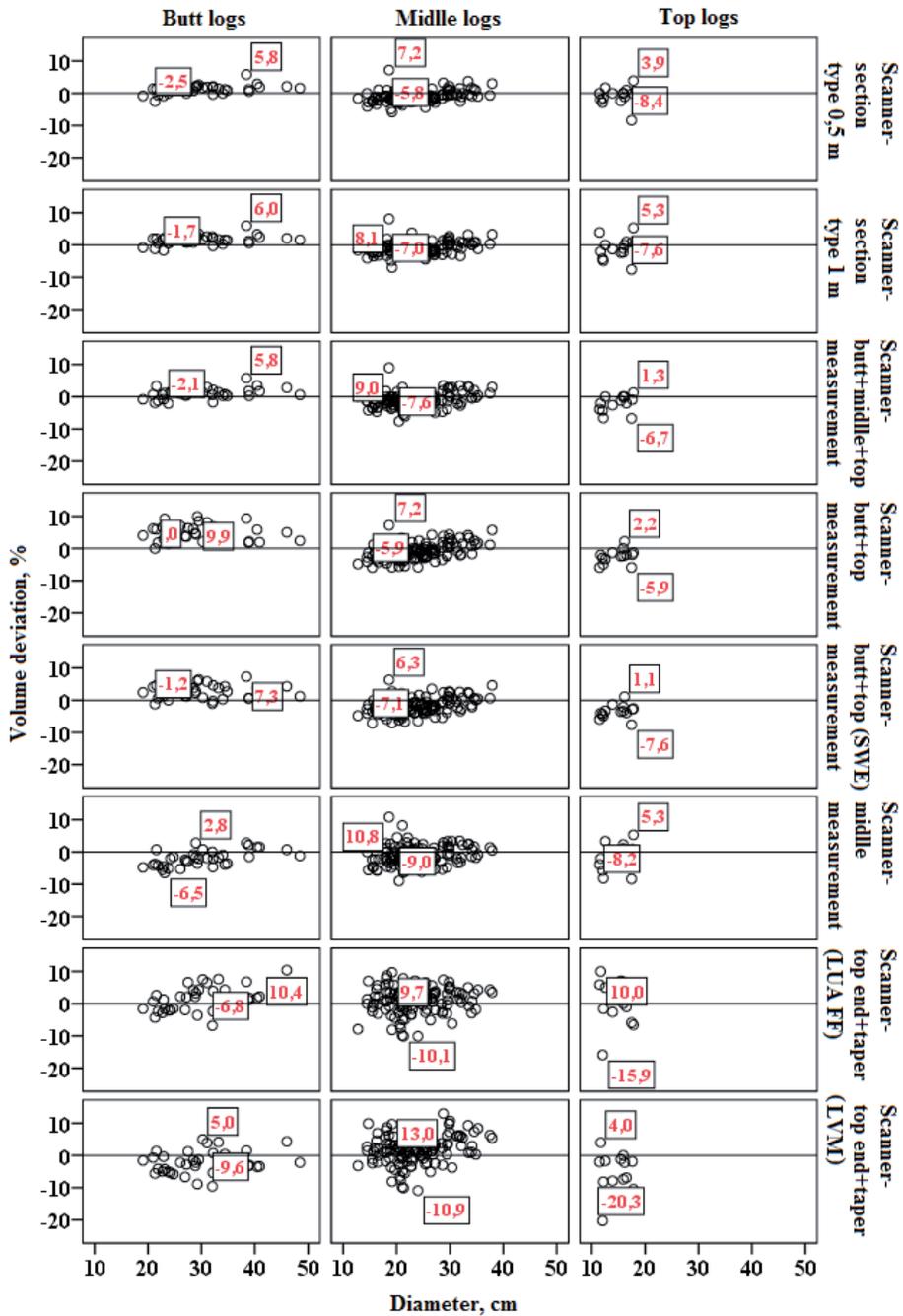
Figure 1. The difference of volume compared to scanner for pine assortments.

By analyzing the middle part of the trunk in section type measurement method for most of the data deviations were negative, respectively volume is calculated smaller than the actual. Assortment volume control measurement method showed equal positive and negative deviations. Timber trade measurement methods (middle part measurement and top end + taper) shows significantly higher volume deviations compared to the control measurement methods (top end diameter + butt end diameter).

Top part of the trunk assortments has a small number of observations, but the trend is likely to be encountered. Section type methods have relatively small deviations. Control measurement methods (top end diameter + butt end diameter) showed similar deviations as the butt and middle assortments, but the timber trade measurement methods (middle, top end + taper) showed higher maximum negative deviation of the actual volume.

Assessing the total deviation for different volume determination methods compared to scanner, average oscillation amplitude is obtained, which is:
- section type with step 0,5 m – max 3,5 %, min. – 3,6 %;
- section type with step 1 m – max 3,9 %, min. – 4,0 %;
- top+middle+butt measurement – max 3,4 %, min. – 4,5 %;
- top+butt measurement Latvian method – max 4,3 %, min. – 3,6 %;
- top+butt measurement Swedish method – max 2,9 %, min. – 5,0 %;
- middle diameter measurement – max 4,7 %, min. – 6,2 %;
- top measurement+Forest Faculty (LUA) taper values – max 7,6 %, min. – 6,5 %;
- top measurement+JSC Latvia's State Forests taper values – max 6,7 %, min. – 8,0 %.

Evaluating the total deviation for different volume determination methods compared with the scanner following amount of round timber that fits into the 3 % margin of error has been obtained:
- section type with step 0,5 m – 91,7 %;
- section type with step 1 m – 87,0 %;
- top+middle+butt measurement – 76,3 %;
- top+butt measurement Latvian method – 66,3 %;
- top+butt measurement Swedish method – 58,6 %;
- middle diameter measurement – 66,3 %;
- top measurement+Forest Faculty (LUA) taper values – 52,1%;
- top measurement+JSC Latvia's State Forests taper values – 50,3 %.

The most accurate results now can be obtained by control measurement methods. The volume determination using top end + taper show bigger differences in volume, because cutting type, part of the trunk (JSC Latvia's State Forests taper values) and site conditions are not distinguished.

Keywords: *measurement, volume, sawlogs*

ANALYSIS OF MICROORGANISMS IN DISCOLOURED *BETULA PENDULA* WOOD

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Discolouration of silver birch (*Betula pendula* Roth) wood results in lower added value for wood products, especially in plywood production. Microbial wood discolouration does not affect mechanical timber properties but is undesirable due to visual considerations. Pure fungal cultures were isolated from discoloured birch wood, aged 40–70 years, from different sites in Western, Eastern and central regions of Latvia. Identification of microorganisms inhabiting living birch wood was done by direct sequencing of fragments amplified with conserved fungal primers from total DNA. Additionally, quantification and diversity analysis of total fungal DNA was performed using qPCR and capillary electrophoresis. PCR-DGGE was used to compare ribosomal DNA gene fragment profiles of fungi which were amplified directly from total DNA extracted from wood samples. No single species of microorganism was found to be present in all discoloured wood samples, although preliminary results from DGGE shows that discolouration may be connected with such fungal species as *Pholiota squarrosa, Cadophora fastigiata, Phialophora* sp. Discoloured wood contained a much higher quantity and diversity of microorganisms as compared to the unaffected wood samples. Results of the present study showed that a wide range of fungi may be responsible for discolouration of both living and dead birch wood.

Keywords: *wood discoloration, fungal sequencing, fungal diversity, ITS, quantitative PCR, plywood production*

MAPPING OF TREE CROWN COVERAGE USING SATELLITE AND ORTO-PHOTO IMAGES

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Introduction

Earth observation data obtained from satellites and aircraft offer detailed information about vast areas in digital format. Spatial resolution of the image is one of the most important remote sensing parameters which affect data expenses and application possibilities. Spatial resolution refers to the size of the smallest object that can be identified in the image and it is defined as size of the area on the ground corresponding to one pixel.

The aim of this research was to develop methods and work-flows for automated mapping of tree crown coverage using freely available Landsat satellite images (30 m spatial resolution) and orto-photo images (0.4 m/0.25 m spatial resolution, year 2013) provided by Latvian Geospatial Information Agency.

Motivation for the use of remote sensing methods is afforestation problem in former agriculture lands in Latvia. Country wide, up-to date tree crown coverage maps could be used for afforested land identification.

Mapping of tree crown coverage using Landsat satellite images

Tree coverage mapping is usually performed by using statistical machine learning algorithms. Efficiency and accuracy of these algorithms depend on quality of the sample data which in daily practice can be hard to achieve. We tested the solution based on unsupervised fuzzy c-means (FCM) for Landsat satellite images. Unsupervised classification aims to identify natural groups of spectrally similar pixels called spectral classes. Spectral classes represent actual information measured by remote sensing sensors. FCM method was complemented by stability check and spectral classes were labelled with land cover classes (tree crown coverage/ other) using k-nearest neighbours. Fifty one pixels were randomly selected from each spectral class and classified using sample data. Spectral class is assigned to corresponding land cover class to which the majority of 51 test pixels are assigned to. Spectral classes are united in two thematic maps (tree crown coverage/other) by using image addition of the spectral classes with the same land cover class. This approach allows to use general, low quality sample data and sample data do not have to be selected from the same image.

Accuracy assessment was performed for Ropazi region using 1000 random test points, see Figure 1. Points overlapping with forest stand map of the forest inventory data base were assigned to tree crown coverage class, but other points were manually classified using visual interpretation of orto-photo images. Overall accuracy for 2014 was 94.2 % and kappa=0.89. Analysis of 14 Landsat images showed that seasonality does not affect tree crown coverage estimation significantly, but overall accuracy in 10 % range is influenced by illumination and atmosphere conditions during the image acquisition. Detailed accuracy assessment is shown in Table 1. Stands with standing volume over 100 m3/ha can be identified consistently between different images, but sparse, low standing volume stands form unstable spectral classes whose spatial distribution depends on the unique conditions during image acquisition. Analysis of the errors showed than 80 % of other land cover points misclassified as forest were located on

the borders between different lands cover types and the rest 20 % were misclassified due to spatial shifts. Approximately 59 % of forest points misclassified as "other" were recorded in the forest inventory data base as "cutting", "reforestation" and "cultivation of young stands". The rest misclassified points were located in swamps, recent clear cuts, young stands and on the borders with different land cover types.
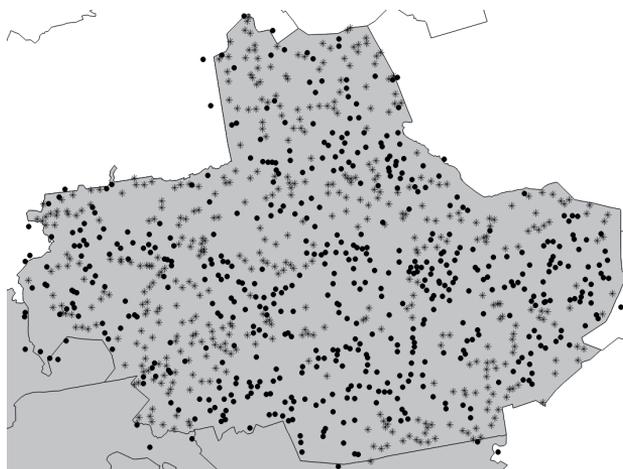

Figure 1. Locations of the 1000 test points.
Tree crown coverage points are marked by black circle, but other land cover points are marked by a star.

Image No.	Test pixels available	Overall accuracy (%)	Producer's accuracy (%) (tree crown coverage/ other)	User's accuracy (%) (tree crown coverage/ other)	kappa
LC81870202014023LGN00	1000	94.2	98.7/90.5	90.0/98.8	0.89
LC81870202014055LGN00	1000	91.2	95.5/87.5	86.9/95.7	0.82
LC81870202014087LGN00	1000	93.6	97.8/90.0	89.6/98.0	0.87
LC81870202014135LGN00	1000	83.7	98.9/70.5	74.4/98.7	0.68
LC81870202014215LGN00	1000	86.2	98.9/75.1	77.6/98.8	0.73
LC81870202014247LGN00	973	88.4	98.9/79.2	80.6/98.8	0.77
LC81870202014263LGN00	936	92.8	98.2/88.1	88.0/98.2	0.86
LC81870202015074LGN00	1000	86.6	99.6/75.3	77.8/99.5	0.74
LC81870202015186LGN00	992	86.0	98.5/75.0	77.6/98.3	0.72
LE71870202002238KIS00	1000	83.8	97.2/75.2	72.1/96.7	0.68
LT51870202000241FUI00	656	80.9	95.5/69.2	71.3/95.0	0.63
LE71870202000137EDC00	982	93.2	97.8/70.8	74.2/97.4	0.67
LT51870201988288KIS00	1000	79.9	99.1/63.2	70.2/98.8	0.61
LT51872021987285XXX03	1000	78.8	99.6/60.9	68.9/99.4	0.59

Mapping of tree crown coverage using orto photo images

High spatial resolution data are required for the mapping of complex stands. During the project tree coverage mapping based on shadow identification was developed for the processing of orto-photo images. Method is based on the assumption that forested areas can be described by rough texture formed by sunlit tree crowns and shadows. The use of orto-photos allowed to increase overall accuracy to 98 % and enabled to identify afforested agriculture lands, if urban areas could be masked out. However orto-photo images are mosaics of aerial images acquired in different dates and from different view angles. Accuracy could be improved by including masks showing the actual borders of individual aerial photos. Typical reasons for the classification errors were shadows with the very low NDVI (Normalized Difference Vegetation Index) value, shadows of the other objects than tree crowns and soil reflecting through the tree crowns. We also evaluated a classical approach using image segmentation in regions with similar spectral and texture information and region classification in land cover classes. Comparison of the shadow based method and segmentation method showed that segmentation method can handle urban areas more accurately. But shadow based method was much faster. Depending on the implementation properties shadow based method can be approximately 300 times faster than segmentation followed by classification.

Keywords: *remote sensing, tree crown coverage, unsupervised classification*

THE PRACTICE OF URBAN FOREST MANAGEMENT

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Urban forests play an important role in providing environmental, social and economic benefits as well as in improving the quality of life and human health in urban landscapes (Young and McPherson, 2013). It is known, that urban forests provide many ecosystem services with relevant monetary value (Roy *et al.*, 2012; Young and McPherson, 2013). Therefore long-term management of urban forests is required for the provision of these services (Miller *et al.*, 2015). Urban forestry is multidisciplinary and often numerous stakeholders are involved in land planning and management process. Due to usage intensity and diversity of users, urban forests are frequently called "hotspots" for development and adaption of innovative forest management practices (Konijnendijk *et al.*, 2006), which may improve benefits such as opportunities for recreation, aesthetics and the quality of life (Madureira *et al.*, 2015).

Our study investigates the methodology of integral forest management and latest technologies in the management of urban forests. In this study integral management system for ecological, economic and social values of urban forests are studied, including the technologies for inventory, planning and felling. As the outcomes of this study, recommendations for sustainable and multifunctional management of urban forests and instructions for selection felling will be prepared, as well as demonstrated on an experimental management site. This approach and technologies will ensure the sustainability of social and environmental functions and will increase the efficiency of forest management actions.

Keywords: *urban forests, management, ecosystem services, innovative technologies*

METHODS OF VEGETATIVE PROPAGATION OF GENETICALLY SUPERIOR SILVER BIRCH AND NORWAY SPRUCE – GAINS FOR TREE BREEDING AND FOREST PLANTATIONS

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Silver birch (*Betula pendula* Roth.) and Norway spruce are two of commercially most valuable tree species in Latvia; therefore it is necessary to develop effective vegetative propagatoin methods in order to accelerate breeding process. Currently they are: different tissue culture techniques and conventional vegetative propagation. As the main task of the forest breeding is to improve the economical value of trees, these propagation methods are important for developing the basis of highly qualitative reproductive material, suitable for use in definite territorial regions, climatic conditions, at the same time providing genetic diversity.

Silver birch is propagated by micro-cuttings in order to produce plants for experimental plantations. Clones are grown on Woody Plant Medium (Lloyd & McCown, 1981) supplemented with different combinations of plant growth regulators. Morphological parameters – shoot lenghth, lateral shoot number, rooting and multiplication rates are measured; best results achieved on culture medium supplemented with 1,0 mgL^{-1} for BAP and 1,0 mgL^{-1} for Zeatin.

There are 46 Silver birch clones in the collection of LSFRI Silava, the explants used for initiation are taken from selected plants growing in different experimental breeding plantations. During the spring and summer 2015 3000 explants from 160 selected trees are used for initiation *in vitro*, 5000 micro-cuttings from 27 clones were established *ex vitro*. Substrate for rooting: peat KKS-M2, rooted – 95 %.

In comparison with other vegetative propagation methods (f. e. somatic embryogenesis) Norway spruce propagation by cuttings is costly-effective and as a result good plant type is obtained. Disadvantages are: different rooting possibilities between clones, low multiplication rate, large areas needed for donor plants and ageing problem, which complicates clone testing.

In Latvia the method was developed under the guidance of V. Rone during the 70-ties of last century. In 2013 it was experimentally re-established in LSFRI Silava. During 2015 about 39 000 cuttings in different biological and physiological ages from 227 clones and progenies of 193 free-pollinated families were rooted in greenhouse with controlled climate conditions. Rooting results were strongly influenced by the age of parent plants.

By applying clonal progeny tests, breeding cycle is shortened; test results are influenced only by environment conditions, not by genetic background, reduced amount of plants are necessary to obtain correct test results. Vegetative propagation can be used in breeding programs: for candidate tests, for propagation for improved high quality clones, for mass propagation of selected families.

FAST GROWING POPLARS FOR PELLET PRODUCTION

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Renewable energy is increasingly used to ensure energy independence and reduce use of fossil materials, and more than half of it could be produced from biomass. However, the most productive native tree species in the region, European aspen, undergo high browsing pressure, thus fast growing alternative is necessity. Noticeable areas of abandoned land are available in Latvia, suitable for establishment of fast growing tree plantations of several *Populus* hybrids, differing in number of traits.

Hybrid poplar *Populus balsamifera × P. laurifolia* exceeds growth of forest tree species in the region. Mean annual volume increment found in experimental plantation on forest land was 11.8 m^3 ha^{-1} y^{-1}, reaching maximum of 21.0 m^3 ha^{-1} y^{-1}. Mean annual volume increment was noticeably (37–60 %) higher compared with most productive European aspen, birch and Norway spruce stands at same age. The dry mass ranged from 212 to 634 t ha^{-1}, corresponding to 4.2–9.8 t dry mass per year.

The bole of trees could be used for solid wood (e.g. boards, veneer) production while there is increasing interest in use of hardwood logging residuals in pellet production, mostly due to high price and insufficient availability of softwood. The aim of this study was to assess suitability of admixture of fast growing hybrid poplar for pellet production, in comparison to European aspen.

Pellets of two compounds were compared: both contained 70 % Scots pine with admixture of 30 % of either aspen or hybrid poplar wood. Pellets of both compounds had similar characteristics: mean density and durability was 715.0 and 715.5 kg m^{-3} and 93.7 and 93.6 % for pellets with admixture of aspen and hybrid poplar wood, respectively. The relative moisture was slightly lower for pellets based on hybrid poplar wood – 4.6 %, in comparison to 5.0 %. Thus, the results suggest that poplar could be suitable species for production of pellets.

Keywords: *Populus balsamifera × P. laurifolia, poplar, renewable energy*

WOOD MOISTURE AND DENSITY CONTENT CHANGES IN CONIFER (*PINUS SYLVESTRIS* L., *PICEA ABIES* (L.) H. KARST.) TRUNK DEPENDING ON HEARTWOOD PROPORTION

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Two types of wood are distinguished in pine and spruce – sapwood and heartwood. According to one of the most common theories, the heartwood formation process can be explained by the aging and dying of parenchyma cells. The proportion of those parenchyma cells which die varies within a species. This proportion is influenced by different factors, for instance – age of tree and growth conditions (forest type).

Heartwood and sapwood relation in pine and spruce trunks is one of the factors which influence the quality of sawlogs and pulpwood. Both stem parts have different properties and processability. Sapwood can be easily tinted, impregnated or otherwise treated. Heartwood has less moisture fluctuations and it is dimensionally more stable, more decorative and it can serve longer because resin saturation.

In most coniferous species two types of wood can be distinguished – sapwood and heartwood. Sapwood is found in the outer part of the trunk, but heartwood (in pine) and colorless heartwood (in spruce) – in the inner part. From the trunk heartwood and sapwood two different products of wood can be made. To determine the proportion of heartwood in pine and spruce and its influence on wood moisture and density in a freshly felled condition depending on the place in the trunk and the sample disc diameter, 989 pine and 676 spruce sample discs were prepared and treated. The sample plots, from which the sample discs were obtained, are scattered all over Latvia's territory in the most widely represented pine and spruce forest types where the age of the trees ranged from 61 to 143 years old.

Usually greater attention is paid to the log diameter, so that the heartwood proportion could be forecasted. As a tree gets older, the proportion of heartwood increases and with the increase in age the dimensions of the tree trunk also increase, therefore the diameter correlates with the proportion of heartwood. The trunk diameter, similarly as it is in the case of heartwood proportion, decreases towards the top of the trunk, but the moisture content and density of wood increase towards the top of the trunk.

Sapwood moisture content and density significantly differ from heartwood moisture and density. Sapwood is 3 to 4 times moister and 1.6 to 1.8 times denser than heartwood. Wood moisture and density has tendency to decrease by increase of diameter which can be explained with heartwood proportion increase. (Table 1).

