Latvian State Forest Research Institute "Silava"

SILAVA

Conference

ADAPTATION AND MITIGATION: STRATEGIES FOR MANAGEMENT OF FOREST ECOSYSTEMS

&

ENERWOODS SEMINAR

Book of Abstacts

EFI ASSOCIATED EVENT

Sustainable Energy Systems 2050

norden Nordic Energy Research

ENERWOODS

ESF EIROPAS SOCIĀLAIS FONDS

ERAF EIROPAS REĢIONĀLĀS ATTĪSTĪBAS FONDS

EIROPAS SAVIENĪBA

MNKC Meža nozares kompetences centrs

LIAA Latvijas Investīciju un attīstības aģentūra Investment and Development Agency of Latvia

IEGULDĪJUMS TAVĀ NĀKOTNĒ

Riga, 23.–24.04.2015.

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Preface

Conference attracted participants from 8 countries, most of them representing three major research areas: improvement of tree growth (breeding, soil preparation, fertilization), bioenergy production and natural disturbances (including the effect on forest carbon balance).

First day was mainly dedicated to on-site experience: 9 presentations were covering the growth cycle of trees staring from selection of seed source. Results of silver birch and hybrid aspen breeding were presented, demonstrating significant gain from use of selected material not only in productivity, but also quality (including natural pruning). Genetic factors were shown to notably affect height increment of Norway spruce both directly (influencing the growth intensity) and indirectly – several open-pollinated families had notably higher proportion of trees with lammas shoots, that, in turn, had cumulative positive influence on tree height. Positive effect from use of seed orchard seed in direst seeding, previously known from studies in Finland, was demonstrated also in hemiboreal forests. Applicability of spot-mounding and mechanized planting in Latvia's forests were discussed based on times studies (and financial calculations) including not only the particular operation, but whole regeneration cycle (weed control, precommercial thinning) and concluding, that these methods can be justifiable only in sites where they can significantly improve survival of planted trees. Importance of soil aeration to improve growth of trees was demonstrated: on peat soils mean annual increment of Norway spruce can be event tripled using this measure. Spatial and temporal changes of one of the factors affecting forests – fire – was analysed, concluding, that forest fires are very frequent in vicinity of largest cities, therefore un-intentionally creating habitats for fire-dependent species, but adversely affecting risks for the forest owners.

Second day of the conference (including 19 presentations) was used to elaborate the topics initiated during visits in experimental sites. Results from comprehensive set of trials in Finland confirmed the superiority of Scots pine seed orchard progenies in comparison to average stand progenies. Wood properties of Scots pine were linked with presence of specific genetic characteristics. Provenance-environment interaction was analysed in the context of climatic changes to develop the appropriate deployment zones for particular seed orchards. Mitigation of climatic changes (impact on greenhouse gas emissions) was analysed both for the whole sector (use of logging residues for bioenergy) and for specific aspects (emissions from low intensity surface fire). Biomass (both above and below-ground) equations for the most common tree species in hemiboreal forests, developed to estimate the carbon sequestration, were presented. Natural disturbances (fire, wind) were proven not only to significantly impact

the carbon budget of the forests, but also create legacies important for biodiversity. Also root rot (*Heterobasidion annosum* s.l.) has notable impact in coniferous stands and it was demonstrated, that spores of this fungi are spreading not only during the vegetation period, but also before and after it (in the relative cool period of the year). Positive effect of forest fertilization on the productivity and carbon sequestration of spruce stands was confirmed. A benefit from wood ash spreading in forest was linked to the soil properties and the financial benefits from the activity evaluated. Results from series of different experiments in commercial thinning were presented, demonstrating possibilities to enhance productivity, reduce costs and soil damages during this operation.

Poster presentations (altogether 21) covered not only the above-mentioned topics, but also demonstrated results of wood chemical analysis: pulping characteristics of wood used for bioenergy and influence of mechanical pre-treatment on the properties of pine fibres.

Support for organization of the conference from EFI, ENERWOODS and the Latvian Council of Science project "Adaptive capacity of forest trees and possibilities to improve it" is acknowledged.

Dr. silv. Aris Jansons
Latvian State Forest Research Institute "Silava"