Table 1. Wood moisture content and density changes depending on diameter

Scots pine				Norway spruce			
Diameter, cm	Mean	N	Std. D.	Diameter, cm	Mean	N	Std. D.
Moisture content, %							
5	142.3	5	11.8	5	137.5	14	12.7
10	139.3	141	21.0	10	128.6	149	18.4

	Scots pine				Norway spruce		
Diameter, cm	Mean	N	Std. D.	Diameter, cm	Mean	N	Std. D.
15	117.0	251	23.1	15	113.1	185	17.9
20	99.9	263	17.9	20	105.1	168	19.0
25	91.3	190	14.7	25	99.1	110	17.3
30	86.0	97	12.0	30	96.6	42	12.9
35	85.5	42	11.2	35	89.7	8	13.6
Freshly felled (green) density, kg m⁻³							
5	963	5	25	5	951	14	33
10	939	141	69	10	910	149	65
15	862	251	76	15	846	185	69
20	814	263	61	20	815	168	69
25	803	190	57	25	796	110	68
30	805	97	58	30	800	42	51
35	813	42	57	35	784	8	48

No significant interrelated differences were observed in the pine wood moisture content and density between the sample discs with the diameters of 5 and 10 cm ($p \geq 0.05$ according to the Tukey HSD test). Similarly, no significant interrelated differences were observed in the pine wood moisture content among the sample discs with the diameters of 25, 30 and 35 cm and pine wood density among the sample discs with the diameters of 20, 25, 30 and 35 cm. In spruce significant interrelated differences were not found in wood moisture and density between the sample discs with the densities of 5 and 10 cm. Similarly, there were no significant interrelated differences in spruce moisture content and density among the sample discs with the diameters of 20, 25, 30 and 35 cm. In other interrelated cases within a species, significant wood moisture content and density differences were found ($p < 0.05$ according to the Tukey HSD test).

The changes in wood moisture content and density in a freshly felled condition depending on the diameter can mostly be explained by the proportion of heartwood. When the trunk diameter decreases towards the top, the proportion of heartwood also decreases, and the moisture content and density also increase. The influence of heartwood proportion on the wood moisture content and density is characterized by comparatively high determination coefficients (R^2) of regression equations. The value of the coefficients is within the range of 0.634 to 0.788 (Figure 1).

PINE

SPRUCE
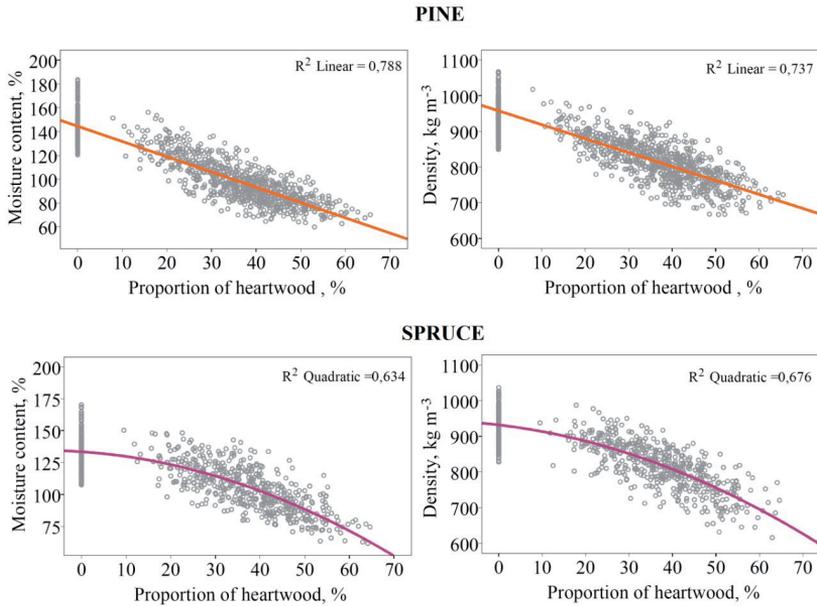
Figure 1. Wood moisture and density (freshly felled) changes depending on heartwood proportion.

Determination coefficient (R^2) values ranging from 0,634 to 0,788 indicates that from 63 to 79 % of cases, the wood moisture and density changes can be explained by the proportion of heartwood.

Keywords: *pine, spruce, moisture, density, heartwood*

RESULTS OF SOIL ANALYSES AND REMOTE SENSING METHODS IN DETERMINATION OF CO2 EMISSIONS FROM DRAINED ORGANIC SOILS

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Drainage is assumed to be one of the key sources of CO_2 emissions under LLUCF in GHG inventory causing significant CO_2 contribution to atmosphere. Currently, default CO_2 emission factors for temperate climate are used to calculate CO_2 emissions from drained organic soils in Latvia. These emission factors are not calibrated according to climatic conditions in Latvia and most probably are leading to overestimated CO_2 emissions. This assumption was strengthened after recent case study on drained and afforested transitional bog near Jaunkalsnava. The results of the study indicates no decreases on carbon stores in soil. Slight accumulation of carbon stock in soil by 20 ± 48 t C ha^{-1} was observed during 54 years of drainage corresponding to annual accumulation of 0.36 ± 0.89 t C $ha^{-1}a^{-1}$ or 1.3 ± 3.3 t CO_2 $ha^{-1}a^{-1}$, however increase is not statistically significant ($\alpha = 0.05$). Drained plots became a strong carbon sink on ecosystem level, if the carbon accumulation in trees is evaluated. It is necessary to calculate national emission factors to improve GHG reporting, however, it demands national scale assessments on carbon stores in peatlands and we need to determine peat subsidence rates to calculate emissions. Total workload and costs of such assesments can be reduced and measurement accuracy significantly improved if the remote sensing methods are used. One of the remote sensing technologies – LIDAR provides solution to measure current ground surface altitude and calculate subsidence from data available about ground surface altitude before drainage from drainage system establishment surveys. Furthermore, LIDAR would be useful to analyze impact of spatial variability to peat subsidence and changes in carbon store to develop carbon balance models in drained peatlands. First study results run by LSFRI Silava where LIDAR data are used shows peat subsidence close to a recent study in Jaunkalsnava and results from studies of other authors approving potential of methodology applied.

Keywords: *CO2 emissions, LIDAR, drainage, peatland*

ABOVE- AND BELOW-GROUND BIOMASS FUNCTIONS FOR FOUR MOST COMMON TREE SPECIES IN LATVIA

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The necessity of the assessment of total amounts of biomass and carbon stored in forest stands has been highlighted internationally during the last decades when the mitigation of climate change by means of carbon sequestration became a priority worldwide. On 11 December 1997, the Kyoto Protocol of the United Nations Framework Convention on Climate Change was adopted. Countries that have ratified the Kyoto Protocol are obligated to report emissions of greenhouse gases (GHG) and removals of CO_2. In accordance to the guidelines for the GHG inventories, parties have to develop a scientifically verified methodology for assessment of the carbon stock in all carbon pools, including living biomass. Besides the elaboration of the methodology for reporting of changes in carbon pools, a reliable biomass estimates for whole tree and above and below-ground tree components are needed for practical assessment of wood biomass as well for research purposes. Biomass estimates, usually expressed as dry weight, are commonly obtained by means of regression models which, in turn, are based on easily measurable tree parameters such as tree diameter and height.

The objective of the study was to find an appropriate equation for the calculation of above and below-ground tree components biomass for Norway spruce (*Picea abies* [L.] Karst), Scots pine (*Pinus sylvestris* L.), silver birch (*Betula pendula* Roth.) and aspen (*Populus tremula* L.). The suitability of three different mathematical models for prediction of above-ground and below-ground biomass was evaluates. Variables that can be easily obtained in forest inventories were used as independent variables. The equation (1) is a simple power function with the tree diameter at breast height as only argument that has often been used in modelling of tree biomass in various studies The equation (2) is a modified power function having two independent variables – tree height and diameter at breast height while the equation (3) is a two parameter Gaussian function. Coefficients of equations were derived by minimizing the residual sum of squares using software Curve Expert Professional.

$$y = a\,D^b\,;\qquad\qquad\qquad(1)$$

$$y = a\,H^b\,D^c\,;\qquad\qquad\qquad(2)$$

$$y = a\,exp\left[-\frac{1}{2}\left(\frac{H-b}{c}\right)^2 + \left(\frac{D-d}{e}\right)^2\right];\qquad(3)$$

where:
y – biomass (absolutely dry), kg;
H – tree height, m;
D – diameter at breast height, cm;
a, b, c, d, e – regression coefficients.

Empirical material was collected in 27 Norway spruce, 34 Scots pine, 35 silver birch and 28 common aspen forest stands on mineral and drained soils representing a large part of forest stand types in Latvia. The aboveground biomass equations were based on detailed measurements of 372 sample trees (Table 1).

Table 1. Sample tree characteristics

	Height, m				Diameter, cm			
	Aspen	Birch	Spruce	Pine	Aspen	Birch	Spruce	Pine
Mean	16.6	18.1	16.6	17.3	13.8	14.7	17.5	19.0
Standard error	0.9	0.8	0.9	0.9	0.9	0.7	1.0	0.9
Standard deviation	8.5	8.1	8.9	9.2	8.3	7.5	9.0	9.4
Min	3.7	4.8	2.8	1.9	2.7	2.7	2.3	1.5
Max	29.9	32.3	30.8	34.5	34.0	37.1	36.3	45.2
Number of sample trees	84	105	81	102	84	105	81	102

In each of the selected forest stand the three sample trees were felled down representing the range of dimensions of the dominant stand (Craft class I, II or III). Selected stands were located in three regions of Latvia, representing different climatic regions and populations of trees. Above-ground biomass measurements were performed during the winter period when deciduous trees are leafless and young shoots are mature.

The below-ground biomass equations were based on data measured from 144 sample trees of various dimension. The stumps and roots (Table 2) were extracted and measured in next spring and summer after tree felling.

Table 2. Below-ground dry weight biomass, kg

	Aspen	Birch	Spruce	Pine
Mean	16.9	22.7	33.5	33.4
Standard error	5.46	4.76	8.66	8.83
Standard deviation	31.41	30.91	46.67	55.86
Range	136.0	153.5	178.9	244.3
Min	0.26	0.43	0.89	0.12
Max	136.3	153.9	179.7	244.4
Number of sample trees	33	42	29	40

Stump biomass includes both above-ground and below-ground portions, defining the stump height as the basal part of the stem being at height of 1 % of the tree height. The stumps and whole root system were dug up limiting the extracted root diameter to 2 mm. Statistic model fit was evaluated by comparison of determination coefficient (R^2) and root mean square error of the estimation (RMSE).

The best results in predicting of above-ground and below-ground biomass were achieved using regression equations with two independent variables from those the Gaussian function – equation (3) produced the highest R^2 and lowest RMSE values for all studied tree species (Table 3).

Coefficients of determination for all tested equations are very high and are ranging from 0.956 to 0.992. The suitability of Gaussian functions for modelling of biomass is also confirmed by the high correlation between the observed and predicted biomass value across the interval of data distribution, determination coefficient ranging from 0.964 to 0.992. The prediction ability of models based on power functions tested in our study also produced good results, however, applying of aforementioned models resulted in underestimation of below-ground biomass of pine, especially for trees of bigger dimensions.

Table 3. Goodness of fit statistics of the biomass models

Tree species	Equation	Abowe-ground biomass			Below-ground biomass		
		R^2	RMSE, kg	AIC	R^2	RMSE, kg	AIC
Aspen	1	0.980	18.56	481.1	0.985	3.74	89.0
	2	0.991	14.19	439.1	0.986	3.69	90.8
	3	0.990	14.34	445.2	0.986	3.71	95.7
Birch	1	0.957	35.15	742.4	0.976	4.75	132.2
	2	0.985	20.92	636.6	0.976	4.73	134.4
	3	0.986	20.34	634.9	0.978	4.50	135.6
Spruce	1	0.979	31.08	558.8	0.961	8.97	125.1
	2	0.989	23.03	512.3	0.961	8.97	127.4
	3	0.990	21.44	505.1	0.964	8.55	129.9
Pine	1	0.977	34.99	705.9	0.956	10.85	192.9
	2	0.988	24.88	640.5	0.963	9.87	187.5
	3	0.989	24.29	640.0	0.992	4.67	132.4

The equations elaborated within the scope of the study are sufficiently accurate for practical and scientific use to determine above-ground and below-ground dry biomass of trees in Latvia.

PRELIMINARY DATA ON PRODUCTIVITY AND COST OF WOOD ASH SPREADING IN FOREST

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Wood ash utilization is essential problem, which is increasing because of policy targets for generating energy from biofuel end decreasing of fosil fuel consumption. One of the wood ash utilization options is spreading in forest for soil amendment. This option is often used in Scandinavia, however in Latvia it is not common practice. To get some steps closer to wood ash use for fertilization implementation in practice, field experiments and assessment of ash spreading should be done. Therefore trial of forest fertilization was carried out using spreading trailer which was connected with tractor Valtra 6350 equipped with wheel loader.

Experiment was held in end of November 2014. Forest stands are distributed at JSC *Latvia's State Forests* Viesite forest district. Experiment of wood ash spreading was made in 4 Norway spruce *Picea abies* (L.) Karst. stands (2 *Hylocomiosa* and 2 *Oxalidosa turf. mel.*) from age of 43 to 48 years which were thinned in last two years. In total 20 t of wood ash were spread in 10 ha area. To calculate productivity time for all work elements in total productive time consumption were received. Observation of spreading trailer imperfections was made during experiment. Suggestions for spreading trailer improvement were set.

Total time consumed for fertilization was 17 hours and 29 minutes, productivity of ash spreading vary from 0.38 to 0.70 ha h^{-1}. Costs for one hour implements services were 25.00 EUR, total spreading costs were 437.13 EUR or 43.71 EUR ha^{-1}. Main problems faced during operation were related to the ability to overcome difficult obstacles, so it is required to equip rear axle with hydraulic drive.

Keywords: *wood ash, spreading productivity*

SECTION 2

FORESTRY

PART B

FOREST ECOLOGY

Key note

MANAGEMENT OF FOREST GENETIC RESOURCES – AN IMPORTANT PART OF KNOWLEDGE BASED FORESTRY

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Forest management in fact is a management of genetic resources of forest trees in a way to maximize a specific vale (e.g. volume of high-quality timber) or reach a certain target. Knowledge about these resources, their properties is one cornerstone of sustainable forest management, especially in areas where targeted forest regeneration (planting or seeding) is practiced. It is also essential to ensure highest value of forests in mitigation of climatic changes as well as to ensure adaptation of forestry to these changes.

The most efficient tool to collect information on genetic properties of forest trees and use the information to boost adaptive capacity and growth of forest trees is forest tree improvement (breeding). Importance to use improved reproductive material was stated already 25 years ago by MCPFE Strasbourg Resolution S2 „genetically-improved materials is of great importance for afforestation and restocking, in particular where this is for the purpose of the production of timber". Similar statement is emphasised by recently released ForestEurope Madrid Resolution (M2) „Promote national implementation of strategies and guidelines for dynamic conservation and appropriate use of forest genetic resources under changing climate conditions" Failures by long distance transfer of forest reproductive material in the past and effectiveness of forest tree breeding programs are clear evidences that knowledge based management of forest genetic resources is an essential part sustainable forestry.

Keywords: *tree breeding, genetic gain, improved forest reproductive material*

Key note

INVASIVE ALIEN PESTS AS THE MAJOR THREAT TO EUROPEAN WOODLAND ECOSYSTEMS: ASH AND ELM AS THE EXAMPLES

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In recent years, a number of invasive alien pests caused severe damage to woodlands of Europe. Those include *Dothistroma-, Diplodia-, Fusarium circinatum-* and pinewood nematode-diebacks of pines, *Phytophthora diebacks* on deciduous trees and larch. Chestnut blight caused by *Cryphonectria parasitica* and plane blight caused by *Ceratocystis platani* are typical examples of invasive aliens formerly and currently observed in southern Europe. More recently devastating disease of *Buxus* has emerged, the agent of which is *Cylindrocladium buxicola,* infections of which are often followed by a secondary infestation from *Volutella buxi,* another fungal blight. It is currently acknowledged, that due to increasing international trade with (potted) plants for planting, more alien pests are to come. In this presentation, lethal diseases caused by invasive alien fungi to ash and elm will be discussed, that are much actual to northern Europe, including Latvia.

Recently and nowadays, severe Ash DieBack (ADB) is observed in most European countries. This is an emerging disease caused by invasive alien fungus *Hymenoscyphus fraxineus* originating from Far East Asia. The disease results in massive ash mortality, and currently threatens the existence of tree species on a continental scale. Also Dutch Elm Disease (DED) is a lethal disease, which during the last 100 years has led to a massive mortality of elm trees in Europe, threatening the existence of the species over large geographical areas. DED is caused by invasive alien fungi from the genus *Ophiostoma* originating both from Asia and North America.

However, data from European clonal seed orchards of ash have demonstrated that different tree genotypes exhibit different levels of susceptibility to ADB. Reports from numerous countries indicate that there are individual ash trees without any symptoms in otherwise ADB devastated areas. Due to the fact that the massive amounts of pathogen spores are distributed by wind, all ash in such areas must have been about equally exposed to the disease. Therefore presence of symptomless ash would suggest tolerance or resistance to the disease. Consequently, breeding programs of ash against ADB have been recently initiated in many European countries. Moreover, it has been known for decades ago that different elm genotypes are not equally susceptible to DED, and trials for breeding of elms against DED in Europe have historical roots. As a result, recently a number of DED-resistant elm clones were developed and registered for practical use in horticulture and forestry, and are to be continued and expanded.

Therefore, the objectives for long-term strategy to control and restrict impact of those tree pests are: i) to create (GPS-mapped) pan-European database of ash and elm resistant / tolerant to ADB, respectively DED; ii) to exchange genetic material of resistant / tolerant between research groups; iii) to initiate breeding for resistance trials on a continental scale; iv) to establish pan-European network of seed orchards by planting available resistant genotypes of ash and elm; v) to initiate silvicultural trials by replanting resistant trees in affected ecosystems / woodlands; vi) to initiate the experiments for biological control of DED with viruses; vii) to continuously perform biodiversity studies in areas devastated by ADB and DED

(focusing also on ontroduce Siberian ash and elm which are apparently resistant to ADB and DED), and mediate the results to society; x) to conduct demonstration meetings and seminars for stakeholders and general public.

Already at this stage, there are two principal messages to European (incl. Latvian) stakeholders: i) BOYCOTT imported plants for planting; ii) promote propagation, marketing and planting of locally produced plants.

DIURNAL AND SEASONAL DYNAMICS OF SAP FLOW AND WHOLE TREE MACROSTRUCTURE (CROWNS WITH FOLIAGE AND CONDUCTING PLUS ABSORPTIVE ROOTS) VIA FIELD APPLICABLE INSTRUMENTAL METHODS

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Many excellent studies are going on at perfectly equipped stationary research sites at present. However some problems can appear, when the task is, to answer some practically important questions in specific sites occurring in open (not equipped) forests situated in different parts of the landscape.

We tried to develop or apply a series of mobile methods based on different principles and allowing such studies, which can be applied elsewhere, even when they are not covering all scientific fields yet as it is desirable. However, further development goes on all the time. Presently we can measure whole tree water relations and macrostructure when using non-destructive thermodynamic and electric (eventually acoustic) methods. Here described are some results characterizing aboveground as well as belowground parts of whole trees and stands, crowns, stems and root systems. Quantitative estimates of the effective tree parameters and their spatial distribution we apply routinely now.

Tree foliage is usually characterized by the leaf area index, often estimated by optical methods. This works, but for more detail distributions analyses are still sometimes used allometric relationships based on classical methods (we prefer using at least two methods). Other instrumental methods include especially sap flow measurements, which allow estimates the diurnal and seasonal dynamics of water consumption, identification of the level of environmental (drought or hypoxia) stresses or water holding capacity and also of the effective crown size and its form. About a dozen of different parameters can be derived of sap flow records. Estimation of total and sunlit leaf distribution, help also for calculation of absorbed solar energy. Information about tree stems, especially large tree trunks is needed for wood quality and eventual rot assessment, which is important also for safety when considering e.g., trees growing in cities or along roads. We demonstrate practical examples of acoustic or electric impedance methods, which are of great help here.

Root systems represent very important part of plants, which can be studied in more details now, due to further development of corresponding instrumentation. This includes georadar, acoustic or electric scanning, sap flow vectors, modified earth impedance and supersonic air stream. Acoustic methods can detect distribution of large roots. Georadar detects also smaller coarse roots and this even through hard materials (asphalt, concrete, etc.). Supersonic air stream can visualize 3D root details, but it is the single method, which partially damage fine roots, but it is not easy to repeat it and additional methods are needed to evaluate (at least partially) the opened roots. The modified earth impedance method gives the effective absorptive root area (m^2) in sections around trees and tree total. Root Area Index (RAI) comparable to leaf area index (LAI) and their ratio as an important tree parameter can be calculated too. The radial

pattern of sap flow in stems gives amount of water coming from superficial and sinker roots from different directions around stems. Evaluation of water redistribution between roots and soils is also possible this way.

Examples obtained in different species and contrasting soil conditions indicate, that measured water relations, structural and effective tree parameters allow functional assessment of roots and crowns of whole trees and stands, which makes it possible to apply such methods for providing objective information as a background for forest management applicable for practical purposes for individual trees and forest stands up to the landscape level.

Keywords: *root area index, leaf area index, tree-environment interaction*

FOREST TREE BREEDING TO RISE THE VALUE OF FUTURE FOREST STANDS

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Systematic forest tree breeding activities began in Latvia in the 1950-ies with the selection of Scots pine plus trees, propagation of clones and seed orchard establishment. Thanks to this almost 30 years forest regeneration uses bred seeds to ensure better and more productive forest stands formation. Whereas the breeding cycle of forest trees is long it's essential, not only to keep the information about breeding activities of previous years when the generations of researchers changes, but also the long-term breeding objects (mainly the progeny trials) establishment and maintenance. Forest tree breeding studies are now being carried out in research sites almost 700 hectares and breeding work is structured in «Tree breeding programme for commercially important forest tree species (Scots pine, Norway spruce, silver birch) and aspen in JSC *Latvia's State Forests* for 30 years» (Jansons, 2008) for the single goal – the enlargement of capital value of forests by using in forest regeneration the seed orchard material. In the duration of the programme until year 2015 the controlled crossings were done – 360 new crossing combinations for Scots pine, 120 for Norway spruce, 45 for aspen hybrids and 8 for common aspen to provide material for the next breeding cycle, new progeny tests in area of 183 hectares were established. The result of research activities of previous years are the composition of new, high quality set of clones for the establishment of new generation seed orchards for Scots pine, Norway spruce and silver birch. The establishment the new set of seed orchards is already started to ensure that the results of breeding work as quickly as possible should be used for forest regeneration.

For the production of high value planting material using methods of vegetative propagation 21 Norway spruce clone and 10 new hybrid aspen clones as basic material is registered.

In Latvia around 50 million seedlings and plants for forest regeneration are produced (www.vmd.gov.lv), of which approximately 80 % are bred planting material (category "qualified" and "tested"), thus ensuring the exploitation of the results of breeding work in establishment the new forest stands.

Keywords: *forest tree breeding*

THE DESTRUCTION AND TRANSFORMATION OF *FRAXINUS EXCELSIOR* L. FOREST STANDS IN LATVIA

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According to the State Forest Service data (2011), common ash (*Fraxinus excelsior*) was the most distributed broad-leaved tree species in Latvia. Currently this species is threatened by the fungal pathogen *Hymenoscyphus pseudoalbidus* causing tree death in ash forests in Latvia since end of 1990s. This research aims to provide an overview about the intensity of ash stands decline and to assess the potential for ash natural regeneration. At the moment, there is tendency for the total area of *F. excelsior* stands to decrease. During the time period 2000–2013, the total area of *F. excelsior* stands has decreased in about 1.5 times, therefore losing 531 ha of ash forests per year. The results showed the most rapid decrease of total area for ash stands younger than 40 years. The most intense loss of total area of young *F. excelsior* stands was determined between the years 2001–2003 in the south of the Latvia and 2004–2005 in the north of the Latvia, respectively.

The transformation stages of tree species composition in *F. excelsior* stands has been determined based on long-term investigations over entire Latvia. Nowadays the permanent sample plots in *F. excelsior* stands are mixed stands with some resistant ash trees. The tree composition is presumption and depends on the environmental conditions in region. The Coastal Lowland stand had larger dominance of *Alnus glutinosa*, while the stands of Middle Latvian Lowland were more characterized with tree species *Acer platanoides* and *Quercus robur*. The ash stands in East Latvia had tendency to be replaced by *Tilia cordata*. In some cases even the tree species *Picea abies* could admix in destroyed ash stands.

The main results about natural regeneration of *F. excelsior* stands indicated that ash is maintained as an admixture species. The dominant undergrowth species that regenerated in ash stands were *Padus avium* (58.8 %) following by *Corylus avellana* (18 %) and *Lonicera xylosteum* (9.2 %). The ash regeneration density was significantly influenced by the dominant species in canopy layer and forest type. Besides it has been determined that degree of damage of ash advance regeneration significantly differs between forest types and increases with height/age of ash tree saplings.

STUDIES ON ROOT ROT CAUSAL FUNGUS
HETEROBASIDION ANNOSUM IN LATVIA

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Root and butt rot caused by several species of *Heterobasidion* is one of the most destructive diseases of conifers in the northern temperate regions. In Latvia, an inventory of 25 000 Norway spruce stumps revealed that 21.8 % of them contained butt rot. *Heterobasidion* infects a healthy tree stand by basidiospores and is spread in stands via root contacts.

In Latvia, the most abundant development of fruit bodies was found in the *Oxalidosa turf. mel.* forest type and maximum spore production (on average 35 000 spores per dm^2 in 1 min) was measured in August–September. Results of the study strongly suggest removal of decayed logs and, when possible, stumps from harvested *P. abies* forest sites.

Heterobasidion basidiospore infection frequency differs depending on tree species: in *P. abies* small diameter stumps (55 %) it was significantly higher than in *P. sylvestris* (15 %). Probability of infection by *Heterobasidion* and *Phlebiopsis gigantea* increases with increasing stump diameter for both tree species.

Heterobasidion can transfer via root contacts from *Pinus sylvestris* and *Pinus contorta* stumps left after pre-commercial thinning and clear cutting to adjacent/next generation live trees. *Heterobasidion* genet size and number of genets in *Pinus contorta* stands differs according to site history (in agricultural site – av. 1.7 tree/genet, 186 genets/ha; forest site av. 5.4 trees per genet, 34 genets/ha).

Stump harvesting from clear-cuts is one of the most effective options to reduce *Heterobasidion* and *Armillaria inoculum* on infested forest sites. In 5 experimental plots (established in clear-cuts; with and without stump removal) wood samples were taken for the isolation of the fungi causing root rot. All sites were replanted, establishing permanent plots for long-term observations of root rot development in *P. abies*, and regeneration of deciduous trees such as birch, alder and aspen.

Keywords: *root rot, pine, spruce*

LONG-TERM CHANGES IN FOREST STAND AND GROUND VEGETATION IN HISTORICALLY FORMED LARGE-SCALE CUTTINGS

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Large-scale cuttings are most often result of salvage-logging after natural or anthropogenic disturbances. Size of the cutting is expected to have an influence on moisture level and impact tree growth. To test this assumption, sample plots have been placed in different distance from the edge of cutting site in 5 territories in western part of Latvia, where large-scale logging (creating 200–400 m wide clearcuts) was done after storm of 1967. Previously these sites were assessed by A. Aire (in 1977) and J. Jansons & P. Zālītis (1997) therefore it was possible to characterize long-term changes in the areas.

Distance from the edge of the cutting site was not a significant factor affecting height or composition of young stands, formed after the storm. Such a conclusion had been reached also in previous inventories. Similarly, results of all inventories did not reveal any significant changes in ground vegetation linked to the distance from the stand edge – neither in presence (abundance) of hygrophyte species or species richness, nor values of Ellenberg index. Number of detected ground vegetation species ranged from 35–51 at the outer part of cutting site (up to 50 m from the edge) to 22–40 in the centre of the former clearcuts.

Salvage-logging can be carried out in a way that whole tree biomass (including stumps) is removed from the site. In order to obtain preliminary information on long-term influence of such activity, sample plots for assessment of ground vegetation had been placed in area where whole-tree harvesting (including stumps) was carried out 40 years ago in *Vacciniosa* forest type in Scots pine stand and in neighbouring compartments with mature and young Scots pine stands in the same forest type. Higher number of ground vegetation species was found in the whole-tree harvest (WTH) area (20.5 species per plot on average) in comparison to young (15.0) and old (12.5) stands. Shannon diversity index was higher in young forest stand and WTH area (2.85 and 2.66, respectively) than in old forest (2.31). Additionally, one of the dominant specie in the WTH territory was *Lycopodium clavatum* (24 %) which is threatened species in Latvia. Results indicate complete recovery of ground vegetation diversity even after very intensive silvicultural treatments; however, to generalize the conclusion, more sites need to be surveyed.

Keywords: *forest adaptation, resilience, biotic risks, abiotic risks*

DENDROCHRONOLOGICAL RESEARCH IN ESTONIA: CLIMATIC EFFECTS ON TREE RADIAL GROWTH

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Dendrochronology is one of the most important environmental recording techniques for a variety of natural environmental processes and a monitor for human-caused changes to the environment. Dendrochronology examines events through time that are recorded in the tree-ring structure or can be dated by tree-rings. Trees record any environmental factor that directly or indirectly limits a process that affects the growth of ring structures from one season to the next, making them a useful monitor for a variety of events. Because trees respond to their surroundings, they are subject to climatic stresses such as variations in temperature, rainfall, soil moisture, cloudy days, and wind stress. The relationship between weather and tree growth is not easy to explain, because short- and long-term weather events as well as local ecological conditions affect growth differently.

Due to changing environmental conditions and changing forest management objectives, updated information about trees and their growth is needed. Tree-rings and re-measured Estonian Network of Permanent Forest Research plots (ENFRP) are valuable tools to provide information about tree growth and growth reactions. The dendrochronological studies help to improve the understanding of the growth in forests under the changing weather conditions. Periodic (5-year) re-measurement of ENFRPs provides accurate estimates of tree condition and size at fixed intervals, the dendrochronological approach can provide annual resolution data that also follows the fate of individuals over time. The knowledge of the absence or presence of trends could be used in the decision-making process or building a simulation system.

Keywords: *climate, tree-rings, growth modelling*

MANAGEMENT POTENTIAL OF EVEN-AGE SPRUCE STANDS IN LATVIA – SOME ASPECTS OF STATE RESEARCH PROGRAMME "FOREST AND EARTH ENTRAILS RESOURCES: RESEARCH AND SUSTAINABLE UTILIZATION – NEW PRODUCTS AND TECHNOLOGIES"

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Norway spruce is native to Latvian forests but in forest ecosystems unaffected by forest management even-aged spruce forests are not found. The problems related to the management of even-aged spruce stands are escalated by historical overstocking of young stands and planting of spruce in mesotrophic forest ecosystems, thus attempting to avoid risks created by high population density of browsing herbivores in the past.

According to forest legislation in Latvia, rotation period for Norway spruce is 80 years. Spruce stands may be felled also when mean breast height diameter of overstorey spruce in the stands corresponding to the highest site indices has reached 29–31 cm. This corresponds to the mean diameter in 80 years old stands at present. If spruce stands are intensely managed already from early age, this diameter can be reached sooner. In other cases criteria of sanitary felling must be met but in this case the tree stand has already lost part of its economic value.

In the beginning of 21st century the concept of spruce stand growth potential was introduced (1). It was included in the legislation, and according to this concept spruce stands of reduced growth potential may be clearcut. Evaluation must be carried out using a rather complex methodology based on the relations between annual ring widths of last 5 years and tree diameters. According to calculations performed in 2004, only 20 % of 30–50 years old spruce stands corresponded to criteria of productive and stable forest. 20 % of the stands were evaluated as declining stands and 60% were included in the increased risk group.

To clarify the present condition of even-aged spruce stands in Latvia and to prepare management recommendations, 4 years long research project was started in 2013 in the frames of State Research Programme. The planned activities will provide evidence-based information on the present state of even-aged spruce stands, allow to identify most important management risks and suggest changes in the legislation for the most rational use of even-aged spruce monocultures.

Detailed analysis of the growth potential of even-aged spruce stands will provide information whether the distribution of growth potential groups (declining, increased risk and productive stands) has changed over 10 years since the first evaluation. Obtained results will help to identify those fertile forest ecosystem types where the risks for growing spruce are highest.

Growth rate analysis of even-aged spruce stands of different initial planting density and management regime and stand structure analysis with regard to different timber assortment outcome and economic value are also planned. These results will give basis for management recommendations with the aim to avoid substantial economic losses.

For the management model development, information on the impact of genetic factors on even-aged spruce stand growth and vitality is essential. In the experimental plantations used

for spruce selection some features of stem quality (e.g., stem straightness, branch thickness) are analysed but others, for example, formation of cracks and game damage are not.

Studies in Latvia and elsewhere in the Baltic region have demonstrated that the presence of pollen from forest stands may decrease the genetic quality of seeds from pine seed orchards but there are no corresponding data on spruce. Also relations between genetic factors and spruce growth potential and possibilities to improve the growth potential from this perspective are not studied yet.

There is also a lack of information on the development of root rot in spruce plantations on drained peat soils. During the project sample plots in even-aged spruce stands in different parts of Latvia will be established with a purpose to study the occurrence of root rot, main fungi species causing this disease and the structure of fungal populations.

It is planned to test the hypothesis that in even-aged spruce stands, while volume accumulation continues, so does the spread of root rot in the stem, thus decreasing the economic value of timber. This approach is novel in Latvia, so far tree growth has been evaluated according to external features. These results will be very important for the development of economic model of forest management. Trees infected with root rot often produce wide annual rings and good height increment but formal volume increase does not compensate for the loss of timber value caused by root rot.

At the end of the first decade of 21st century a regional withering of Norway spruce stands was observed in Latvia. One of the cases was the dieback of 40 years old spruce forest in the research forests of Kalsnava forest district. Spruce stands in this area were initially highly productive, at the age of 20 years their current annual increment reached even 20 m^3 ha^{-1}. However, at the age of 40 yellowing of needles and subsequent dieback of stands without any externally noticeable reason took place. As a result, approximately 40 ha large clearcut was formed. In the first year of the project this area was used for experimental plantation with different tree species and initial planting densities.

Programme activities are managed by:
Zane Libiete, PhD
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Dainis Rungis, PhD
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POTENTIAL IMPACTS OF CLIMATIC CHANGES ON FORESTRY: MAJOR ASPECTS IN LATVIA

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Notable changes in meteorological indicators important for tree growth and vitality are predicted. Due to rise of temperature sum of active temperature will increase by 780–900 degree days and length of vegetation period by 35–62 days, leading to earlier onset and later cessation of growth. Total amount of precipitation will remain unchanged or increase slightly (during winter), but its distribution will change – longer (5–7 days) periods without precipitation will become more common.

Results of process-based growth models as well as dendrochronological analysis suggests increase of tree growth (annual increment) due to climatic changes, however, genotypes adapted to current climate will not be able to fully utilize improved growing conditions. Storms will be the major factor causing damages in forests both due to rising frequency of the event and longer periods of un-frozen, wet soil during the winter (decreasing the stability of trees), when most of storms occurs in Latvia. Additionally, longer vegetation period might lead to storms in a situation when broadleaved trees still have leaves, increasing the amount of damages in their stands. Climatic conditions will become more favourable for most of dendrophagous insects both due to increasing temperature (closer to optimum temperature for most of species) as well as longer vegetation period (allowing successfully formation of more than one generation per year). Therefore modelling results suggest that forest areas affected will increase.

To reduce the potential damages measures increasing individual tree stability (wide initial spacing, early precommercial thinnings) are recommended, especially in most wind-prone territories or regions likely to be affected by freezing rain. Preventive measures, improving the living conditions for natural enemies of dendrophagous insects, as well as efficient system to stop mass outbreak of insects, if it is predicted to cause notable mortality of trees, are recommended. Measures to increase vitality of trees (melioration systems in wet sites, wood ash fertilization in peat soils) can significantly reduce the amount of damages (and mortality) during an insect outbreak and considerably improves the recovery of trees in specific cases.

EFFICIENCY OF WATER QUALITY PROTECTION MEASURES AFTER DRAINAGE SYSTEM RENOVATION IN STATE FORESTS OF LATVIA

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In Latvia, approximately 700 000 ha of forests are ditched; most drainage systems were established between 1960 and 1980. 25 % of state-owned forests are located on drained soils. To ensure proper functioning of ditches, it is necessary to carry out maintenance works and periodic renovation of drainage systems. Renovation works can cause erosion and transport of nutrients and solid particles, causing pollution and eutrophication of water courses and water bodies. Dissolved nutrients increase the intensity of biological processes, accumulation of organic matter, development of algae and cause overall decline of water quality. Suspended solids decrease water transparency and photosynthesis, thus influencing occurrence of aquatic plants and other aquatic organisms. There are several methods to decrease risk to water quality, aiming to prevent erosion by reducing stream velocity and to stop transport of particles, e.g., barriers, sedimentation ponds, overland flow areas and buffer areas. One of the most common methods is the establishment of sedimentation ponds before the inflow of the main ditch in the water course. Main ditches collecting water from the feeder ditches, transport the largest quantities of water and thus have most important role in erosion and sediment transport. It is mandatory to establish sedimentation ponds when renovating a drainage system longer than 0.8 km in the state forests of Latvia. An alternative method, mainly used in Nordic forestry, is the establishment of overland flow areas slowing down the water flow and facilitating infiltration of water before it can reach the water body.

Two pilot projects were carried out in the frames of the Forest Sector Competence Centre program to obtain first results on the efficiency of standard sedimentation ponds and experimental overland flow area in the state forests. Water samples from seven sedimentation ponds and one experimental overland flow area were analysed during the project from 2012 to 2014. General principles of water protection while implementing drainage system renovation, as well as results from the pilot projects are presented.

Keywords: *water quality, drainage system renovation, sedimentation ponds, overland flow areas*

ASSESSMENT OF CARBON SEQUESTRATION DYNAMICS IN OLD FOREST STANDS

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Forest has an important role in carbon sequestration and mitigation of climatic changes. Precise and accurate models are available to characterise carbon sequestration in forest up to mature age, however information about carbon accumulation and release in over-mature stands without any management is scarce and there are no previous studies covering this aspect in hemiboreal forests. Therefore, to acquire preliminary information on factors affecting these processes, sample plots have been placed in 22 over mature (exceeding cutting age by at least 2 age classes) stands (dominated by Scots pine, Norway spruce, birch, black alder, common aspen) in forest types where particular tree species are most common.

Total amount of carbon accumulated in over mature stands on average exceeded that in mature stands. Major differences were observed both in accumulation in biomass and soil. Differences in accumulation in biomass were mostly linked amount of carbon in dead-wood: volume of dead wood in over mature stands notably and significantly exceeded that in mature stands (data: NFI). It was found, that current growth models needs to be calibrated to accurately estimate the increment in over mature stands. Radial increment of Scots pines at the age 80–160 years was significantly higher than that at the age exceeding 160 years; similarly significantly lower increment was found for Norway spruces exceeding age 200 years and black alder exceeding age 100 years.

Somewhat surprisingly proportion from total amount of carbon in soil was lower in older stands, reaching on average 52 % (from 33 to 60 %) in comparison that in mature stands, where mean value was 64 %. Amount of carbon accumulated in soil decreased, when the stand exceeded mature age and increases again, when second layer in stands were formed. However, notably higher number of samples would be needed to accurately describe changes in soil carbon in relation to age of the stand, therefore the studies will continue.

REFORESTATION WITH PLANTING OF SILVER BIRCH: ESTABLISHMENT AND PLANTING STOCK

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Silver birch (*Betula pendula* Roth.) is an economically most important broadleaved tree species in Latvia. High quality birch logs are desirable raw material for the plywood production industry, which has become one of the leading branches of the domestic wood processing industry. Silver birch is included in national forest breeding programme and production of birch planting stock is ensured using genetically improved seeds from indoor seed orchards.

As the pioneer tree species the silver birch has ability to regenerate naturally after final felling in forest lands. Therefore main use of silver birch planting stock so far was the establishment of plantations on former agricultural fields. In nowadays there is an increased interest in establishment of birch plantations also in forest lands to ensure the wider use of genetically improved birch material for better productivity and quality of future birch stands.

Over the last years the amounts of silver birch plantations on forest lands has increasing trend reaching 980 ha in year 2015 mainly being practiced in state and companies owned forests. However, a relatively high mortality of birch seedlings in first years after outplanting observed in many plantations has challenged the forest professionals and researchers to improve the planting stock quality and establishment technologies to achieve better results. A series of studies has been performed to discover the shortcomings during the establishment process starting at forest nurseries an ending up with tending of new stands. In current study the first results in identification of potentially harmful pests causing dieback of birch seedlings after outplanting are presented. The research is still in progress, however, a few practical recommendations can be suggested already to improve the establishment of birch plantations on forest land including development of better practice in birch planting stock production at forest nurseries and ensuring the proper weed control of newly planted seedlings on fertile sites.

IMPACT OF FREEZING RAIN ON FOREST STANDS: A CASE STUDY IN EASTERN PART OF LATVIA

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Snow and ice accumulation on trees caused by freezing rain is an important abiotic factor with strong influence on forest composition, structure and dynamics over large portion of the northern Europe. Only specific combination of meteorological conditions can cause this phenomenon, therefore freezing rain events are local i.e. do not affect large regions. Even so the mean temperature is predicted to rise in future, there is no basis to expect, that assess factors determining the amount of freezing rain damages in forest stands. Tree species composition, structure, age and amount of damage were evaluated in 156 stands in eastern part of Latvia (Ziemeļlatgale region) after a freezing rain event at the end of December. At the time of the event soil in forest was not frozen. In each stand tree height, height of the crown base (the height of the lowest living primary branch), diameter at 1.3 m height and condition of tree (no damage, bent, uprooted or broken) were assessed in ten sample plots (size 500 m²), altogether characterizing 16 875 trees. Weighting of Scots pine sample trees demonstrated that accumulation of ice on trees was strongly correlated with their above ground biomass ($r = 0.92$, $p < 0.01$) increasing its weight 1.5 ± 0.27 times.

Proportion of damaged first layer trees was similar for both coniferous species: for Scots pine (*Pinus sylvestris*) 19 % of trees were broken and 7 % bent or uprooted, for Norway spruce (*Picea abies*) – 22 % broken, 5 % bent or uprooted. Proportion of damaged trees was significantly influenced by forest type. Tinning in last 3 years prior to freezing rain event influenced the proportion of damaged trees; however, mostly slender, lower canopy (partly suppressed) trees were affected. Height of stem breakage point was dependent both from tree species and age and most frequently it was 25–30 % from total tree height.

Binary logistic regression was used to detect stand parameters determining, if the stand was severely affected (basal area of remaining trees below 50 % of the minimal basal are). Stand basal area before the freezing rain event (in relation to basal area of fully stocked stand) was the only parameter in the model for Scots pine. In contrast, for Norway spruce also mean height, diameter and height/diameter ration were significant.

Keywords: *stem damages, uprooting, ice damages, coniferous stands*

ECOLOGICAL RISKS OF FOREST MANAGEMENT: ASSESSMENT METHODS AND RECOMMENDATIONS – DEER BROWSING

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In Latvia, data on forest damage due to ungulate browsing has been collected randomly and only concerning particular tree species (ash in early 1980-ties, spruce in early 1990-ties) or immediately recognised damages, caused during winter (by Latvia's State Forest Inventory Institute and State Forest Service). The damages across young forest stands, their dynamics and delaying impact on forest regeneration are unknown. Also information on damage scale according to ungulate density, use of tree protection methods, hunting intensity and management activities at damaged and also intact forest stands is lacking. These problems have been investigated by a research, started in 2014, in which sample plots at young pine, spruce and aspen stands were selected and first 150 plots were investigated. The plots were distributed across the whole territory of the state according to forest distribution and tree-stand composition, regardless to forest ownership or judicial manager.

Preliminary conclusions and suggestions:

Although 150 plots sampled in one year can not provide statistically probable estimates on condition of young tree stands and impact of deer browsing on forest regeneration, one can conclude that the primeval results of the research confirm the concern of forest specialists about increased damages, caused by animals. Yong pine stands are particularly vulnerable.

Not all cases of low tree numbers at young stands result from recent browsing damages. Damages may have occurred earlier, the dominant species may have disappeared due to other biotic and abiotic disturbance or management failures, and also obvious errors in forest inventory data have been found.

Unlike to popular opinion, that most forest damages are caused by elk, this research indicate, that out of the three species (elk, red deer and roe deer), the most significant risk to forest regeneration is caused by the red deer.