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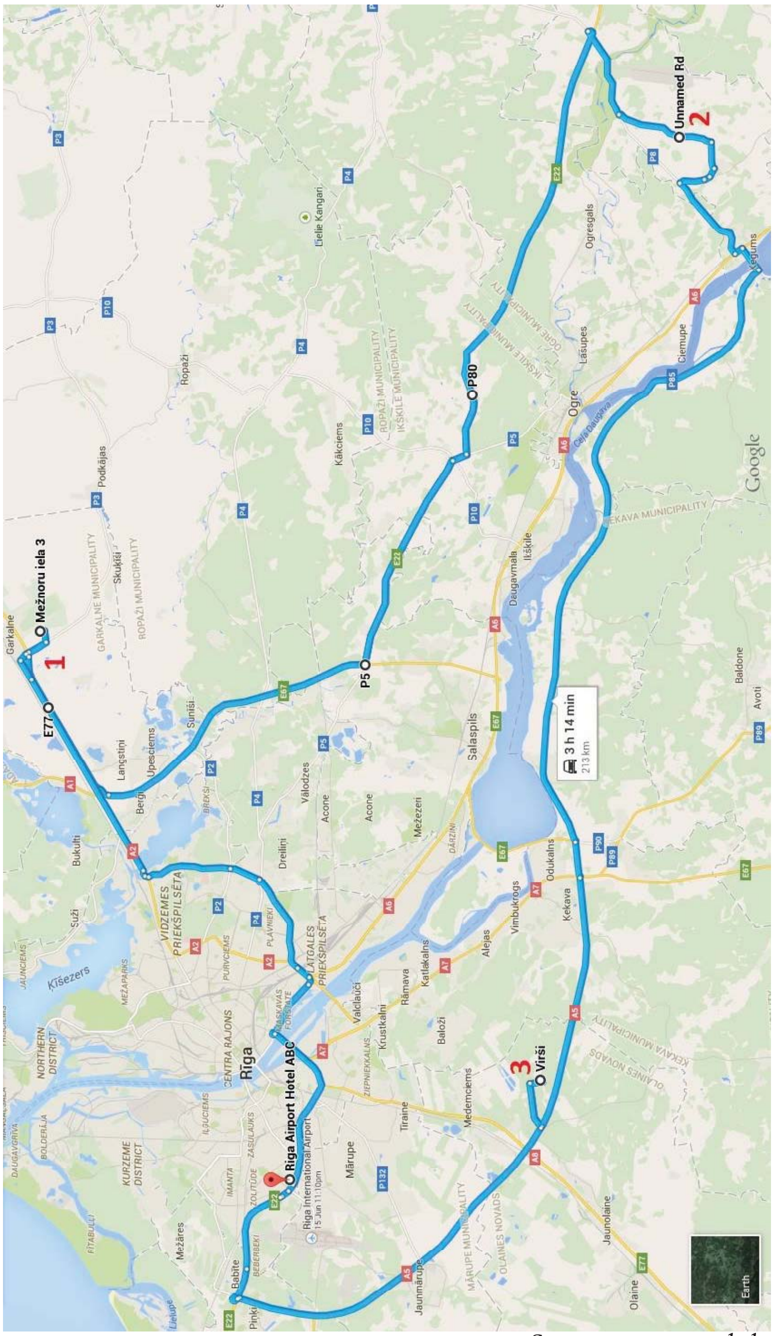
ROUTE OF THE FIELD TRIP



Source: maps.google.lv

CURRENT AVAILABILITY OF BIOMASS FOR ENERGY PURPOSES IN NORDIC AND BALTIC COUNTRIES

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Nordic and Baltic countries have a large potential for producing biomass where a significant part can be used as a renewable source for the energy sector. A summary of land areas available for tree growth shows that forest areas are large and that substantial agriculture land areas are also available. The forest area is 62 million ha in total for the countries Denmark, Estonia, Finland, Latvia, Norway and Sweden; 16 million ha is public and 46 million ha is private land. Although some forest areas are protected, 75–92 % of this area can still be used for wood production. Coniferous species dominate the forests in Finland, Norway and Sweden, while conifers and deciduous species are more evenly distributed in Denmark, Estonia and Latvia. The total standing volume is over 7,000 million m^3 and the annual increment is estimated to about 275 million m^3 yr^{-1}.

Annual growth currently exceeds annual harvest in all countries, leading to the conclusion that some part of this difference may be used as an energy source in a near future. The current potential for forest energy resources was estimated to over 400 TWh yr^{-1} (1,500 PJ) for the countries included and forest energy will thus be of utmost importance for the future energy supply in the region.

The Danish potential of forest energy resources were studied with four scenarios where the most active scenario resulted in 10 TWh yr^{-1} by the year 2020. In Finland current potential for forest energy biomass is up to 35 million tons yr^{-1} (186 TWh) in a maximum cutting scenario. In Norway 5 million tons DM yr^{-1} (27 TWh) should be possible to use when no restrictions are considered. The Swedish figure on potential harvest levels for energy is 29 million tons yr^{-1} (143 TWh) without restrictions. Analyses in Estonia show that up to 15 million m^3 (33 TWh) is available annually, while in Latvia almost 50 TWh is annually extractable as forest biofuel. However, probable restrictions will reduce the figures for all countries, but they will still be substantial for energy supply in respective country.

A changing climate and increased standing volumes may affect the future growth positively and increase the potential harvest levels further. Estimates of climate effects show an average forest growth increase of over 30 % within the next 100 years, but also substantially higher figures for specific regions and specific management strategies.

Wood is extensively used for energy purposes in the region and the forests hold a large potential for increasing the production of renewable energy. The potential may be further increased with increased fertilization, extended breeding for enhanced biomass production, larger cultivation areas and changes of tree species and management systems.

REGENERATION AND SAPLING GROWTH OF EUROPEAN HORNBEAM IN LATVIA

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The regeneration of European hornbeam (*Carpinus betulus* L.) has been assessed in stands in south-western part of Latvia, which is the northernmost point of hornbeam distribution in Europe. In the studied stand, six sampling plots (20 × 20 m) and four transects were established to assess stand structure and effect of irradiation parameters on stand regeneration. Successful regeneration of hornbeam was shown by its presence in all height and diameter classes: it was more abundant than other tree species (Figure 1). Nevertheless, in the smallest height and diameter classes, increased abundance of other shade tolerant species (maple and lime) was observed. Light parameters, particularly diffuse radiation, had significant effect on distribution and abundance of hornbeam understory. The threshold values of irradiation parameters for hornbeam were notably higher compared to other species. The number and height of hornbeam saplings correlated tightly with the amount of available light. Nevertheless, under sufficient light conditions hornbeam showed good vitality, thus suggesting suitability of growing conditions.