Some corrections in sampling methods are necessary, which have already been introduced in year 2015. One of such corrections is inclusion of data on birch and other tree species in young pine, spruce and aspen stands, which will permit to follow the stand development, particularly when the dominant tree species is naturally replaced with another, but still remains in the inventory data at State register of wood land cover.

ABSTRACTS OF POSTER PRESENTATIONS

WOODWORKING WASTEWATER TREATMENT WITH ALUMINIUM-BASED COMPOSITE COAGULANTS AND SORPTION PROPERTIES OF FORMED COAGULATES

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Wastewater of woodworking plants are characterized by the high degree of contamination, because they contain hemicelluloses, lignin and wood extractive substances (HLES). The usage of physico-chemical methods, especially methods of coagulation is an effective way to purify wastewater. In the work, a comparative study of the coagulation effectiveness of a model solution, simulating woodworking wastewater, with the known composition of polyaluminium chloride (PAC) with aluminium sulphate and a new PAC-based composite coagulant was carried out. In comparison with the known coagulant, the developed composite coagulant essentially enhances the efficiency of the wastewater treatment and decreases the content of residual aluminium therein, which allows to recycle the treated water in the technological cycle. The enhancement of the coagulation ability of the developed composite coagulant is governed by the formation of the polynuclear Àl-complexes with a high-molecular structure. In the process of wastewater treatment by coagulation, a large amount of sediment is being produced. Within the scope of this work the coagulates that are being formed during the coagulation of the model wastewater were studied. The formed coagulates are characterized by the low sludge volume index within 30 minutes (89 ml g^{-1}), and the optimal time of sedimentation is 20–30 minutes. The coagulate particles have an average size of 45.8 μm. The obtained coagulates contain carbon (27.9 %), oxygen (49.4 %) and aluminum (10.9 %). Carbon, oxygen and hydrogen belong to an organic part of coagulate – the wood pollutants, which, in turn, has a high content of hemicellulose. It was found that the formed Al-containing coagulates may be used to modify a clay in order to increase its sorption properties in relation to inorganic and organic oils and heavy metal ions.

Keywords: *woodworking wastewater, PAC-based composite coagulants, coagulates, sorption properties*

SYNTHESIS OF LIGNOPOLYOL AND PRODUCTION OF POLYURETHANE FOAMS

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Rigid polyurethane (PUR) foam is one of the most important materials used as thermal insulation of buildings, refrigerators, cold stores, pipes, refrigerated transport, and in chemical and food industries. PUR foam consumption is predicted to increase in the future steadily. The application of renewable resources instead of petrochemical raw materials is one of the main directions in modern development of PUR foam chemistry and technology.

Lignin, the most abundant natural phenolic polymer, is separated from the plant biomass as by-products in results of hydrolysis and pulp making processes. Free phenolic and aliphatic hydroxyl groups allow lignin application in PUR foam compositions. In present work the Biolignin™ obtained in the result of wheat straw organosolv processing was investigated as a component of PUR foam systems. Different separate approaches of lignin introduction into PUR foam system were studied: as filler without chemical preprocessing and as liquid lignopolyol obtained by lignin oxypropylation in alkali conditions. The incorporation of increasing amount of lignin as filler into reference PUR foam systems on the basis of mixture of commercial polyethers Lupranol 3300 (70 %) and Lupranol 3422 (30 %) steadily decreased the compression characteristics of foams, their dimensional stability and hydrophobicity. The complete substitution of Lupranol 3300 by lignopolyol increases its cell structure uniformity and dimensional stability and does not reduce the physical-mechanical properties of foam. In both cases the incorporation of lignin into PUR foam leads to the decreasing of maximum values of thermodegradation rates. The lignin filler can be introduced into lignopolyol based PUR foam in higher quantity than in the reference Lupranol based PUR without reduction of compression characteristics of material. In this work the optimal lignin content in PUR foam as both polyol and filler is 16 %.

During outdoor exposure, polymers chemically degrade due to the influence of short wavelength ultraviolet (UV) rays present in the solar spectrum. The service life of polymers in outdoor applications becomes limited due to weathering. The weathering leads to a rapid decrease of the polymer's physical properties. Overall results suggest that PUR foams from lignopolyol show better performance against photodegradation.

THE EFFECT OF FUNCTIONALIZATION OF LIGNOCELLULOSIC MICROPARTICLES ON WETTABILITY OF POLYMER COMPOSITE

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The aim of the work was to evaluate the wettability of the initial and the functionalized wood microparticles as well as the composite samples consisting of recycled polypropylene and these lignocellulosic microparticles using contact angle, water sorption and Zeta potential (ζ) measurements. The contact angle was determined with a tensiometer Kruss 100M. For the modification, at first, the hardwood lignocelluloses were treated with low temperature acid hydrolysis under mild conditions, and then, the fractionated hydrolysed microparticles were modified by introducing the new functional groups at their surface. The composite samples were prepared from the raw blends composed from recycled polypropylene and the lignocellulosic microparticles in the wide range of a filling degree (10–50 %) by the extrusion and the moulding method using HAAKE MiniLab II and MiniJet device. The composites containing the modified microparticles were characterised by the enhanced advancing and receding contact angles, which did not dramatically decrease with the growth of the filling degree, as well as by a smaller contact angle hysteresis in comparison with the same indexes of the composites filled with the hydrolysed microparticles. All the factors indicated the improvement of the wettability of the modified lignocellulosic microparticles towards the polymer matrix. This conclusion was supported by better physico-mechanical properties of the composites filled with the modified microparticles in comparison with the same properties of the composites containing the initial and hydrolysed wood particles.

Keywords: *functionalized lignocellulosic microparticles, wettability, polymer composites, contact angles*

THE BIOREFINERY BASED APPROACH TO THE BARK PROCESSING

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The yield of bark varies from 2–4 % up to 10–12 % from the total tree biomass. Low cost bark as fuel is major argument for its usage for energy production. Unique composition of bark biomass, possibility of obtaining of numerous value-added products make tree bark the classic object of biorefinery. In this work the different schemes of hard and softwood bark biorefinery processing are discussed. The elaborated regimes of sequential extraction allow to isolate a wide range of biological active products: diarylheptanoids, pinosylvins, salicin, tannins etc. The yield and composition of these products depend on the tree species origin and method of isolation. The identification of extracted components was realized using variety of chromatography methods. The antioxidant properties of extracts obtained their microbiological and biological activity for plant and human organism, were proved by authors using various independent tests and made the basis for proposal of high value added products for cosmetic and pharmacy, food industry, agricultural and production of ingredients for composite material. At the same time, it was shown that it possible to develop different biorefinery links for some of extracted products: e.g., condensed tannins can be used for production of adhesives or for polyetherpolyol synthesis etc., or not to be extracted and remains in solid residue. The lower viscosity of tannins based polyols is the significant advantages of this products. Oxypropylated tannins were successfully applied as macromonomers for rigid polyurethanes (PUR) foam production using handle mix method. The solid residue after extraction (about 80 %) could be used in two different manners: high durable fuel pellets production and oxypropylation of bark residue for liquidpolyols production usable for PUR foams making. PUR foams from polyols containing both 30 % of bark residue and tannins were characterized by closed cell content >90 % and high compression strength. The choice of the final biorefinery scheme will be regulated by market demands and regional conditions.

Keywords: *biorefinery, bark*

EVALUATION OF OXIDATIVE RESISTANCE OF MAYONNAISE ENRICHED WITH ALDER BARK EXTRACT

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Alder bark (*Alnus incana, Alnus glutinosa*) is a rich source of diarylheptanoids that reveal a strong antioxidant activity. It was estimated that dominating compound in bark ethyl acetate extracts of alder trees grown in Latvia is oregonin. Oregonin is structurally close to curcumin – a natural polyphenol extensively used as food supplement and widely known to experts in medicine by its high level of human health protection. The concentration of oregonin in dry extracts varied between 70 % and 85 %. High antioxidant activity of ethyl acetate extracts was confirmed by several antioxidant tests (ABTS•+, DPPH•, ORAC and Oxipress). Addition of 0.5 %, to 0.01 % of alder extracts to mayonnaises significantly improves its oxidative stability. The data of Oxipress test have shown that induction period (IP) of oxidation for mayonnaise without antioxidant is 1.9 h. Addition of 0.25 % of alder bark extract increase IP up to 4.4 h. Mayonnaise enriched with alder bark extract was more resistant than commercial mayonnaise, used as a sample for comparison and prepared from the same basic ingredients. Ethyl acetate extracts from alders bark are useful for mayonnaise or other salad dressing stabilization against rancidification when these dressings are stored after opening for a long time in a refrigerator.

Keywords: *alder extracts, mayonnaises, oxidative stability, food additive*

SCOTS PINE GROWING IN LATVIA AS A SOURCE OF PINOSYLVIN STILBENES

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The content and distribution of pinosylvin stilbenes in Scots pine (*Pinus sylvestris*) wood, sampled in Latvia, have been investigated. Results indicated that heartwood from pines grown in the wet forests have higher pinosylvins content than for trees grown in the dry forests. Our results showed that contents of pinosylvin andpinosylvin monomethyl ether in heartwood varied in the range of 0.1–2.0 % (w/w), depending on the height of sampling from the ground. The highest content of pinosylvins was observed for the samples taken at 0.5 m height of tree from ground. Comparison of pinosylvins content in the heartwood of 90 and 60 years old pine trees has shown that for the latter it is higher (0.86 and 2.0 % w/w, respectively). Screening of pinosylvins content in pine trees, using boring technique, (heartwood was taken at the height 0.5 m from 30 pine trees of 50–60 years old grown in wet forests) showed that pinosylvin and pinosylvin monomethyl ether content can achieve more than 2 % on wood dry mass. All heartwood hydrophilic extracts showed antioxidant activity close or higher than the reference sample Trolox (water-soluble analog of vitamin E). The crude ethylacetate and ethanol water extracts of heartwood were purified by preparative liquid chromatography. The results showed that pinosylvin with a higher purity (> 85 %) can be obtained from water ethanol extract, but pinosylvin monomethyl ether with higher purity (> 95 %) can be obtained from ethyl acetate extract. The analysis of extracts from industrial waste of wooden windows frames (Scots pine taken from Latvian forests) manufacture demonstrated that these waste have good prospects for pinosylvins production due to the pinosylvins yield was of 2 % w/w).

Keywords: *heartwood, Scots pine, pinosylvins*

EVALUATION OF GREY ALDER BARK TANNIN AS PHENOL SUBSTITUTE IN THE SYNTHESIS OF PHENOL-FORMALDEHYDE RESINS SUITABLE FOR PLYWOOD

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With the aim to develop green adhesives for wood, an adhesive system formed by condensed tannins (CT), isolated from grey alder bark, polyethyleneimine (PEI) and phenol-formaldehyde resins (PF) including this one containing micro/nanoparticles of extracted bark as a filler, and a PF resin, where CT were used as phenol substitute on the synthesis stage were studied for plywood manufacture. The results of the gluing quality tests have shown that the modulus of elasticity of plywood glued using the (CT-PEI):PF based adhesives with 40–60 % substitution of PF was very close to that for plywood obtained with the traditional 100 % PF glue and meet the European norms EN 312 (2004) in terms of share strength for plywood used both in indoor or outdoor conditions. Introduction of extracted bark residue micro/nanoparticles into composition of adhesives investigated led to increasing of physical-mechanical properties and strength of gluing. The experimental PF resin was prepared by substitution of 20 % phenol following processes proprietary of CHIMAR. The produced resin had properties close to that of a typical PF resin. Plywood panels produced with this CT:PF resin (PFT) may be used for exterior application. The resins obtained using both (CT:PEI) gel and CT extract are suitable for the fabrication of plywood panels for interior application because their formaldehyde emission is very low.

Keywords: *wood adhezives, grey alder bark, condensed tannins, polyethylenimine*

NOVEL ALKYD-LINSEED OIL EMULSION FORMULATIONS FOR WOOD COATINGS

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In our experiment a water-based emulsion, suitable as a coating for wood protection, was obtained. The binders of this emulsion are linseed oil and an alkyd, mixed in a ratio 1:2, together they constitute 15 % in concentration of the formulation, and water is 80 %. The first step consisted in testing of several surfactants: the main factors considered were the nature of the surfactant and its hydrophile-lipophile balance (HLB). The majority of surfactants used in coatings formulations are anionic and non-ionic amphiphiles, such as fatty alcohol sulfates, alkylaryl sulfonates and alcohol ethoxylates. In our experiment only non-ionic surfactants were used, and results confirmed that the most suitable surfactants are ethoxylated non-ionic types, with a high HLB values comprised between 12.5 and 14.4, while surfactants based on gemini technology showed a poor efficiency, due to scarce solubility in water, which led to separation of phases. An ultrasonic homogenizer was used to facilitate the formation of the emulsion. A good achievement was the elimination of co-solvent, which is usually always present also in water-based coatings. Once the optimal emulsion composition was obtained, tests were carried out to compare the efficiency of three driers Co, Ca and Zr in the formation of film from water emulsion. Each drier was tested singularly, and added to the emulsion at the same concentration (0.10 %). To evaluate the drying rate 2 g of emulsion were put in an aluminium plate and let dry at room. Quite a number of studies have been reported comparing the efficiency of different combinations of driers in both water-borne and solvent-borne alkyd paints (Van Gorkum *et al.,* 2005). According to our results, Zr and Ca, respectively secondary drier and auxiliary drier, used alone are not effective in promoting the cross-linking reactions in the film formation: even after a week the binder is not dried yet and it has an oily consistence. Co, a primary drier, is more efficient: the formation of the film is visible after 24 hours, but it's not complete, it takes about 2 days to the complete evaporation of water.

Keywords: *water-borne, wood coating, surfactants, linseed oil-alkyd emulsion*

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LIFE CYCLE ASSESSMENT AS A TOOL TO EVALUATE WOOD PRODUCTS IMPACT ON ENVIRONMENT

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Life Cycle Assessment (LCA) is a methodology to ascertain product or process impact on environment that takes into consideration energy and other resource inputs, as well as waste and pollution outputs. The application of this methodology lately becomes widely used and to ensure comparable results, the area is highly standardized. The LCA conducting is regulated by International Standards ISO 14040:2006 and ISO 14044:2006. Environmental Product Declaration (EPD) is a tool to communicate LCA results and it must comply with a standard ISO 14025:2006. EPD for various products is regulated also with Product Category Rules (PCR) and in case of construction products PCR are included in standard EN 15804:2012+A1:2013. LCA of wood construction products include forest management, harvesting, transportation, wood product manufacturing, building construction, usage, demolition, transport, waste processing, disposal as well as reuse, recovery and recycling potential. Apparently – quite an extensive circle. And this leads to the main problem of conducting LCA – limited accessibility of relevant data, as well as variance of data quality. This makes LCA time and money consuming. Data usage from generic databases (such as Ecoinvent) can facilitate data obtaining, however, obtaining raw data requires team work with forest sector. The results of this team work could be highly beneficial: Fouquet *et al.* states that the energy use for constructing concrete houses (cast concrete and concrete block house), takes up to 40 % of its overall impact on global warming. For timber-frame houses, the total impact reduction due to biogenic carbon, leads to an increase of the share of energy use to 70 %. LCA is a convenient methodology to highlight advantages of wood product sustainability and EPD`s are expected to become a part of an effective marketing communication in order to give consumers information about environmental effects of products and production processes to satisfy their demand for enhanced environmental achievements.

Keywords: *life cycle assessment (LCA), wood products, impact on environment*

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FINANCIAL VALUE OF SILVER BIRCH BREEDING

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Stands dominated by birch cover almost one third of Latvia's forest area according to data of National forest inventory (NFI). Therefore considerable effort has been put into breeding of *Betula pendula*: more than 900 trees were selected and open-pollinated progeny trials established.

Results of these trials, obtained at the age of 10 and 14 years, demonstrate that selection would result in a notable gain both in productivity and quality, since measured traits had high heritability: height up to the first green branch (determining the length of the stem section, where natural pruning had begun), number of dry branches in first two meters (characterizing the speed of natural pruning) as well as tree diameter (describing the potential speed of healing-over of branch wounds) had high heritability: $h^2 = 0.33 \pm 0.023$, $h^2 = 0.27 \pm 0.010$ and $h^2 = 0.45 \pm 0.026$, respectively.

Information from trials was used as input for growth models (developed based on NFI data). Simulation demonstrated that use of selected (improved) birches in forest regeneration would ensure 30 % higher yield in final harvest (determined by age – 71 year). To test these results data from a grafted seed orchard (no pruning or other silvicultural treatment carried out prior to measurements) at the age of 40 years, but reaching the target diameter for final harvest (28 cm) were used. In the seed orchard yield significantly exceeds the average in birch stands at the same age (275 ±9.9 m^3 ha^{-1} *vs.* 228 ±14.9 m^3 ha^{-1}, respectively) and didn't differ from the average at cutting age (71 year). Selection of 10% best clones (the selection intensity used in praxis) ensured 28 % gain in yield – similar to that calculated based on growth models. Also similarly than in younger open pollinated trials, genotype (clone) had significant effect on all traits characterizing productivity (heritability for height and diameter: $H^2 = 0.14$ and $H^2 = 0.21$, respectively), quality (for branch traits $H^2 = 0.14...0.33$) and defects (e.g. stem cracks). Notable variation in monetary value (based on assortment structure, considering both diameter and quality) was found between clones, ranging from 16.5 to 42.0 EUR tree^{-1} on average. No significant correlation between ring productivity and wood density were found.

Results indicate a notable potential to improve productivity and reduce rotation age of silver birch stand while combining the best genotypes with appropriate silviculture.

Keywords: *Betula pendula, spacing, wood quality, stem value*

ASSESSMENT OF SUPERIORITY OF SCOTS PINE PLUS TREES

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Monetary value of Scots pine to a large extent is determined by its branch quality, in particular – length of branch-free section of a stem and its volume. Therefore already in a plus tree selection process quality traits, like shape, width and length of the crown, branch thickness and angle, length of branch-free part, were assessed. Progeny trials are used to estimate heritabilities and breeding values of particular traits, however, their age limits assessment of several quality traits, for example, natural pruning rate. Information on potential improvement of the quality of trees is important in calculation of financial gains from Scots pine breeding. Therefore aim of our study was to assess the branch quality traits of plus-trees and factors affecting them.

Analysis was based on 192 plus-trees, selected in *Vaccinosa* and *Hylocomiosa* forest types, assessed at the age of 71–135 years; for a comparison dominant trees from National forest inventory sample plots in pure Scots pine stands (altogether 569 trees) were used.

Breast height diameter of plus-trees in *Vaccinosa* and *Hylocomiosa* was 35.8 ±0.95 cm un 37.7 ±1.95 cm, respectively, tree height: 29.7 ±0.52 m and 29.9 ±0.99 m; both diameter and height significantly exceeded that found for dominant trees in forest stands. Plus trees, in comparison to dominant stand trees, had higher absolute and relative values of traits, characterizing branch-free section of stem. Average length of branch-free section for plus-trees was 15.3 ±0.50 m (51 ±1.5 % from tree height), its volume 1.0 ±0.06 m^3 (76 ±1.7 % from stem volume). Tree age and forest type had a significant influence on volume of branch-free section of stem; wit the age it was increasing faster for plus trees (0.010 m^3 y^{-1} in *Vaccinosa* and 0.018 m^3 y^{-1} in *Hylocomiosa*) than for dominant trees of stands (0.006 and 0,009 m^3 y^{-1}, respectively).

Tree height in both forest types for both plus-trees and dominant stand trees had a positive correlation with length of branch free part (r = 0.44...0.56) and with its volume (r = 0.63...0.75), but week (for plus-trees – not significant) correlation with the proportion of volume of branch-free part form total stem volume. Notable superiority of branch traits affecting monetary value of a stem was found for plus-trees in comparison to dominant stand trees.

Keywords: *branch-free section of stem, tree height, stem quality*

PLASTICITY OF SCOTS PINE, SILVER BIRCH AND BLACK ALDER FAMILIES AND TREE BREEDING

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Scots pine, silver birch and black alder open-pollinated families of Lithuanian populations were studied in a series of field trials. Phenotypic plasticity of families for total height, stem diameter, stem straightness, branch thickness and angle, branch number, wood hardness and survival was calculated based on the data from five Scots pine, three silver birch and two black alder field trials. The assessments were done on 140 families from 7 Scots pine populations (at age 30), 100 families from 24 silver birch populations and 85 families from 17 black alder populations (both broadleved species at age 8–13). The progeny trials have randomised complete-block design with 5 replicates and 10 tree line plots per family at spacing of 1...2 × 1.5 m.

The highest percentage of plastic families in all three species was observed for branch thickness and number, also for wood hardness. Majority of Scots pine and black alder families showing plasticity in several traits had the highest complex selection index estimates and were selected to the next breeding cycle. The number of plastic families will increase with progressing practical breeding in Scots pine and silver birch.

Keywords: *Pinus sylvestris L., Betula pendula L., A. glutinosa (L.) Gaertn., half-sib families, field trials, tree breeding, phenotypic plasticity*

THE EFFECT OF TENDING AND COMMERCIAL THINNING ON GENETIC DIVERSITY OF SCOTS PINE STANDS

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We aimed to investigate the effects of pre-commercial and commercial thinning on the genetic diversity of Scot spine stands. The material consisted of two autochthonous Scots pine stands. We studied the DNA polymorphism in a natural stand of age 60 and a young stand of age 20 planted with seed orchard seed at 5 genomic and 7 gene based microsatellite markers. Within each of these stands ca. 400 trees were systematically sampled within 1 ha plots (800 trees in total). There was no significant association between heterozygosity, common allele frequency and tree diameter in both stands. Inbreeding coefficient tended to increase with increasing diameter in the mature but not in the young stand. There was a tendency for a higher allelic richness of the thick trees in the mature; however no such tendency was observed in the young stand. Even at a high intensity, both the simulated tending treatment and commercial thinning had minor effects on heterozygosity and allelic diversity but caused a significant loss of rare alleles. However, there was a nonlinear relationship between the loss of rare alleles and the thinning intensity in the young stand, such that below 30 % thinning intensity, the rare alleles were lost at a markedly lower rate.

Keywords: *forest management, genetic diversity, heterozygosity, thinning*

PROPAGATION OF COMMERCIALLY SIGNIFICANT TREE SPECIES (SILVER BIRCH, NORWAY SPRUCE AND HYBRID ASPEN) BY TISSUE CULTURE

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Various tissue culture techniques can be used in order to accelerate breeding process and thus are important tool in modern forest science. Silver birch (*Betula pendula* Roth.), hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) and Norway spruce (*Picea abies* L.) are some of commercially most valuable tree species in Latvia and therefore adequate propagation protocols should be established for these taxa.

Silver birch is propagated with microcuttings in order to produce plants for experimental plantations. Current aim was to determine optimal concentration of cytokinin 6-benzylamino-purine (BAP) and zeatin for multiplication of genotype Bau 40-17. Plants were propagated on Woody Plant Medium supplemented with three different cytokinin concentrations. Morphological parameters – shoot length, lateral shoot number, rooting rate and multiplication rate were determined. Best multiplication of particular genotype was observed when propagated on media supplemented with 1.0 mg L^{-1} for BAP and 1.0 mg L^{-1} for zeatin.

Hybrid aspen is also propagated with microcuttings. Current aim for hybrid aspen propagation was to determine multiplication abilities of most productive clones (86-15-06, 97-13-07, 105-23-06, 130-13-07). Plants were propagated on two Murashige & Skoog type media supplemented with either 0.1 mg L^{-1} Indole-3-butyric acid (IBA) and BAP 0.2 mg L^{-1} or 0.1 mg L^{-1} IBA and the multiplication rate was determined. We observed that addition of cytokinin BAP increases multiplication rate significantly reaching values 3.18 ±0.11 to 3.96 ±0.28 and thus should be used for propagation.

Somatic embryogenesis is acknowledged as most superior technique for conifer propagation. Some progress has been achieved in current work with norway spruce using protocol developed by Y.S. Park but there are still a lot of problems encountered mainly due to explant incapability to continue rooting during last stage of propagation (when propagated plants are transferred to peat substratum).

Keywords: *Silver birch, hybrid aspen, Norway spruce, microcuttings, somatic embryogenesis*

GENETIC DIVERSITY, FINGERPRINTING AND POPULATION STRUCTURE OF ECONOMICALLY SIGNIFICANT *SALIX* SPECIES

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Current estimations predict that the use of wood biomass for energy production will increase over the next decade. One way to meet the increased demand would be the establishment of short rotation plantations using willow, osier, alder and other species; given that Latvia has appropriate agroclimatic conditions for the cultivation of these species.

The willow and osier genus (*Salix*) is in the willow family (*Salicaceae*). Species with tree forms are designated as willows, but shrub forms – as osiers. There are 18 native *Salix* species in Latvia, of which *S. viminalis*, *S. triandra* and *S. dasyclados* could potentially be used for biomass production. In addition, the species *S. purpurea*, *S. alba*, *S. viminalis*, *S. triandra* and *S. acutifolia* are used for wicker production.

Salix samples collected from throughout Latvia were analysed with 5 chloroplast DNA markers: ccmp 2, ccmp 3, ccmp 10, ccmp 7, ccmp 4, ccmp 6 (Weising *et al.*, 1999), and genetic diversity was determined with 6 nuclear microsatellite markers: SB 38, SB 80, SB 243, SB 201, SB 194, SB 199 (Barker *et al.*, 2003).

Genotyping of Latvian populations of *Salix alba* and *S. viminalis* with nuclear and chloroplast SSR markers enabled investigation of the genetic diversity, population differentiation and the extent of clonal propagation. The investigated *S. alba* populations were less differentiated than the *S. viminalis* populations, which was also supported by the chloroplast data. Only two chloroplast haplotypes were found in *S. alba*, while seven were found in *S. viminalis*. Both species showed a high level of clonal propagation. The utilised nuclear SSR markers were also able to distiguish commercially cultivated *Salix* cultivars, confirming their utility for genetic fingerprinting.

Keywords: *short rotation plantations, biomass, Salix, population structure*

SUITABILITY OF HYBRID POPLAR *POPULUS BALSAMIFERA* × *P. LAURIFOLIA* FOR FOREST REGENERATION IN LATVIA

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High productivity and wide potential of wood utilization facilitate interest in *Populus* species and their hybrids in Northern and Baltic countries, thus information of potential yield, dimensions and biomass is necessity to increase cultivation of these species. The aim of the study was to assess the suitability of poplar hybrid for forest regeneration in Latvia.

The study was based on 14 stands of hybrid poplar *Populus balsamifera × P. laurifolia*, located in the central and western part of Latvia (56…57°N, 22…23°E). Stands were established at the density of 5000–7000 trees ha^{-1} on mineral soil with normal moisture regime (forest types *Oxalidosa* and *Aegopodiosa*) and fertile drained mineral soil (*Mercurialiosa mel.*). No silvicultural measures had been carried out prior to data collecting at the age of 51–65 years. Diameter and height was measured for each tree and an equation developed based on 24 sample trees was used to estimate above-ground biomass.

Forest type significantly ($p < 0.05$) affected the average diameter at breast height and stem volume. The mean diameter and height in stands varied from 29 ±1.6 cm to 45 ±3.9 cm and from 24 ±0.9 m to 31 ±0.8 m, respectively. The stands on fertile drained mineral soil reached superior dimensions with the mean volume of stem 1.88 ±0.15 m^3, in comparison with 1.31 ±0.04 m^3. The radial growth peaked at the age of 15–20 years. Yet, even in stands much older than that the mean annual increment reached 11.8 m^3 ha^{-1} per year, in some stands exceeding 21 m^3 ha^{-1} per year. The above-ground biomass (leafless) ranged from 212 to 624 t ha^{-1} dry matter, corresponding to mean annual increment 4.2–9.8 t ha^{-1}. Stem biomass formed 86.0 ±3.6 %, however trees with larger diameter tended to allocate more biomass in living branches. The results suggest that hybrid poplar could be suitable for forest regeneration in Latvia.

Keywords: *productivity, yield, above-ground biomass*

GROWTH AND WOOD PROPERTIES HYBRID ASPEN CLONES IN LATVIA

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Hybrid aspen (*Populus tremuloides* × *P. tremula*) is the most widely used *Populus* hybrid in Northern Europe, characterised by a relatively fast growth on fertile soils. Breeding objectives of hybrid aspen include not only productivity, but also stem quality, wood density, fibre properties and cellulose content in wood, since the plantations of it can be establish and managed with main goal of solid wood or pulp wood production (varying with the initial spacing and thinning regime).

Growth models for selected hybrid aspen clones have been developed, indicating, that its men annual increment reaches 18 m^3 ha^{-1} y^{-1} at the age of 15 years, and close to 20 m^3 ha^{-1} y^{-1} at the end of recommended rotation period (20 years). To assess the potential additional income, above-ground biomass models have been developed, using sample trees from 12 and 19 years old stands. Results revealed that larger trees tend to allocate higher proportion of biomass in branches (on average 36 % from total above ground biomass) in comparison to smaller tree (22 %). Overall, collection of logging residues for chip-wood production in final harvest of hybrid aspen stand can be a profitable operation.

Mechanical strength of wood correlated tightly with its basic density. Analysis of sample tree from different plantations was used to estimate that basic wood density ranges from 350 to 434 kg m^{-3} for hybrid aspen and it does not correlate with productivity of a particular clone i.e. clones having fast growth and relative high wood density can be found and selected for commercial propagation.

Wood chemical analysis demonstrated, that outcome of Kraft pulp (50.6 ±1.4 %) for hybrid aspen was slightly lower than that of common aspen both on forest (52.2 ±1.2 %) and former agricultural lands (52.5 ±0.1 %), but wood fibres were significantly longer (0.99 ±0.05 mm). The thin and long fibres of hybrid aspen form a mechanically strong paper.

Keywords: *mean annual increment, basic wood density, Kraft pulp yield*

ESTABLISHING A SYSTEM FOR GENETIC MONITORING IN WILDLIFE POPULATIONS

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Information about the status of wildlife populations is essential for development of conservation plans, to set hunting quotas and restrictions, as well as to monitor changes in the populations over time or due to particular disturbances. As a member of the European Union, Latvia has undertaken a series of commitments to maintain a favourable status for wildlife populations.

Monitoring of wildlife populations is complicated by the difficulty of obtaining an accurate population size, determination of reproductive success, identification of migrant individuals and estimation of demographic stability. A large amount of information can be obtained by undertaking a census of hunting bags (for species where hunting is allowed), including age, fecundity, health status etc. However, no information is obtained about family structure, genetic diversity or relationships with other neighbouring populations.

DNA markers are increasingly being utilised to investigate these aspects of wildlife populations. They can be used for determination of genetic diversity and familial relationships, as well as large scale population structure.

The aim of this project was to establish an integrated system of wildlife monitoring, including demographic surveys, genetic analyses and the integration of these approaches to enable development of comprehensive wildlife management plans in Latvia.

Keywords: *wildlife monitoring, genetic analysis, game management, pedigree reconstruction*

POST-STORM REGENERATION AND STAND STRUCTURE OF NORWAY SPRUCE (*PICEA ABIES* (L.) KARST.) IN *OXALIDOSA* FOREST TYPE

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Studies of natural succession using series of repeated measurements are very time consuming, therefore different stand parameters are used to reconstruct the possible stand development as well as reveal the impact of natural disturbances. Aim of our study was to quantify parameters of stands forming after large-scale windstorm in absence of any management.

We conducted our study in Slitere Nature Park – in a forest landscape with total area 1645 ha. Most of SNP was affected by windthrow in November 2, 1969, no management has been taking place after the storm. Altogether 28 circular sample plots (within stands of different dominant tree species: aspen (9 plots), birch (5), mixed – aspen, birch, black alder, spruce (6) and spruce (8)) with radius 12.62 m were established in *Oxalidosa* forest type. In each sample plot diameter of trees at breast height (if ≥6.1 cm) was measured; tree height was measured and increment cores taken from at least 15 trees per plot and from all trees surviving the wind storm.

Influence of windthrow on forest landscape was considerable as forest reduction by 53.3 % in year 1972. Norway spruce has not regained its dominance in most of the study area even 44 years after the storm. Basal area of stands was significantly (p < 0.01) affected by dominant species: for areas dominated by aspen it was 47.4 ±1.05 m^2 ha^{-1} (mean ±SE), for birch 42.6 ±0.97 m^2 ha^{-1}, mixed 38.3 ±2.30 m^2 ha^{-1} and spruce 36.1 ±2.72 m^2 ha^{-1}. Regeneration by seeds has played important role in establishment of stands both for Norway spruce and other tree species. Our results suggested that only 5 % of all trees currently present in the plots have survived the storm; majority of these trees (70 %) had been advance regeneration when the storm occurred. In the first ten years after the disturbance 50 % of currently growing other tree species and 45 % of spruces had been established. Diameter distribution in Norway spruce stands differed significantly (χ^2 = 350.6, p < 0.001) from diameter distribution in stands dominated by other tree species. Our results reveal statistically significant (p < 0.05) differences of the mean values of the parameters of three-parameter Weibull distribution between stands in *Oxalidosa* forest type.

Keywords: *natural succession, advanced regeneration, natural disturbances*

DORMANCY RELEASE AND WINTER FROST DAMAGE IN SCOTS PINE SEEDLINGS

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In this study we investigated dormancy status of one-year-old Scots pine seedlings under semi-controlled environment with the aim to assess (a) how much forcing is needed to break the dormancy an induce an active growth of one year old seedlings of Scots pine (free growth) under different dates in winter, (b) the response of different populations to the forcing treatments. The material consisted of seedlings from 4 populations: Finland, Lithuania, Russia (Ural region) and Spain. Seedlings were grown outdoors in containers in a nursery in central Lithuania. Staring from November 2013, the seedlings were treated with high temperatures of various duration, and fluctuation manner. The results showed that in general the effects of forcing were less significant at the firs than at the second half of winter. At the start of winter, the one year old seedlings treated with 3 weeks of +18C (natural photoperiod) initiated active growth. Whereas, one week was sufficient for active growth initiation when seedlings were sampled at the second half of winter. However, the duration of forcing was population specific, where the continental populations were least dormant. We concluded that warm temperatures especially during the second half of winter when the one-year-old seedlings are at the stage of quiescence may lead to frost damage, especially if continental origins are used.

Keywords: *Pinus sylvestris, quiescence, rest, population, provenance, continental-maritime*

LOW DENSITY NORWAY SPRUCE STANDS: PRELIMINARY ASSESSMENT

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Increasing frequency of wind storms and favourable conditions for spruce bark beetle are predicted in future due to climatic changes. Therefore it is important to assess the potential to use plantations with low initial density to increase the stability and shorten the rotation period of Norway spruce in production forests.

Tree height and diameter has been measured in three experimental sites in central (Valgums E1 and Valgums E2, 56°59'N, 23°18'E) and eastern (Kalsnava, 56°42'N, 25°53'E) part of Latvia, established on former agricultural land on fertile mineral soil with normal moisture regime (corresponding to *Oxalidosa* forest type). Clones of Latvian Norway spruce plus trees were grafted and planted in 1964 with initial spacing 5 × 5 m, no thinning carried out before the measurements in 2014. Stem volume and volume of branch-wood was calculated using formulas developed in Latvia (Liepa, 1996; Liepa, Blija, 2008). For a comparison National Forest Inventory data from Norway spruce stands on fertile soils at the same age and at the rotation age were used. Assortment structure was calculated according to Ozolins (2002) and average prices of year 2014 used.

Stand density in the trials was extremely low, mainly due to low survival at first years: in Valgums E1 – 200, in Valgums E2 – 220 and in Kalsnava – 264 trees ha^{-1}; that was twice lower than in spruce stands at the same age (528 trees ha^{-1}) and significantly lower than density of mature stand (357 trees ha^{-1}). Mean breast height diameter in trials was from 37 ±0.7 to 40 ±1 cm, notably exceeding target diameter for final felling and diameter in stands at the age of 80 years. Differences in tree height between two of the trials and mature stands were not significant. In one trial height was lower than in mature stands, but exceeded mean height of trees in stands at the same age (50 years). Consequently, also mean stem volume at the age of 50 years in trials was significantly larger than in forest stands and exceeded also that of mature stands; selection of 10 % most productive clones resulted in 39 % higher stem volume than for the rest of the clones in the trials. Mean annual increment in trails was from 4.7 ±0.5 to 8.6 ±0.95 m^3 ha^{-1} y^{-1}. Net present value in two of the trials was higher than in stands of the same age and in all – than in mature stands. Results demonstrate considerable potential to use stands with low density, established by selected seed material, to reduce length of rotation period, achieve high financial return and reduce the risks of damages.

Keywords: *risk management, plantation, rotation period, increment*

INFLUENCE OF NEEDLECAST ON GROWTH OF YOUNG SCOTS PINE STANDS

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Favourable weather conditions for needlecast caused by *Lophodermium seditiosum* were observed in recent years – humid and warm autumn and mild winters. Impact of meteorological and genetic factors on needlecast damage, and relationship between degree of damage and growth of trees had been assessed for Scots pine.

Three series of experiments were analyzed at age 2–4: a) open-pollinated progeny trial that consists of 226 families from 13 provenances of Latvia, established in two localities (Tukums and Kalsnava); b) control-crossed progeny trial that consists of 72 crosses from 10 parent trees (7 Ugale clones «Ug» and 3 Kalsnava clones «Ka»), established in two localities (Zvirgzde and Kalsnava); c) open-pollinated progeny trial that consists of 60 families from 5 provenances of Latvia, established in Daugmale.

Needlecast damage was assessed in five grade scale according to proportion of damaged needles of the last height increment: 1st grade – 0–5 %, 2nd grade – 6–35 %, 3rd grade – 36–65 %, 4th grade – 66–95 % and 5th grade – from 96–100 %. Meteorological data were obtained from the Latvian Environment, Geology and Meteorology Centre.

Needlecast damage grade in open-pollinated and control-crossed progeny trials are statistically significantly ($p < 0.001$) influenced by location (climate). Genetics (family, group of controlled crosses, provenance) has a statistically significant ($p < 0.05$) influence on needlecast damage grade in all sites; also genotype x environment interaction was significant.

Mean height increment was significantly ($p < 0.05$) lower for the trees with a higher degree of needlecast damage, and the difference increased from the first year of observed infection to the third.

Keywords: *needlecast, Scots pine, young stands*

INFLUENCE OF FOREST FIRE ON SCOTS PINE (*PINUS SYLVESTRIS* L.) AGE STRUCTURE AND REGENERATION PATTERN

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The occurrence of forest fires in hemiboreal forest ecosystem is a part of natural disturbance regime which has significantly changed in last few centuries: human activities became a dominant (>90 %) cause of forest fires and fires suppression became increasingly more efficient. There is very limited information on the historical fire regime in hemiboreal forest zone and it is hard to reconstruct, since areas dominated by Scots pine stands older than 200 years, suitable for collection of data on former forest fires, are very scarce. Aims of our study were: 1) to compare regeneration and growth dynamics of Scots pine in post-fire and clearcut areas; 2) to assess historical forest fire regime and stand structure in the part of ancient Baltic Sea basin in Slitere National Park.

The data to assess regeneration and growth dynamics differences between post-fire and clearcut areas were collected in four Scots pine dominated forest stands located in northern and central parts of Latvia (56°45´...57°40´N; 22°32´...24°98´E) burned or clearcut in 1992, 2004 and 2006. In each study site height and height increment of Scots pine and other tree species was measured. The data to assess historical forest fire regime were collected on dry sandy soil (former sand dunes) in the area of large forest fire that occurred in 1992. Full or partial cross sections of dead wood were taken to stump height and processed. For reconstruction of age structure increment cores were taken from largest living pines across the area with an interval of approximately 500 m.

The most abundant tree species in natural regeneration in post-fire area on poor wet and dry soils was Scots pine. However on sandy loam soils and peat soils birch dominated. Birch dominated also in all forest types in natural regeneration. The density of Scots pine trees was significantly affected by the forest type but not by regeneration method. Our results demonstrated that 6–8 years after the forest fire mean height of Scots pine was notably and significantly lower in burned areas compared to clearcut. Differences were not observed in stands at the age of 22 years, indicating only temporal effect of fire on growth of next generation of trees. From all sampled Scots pines 33 % were more than 200 years old. Last fire of 1992 left scares on 16 live trees and 11 % of sampled dry trees (average age 160 years) had died as a result of it. Based on fire scars 23 different fire events were identified in the studied forest landscape.

Keywords: *natural disturbances, natural succession*

IMPACT OF WIND AND FREEZING RAIN DAMAGES ON FRAGMENTATION DYNAMICS OF FOREST LANDSCAPE: CASE STUDIES IN LATVIA

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Changes of structure of forest landscape depend to a large extent from natural disturbances. Storms are the major natural disturbance in Northern Europe. Its impact is predicted to rise in future due to climatic changes. In contrast freezing rain usually affects relative small areas, but also its impact can be stand-replacing and frequency has not been predicated to decrease due to climatic changes.

Impact of natural disturbances depends not only from stand parameters, but also from characteristics of particular event (like amount of freezing rain and wind speeds during it or maximum wind speeds, their duration and frequency) and other external factors, e.g. if soil is frozen, dry or wet. Therefore results of the study of a specific case have to be generalized with caution; however, it still provides useful insides into effect at landscape-scale.

We selected two separate disturbance areas. First was located in north-western Latvia in forest area (~1600 ha); that was un-managed since 1923 and affected by large storm in November of 1969. The second study site was located in south-eastern Latvia in managed forest area (~6000 ha) that was affected by freezing rain event in December 2011.

Supervised classification of Corona and Landsat 5 images of the area from years before and after the storm (1966 and 2010) was carried out, while to assess freezing rain impact on the forest fragmentation image data consisted of Landsat 5 and 8 images acquired in 2011 and 2013, respectively. Information extraction from remote sensing images was carried out with segmentation and supervised classification in Grass Gis 6.4.3. and Quantum-Gis 2.2.0. Based on field observations and visual inspections of recent Google Earth® images and 1973 forest inventory maps from archive of LSFRI Silava, 3 different land classes were delineated: forest areas, areas with low woody biomass, non-forest areas. FRAGSTATS 4.2 spatial pattern analysis software was used to quantify fragmentation, we selected eight landscape metrics: class area (CA, ha); class proportion in landscape (PLAND, %); mean patch size (AREA_MN and AREA_AM, ha); number of patches (NP); patch density (PD, number/100 ha); edge density (ED, m/ha); mean shape index (SHAPE_MN).

After the disturbances number of patches in forest landscape decreased, but mean patches size increased. Also other parameters (shape index, edge density etc.) changed notably proving, that natural disturbance (windthrow) can temporarily increase fragmentation in the landscape. Similar effect of freezing rain was observed. Most of the analysed landscape indicators had returned to values observed prior the storm in 20 years.

Keywords: *natural disturbances, forest landscape, long term natural succession*

MONITORING OF *FRAXINUS EXCELSIOR* L. FOREST STANDS IN LATVIA – A REVIEW OF RECENT RESULTS

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In Latvia, intensive destruction of ash stands started around 15 years ago. Because of this 20 sample plots were chosen in year 2005 with the aim to describe transformation of ash stand structures over the entire Latvia. The established sample plots were located in different regions of Latvia for long-term investigations. The studied plots were selected from middle-aged, pre-mature, mature and over-mature stands. In each chosen forest stand the volume of *Fraxinus excelsior* was higher than 50 % from total volume (living trees).

The plots had circular shape with radius 15 m (total area 706.5 m^2). The inventory of ash sample plots was planned to be done in three years 2005, 2010 and 2015. In each plot the following parameters of stand were counted: living trees, dead standing trees, logs, stumps. The tree-ring width measurements were collected and assessments of tree crown condition were described. In additionally the advanced regeneration and undergrowth species were counted, as well inventory of plant species and analysis of soil chemical properties were done.

During the period 2005–2015 15 sample plots were surveyed while 5 were destroyed for various reasons. The results showed (total 15 plots) that in this time period 2005–2015 the number of ash trees has been decreased by 63.5 %. In the same way the amount of living tree species *Ulmus glabra* (–14.7 %), *Alnus glutinosa* (–2.6 %) and *Picea abies* (–6.1 %) was reduced. However the number of individuals of *Acer platanoides* (150.0 %), *Tilia cordata* (50.0 %), *Quercus robur* (7.7 %), *Populus tremula* (155.6 %) and *Padus avium* (90.0 %) has been increased in canopy layer.