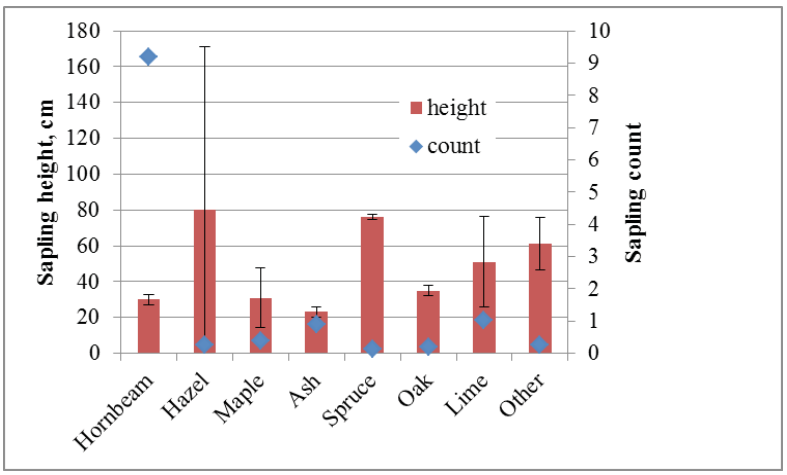

Figure 1. Sapling size and count in sample plots.

Keywords: *natural regeneration, understorey, stand structure.*

The study was funded by The Latvian Council of Science project "Adaptive capacity of forest trees and possibilities to improve it" (No 454/2012).

STEM QIALITY OF MATURE SCOTS PINE IN LATVIA

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Length of branch-free section of a stem and its volume are the major factors determining the monetary value of Scots pine. Parameters characterizing branch properties of trees, like shape, width and length of the crown, branch thickness and angle, length of branch-free part, were assessed during the plus-tree inventory and some of the parameters (height up to first dry and green branch) also for a sample of trees in National forest inventory. Aim of our study was to analyses both these datasets to assess the branch quality traits of Scots pine and factors affecting them.

Altogether 192 plus-trees and 596 dominant stand trees, growing in *Vaccinosa* and *Hylocomiosa* forest types, measured at the age of 71–135 years were used for analysis.

Breast height diameter of plus-trees in *Vaccinosa* and *Hylocomiosa* was 35.8 ±0.95 cm and 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). Also tree age and forest type had a significant influence on volume of branch-free section of stem; as trees were getting older 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.

Keywords: *natural pruning, forest type, crown height.*

The study was funded by The Latvian Council of Science project "Adaptive capacity of forest trees and possibilities to improve it" (No 454/2012).

RECENT FOREST FIRE REGIME IN LATVIA: 1922–2014

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In accordance with the projections of climate change in the future, it is expected that in Latvia will increase frequency and length of drought periods.

Goals of the research were (1) to assess spatial and temporal distribution of fires, (2) to assess the actual relationships between the numbers of forest fires and stand types (forest fuel type (FFT)) depending on weather conditions.

Historical wildfire data were searched in literature, archives; most recent data were received from State Forest Service. Weather data we obtained from "Latvian Environment, Geology and Meteorology Centre".

During last 90 years in average there were 628 wildfires per year (min 150, max 1929). There is a trend in increase of number of fires. Mean area of forest fires is 1014 ha per year (min 37, max 12013 ha). In both analysed periods (1975–1984 and 2004–2014) for with we have district level data, most of forest fires are in the vicinity of largest cities – Riga and Daugavpils.

We analysed relationship between number of fires and weather conditions characterised by Nesterov index (NI), for period 2007 till 2011. During analysed period 50 days were with very high fire danger index and 205 to 250 days with high fire danger index. During these days emerged 65–75 % of registered fires. Relationship between emergence of fires and forest fuel type group was not as strong as expected. The highest probability of fire emergence was during average or high NI periods in stands of high fire danger class (FFT).

Keywords: *fire regime, fire history, Nesterov index.*

The study was carried out in Forest Competence Centre (ERAF) project "Methods and technologies for increasing forest capital value" (No L-KC-11-0004).

MECHANIZED PLANTING IN LATVIA FIRST TRIALS WITH BRACKE P11.A

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Aim of the study were to estimate potential of increase of the efficiency of mechanization of artificial forest regeneration, by combined soil preparation – mounding and planting technology – to replace traditional reestablishment of forest by using container seedlings and planting with planting tube. The key activities of the study are (1) evaluation of experience of mechanized planting of container seedlings; (2) estimation of productivity and working quality of Bracke P11.a discrete planting head in different soil conditions; (3) elaboration of recommendations for the mechanized forest regeneration on mounds – current and future benefits.

The base machine, Daewoo 155CLV excavator, with length of the boom 7.8 m and Bracke P11.a planting head had used in the study. Operator was well trained with experience in planting, stump harvesting and forwarding. Planting (13.10.–16.10.2007) had been done in sandy (pine), silt (spruce) and clay soil (birch) not survived till 2015. In Figure 1 are showed results of survival of coniferous trees at next year after planting. In the most cases operator planted seedlings on top of mounds, but other planting methods – on a "bridge" and hollow were evaluated as well. Planting density – 2.5–3 thsd. ha, depending from species.

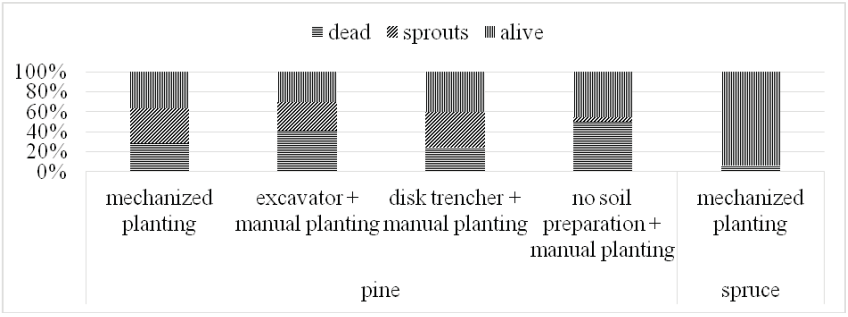

Figure 1. Survival of plants one year after regeneration.

Within of the scope of time studies 7 separate operations (driving, boom manipulations, mounding, planting, refilling, other and non-work operations). Considerable variations of productivity causes planting density and time consumption for refilling of the cartridge. Average productivity of the efficient hour is 190–199 seedlings, but of the working hour – 178–187 seedlings. Reduction of number of trees to minimum requested by regulations in plantation forests would reduce costs of planting significantly: in case of spruce by 58 %, birch – 37 %, and pine 62 % in compare to requirements for natural forests. More research should

be done to evaluate Silvicultural effect of the mechanized forest regeneration using planting units able to adjust planting space for each seedling in 2015 evaluated only on spruce stands, because in pine stand were no marked mechanized planted trees and replaced-replanted after bad surviving in next springs. Grows on mounds in comparison with tradition althod furrow is at least 12 % faster (Figure 2).

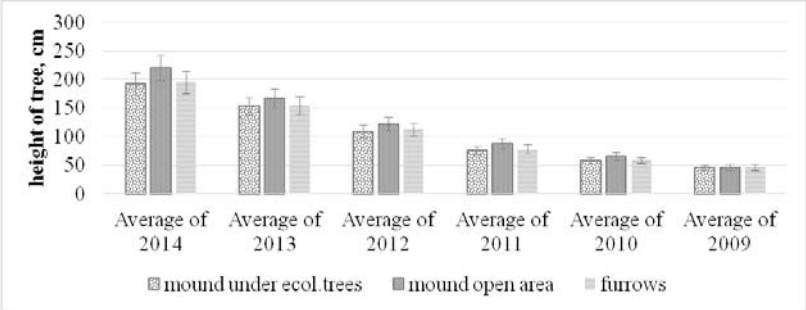

Figure 2. Height of mechanized on mounds and manually planted spruce in furrows.

Planting spaces formed by Bracke P11.a unit as well as planting density in the studied areas corresponds to the national forest regeneration requirements. Planting costs in Latvia using Bracke P11.a unit at the same planting density (1700 plants ha^{-1}) would be less than in Finland, because of higher average productivity estimated in parallel studies and lesser machine costs (Figure 3).

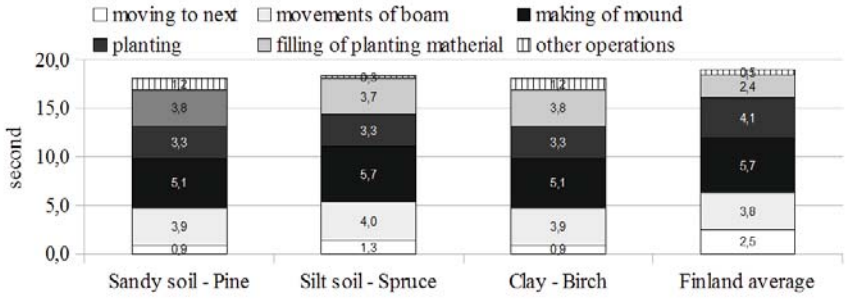

Figure 3. Time consumption for mechanized planting.

Costs of mechanized planting are still higher in compare to manual planting in Latvia, but better survival and, consequently, lesser planting density can make mechanization of the forest regeneration feasible

Keywords: *spruce, mechanized planting, mound.*

Study was financed by European Social Fund project „Management of vital Norway spruce stands: ecological and technological aspects" (No. 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

PRODUCTIVITY OF CLEANING IN SCOTS PINE STANDS DEPENDING ON SOIL PREPARATION METHOD

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In Latvia most of regeneration of coniferous stands after the clearcut is done by planting, especially on fertile soils, where competing vegetation is an important factor for survival and growth of planted trees. Spot mounding has been tested in recent years as an alternative soil preparation method to a widely used disc trenching, with the goal to ensure better moisture regime and decrease the frost damages, especially in periodically wet sites in micro relief depressions. To assess the potential financial benefits of this soil preparation method, it is important to evaluate the productivity (costs) and quality of all regeneration process (not only soil preparation itself), including also cleaning (tending) operations. Therefore time study of first cleaning (at the beginning of September) was carried out in four nearby sites on drained mineral soil (forest type *Myrtillosa* mel.), where spot mounding and disc trenching was used for soil preparation in previous autumn and one-year old containerized Scots pine seedlings planted in spring. In each stand four blocks (area 0.25–0.5 ha) were placed to assess the time used for cleaning (carried out by 4 brash-saw operators) and vegetation cover within each of the blocks estimated in 10 sample plots (area 25 m^2).

Before the cleaning operation neither the height, nor composition of the competing ground vegetation differed between the plots with different soil preparation, but proportion of the area covered by ground vegetation was significantly higher in blocks with spot mounding (Fig. 1). Nevertheless, after cleaning operation the ground-cover of remaining vegetation was slightly lower in blocks with spot mounding and only one of the planted trees was damaged by brash-saw during the operation in blocks with spot mounding. Also the effective working time did not differ significantly between blocks with spot mounding and disc trenching (469 ±98 and 532 ±95 min ha^{-1}, respectively).

Therefore it can be concluded that spot mounding ensured similar results of the cleaning operation than disc trenching both in terms of quality and time spent.

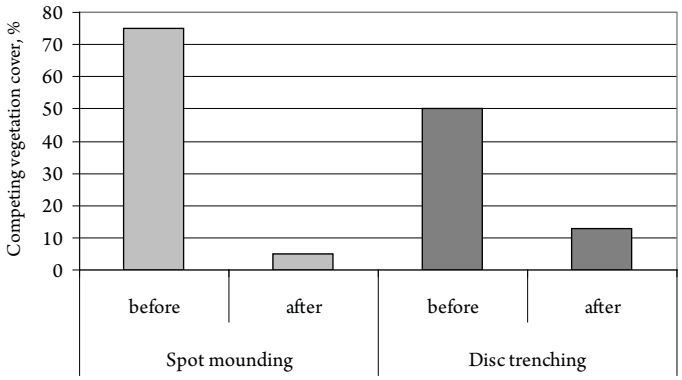

Figure 1. Cover of competing vegetation before and after the cleaning operation depending on soil preparation method ('before' – before cleaning; 'after' – after cleaning).