The obtained results indicated that the number of ash individuals has been decreased in plots that are characterized with higher proportion of *F. excelsior* in canopy layer. The first two research periods were showing the most rapid destruction of *F. excelsior*. As well there was tatistically significant correlation between number of ash individuals and other tree species individuals ($r = 0.79 > \alpha_{0.05}$). Summarizing the observed relationship could indicated that *F. excelsior* are more resistant in mixed forest stands.

Keywords: *Fraxinus excelsior, long-term investigation, ash stands*

THE DYNAMIC OF SHRUB LAYER IN *FRAXINUS EXCELSIOR* L. FOREST STANDS IN RESPONSE TO ASH DIEBACK IN LATVIA

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Due to intense extinction of common ash *Fraxinus excelsior* caused by pathogenic fungus *Hymenoscyphus fraxineus*, the rapid changes in new trees (advance growth) and shrub (undergrowth) species composition and densities were observed in the ash forests. This process indicates the beginning of shrub overgrowth. Therefore, the aim of this research was to determine potential stand species composition und examine how successful the natural regeneration could be in the future.The investigation was carried out in 15 plots in different regions of Latvia during the period of 10 years (2005, 2011, 2015). In each plot (235.5 m^2) the number of new trees and shrub shoots was counted and their height was measured. In total 10 species were examined in advance growth, mostly *Fraxinus excelsior, Acer platanoides* and *Ulmus glabra* (occurrence >70 %). In total 20 species were determined in undergrowth, mostly *Padus avium* and *Corylus avellana* (occurrence >70 %). The density of new trees and shrubs was quite similar in years 2005 and 2011, but in the year 2015 it was significantly different and had almost doubled. During the 10 years period he proportion between new trees and shrubs was 36 % : 64 %. Together the highest density of new trees was for tree species *Ulmus glabra, Acer platanoides* and *Fraxinus excelsior*. In the year 2015 the density was significantly increased of two species – *Acer platanoides* (5189 tree ha^{-1}) and *Fraxinus excelsior* (5792 tree ha^{-1}) comparing with previous years. In undergrowth the highest density in all periods was for three species *Corylus avellana, Padus avium* and *Lonicera xylosteum*, the density for these species significantly increased in 2015. There is a tendency that the average height of shrubs and new trees decreased. It has been more pronounced for young trees with could be the result of height number of small (0.5 m) ash trees. The largest average height of new trees was compared for *Picea abies, Betula pendula* and *Ulmus glabra*, but in undergrowth for *Corylus avellana*. According to changes in species composition in stands we could predict how ash stands are changing in time. That could indicate the various ash stands transformation trends in the future.

Keywords: *advance growth, undergrowth, Fraxinus excelsior*

BILBERRY RAMET AGE AND SIZE STRUCTURE

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The dwarf shrub layer is an important part of forest ecosystems that is affected by tree canopy. While development of tree layer (stand) has been much studied, little is known of dwarf shrub growth or age and size distribution. In this study, bilberry samples were taken from a managed Scots pine *Vacciniosa stand* with age ~110 years and a semi-natural (un-managed) Norway spruce *Myrtilloso-polytrichosa* stand with age > 270 years. Three plots were randomly placed in each site. Within every plot, 10 to 12 subplots were regularly placed. Five bilberry ramets were collected from each subplot. In the laboratory, length of the aboveground part, stem diameter and annual ring widths for collected ramets were measured. In both sites, relative cover of bilberry, which might be used as an indicator of habitat quality, was ~30 % and the differences between sites were non-significant (p-value > 0.05). Mean annual ring width was significantly smaller (p-value = 0.03) in the *Vacciniosa* compared to the *Myrtilloso-polytrichosa* site that might be explained by differences in stand parameters and management history. The distribution of height, diameter and age of the ramets differed between the sites. In the *Myrtilloso-polytrichosa* site, ramets with diameter of 3.1–4 mm were the most abundant, compared to diameter class of 2.1–3 mm in the *Vacciniosa* site. Bilberry ramets, like trees in a natural forest, had diverse height, diameter and age structure. The *Myrtilloso-polytrichosa* site was dominated by ramets of 20.1–40 cm in height. The maximum age of the studied ramets was 12 years, which is common in southern boreal forest, although it was considerably lower than the maximum age of 40–100 years in alpine environments where growth and decomposition is slower. The age structure of ramets in both sites had a reverse J shape, with the exception that the occurrence of 5–6 year old ramets was considerably higher than other age classes. Comparing both sites, the kurtosis indices were lower in *Vacciniosa* than *Myrtilloso-polytrichosa* (3.09 and 3.71, respectively) suggesting smoother distribution of ramet parameters.

Keywords: *Vaccinium myrtillus, dwarf shrubs, ground cover vegetation, dwarf shrub dynamics*

THINNINGS IN YOUNG STANDS

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Targeted forest management that includes both forest regeneration and precommercial thinning leads to notable increase of the monetary value of a forest stands. Significant information has been gathered on thinning effect in birch stands; however, additional data are needed on the reaction on thinning in stands of other species as well as on effect of different thinning regimes. Therefore during last 4 years more than 150 new experimental sites with various thinning intensities have been established in young forest stands across Latvia, mainly in areas managed by Forest research station. Results from these sited will be available in years to come, therefore, to obtain data for modelling immediately, temporary sample plots have been placed in thinned and un-thinned stands. Data form increment cores were used to calculate effect of thinning (changes in increment) according to methodology developed by Prof. I. Liepa.

Results from 18 thinned (during the recent 10 years) and 10 unthinned stands of silver birch growing on fertile soil demonstrated, that additional increment differed notably between sites, but mainly it was positive, ranging from 0.94 m^3 ha^{-1} (from −6.1 to +9.1 m^3 ha^{-1} in particular sites) to 4.28 m^3 ha^{-1} sixth and tenth year after the thinning, respectively. The results of modelling suggested that highest financial value can be obtained by planting the stand and thinning at the age of five rather that than currently advised 15 years. Results from 15 Scots pine stands (age of 14–28 years) demonstrated a similar trend: increase in average annual ring width 4–6 years after the thinning ranged from 2 to 71 % (26 % in average). Both thinning intensity and age of the stand at the moment of thinning were statistically significantly linked to magnitude of changes of radial increment resulting from thinning ($r = 0.88$, $p = 0.01$ and $r = 0.64$, $p = 0.05$ respectively) – higher thinning intensity (lower remaining basal area after thinning) in younger stands (average tree height 6.1 m) lead to larger increase of the increment.

Keywords: *thinning intensity, additional increment, growth response*

EDGE EFFECT IMPACT ON ADDITIONAL STEM VOLUME INCREMENT AFTER GROUP SHELTERWOOD CUTTING IN PINE STANDS IN *MYRTILLOSA* FOREST TYPE

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Previous investigations show different reaction of trees to the stand spacing and mainly these studies are done in middle-aged and pre-mature stands. There are only a few studies of the reaction of stands after a shelterwood cutting. The study was done in 5 Scots pine stands in *Myrtillosa* forest type where group shelterwood cutting were performed 6 to 10 years ago. There were selected 2 or 3 gaps in each stand. Around each gap were measured 4 circular plots in uncut forest part. In each plot were sampled pines with increment borer (totally 269 pines). At least 40 trees per stand in 5 control stands were sampled with increment borer as well (totally 234 pines). Additional increment method was used in order to determine the response of trees to the gaps. It was found out that in the uncut stand parts closer than 7 m from gap edge additional increment was positive already in the first years after group shelterwood cutting. Six years after cutting the cumulative additional increment in the stand parts closer than 7 m from the gap were 2 to 5 times greater compared to the stand parts in the distance greater than 7 m and the differences were significant (at the 95 % confidence level) in 4 of 5 stands. Our results shows that when evaluating the stand increment after group shelterwood cutting, it must be taken into account that additional volume increment will be observed only around harvested gaps, and the longer the distance between gaps, the larger the area where additional volume increment will not be observed. The tendency of decreased width of annual rings and additional increment in a part of the stands was observed after the storm of 2005, however no significant ($p > 0.05$) effect regardless of the distance of trees to the gap edge has been observed.

Keywords: *Pinus sylvestris, group shelterwood, additional increment, distance to the gap edge*

RESULTS OF HYBRID ASPEN PLANTATION FOREST FERTILIZING

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Necessity for alternative energy sources, in order to diminish usage of fossil fuel and increase local renewable energy sources, are increasing worldwide. The biomass is considered as one of the most perspective alternative energy sources in Latvia and Hybrid aspen is fast growing tree used for biomass production in short rotation coppice cultures in Latvia. *Populus* spp. is one of three SRC which are financially supported by direct support scheme [1;2]. As the fertilization positive efficiency on tree growth is proven by several researchers but with discrepant results the aim of this study is to determine the most appropriate soil fertilization method and type of fertilizer installing hybrid aspen plantations on agricultural land.

During the study were measured heights and diameters to aspen clone No 4 (*Populus tremula × tremuloides*) after four year rotation cycle in two different plantations with similar soil chemical structure. Each plantation is divided into four replicates with different fertilizers – digestate, wastewater sludge, wood ash and one replicate with no fertilizer – control. In each plantation was used the same fertilizer in the same amount but with different fertilization method – in planting spot under the root system during planting and scattering in soil before planting.

During the work were recognized significant differences in tree growth among fertilization methods. It was concluded that using fertilization method by scattering the fertilizer in soil the best effect on the growth and only relevant difference among control to the aspen hybrid No 4 gives the digestate fertilizer. But using other fertilization method – applying fertilizer strait under the roots, best effect on the growth is recognized to waste water sludge fertilizer.

Keywords: *Hybrid aspen, fertilization*

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RESULTS OF PRIVATE FOREST OWNERS SURVEY ON FOREST REGENERATION AFFORESTATION OF NON-FOREST LANDS

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Within the project «Monitoring of private forest management and forest ownership consolidation and cooperation process» 1,124 from all 111,836 forest owners were surveyed. Most of the forest owners (97 %) property size in Latvia is up to 50 ha and most of the forest owners (84 %) that were surveyed in this project represented small forest estates or estates up to 50 ha. More then a half of forest owners (58 %) with property size more then 50 ha deal with coppice forestry and 70 % of them some part of the property manage as coppice forest. Common species in coppice forests are birch (71 %), aspen (60 %), gray alder (51 %), black alder (12 %), willows (9 %), other species (7 %) and 3 % didn't answered on this question. Forest owner with property size up to 50 ha or small size property owners more often mentioned willows and grey alder as main coppice forest species. Coppice system where coniferous trees are planting additionally to deciduous trees are using half of he forest owners. Mainly because of the final felling age for aspen, 30 % of respondents answered that they use rotation period of 40 years for coppice forest, 29 % practice rotation period under 15 years, what is common cutting age for grey alder and plantations forests, rotation period longer then 40 years practice 8 % of respondents. Soil preparation before planting do 20 % of all respondents, from them 23 % prefer mounds and 75 % prefer furrows. From all respondents 24 % are not decided yet about short rotation coppice (SRC) establishment in nearest future and 9 % are considering possibility to establish SRC plantation within the next few years.

RESEARCH ACTIVITIES OF MECHANIZATION OF THE FOREST REGENERATION PROCESS

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The forest regeneration and afforestation research group resumed investigations on mechanization of forest regeneration in 2007 after a gap of twenty years since the last activities in this area. Main experimental activities took place nearby Riga in cooperation with *Rīgas meži* Ltd. and JCS *Latvia's State Forests* (Fig. 1). The first studies were targeted on mechanized planting of coniferous and deciduous container seedlings on mounds. In cooperation with *Intrac* Ltd. mechanized planting device Bracke P11a was tested to evaluate productivity in Latvian conditions when pine, spruce or birch seedlings are planted on various soils (silt, loam and clay). Two methods were compared in the study: direct mechanized planting on mounds and manual planting in area prepared by disc trencher. The study approved that in conditions characteristic to Latvia mechanized planting of one seedling takes less time, but due of requirement to plant more trees per ha in compare to Nordic countries, planting of one ha takes more time. Ingrowth of seedling was the same or better in compare to ordinary in late autumn plantings.
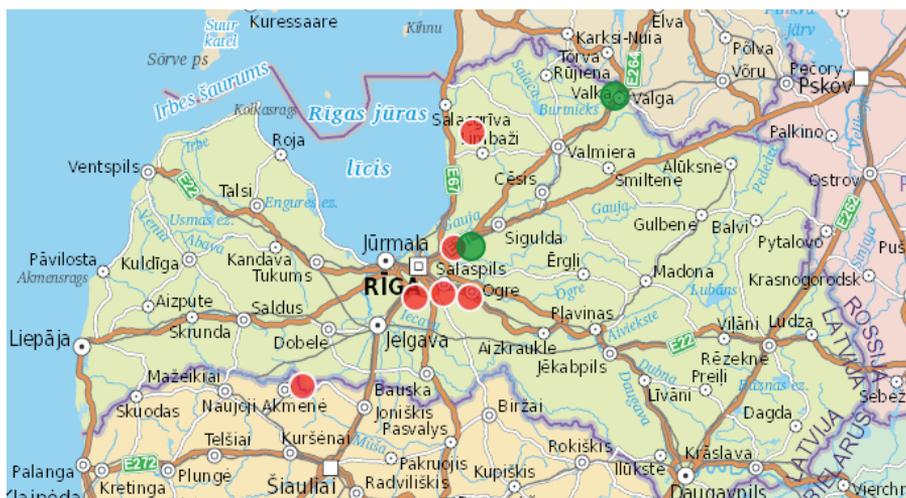
Figure 1. Location of forest regeneration mechanization trials in Latvia
(green – sowing, red – planting on mounds).

One year later mechanized planting device M-planter was tested in *Rīgas meži* Ltd. forests. Results of mechanized planting with the device having two planting tubes, which is able to prepare simultaneously two planting spots, demonstrated better productivity (25 % less time per ha in compare to Bracke P11.a).

Trials of mechanized sowing were done twice – the first experiments with Bracke S35 sowing device mounted on Bracke M25.a mounder were established nearby Riga in 2008, second set of trials of mechanized sowing by Sigma and disc trencher was established nearby border of

Estonia, close to Valka city. Both sowing experiments established hiring service from Estonia, where sowing is ordinary forest regeneration practice. Results of sowing in all stands are good and sowing was recommended for implementation as forest regeneration practice for pine on bare sandy soils.

IMPACT OF APPLICATION OF LARGE AMOUNT OF WOOD ASH ON NORWAY SPRUCE (*PICEA ABIES* (L.) H. KARST.) AND SCOTS PINE (*PINUS SYLVESTRIS* L.) SEEDLINGS AND SOIL PROPERTIES

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Effect of wood ash on spruce and pine juvenile growth and nutrient concentration in soil after spreading of ash in high concentrations before and after planting of seedlings were investigated in peat forests in the eastern part of Latvia. Objective of the study is to investigate the effect of wood ash application on the development of seedlings and the chemical content of the soil after the application of wood ash and ten years later. Wood ash (6 and 12 thousands kilograms per hectare) was applied before the planting of spruce and pine containerized seedlings in 2003. In the peat forest site wood ash was used for fertilization and liming in concentrations of 5, 10, 15, 20 thousands kilograms per hectare immediately after the planting of pine containerized seedlings in 2004. Changes of soil pH, content of macro-nutrients P, K, as well surviving of trees and height of trees were measured in the fourth and twelfth month after planting and after ten years. Fertilization with wood ash one year before planting of seedlings using 6, 12 thousands kilograms per showed more positive response on coniferous growth. Even after ten years spruce planted on fertilized plots are significantly taller, sturdier and more vigorous.
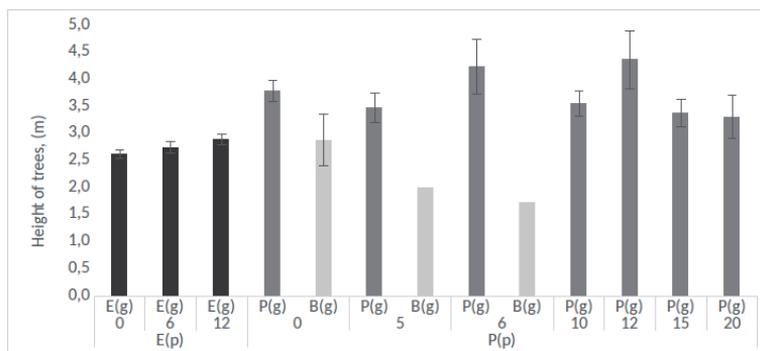
Figure 1. Height of trees 2014.
Tree planted specie (E(p) – *Picea abies,* P(p) – *Pinus sylvestris*)/treatment (0–20 thousands kg ha^{-1}); tree growing on plot specie (E(g) – *Picea abies,* P(g) – *Pinus sylvestris,* B(g) – *Betula pendula*).

Needles of trees which grew on more intensively fertilized plots contained more potassium and lower content of nitrogen. Soil samples from fertilized plots contained more P, K in soil below 20–40 cm and showed up to two units higher levels of pH than samples from control plots. Concentration of P in needles increased, but N contend were decreased by increasing of amount of wood ash used for fertilizing.

Keywords: *Fertilizing, wood ash, spruce, pine, soil, forest regeneration*

WOOD PROPERTIES AND LINKED GENE EXPRESSION IN SCOTS PINE (*PINUS SYLVESTRIS* L.) DURING EARLY AND LATE WOOD FORMATION

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Scots pine (*Pinus sylvestris* L.) is one of the most ecologically plastic and variable forest tree species, and it is also a species of high economic importance in Northern Europe. Wood properties like wood density, secondary cell wall thickness are highly variable even within a single tree and are affected both by endogenous and exogenous factors, but some of them are more geneticaly controlled than others. Information about gene expression involved in wood formation are mostly available for crop or model plants, for forest tree species there are still lot of knowledge to gain. From our selected wood formation related candidate genes three genes are involved in lignin biosynthesis (*PAL1, CCR, CAD*), one in water transport (*Aqual*) and one in sucrose biosynthesis (*SuSy*). Genes from developmental processes were selected to investigate whether a link can be established between candidate gene expression and wood density and to estimate variation of gene expression in trees from open pollinated tree families growing in natural conditions.

SilviScan was used to comprehensively characterise the wood properties of 50 trees. First year samples for gene expression analysis were collected from 50 29 years old trees with known wood density in spring and autumn. For second year gene expression analysis only 15 trees were sampled, with higher gene expression variation, detected during first year experiment. These trees were sampled at five time points during early wood (EW) and 5 time points during late wood (LW) formation. Gene expression analysis was performed using Real time PCR using the relative standard curve method.

Significant positive correlation was found between wood density and gene *SuSy* expression during early wood formation. For the *Aqual* gene, there was a negative correlation between gene expression and wood density during early wood formation. Additional wood trait data obtained with SilviScan will be presented and discussed in relation with the gene expression data.

Keywords: *wood properties, Scots pine, SuSy, Aqual, PAL, CCR, CAD*

SEASONAL GROWTH DYNAMICS OF NORWAY SPRUCE AND BLACK ALDER

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Increase of air temperature and prolongation of periods without precipitation, forecasted for Northern Europe during next century, may have notable implications on growth of Norway spruce and black alder, known as water deficit intolerant species. Increased transpiration and reduced availability of soil water may affect rehydration rate of xylem and phloem tissues. Hydration of tissues in combination with a formation of the xylem causes a shrinkage/swelling dynamics of the stem. Therefore, data on changes of stem circumference obtained from dendrometers is favourable information to explain changes in water storage of tissues and stem growth. The aim of the study was to compare differences in fluctuations of stem circumference of Norway spruce and black alder during a whole vegetation season.

Observations of seasonal tree growth dynamics showed frequent changes of stem dimensions during the vegetation season. Onset of the enlargement of stem circumference in black alder started 20 days later than in spruce; however, both trees had similar cumulative growth in the end of the season. Stem circumference of black alder enlarged more rapidly than in spruce in days with high amount of precipitation following warm days with high vapour pressure deficit (VPD) in the end of June and the begging of August. Water used in transpiration initially is supplied by inner storage which refills in following evening or rain event. Magnitude of rehydration reflects both water consumption in transpiration previously (during the day) and refiling capacity of inner storage. Compared with spruce, black alder had notable reactivation of circumference fluctuations after mid-July, a period without precipitation, increased VPD and mean daily maximum temperature around 20°C. Moreover, black alder had larger decrease of stem circumference in following no-precipitation days with high temperature and VPD after moist and cool period in mid-August suggesting less efficient inner water storage of the stem compared with spruce.

Results suggest that predicted altered precipitation regime in future may negatively affect growth and vitality of both species, but black alder is more sensitive to expected changes.

Keywords: *radial increment, growth intensity, precipitation and temperature regime, stem circumference changes*

SOME ASPECTS OF TREE GROWTH IN LATVIA

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Weather affects physiological conditions of trees altering assimilation and hence the growth. Thus, information about the effect of varying weather conditions on tree growth is crucial for predicting possible changes in forest productivity in future. Trees are perennial plants and information about their "growth success" is stored in their wood. Hence, detailed information about environmental factors affecting tree growth can be obtained by a retrospective analysis of different increments applying dendrochronological techniques. The effect of climatic factors on growth can change with time due to the ageing of trees and climatic changes, hence temporal changes of climate growth relationships should be considered.

Growth of Scots pine, the most common tree species in Latvia, has been significantly affected by weather conditions, but increment-weather relationships differed regionally and changed over time. For instance, height increment in the western part of Latvia was mainly influenced by temperature in the winter one year prior to growth, but such effects have weakened since the mid-part of the 20th century. In contrast, positive effect of temperature in April and September has become significant in the latter part of the 20th century. The effect of July temperature appeared more stable. In the eastern part of Latvia under harsher climate, height increment was sensitive to a higher number of factors. Although precipitation in previous and current summer has been significant throughout the 20th century, the limiting effect of temperature in previous autumn has appeared since the 1970s, likely due to the extension of vegetation period. Radial increment of pine has been sensitive to temperature in winter prior to growth and in autumn as well as to precipitation in previous summer. Nevertheless, during the 20th century, sensitivity has shifted from temperature in winter to temperature in previous summer and current and previous autumn, likely due to changes in climate.