Keywords: *forest regeneration, competing vegetation, survival.*

Study was financed by European Social Fund project "Management of vital Norway spruce stands: ecological and technological aspects" (No 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

SCOTS PINE REGENERATION SITE GARKALNE (RIGA CITY FORESTS)

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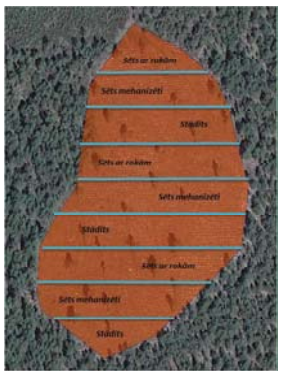
The proportion of young pine stands in forest regeneration is tended to decrease in Latvia, especially in private and companies-owned forests. The profitability of growing pine is low due to the long rotation and relatively high establishment costs.

The experiment was established to compare the establishment costs of pine planting (traditional pine regeneration method in Latvia so far) with manual and mechanized direct seeding.

Experimental site: *Cladinoso-callunosa* and *Vacciniosa* (IV or III bonity according Orlov site index scale). Clear-cut area harvested in the winter of 2008. Area – 3.2 ha. Manual and mechanized seeding was performed in the spring of 2009; planting – in the spring of 2010. Machines – Bracke M26.a + Bracke S35.a.



Advantages of direct seeding:

- established of high density stands– better timber quality, less risk of animal damages;
- no risk of pine weevil damage;
- naturally developed root system.

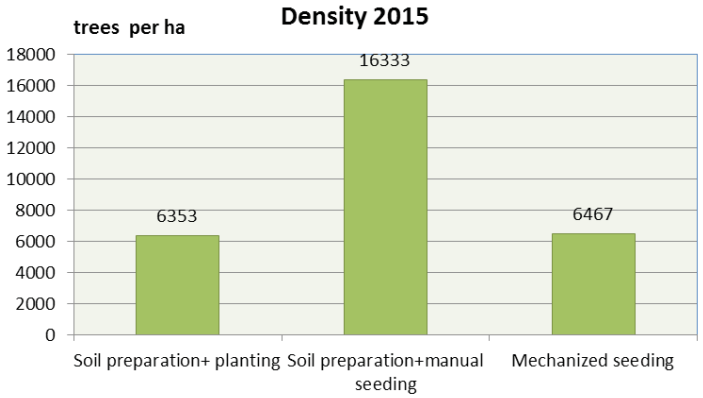
Main argument against direct seeding – the seedlings cannot be distinguished from natural regeneration during the pre-commercial thinning.

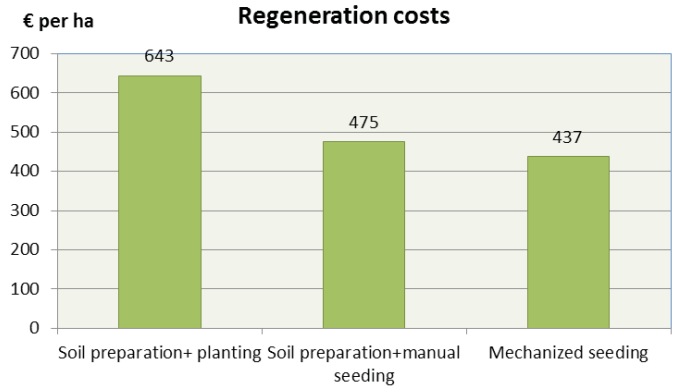
Results

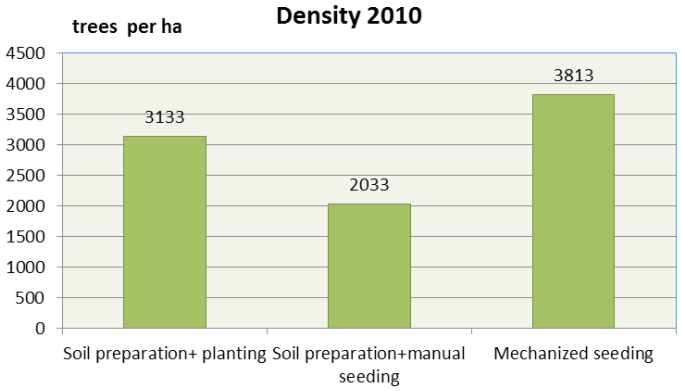
Direct seeding is cheaper than planting. The cost of the seeds accounts for 65 to 75 % of total regeneration costs. In current forest sites no additional weed control was needed to ensure the growth of pine seedlings.

Number of initially emerged seedlings in mechanical seeding did not guaranteed the

regeneration – the minimum density according the Forest Law (3000 trees per ha) was not achieved. During the following years, the abundant natural regeneration has ensured the reforestation success.







IMPORTANCE OF FOREST DRAINAGE IN LATVIA

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Paludification is normally observed in areas with highest precipitation, however, studies in Latvia had found that in regions with highest precipitation the percentage of waterlogged forests is actually the lowest. The explanation to these phenomena lies in hydrogeology: confined aquifer discharge areas ensure additional water input into forest soil. In order to improve forest growing conditions forest drainage has been carried out in large scale in Latvia: currently 33 % of all forests are drained, and still 18 % remains waterlogged. According to calculations, more than 60 % of all forests on drained peat soils and more than 40 % of all forests on drained mineral soils are located in these confined aquifer discharge areas. The positive effects of forest drainage are mainly related to oxygen. Aerobic processes are necessary to support carbon and nutrient cycling, but in waterlogged soils anaerobic processes dominate resulting in poor nutrient uptake, poor growth and formation of harmful compounds. After drainage conditions for the nutrient uptake are improved and in aquifer discharge areas additional nutrients are delivered by nutrient-rich water flows from below, ensuring, that even forests on deep peat soils show a very positive reaction to forest drainage.

According to our research data, the standing volume accumulation after drainage in pine and spruce forests increases 3 to 4 times, in birch forests – 2 to 3 times. Also black alder, aspen and ash respond positively to the improved growing conditions.

Keywords: *waterlogged forests, productivity, water balance.*

BREEDING OF SILVER BIRCH IN LATVIA

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Increasing demand for high quality broadleaved tree timber, mainly for plywood production, was the basis for expansion of tree breeding activities at the beginning of 1990th. Selection of high- quality naturally regenerated silver birch stands was done through the territory of Latvia (Fig. 1) based on forest inventory data and field assessments. In these stand plus trees were selected and used for establishment of grafted first-round seed orchard in greenhouse. Seeds were collected from the selected trees and progeny trials established in three locations, consisting of altogether 921 open-pollinated families. Largest of the trials (experiment No 54; including 637 families) was established in 1999 using one-year old containerized plants in 32 tree block plots in 4 replications. Measurements of the trial were carried out at the age of 8 and 14 years. Results of latest inventory revealed, that tree, growing on former arable land, were on average 14 m tall, had breast height diameter of 11 cm and yield 145 m^3 ha^{-1} (mean annual increment 10 m^3 ha^{-1} y^{-1}). Statistically significant differences were found between the families not only in productivity, but also quality: branch thickness, angle, number of branches in firs two meters of stem, stem straightness, occurrence of spike knots and double leaders. Selection between and within families was based on tree height with restrictions on quality traits and ensured material, that is currently grafted for establishment of next-round seed orchard as well as crossing for continuation of breeding.

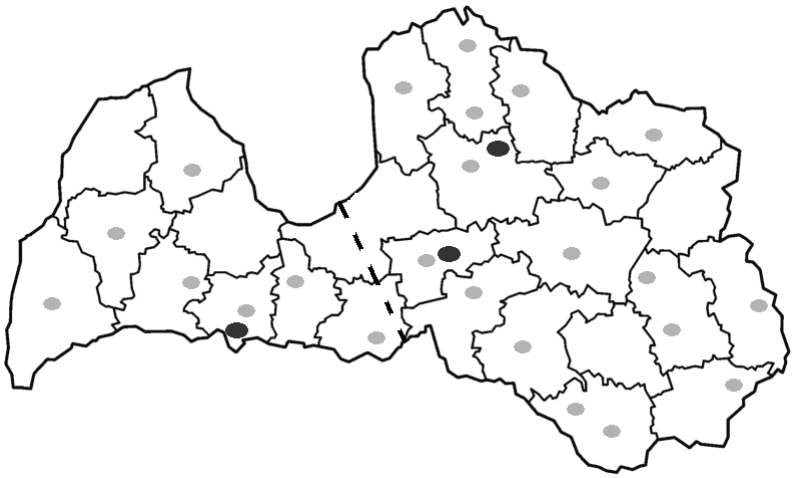

Figure 1. Regions of Silver birch plus-tree selection (grey) and their progeny trials (black).
Dashed line divides two provenance regions of Silver birch: western and eastern.

Keywords: *productivity, quality, birch plantation.*

PRODUCTIVITY OF HYBRID ASPEN IN LATVIA

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Hybrid aspen wood is suitable for production of sawn materials for specific purposes (e.g. for interior of saunas) and high-quality paper. Therefore this hybrid is used for establishment of short-rotation plantations, recently also in larger scale in Baltic States. Joint analysis of a number of trials in Latvia was used to establish a growth curves for hybrid aspen plantations. Results revealed, that at the age of 20 years (end of rotation period) men height of the plantations would reach 24 m and breast height diameter – 24 cm, resulting in mean stem volume 0.57 m^3. Assuming the survival of 600 trees ha^{-1} it will yield 342 m^3 ha^{-1} timber, resulting in mean annual increment 17 m^3 ha^{-1} y^{-1}. Statistically significant and notable differences in productivity were found between clones, the top figures reached 25 m^3 ha^{-1} y^{-1}.

In order to aid the selection as well as understand the potential changes in growth of hybrid aspen as a result of climatic changes, it is important to analyse the intra-annual growth dynamics. Therefore weekly measurements of height increment were carried out through the growing season of trees in three plantations, consisting of 19 clones (10 ramets per clone), on abandoned agricultural land in western, central and eastern part of Latvia. Mean height growth period of hybrid aspen ranged from 119 ±8.9 days for late flushing clones to 137 ±8.6 days for early flushing and was tightly (r = 0.69) linked to total length of height increment. Mean height growth intensity during this period for respective groups of clones ranged from 7.7 ±3.04 mm day^{-1} to 11.7 ±2.93 mm day^{-1}. Growth intensity (and height increment) was significantly affected by genotype (clone) and in both sites tightly (r = 0.57 … 0.84) linked with daily mean temperature, but not with precipitation. Increasing temperature in future might further boost the productivity of hybrid aspen plantations, especially with early flushing clones.

Keywords: *productivity, assortment structure, short-rotation plantation.*

The study was carried out in Forest Competence Centre (ERAF) project "Methods and technologies for increasing forest capital value" (No L-KC-11-0004).