High-frequency variation of tree-ring width varied amongst the most common native tree species, likely due to the differences in climatic sensitivity. When the introduced species were tested (red oak, larch and beech), their growth patterns, in contrast to our expectations, appeared more similar to pine and spruce, which occur in the mid-part of their distribution areal, suggesting suitability of the tested introduced species to current climate.

CLIMATE-RELATED RISKS TO FORESTRY

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Most significant climate-related risks to forestry are storms and dendrophagous insects. Storm damages in forests are expected to increase both due to rising frequency of the event and longer periods of un-frozen, wet soil during the winter (decreasing the stability of trees), when most of storms occurs in Latvia. Additionally, longer vegetation period might lead to storms in a situation when broadleaved trees still have leaves, increasing the amount of damages in their stands.

To reduce probability of wind damages, measures boosting individual tree stability (wide initial spacing, early precommercial thinnings) are recommended, especially in most wind-prone territories (mainly south-western part of Latvia). Reduction of rotation period (stand management to reach target diameter in as early age as possible and financially plausible) is recommended especially in wind-prone regions and forest types with fertile, but un-stable soil. Timely thinnings to increase individual tree stability and symmetry of crowns is recommended also for the region most likely experiencing freezing-rain (eastern part of Latvia).

Climatic conditions will become more favourable for most of dendrophagous insects both due to increasing temperature (closer to optimum temperature for most of species) as well as longer vegetation period (allowing successfully formation of more than one generation per year). Therefore forest areas affected will increase. To reduce damages, it is recommended to widen the annual monitoring of insect species, including more species, sites as well as considering the information from neighbouring regions (countries) that would ensure better prediction of outbreaks. Preventive measures, improving the living conditions for natural enemies of dendrophagous insects, as well as efficient system to stop mass outbreak of insects, if it is predicted to cause notable mortality of trees, are recommended. Detailed analysis of a particular insect (*Physokermes piceae*) revealed, that measures to increase vitality of trees (melioration systems in wet sites, wood ash fertilization in peat soils) reduces the amount of damages (and mortality) during an insect outbreak and considerably improves the recovery of trees.

Keywords: *forest adaptation, resilience, biotic risks, abiotic risks*

INFLUENCE OF CLIMATIC CHANGES ON PRODUCTIVITY OF FOREST STANDS

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Information on the potential productivity of forest stand is an essential part in tree species selection for forest regeneration. Therefore productivity of forest stands in the predicted future climate in Latvia was assessed using two different approaches. Firstly height and survival data from Scots pine (*Pinus sylvestris* L.) provenance trial located in three geographically distant stands in Latvia were analysed together with climatic indices in order to assess climate suitability effect on Scots pine provenances in Latvia. Thirty year average historical climate data values for period 1961–1990 for 64 provenance origin locations in Latvia, Poland, Germany, Belarus, Russia and Ukraine were acquired from the WorldClim project database. Correlation analysis between provenance average values for height and survival and climate index values for the origins of the provenances revealed significant relations between the respective parameters, and the relation differed between the stand locations pointing out the importance of suitability of climate. Cluster analysis confirmed that provenances from very distant origins might have very similar growth and survival rates to provenances originating close to the respective stands if the climate index values for both places were similar. In each of three trial stands the best height and survival rates were for provenances with most similar climate index values, indicating that the results from provenance trials need to be analysed together with climate data from the respective geographical locations in order to make conclusions about suitability of the provenances.

Secondly data from National forest inventory (NFI) plots together with future climate projections (RCP 8.5) were used for simulations of forest growth for spruce and pine stands using forest growth model 4C, developed in Potsdam Institute for Climate Impact Research. The acquired results were compared to growth models developed in LSFRI Silava (Donis *et al.*, 2015) and tabulated values of forest inventory regulations. The results for pine showed that increase in both dominant height and median diameter is expected, resulting in increased stand volumes (up to 23–46 % depending on stand location at the age 100 years), for spruce stands the simulated increase in dominant height and median diameter was even higher, but presumably would lead to increase in self-thinning, resulting reducing the potential gain in stand volume depending on forest type.

Keywords: *forest growth, increment, forest growth modelling*

REGENERATION AND CLIMATE-GROWTH SENSITIVITY OF EUROPEAN BEECH IN LATVIA

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Beech in Latvia is an introduced species growing northwards from its natural distribution range. Its economic importance might considerably increase under warming climate. Hence, knowledge on the development and growth dynamics is necessary to assess its potential. The establishment and early growth of saplings are crucial factors that influence the upcoming growth of stand. Weather conditions also significantly affect tree growth influencing productivity of stands. Hence, analysis of inter- and intra-annual-growth dynamics can provide detailed information on the effect of climatic factors.

Threshold values of solar radiation for the development of seedling of beech and other species in stand near Šķēde (NW part of Latvia) were determined by the regression analysis. Beech had low requirements for light, and hence was able to germinate and developed successfully under poor light conditions in Šķēde (NW Latvia) dominating in canopy gaps. Nevertheless, in beech stand near Kaleti (SW Latvia), seedlings of Norway maple were abundant, hence suggesting increased competition at the seedling stage. Still, maple seedling had notably higher requirements for light. Light requirements of beech differed between the localities that probably might be related to origin of planted material or by climatic differences.

Inter-annual growth dynamics and their relationship with weather conditions were assessed for beech growing in stand near Kaleti (SE par of Latvia) using dendrochronological techniques. High-frequency variation of tree-ring width expressed explicit environmental signal, which was likely caused by temperature in preceding July, August and October and in current May. The effect of temperature in previous summer might be explained by increased evapotranspiration or by masting, which may be triggered by warm weather. Nevertheless, length of growing season also appeared significant for increment.

Intra-annual dynamics of radial increment were assessed for two beeches differing by size and crown position growing near Šķēde during 2014 using band dendrometers. Both trees showed similar patterns of stem diameter variation. Stem growth initiated around May 20 and terminated around August 30 peaking in the mid-July. Although growing northwards from natural range, during the growing period, daily increment of stem diameter was mainly affected by precipitation. Minimal air temperature had effect in spring and autumn.

Keywords: *radial increment, climatic factors, solar radiation, seedlings*

FUTURE CHALLENGES IN GREENHOUSE GAS ACCOUNTING IN LAND USE, LAND USE CHANGE AND FORESTRY SECTOR IN LATVIA

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The research program on evaluation of impact of forest management measures on greenhouse gas emissions and CO_2 removals (2011–2015) provided answers to the most of the questions raised during implementation of the IPCC GPG LULUCF (Penman, 2003), the key source of methodological information for the greenhouse gas (GHG) inventory in Latvia. However, implementation of the new guidelines, IPCC 2006 (Eggleston *et al.*, 2006), and their supplements, IPCC 2014 (Hiraishi *et al.*, 2013a; b) proposed several new challenges, especially in estimation of the GHG emissions from wetlands, drainage systems and drained soils.

The impact of application of the tier 1 methods from different guidelines in Latvia is summarized in Table 1. The difference between the estimations according to IPCC GPG LULUCF 2003 and IPCC 2014 is 13 321 Gg CO_2 eq. annually, which turned land use, land use change and forestry (LULUCF) sector in Latvia from net sink of CO_2 removals into a source of GHG emissions. There are still unsolved issues on interpretation of the guidelines in naturally wet mineral and organic soils; however, drained soils alone produces 6.5 times more emissions (9452 Gg CO_2 eq.) according to the IPCC 2014 in compare to the IPCC GPG LULUCF.

New key source of the GHG emissions is peat extraction (864 Gg CO_2 eq. in 2013). Just like a harvested wood products (HWP) and other key sources of emissions this source requires scientifically validated country specific reporting methodology.

Table 1. GHG emissions from drained soils and wetlands in 2013 in Latvia according to tier 1 method in different IPCC guidelines

Land use category	Gg CO2 eq. annually	IPCC GPG LULUCF 2003	IPCC 2006	IPCC 2014
Drained organic forest soils	CO2	1102.9	1102.9	4216.97
	DOC	–	–	486.57
	N2O	–	124.28	580
	CH4	–	–	27.65
Naturally wet organic forest soils	CO2	–	570.52	2181.42
	DOC	–	–	251.7
	N2O	–	64.29	300.03
	CH4	–	–	14.3
Naturally wet mineral forest soils	CH4	–	–	1715.03
Drained organic soils in cropland	CO2	324.68	1214.32	2565
	DOC	–	–	97.41
	N2O	–	331.73	539.07
Drained organic soils in grassland	CO2	20.98	134.29	511.97
	DOC	–	–	25.18
	N2O	–	85.75	87.9
	CH4	–	–	9.16

Land use category	Gg CO2 eq. annually	IPCC GPG LULUCF 2003	IPCC 2006	IPCC 2014
Drained organic soils in wetlands	CO2	9.9	19.8	277.2
	DOC	–	–	20.79
	N2O	–	–	3.79
	CH4	–	–	4.12
Peat extraction for horticulture	CO2	–	864.08	864.08
Total emissions	CO2 eq.	1458.47	4511.97	14779.33

Further investigation of impact of the new guidelines approved concerns proposed by researchers in Nordic countries that, in spite of neutral or neglicible impact in the most of European countries, the most dramatical increase of the GHG emissions takes place in Nordic and Baltic region. According to the GHG inventories in 2012 share of organic soils in Nordic and Baltic region (Finland, Sweden, Denmark, Norway, Iceland, Estonia, Latvia, Lithuania) was 92 % of the total area of reported organic soils in EU countries; share of CO_2 emissions from organic soils in this region was 98 % of the emissions in EU countries; and share of N_2O emissions from organic soils was 66 % of the emissions in EU countries. No CH_4 or DOC emissions were reported from organic soils in 2012. The net emissions from organic soil in 2012 in the Nordic and Baltic region are 17539 Gg CO2 eq. Application of the default emission factors from the IPCC 2014 would increase the net GHG emissions in 2012 to 99401 Gg CO2 eq. (by 467 %, Table 2). The most of the difference is due to CO_2 emissions (Figure 1). For different countries the potential increase of emissions from organic soil is from 140 % to 3589 % (430 % for Latvia) in spite several countries already uses tier 2 methods and there are studies approving that the default factors are overestimating the emissions (Lazdiņš *et al.*, 2014a; b).

Table 2. summary of results of comparison of tier 1 methods in IPCC GPG LULUCF 2003 and IPCC 2014 in Nordic and Baltic region

Gg CO2 eq	CO2	N2O	CH4	DOC	Net emissions
IPCC GPG LULUCF 2003	17 373.85	165.01	–	–	17 538.86
IPCC 2014	73 832.21	16 123.86	648.72	8 796.34	99 401.13
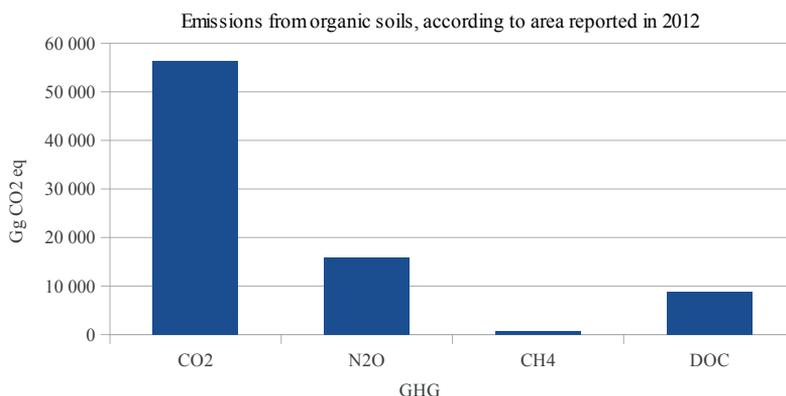
Figure 1. Difference between IPCC GPG LULUCF and IPCC 2014 in Nordic and Baltic countries.

The obtained results highlight need for urgen actions to be able to provide the GHG inventory with realistic estimations of emissions from drained soils and wetlands and to avoid overestimation of emissions due to forest management, as well as grassland and cropland management; where the high estimates of the GHG emissions from soil makes complicated identification and evaluation of climate change mitigation targeted measures. The main priories of further improvement of the GHG accounting system in Latvia are:

- GHG emissions and CO_2 removals in forest soil;
    - soil carbon stock changes in wet, drained and naturally dry mineral soil;
    - DOC, N_2O and CH_4 emissions from naturally wet and drained organic soil;
    - CH_4 emissions from wet and drained mineral soil;
    - impact of specific forest management measures on soil carbon stock.
- GHG emissions and CO_2 removals soil in wetlands;
    - carbon stock change in naturally wet, drained and rewetted organic soil;
    - N_2O and CH_4 emissions from naturally wet, drained and rewetted organic soil.
- GHG emissions and CO_2 removals soil in cropland and grassland;
    - soil carbon stock change in drained and rewetted organic soil;
    - N_2O and CH_4 emissions from drained and rewetted organic soil;
    - CH_4 emissions from drainage systems.

Keywords: *greenhouse gas emissions, forest management, CO2 removals*

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CASE STUDY OF IMPACT OF FOREST FERTILIZATION ON CARBON STOCK IN SPRUCE STAND

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Studies on impact of forest fertilization on the greenhouse gas (GHG) balances are done in several European countries. The most comprehensive information is available in Sweden, where commercial scale application of nitrogen in forest lands is continuing since late 60[ths]. In the most recent large scale study on forest productivity, the *Future Forest project,* Swedish researchers evaluated, what impact would have application of fertilizers in 10 % of forests in Sweden (2.3 mill. ha). According to their estimation it would increase annual increment by 7.4 mill. m³ (6 % of the current increment rate), including 41 % of the increment in large dimensions' timber. Production and application of fertilizers would consume 1.7 TWh of primary energy (0.74 MWh ha⁻¹) annually. Replacement effect of the additional increment would reduce consumption of fossil resources by 42–46 TWh annually, including 22 % as replacement of materials and the rest – as replacement of fossil fuel. The total reduction of energy consumption would corresponds to 7 % the total energy use in Sweden. The net GHG reduction would reach 11.9 or 18.1 mill. tons CO_2 eq. annually (the higher value of GHG reduction corresponds to coal based systems), which corresponds, respectively, to 18 % or 28 % the GHG emissions in Sweden in 2007 (Sathre *et al.*, 2010; Nordic forestry, 2013).

Forest fertilization contributes to considerable increase of carbon stock in living biomass and other carbon pools; however, it can also increase the CH_4, N_2O and CO_2 emissions from soil. Studies in Sweden approves, that gross N_2O and CO_2 emissions in control and fertilized plots doesn't differ significantly (average values are, respectively, 11–17 µg N_2O m⁻² h⁻¹ and 533 611 mg CO_2 m⁻² h⁻¹. Application of wood ash can significantly increase CH_4 emissions, while application of nitrogen reduces CH_4 emissions. Average CH_4 emissions in different trials (control, nitrogen, wood ash, application of N and wood ash) are, respectively, 153 ±5, 123 ±8, 188 ±10 and 178 ±18 µg m⁻² h⁻¹ (Maljanen *et al.*, 2006).

Life time assessment of impact of the forest fertilization approves, that during the 240 years period fertilized forests produces twice more removals of CO_2 in compare to control plots, mainly due to replacement effect. Cumulative replacement effect in 240 years period corresponds to 7000 tons CO_2 eq. ha⁻¹ or 29 tons CO_2 eq. ha⁻¹ annually (Sathre & Gustavsson, 2007).

Forest fertilization in Latvia was topical issue in 70[ths] and beginning of 80[ths], when industrial scale application was introduced using agricultural aviation (Kāposts, 1981). Later this practice was abandoned due to high cost and concerns about economic benefits of the forest fertilization. Considering, that fertilization of mature stands dominated at that time, only few research sites are now available to evaluate impact of forest fertilization. One of these sites is located near Jaunkalsnava (WGS84 coordinates of centre of the compartment are 25.90592, 56.65042) in 33 years old spruce stand on drained mineral soil (stand type *Myrtillosa mel.*), formerly (before the World war II) managed as grassland for a fodder production. Nitrogen fertilizer (120 kg N ha⁻¹) was applied during the establishment of the stand, leaving certain area as a control without fertilizer. The fertilized and control plots were equally distributed across the stand to consider possible site impact on the results.

The scope of the study implemented in 2014 was to evaluate impact of fertilization on

carbon stock in living and dead biomass and soil carbon pool. Four of the plots (2 controls and 2 fertilized) established 33 years ago were selected for the study (Table 1). Round sampling plots (area 500 m²) were established to collect fine fraction of dead wood (D of the thickest end <6 cm), litter and soil down to 80 cm depth. Dead wood was picked from rectangle with area of 1 m²; litter was collected from the same place by cutting undisturbed samples to the whole depth of the litter layer (area of sampler is 100 cm²); soil samples were taken with undisturbed soil samplers from 0–10, 10–20, 20–40 and 40–80 cm depth, locating samplers so that they are characterizing the whole layer (3 soil samples with 100 cm³ volume from each layer). Two sample sets were collected from each plot.

In laboratory (LSFRI Silava) the collected samples were air-drayed; then organic samples were milled and screened to 1 mm diameter for analyses, while mineral soil samples were gently crushed and screened with 2 sieve to separate fine earth fraction, which is used in analyses. It is considered that coarse soil fraction doesn't contain organic carbon. Total carbon was determined with ELTRA elemental analyser, carbonates in mineral soil were determined with calcimeter. Difference between total and mineral carbon is organic carbon in mineral samples and total carbon is equal to organic carbon in organic samples. Carbon stock is calculated using data on volume, density and carbon content in the particular soil layers and other carbon pools. Biomass expansion equations elaborated in LSFRI Silava are used to estimate carbon stock in living biomass.

Table 1. Characteristics of sample plots

ID	Variant	Height of trees, m	Diameter at 1.3 m height, cm	Growing stock, m³ ha⁻¹	Number of trees ha⁻¹	Biomass, tons ha⁻¹	Carbon in living biomass, tons ha⁻¹
11-237-19-4	control	13.8	12.8	257	2305	152.3	80.26
11-237-19-5	fertilized	14.8	15.1	363	2337	225.18	118.52
11-237-19-6	control	14.7	14.8	320	2142	197.15	103.78
11-237-19-7	fertilized	14.9	15.2	360	2315	226.45	119.18

Considerable increase of carbon stock due to fertilization is found in all soil layers (Table 2); however, due to high level of uncertainty the difference is statistically significant only at 10–20 cm depth.

Table 2. Carbon stock in different soil layers (kg C ha⁻¹)

Variant	0–10 cm	10–20 cm	20–40 cm	40–80 cm
Control	27 001	17 818	25 121	15 539
Fertilized	46 007	54 427	40 088	29 086

Carbon stock in both fractions of dead biomass in fertilized plots is higher than in control plots; however, statistically significant difference is found only for the fine dead wood fraction (Table 3).

Table 3. Carbon stock in litter and fine fraction of dead wood (kg C ha⁻¹)

Variants	Litter	Fine dead wood	Total dead biomass
Control	4 385	818	5 202
Fertilized	5 707	1 507	7 213

Carbon stock in living biomass is also statistically significantly higher in fertilized plots (the difference is 29 % of carbon stock in living biomass in the control plots). Summarizing the carbon pools in Table 4 and Figure 1, statistically significant difference is found between total carbon stock in soil, living biomass and total carbon stock. Annual changes due to fertilization, if considering that initial carbon stock in all plots was equal, corresponds to 12.6 tons CO_2; the most of the removals (70 %) took place in soil.

Table 4. Summary of carbon stock in different pools (tons C ha⁻¹)

Variant	Soil	Litter	Fine dead wood	Living biomass	Total carbon stock
Control	85.5	4.4	0.8	92.0	182.7
Fertilized	169.6	5.7	1.5	118.9	295.7
Annual changes (tons CO2)	9.4	0.2	0.1	3.0	12.6
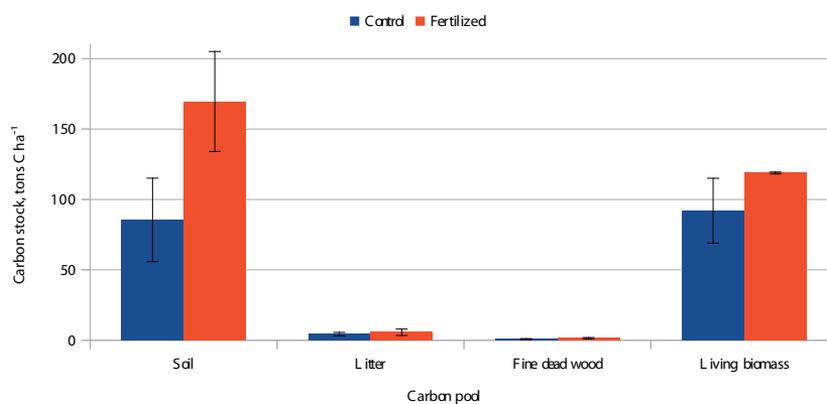
Figure 1. Comparison of different carbon pools.

The project results approves, that forest fertilization have considerable long term positive impact on CO_2 removals in all carbon pools in forests. The additional CO_2 removals in 33 years period ranges from 29–30 % in living biomass and litter to 84–98 % in dead wood and soil. The total additional CO_2 removals in fertilized plots is 62 % of the control plots. The average additional removals of CO_2 in all carbon pools in fertilized plots equals to 12.6 tonnes CO_2 yr⁻¹. The project results fully approves, that fertilization of forest stands during the regeneration stage can be one of the most efficient climate change mitigation measures in Latvia; however, more data are necessary to elaborate mathematical models characterizing this impact.

Keywords: *greenhouse gas emissions, forest fertilization, CO2 removals*

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FUNGAL COMMUNITIES ASSOCIATED TO *P. PINASTER* FORESTS IN A MEDITERRANEAN

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Maritime pine (*Pinus pinaster* Ait.) forests have a relevant economic importance within the Mediterranean area. Fungi play an essential ecological role in forest ecosystems. The aim of this study was to study the influence of different edaphoclimatic conditions on fungal communities associated to *Pinus pinaster* ecosystems. Three different edaphoclimatic sites composed of siliceous, calcareous and sandy soils were considered. Carpophores were collected and identified from nine 100 m^2 permanent plots, three in each site, during the autumn seasons from 2006 to 2012 in order to assess fungal yield and diversity.