Reference: Zeps, M., Sisenis, L, Luguza, S., Purins, M., Dzerina, B., and Kalnins, J., 2015. Formation of height increment of hybrid aspen in Latvia. *Agronomy Research* (in press).

FACTORS AFFECTING HEIGHT INCREMENT OF YOUNG NORWAY SPRUCE (*PICEA ABIES* (L.) KARST.) IN LATVIA

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Norway spruce is commercially important tree species in Northern Europe. In Latvia, it forms ~17 % of forest resources with growing stock of ~100 million m^3. The response of trees to longer periods with favourable growing conditions (increased temperature) forecasted in future, includes more frequent occurrence of lammas shoots – additional height increment due to growth release after the formation of the terminal bud in the second half of vegetation period. Although lammas shoots provide additional increment, they also increase branchiness of stemwood and occurrence of spike knots and double leaders. Therefore, the aim of the study was to assess the influence of lammas shoots on height increment and stem quality of young Norway spruce in Latvia.

Material was collected in planted stands of Norway spruce growing on forest land and open pollinated progeny trials established on former agricultural land in the central part of Latvia (56°37′–56°57′N, 23°37′–24°49′E). In each of 102 randomly selected stands with sapling age ranging from three to eight years growing in different forest types, 20 sampling plots of 25 m^2 were established. For each sampling plot, the proportion of trees with lammas shoots and micro-environmental factors (competition by the surrounding vegetation, moisture conditions and browsing damage) were assessed. In three progeny trials, for 3412 trees from 112 open-pollinated families of plus trees, several parameters – 1) height, 2) height increments, 3) presence of lammas shoots and 4) stem quality (spike knots, double leaders) were determined at the end of 10^{th}, 11^{th} and 13^{th} season (in 2011, 2012 and 2014, respectively). Analysis of variance and correlation were the methods applied for the processing of data.

The mean proportion of trees with lammas shoots in young spruce stands was 6.5 % (ranging from 4.6 to 8.6 %). The occurrence of lammas shoots was not affected by the age nor forest type, but significant effect of micro-environmental conditions was observed. Competition with vegetation reduced the proportion of trees with lammas shoots from 14.5 to 2.2 % in cases of no and strong effect, respectively. Similar response was observed also to increased soil moisture. The degree of browsing damage had the weakest effect on the formation of lammas shoots. In the progeny trials, mean proportion of trees with lammas shoots in a particular year at the end of 10^{th}, 11^{th} and 13^{th} growing seasons was 8.7, 26.9 and 8.1 %, respectively, and 32 % of trees had lammas shoots in at least one of the assessment years. Spruces with lammas shoots had by 10–14 cm larger ($p < 0.001$) height increment during the last three years compared to trees without lammas shoots. The cumulative influence of such differences at the end of

the 13th growing season was significant ($p < 0.01$) as trees with lammas shoots exceeded trees without lammas shoots in height by 14–20 % (Fig. 1). The link between height growth and occurrence of lammas shoots was evident also at the family level ($r = 0.50$, $p < 0.01$); still, notable variation in occurrence of lammas shoots was observed. Genetic correlation for this trait between years 2011 and 2012 was statistically significant ($r = 0.39$, $p < 0.01$). In total, spike knots or double leaders were found for 8 % of trees. Two years after the formation of lammas shoots, spike knots or double leaders in the respective whorl were found for 6 % of trees with lammas shoots and for 3 % of trees without. Three years after the formation of lammas shoots, the respective numbers were 3 % and 1 %. Thus, formation of lammas shoots had only slight effect on formation of spike knots or double leaders.

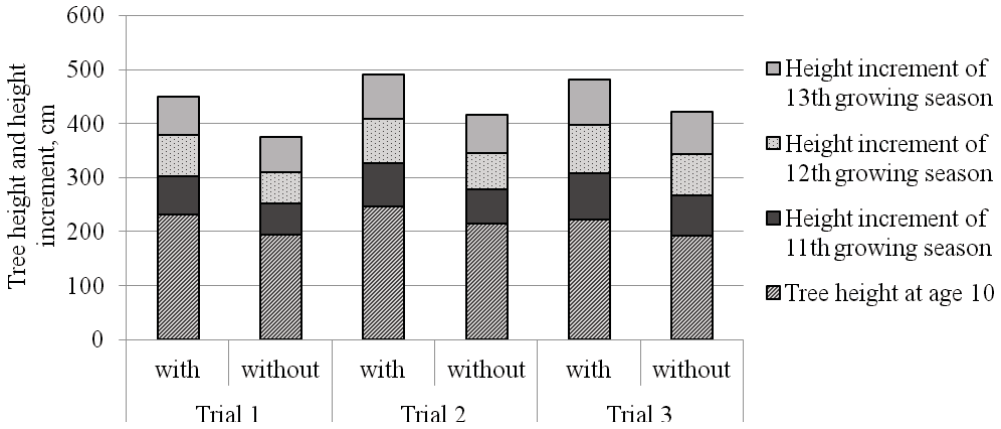

Figure 1. Height and height increment of trees with and without lammas shoots in trials 1–3. ('with' – trees with lammas shoots; 'without' – trees without lammas shoots).