Despite extreme and highly variable environmental conditions, fungal communities associated with *P. pinaster* are highly diverse and productive. The main environmental variables influencing fungal community composition were climatic variables, such as precipitation and temperature. In addition, soil characteristics, such as nitrogen and potassium significantly affected the distribution of species for both saprotrophic and mycorrhizal functional groups. Some fungal species were adapted to a broad range of ecological conditions, eg. *Lycoperdon perlatum, Russula torulosa*, and species within the genera *Galerina* and *Mycena*. However, other taxa were found exclusively in very specific environmental conditions. All species within *Macrolepiota* genus were collected in the calcareous soils, whereas *Laccaria laccata* and *L. bicolor* were only associated with the siliceous areas, characterized by higher amounts precipitation and nitrogen. The ecological implications of these findings are of great importance for managers seeking new options for adding economic value and for sustaining biological diversity in these Mediterranean forests.

Keywords: *fungal production, fungal diversity, environmental variables, Mediterranean ecosystems*

CONTROL OF *HETEROBASIDION ANNOSUM* S.L. USING *PHLEBIOPSIS GIGANTEA*

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Root and butt rot fungi *Heterobasidion* spp. cause serious damage and economic losses in conifer stands in Latvia. Since 2008, to reduce the primary infection of *Heterobasidion* spp. during commercial thinning in State forests (managed by JSC *Latvia's State Forests*), freshly cut stumps are treated with the biological control agent Rotstop (Finland), which contains spores of fungus *Phlebiopsis gigantea* (Fr.) Jül. Mean values of efficacy of Rotstop were 64 % in spruce stumps and 82 % in pine stumps. The large scale use of a single fungal isolate may affect the diversity of local populations of *P. gigantea*. To diminish the use of a single *P. gigantea* isolate, local isolates of *P. gigantea* could be used for stump treatment. More than 100 isolates of *P. gigantea* were collected and analysed in laboratory and field conditions. Some of the analysed local *P. gigantea* isolates showed similar or higher values of efficacy compared to the biological control agent Rotstop.

Keywords: *Heterobasidion spp., Phlebiopsis gigantea, biological control*

FINE ROOT STATUS AND MYCORRHIZAL COLONIZATION OF NORWAY SPRUCE IN *HETEROBASIDION* SPP. INFECTED STANDS ON PEAT SOILS

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Differences in fine root morphology, mycorrhizal colonisation and root-inhabiting fungal communities between *Picea abies* individuals infected by *Heterobasidion* root-rot compared with healthy individuals were examined in four stands on peat soils in Latvia. We hypothesised that decreased tree vitality and alteration in supply of photosynthates below ground due to root-rot infection might lead to changes in fungal communities of tree roots. Plots were established in infected and healthy stands. Within each stand, five replicate 20 cm deep soil cores with roots were taken in each root-rot infected and uninfected plot. Root morphological parameters, mycorrhizal colonisation and associated fungal communities, and soil chemical properties were analysed. In all stands root mycorrhizal colonisation was similar between root-rot infected and uninfected plots, and in three stands root morphological parameters were similar. In one stand there were significant differences in root morphological parameters between root-rot infected vs. uninfected plots, but these were likely due to significant differences in soil chemical properties between the plots. Sequencing of the internal transcribed spacer of fungal nuclear rDNA from ectomycorrhizal (ECM) root morphotypes of *P. abies* revealed the presence of 42 fungal species, among which ECM basidiomycetes *Tylospora asterophora* (24.6 % of fine roots examined), *Amphinema byssoides* (14.5 %) and *Russula sapinea* (9.7 %) were most common. Within each stand, the richness of fungal species and the composition of fungal communities in root-rot infected vs. uninfected plots were similar. In conclusion, *Heterobasidion* root-rot had little or no effect on fine root morphology, mycorrhizal colonisation and composition of fungal communities in fine roots of *P. abies* growing on peat soils.

Keywords: *Norway spruce, root-rot, ectomycorrhizal fungi, pathogens, organic soil*

IMPACT OF SEED ORIGIN AND CULTIVATION SYSTEM ON NORWAY SPRUCE SEEDLING MYCORRHIZATION

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Impact of seedling cultivation system and seed origin on morphological parameters and ectomycorrhizal (ECM) fungal colonisation of Norway spruce (*Picea abies*) seedlings were studied in two experiments. In the first experiment, bare-rooted and containerized seedlings were compared and in the second experiment – seedlings representing five seed origins in Latvia (Western (W1 and W2 provenances), Central (C1 and C2 provenances) and Eastern (E1 provenance)) were compared. Provenance of spruce seedlings and cultivation system were suggested to have impact on seedling mycorrhization and early growth. Seedling provenances with the best growth rate had diverse communities of ECMf. Abundance of ECM species *A. byssoides* and *Wilcoxina* sp. differed significantly among seedlings of different seed origin. Experiments with bare-rooted and containerized seedlings showed some differences between cultivation methods, which could be related to better adaptation to field conditions of bare root seedlings, either due to more developed root systems or mycorrhizal community.

Keywords: *Picea abies, bare-rooted seedlings, containerized seedlings, seed provenance, ectomycorrhizal fungi, fungal community*

ECTOMYCORRHIZAL COMMUNITY IN CONIFER STANDS ON PEAT SOILS 10 TO 12 YEARS AFTER WOOD ASH TREATMENT

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Long-term effects of fertilization with wood ash on biomass, vitality and mycorrhizal colonisation of fine roots were studied in young conifer plantings and three mature conifer stands growing on peat soils. Fertilization trials amounting 0.5 to 2 kg m^{-2} (in young plantings) and 5 kg m^{-2} (in mature stands) of wood ash were established 10 to 12 years prior to this study.

A total of 107 soil samples with roots were collected and analysed. Ectomycorrhizal (ECM) fungi in roots were identified by morphotyping and sequencing of the fungal ITS region.

In analysed mature stands, fine root biomass was higher in fertilized plots than in control plots. Fifty ECM species were identified, of which eight were common to both fertilized and control plots. The most common species in fertilized plots were *Amphinema byssoides* and *Tuber* cf. *anniae*, while in control plots it was *Tylospora asterophora* and *Lactarius tabidus*. In young conifer plantings, fine root biomass, number of living fine roots and number of dead fine roots did not differ significantly among wood ash treatments and the controls for either pine or spruce. Relative abundance of living fine roots and mycorrhizal colonization differed significantly among treatments and the effects of wood ash were largely determined by tree species and the amount of wood ash applied. Species composition of ECM fungi was mainly determined by the host species.

In conclusion, our data provided some evidence of a long-term effect of wood ash fertilization on the diversity and composition of ECM fungal communities of both young and mature conifer stands.

Keywords: *forest fertilization, fine root, ectomycorrhizal fungi, organic soils, Norway spruce, Scots pine*

CONIFEROUS STUMPS AS AN IMPORTANT SOURCE OF THE ROOT ROT FUNGI *HETEROBASIDION* SPP. AND *ARMILLARIA* SPP.

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Stump removal is one of the options to reduce the spread of root rot fungi from heavily infested sites. However, after stump extraction, roots of various diameters are left in the soil and could serve as an inoculum for *Heterobasidion* spp. infection in the next forest generation. The aim of this study was to assess the presence of *Heterobasidion* spp. and *Armillaria* spp. in the roots of decayed and healthy looking stumps after stump removal.

In five experimental plots (clear-cuts), wood samples from more than 1100 Scots pine and Norway spruce stumps were taken to analyse the occurrence of *Heterobasidion*. Also the presence of *Armillaria* spp. rhizomorphs was recorded for each stump. *Heterobasidion* spp. was found in 192 stumps and rhizomorphs of *Armillaria* spp. were present on 234 stumps.

During November and December of 2012, each experimental plot was divided into two parts – in one part stumps were removed and the other part was left as a control. Roots (5 larger roots from each stump) from 20 infected and 20 healthy looking uprooted stumps in each experimental plot were collected and analyzed in the laboratory.

Heterobasidion spp. was found in 11 % of roots of decayed stumps and in 2 % of roots of healthy looking stumps; root diameter was 1.5–14.0 cm (average 6.1 cm). *Armillaria* spp. was isolated from 27 % of roots of decayed stumps and 30 % of roots from healthy looking stumps – diameter of analyzed roots comprises 1.0–18.0 cm, (average 4.5 cm). The presence of other fungi was also analyzed using morphological and molecular techniques.

In further work (in 2017), the incidence of root rot fungi in the remains of roots will be analyzed.

Keywords: *stump removal conifer stumps, Armillaria spp., Heterobasidion spp.*

SCOTS PINE (*PINUS SYLVESTRIS* L.) RESISTANCE GENE EXPRESSION, REGULATION AND EFFICACY IN RESPONSE TO FUNGAL INFECTION

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Scots pine (*Pinus sylvestris*) is one of the most important species for the Latvian forestry sector. Breeding programs have achieved a large increase in productivity and quality, however Scots pine pathogens are an important challenge to the forestry industry. Root rot caused by the fungus *Heterobasidion annosum* causes considerable economic damage each year.

Forest trees have evolved several defence mechanisms against fungal pathogens, including thick cell walls, resin ducts and other specific anatomical structures as well as synthesis of antifungal peptides, proteins and other antifungal compounds. In our research we focus on expression, regulation and copy number of genes producing these antifungal substances, most progress has been achieved in studying the role of Scots pine thaumatin-like protein gene (PsTLP). We have found strong evidence that gene copy number variations of this gene exist between Scots pine individuals and initial evidence that individuals with increased copy number of this gene show a stronger increase of the expression of this gene in response to artificial inoculation with *H. annosum* than individuals with normal copy number. We have also demonstrated the efficacy of the recombinant Scots pine thaumatin-like protein against *H. annosum in vitro*. We have tested several molecular biology methods for the detection of variation of gene copy number of this gene and other genes. This could lead to development of additional selection criteria for Scots pine breeding programs.

We also present initial results about analyses of gene copy number variation of the Scots pine pinosylvin synthase gene (PsBBs). This gene is involved in the synthesis of pinosylvin – a substance accumulated in Scots pine heartwood believed to be a key substance in increasing resistance to decay. The PsBBs gene copy number variation results were also analysed in conjunction with quantitative analysis of pinosylvin content performed at the Latvian State Institute of Wood Chemistry.

Keywords: *fungal pathogens, gene expression, copy number variation*

INDUCED RESISTANCE RESPONSES IN SCOTS PINE (*PINUS SYLVESTRIS* L.)

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Needle cast (caused by *Lophodermium* spp.) is a significant disease of *Pinus sylvestris*, which may become a more frequent and severe problem in the future due to climatic changes and forest regeneration practices. Another strategy for increasing resistance to forest pathogens besides the use of more resistant plant material is the use of induced resistance. Induced resistance is an increased expression of natural defence mechanisms in plants against repeated exposure to adverse factors. One of the most important inducible defence mechanisms is the biosynthesis of pathogenesis – related (PR) proteins. One of them is thaumatin – like protein (TLP), which is believed to be involved in plant defense responses to pathogen infection. Many members of this group have been shown to have antifungal activity against a broad spectrum of fungal pathogens and were induced in plants as response to infection by pathogens, osmotic stress, treatment with abscisic acid, ethylene, salicylic acid, methyl jasmonate (MJa) and wounding.

Previous results from our laboratory indicate that the *P. sylvestris* TLP protein has an antimicrobial activity against *L. seditiosum* and *Heterobasidion annosum*. The next goal was to found the way to increase the *TLP* gene expression. Exogenous application of methyl jasmonate is able to activate defence gene expression therefore we studied the effect of methyl jasmonate application at different concentrations. Analysing samples of 100 different treated one year old seedlings, we found that MJ treatment of *P. sylvestris* seedlings increased the expression level of the *TLP* gene. Also MJ in high concentration was deadly for young seedlings.

We conclude that the exogenous application of MJa to *P. sylvestris* seedlings can elicit plant defence responses by activating gene expression. All these observation (antifungal activity and transcript accumulation only after MJa treatment) concur with a proposed role of TLP in the protection of seedlings against pathogens.

Further research is needed to verify induced resistance of seedlings against *L. seditiosum* and to investigate expression of other defense related genes which are involved in induced resistance in *P. sylvestris* seedlings.

Keywords: *induced resistance, Pinus sylvestris, methyl jasmonate, TLP, gene expression*

REMOTE SENSING DATA USAGE CAPABILITIES FOR THE ANALYSIS OF DISTRIBUTION OF FOREST RESOURCES OUTSIDE NFI SAMPLE PLOTS

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Aim of studies – usage of remote sensing data for regionalization to obtain forest coverage maps of Latvian territory.

Remote sensing data – orthophotos (RGB, IR), LIDAR data (Figure 1). Ground truth data – NFI sample plots. Type of analysis: Multispectral analysis (supervised); Image texture classification; LIDAR data classification.

Multispectral analysis shows a good stand classification at coniferous / deciduous level. However, separating the forest stands by age, using biomass equations, classification of young stands often shows similar results as middle-aged stands.

Image Texture Analysis shows that classification quality is high (Kappa coefficient 0.83 for stand dominant species assessment). However, the reliability of the study is not enough (sample plot number of aspen and alder stands). We need to increase the reliability of the results by higher number of observations.

LIDAR CHM model average height is a close relationship with the forest compartment the average height data. State Forest Register data have marginally higher average height values, which could be explained by the LIDAR measurements with a small number of points per m^2 to obtain measurements directly from the treetops.

LIDAR CHM model average height relationship with the forest statistical inventory measurements is higher than with the State Forest Register data, that we can explain that sample plot measurements are done with instruments instead of surveyor experience.

Keywords: *LIDAR, remote sensing*

LIDAR DATA USAGE CAPABILITIES FOR FORESTRY AND FOREST BIOLOGICAL DIVERSITY EVALUATION

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Airborne LIDAR (Light Detection And Ranging) has recently become a meaningful technology in forest resource management, particularly with the ability to provide a means to evaluate three-dimensional forest structure at broad spatial scales. We set two objectives to our study. Firstly, we used LIDAR data to detect streams located under forest canopy and to analyse structural diversity of riparian forests:
- Watercourses real coastline and Floodplain area delineation;
- Delineation of the true protected areas of rivers;
- Water shading calculations;
- Planning of open areas for better water quality.

We also provided arguments on guidelines for maintaining of complex water-forest ecosystems:
- Water basin division in micro basins to determine the impact of the forestry compartment management on the water quality indicators:
  ◦ Runoff;
  ◦ Sedimentation.
- Drainage systems:
  ◦ Real drain Territories;
  ◦ Sludge pond.
- Catchment soil balance calculations.

Secondly, we used LIDAR data to create DEM and DSM as a means to analyse fine-scale structural indicators of biodiversity and topographical variation of areas designated for Woodland Key Habitats conservation:
- Pine forest openings;
- Horizontal stand structure (capercaillie habitats);
- Large woody debris dimension;
- Regeneration near the forest stand, openings, eco tree groups;
- Abandoned agricultural lands overgrowing dynamics.

Keywords: *LIDAR, Riparian forest, biodiversity*

EFFECTS OF FSC® FOREST MANAGEMENT CERTIFICATION TO THE OCCUPATION HEALTH AND SAFETY IN LATVIA AND FINLAND

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According to the FSC Forest management (FM) scheme, more than 184 million hectares of forests have been certified worldwide. More than 44 % of the world's certified forests are located in Europe. FSC certification is available for 20 years; the popularity of certification is growing constantly.

Occupational health and safety issues within certified areas are governed by Principle 4 Criterion 2 „Forest management should meet or exceed all applicable laws and/or regulations covering health and safety of employees and their families." In Latvia forest industry directly employs 52 thousand people, but in Finland – 89 thousand.

The aim of this study was to determine whether the FSC FM certification can improve occupational health and safety level. During the study all publicly available audit reports related to Latvian and Finnish companies with valid FSC FM certificates were analysed. In addition Corrective action requests (CARs) issued by accredited certification bodies were analysed.

Since year 2010 during the annual FSC FM audits (see Figure 1) within Latvian FSC certified forest areas regarding health and safety 17 finding where discovered, 4 of which where observations (N) and 13 minor CARs (NN), or 11 % of the total number of CARs issued (see Table 1), which is the second highest figure after criterions of Principle No 6 „Environmental impact". Two of the findings, after repeated visits, where upgraded to Major CARs. In Finland, since year 2011, with respect to workers' health and safety 4 observations, 5 minor CARs and 1 Mayor CAR have been issued, it is 7% of the total number of raised CARs (see Table 2), which is 4th highest figure. None of the above mentioned findings have been upgraded to higher grade.

Reviewed audit reports indicates that mostly audit team raise CARs in relation to safe work requirements within cutting site level (for Latvian case – the Cabinet of Ministers Regulations No 310 requirements), it is also the area where most of improvements have been done by FM enterprises. The key element to successful compliance to particular requirement has been intensive control of forest workers and regular training regarding safe work issues.

Statistics of Finland shows that the number of accidents in the agricultural sector of self-employed persons since year 2004 has decreased by 22%, reduction in the number of accidents have happened for employed persons as well. According to information provided by the State Labour Inspectorate of the Republic of Latvia registered number of accidents within Latvian forest industry in the last decade has decreased almost twice (see Figure 2), it should be mentioned that the first FSC Forest Management certificates in Latvia was issued about thirteen years ago. Thus, it is considered that FSC certification has contributed to a reduction of accidents.

Within Finland, large FSC FM groups like UPM-Kymmene Corporate group scheme, which consists of more than 60 group members, exists. Currently, the largest group scheme in Latvia consists of 4 group members. Creation of open and active FSC FM Group scheme in Latvia could enhance safe working practices in Latvian private forest sector. Recommended size of the FM Group in Latvian is from 75 000 to 125 000 ha. It would be a compromise between the risk tolerance of the suspension of the certificate and the effects of the economic benefits

of certification. Up to 25 000 ha property certification are economically most disadvantaged, which is directly related to the number of audit days necessary (see Figure 3).

Table 1. Audit findings regarding FSC principles in Latvia

Principle	I	II	III	IV	V	VI	VII	VIII	IX	X	Other
OBS	1	1	0	14	5	27	3	7	11	1	2
Minor CAR	6	1	0	9	9	27	6	13	14	2	6
Major CAR	2	0	0	3	1	0	0	0	0	0	1
Total	9	2	0	26	15	54	9	20	25	3	9

Table 2. Audit findings regarding FSC principles in Finland

Principle	I	II	III	IV	V	VI	VII	VIII	IX	X	Other
OBS	4	4	0	4	3	17	5	4	2	0	8
Minor CAR	4	2	0	7	0	25	2	6	14	0	9
Major CAR	4	0	0	1	1	1	2	3	2	0	0
Total	12	6	0	12	4	43	9	13	18	0	17

Figure 1. Check of occupational health and safety requirements and living conditions during the audit
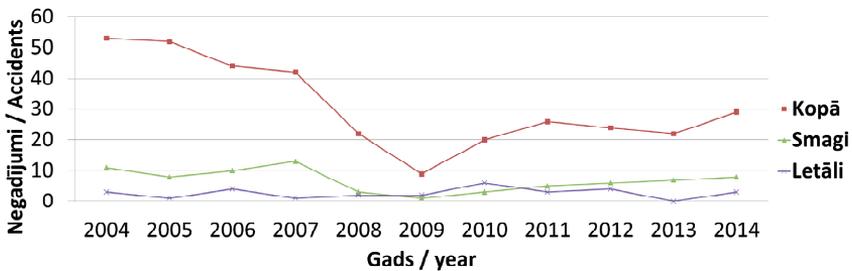
Figure 2. Number of registered accidents in Latvian forestry and logging sector.
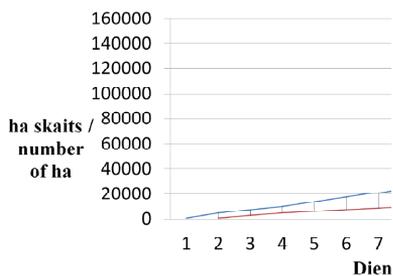
Figure 3. Number of audit days necessary depending on forest area
(according to FSCAdvice-Note-20-007).

Keywords: *FSC, Forest management, certification, corrective action request, occupational health and safety*

MEASURING EQUIPMENT FOR GROUNDWATER FLOW DETERMINATION IN SOIL AND IT'S POSSIBLE APPLICATION IN FORESTRY

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There in the practical forestry has been observed that, in similar growing conditions, some trees grow differently – such phenomena as forming several trunks, enhanced resistance, inhabitation by especially abundant fauna and flora species can be observed or on the contrary – the trees are poorly developed, suffering from ailment, damaged root system, etc.

It was suggested that this might be due to the different underground water currents, their intersections and networks. So far available dowsing or bio-location methods have not been scientifically justifiable, repeatable and were often assessed as subjective.

Now in the 21st century – in Germany, South Africa, the US and Russia measuring devices have been created for precise measurements of the Earth electromagnetic field and its' changes.

In cooperation with *Asola* Ltd. – the measuring device IGA-1-M created in Ufa, Russia has been made available to us. The device is able to measure electromagnetic ingredients of the Earth's geomagnetic field in the range of 5–10 kHz, with a sensitivity of tens to hundreds of piko-volts, the phase shift integral in test frequency is used as the output parameter. The equipment IGA-1 allows to determine the structure of the geophysical anomalies, the so-called Hartmann-Karri networks.

Currently measurements are carried out in premises and plots of land, supplemented by laser remote measurements. For larger areas it would be appropriate to add a GPS or a geographical positioning system as well as to set up an IT program to record linear underground water streams, their intersections, networks and other different radiations.

The aim of the research is to study the impact of the underground water streams on flora of tree species dominant in Latvia – pine, birch, fir-tree, grey alder, aspen, black alder and other species – and their growth changes.

This knowledge can be used for planting young stands or purposefully cultivating already planted stands and seasoning stands.

Keywords: *measuring device IGA-1-M, biophysical and geophysical anomalies, underground water streams, tree growth course changes*

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