Keywords: *lammas shoots, micro-environmental factors, genetic determination.*

Study was carried out in European Social Fund project "Management of vital Norway spruce stands: ecological and technological aspects" (No 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

INGROWING OF TREES IN FORMER PEAT QUARRY

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The aim of the establishment of pilot trial was to find out the effect of different fertilizers on tree growth, dimensions and ground vegetation in a cutaway peatland. The experimental plots located in Olaine district in Virši on a cutaway peatland that has been afforested at 2005. Trees were planted in 10 × 10 m sample plots where sewage sludge (10 t ha^{-1}) and mineral fertilisers (0.5 t ha^{-1}) have been applied. For re-cultivation of former mining area were used silver birch, Scots pine, Norway spruce and black alder seedlings. In fertilized plots where SRC willow clone Tora were unsuccessfully planted twice, finally natural afforestation with birch and Scots pine occurred. Trees ingrown from seeds from neighbor forest site are two years younger as planted ones, but dimensions and growing stock eight years after re-cultivation seams similar, planted ones just have better stems – straighter and less branches.

To analyse the success of afforestation after 6 and 8 years since re-cultivation, the average values for tree morphological parameters – height (m) was used, also the productivity – growing stock was calculated using height and diameter (cm) information (Fig. and 2).

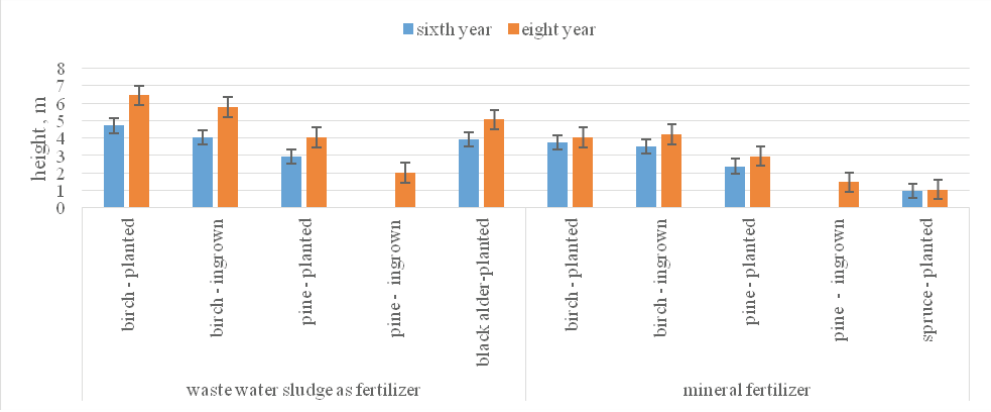

Figure 1. Height of trees six and eight years after recultivation.

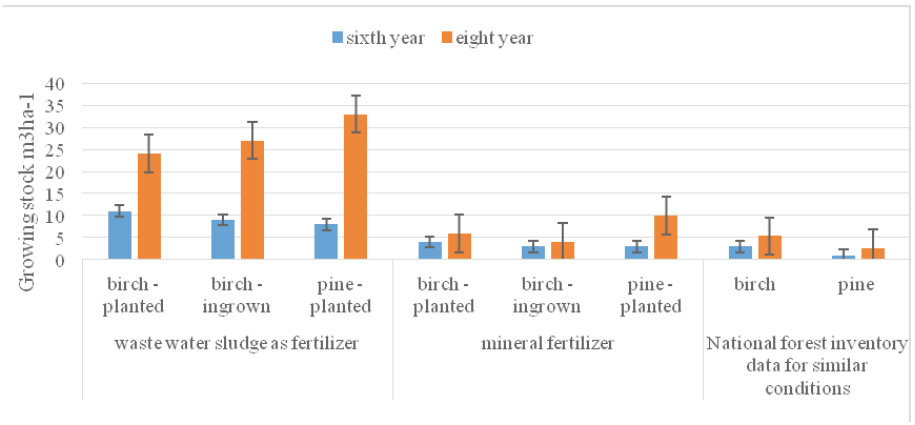

Figure 2. Growing stock of afforested areas.

There is very little ground vegetation cover on the plots fertilised with mineral fertilisation, mainly consisting of mosses and typical wetland species. Fertilisation provides favorable conditions for self-seeded tree regeneration.

To enable the afforestation of cutaway peatland fertilization is necessary, but planting trees is not compulsive and is economically unfounded. At the age of 8 the growing stock of planted birches is 24 m^3 ha^{-1} while for self-seeded trees it is 27 m^3 ha^{-1}, because of higher density. Stand productivity is higher using sewage sludge – an organic fertilized, containing different micronutrients, and it has a lasting effect. This experiment allows to conclude that after adding of lacking nutrient elements in formed peat areas close to forest border natural forest stand is able to self reestablished.

REALIZED GENETIC GAINS OF ORCHARD SEED – THE CASE OF SCOTS PINE IN SOUTHERN FINLAND

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As result of decades of investments in breeding and seed production programs, genetically improved seeds and seedlings are currently widely used in Scots pine regeneration in southern Finland. Moreover, the average genetic value of improved seedlots is on the steady rise, since first-generation orchard materials are currently making way for more superior seedlots from 1.5 generation orchards which comprise the top performers selected on the basis of genetic field testing. The recent emergence of multiple seed categories in the seed market has evoked a fresh interest in the magnitude of actual benefits obtained by the various types of improved stocks, by comparison to both each other and to alternative unimproved seed sources.

Genetically improved stocks are expected to show clear improvements in the traits selected for, i.e., yield and quality. The precise magnitude of genetic gains is, however, complicated and time consuming to obtain. Direct estimates require data from designed field trials where the performance of orchard and unimproved seedlots is compared in similar circumstances. Realized gain trials are commonly scarce. Furthermore, the results on juvenile-age performance of trees may overestimate the true genetic gain on a per unit area basis over a full rotation. To assess the impact of seedlots on yield and the economic parameters over the rotation, the juvenile gain estimates must be appropriately incorporated into growth models. Recent and upcoming Finnish studies on the genetic gains of open-pollinated Scots pine orchard seedlots, based on results from ongoing realized gain trials and subsequent stand simulations, suggest that the increase in the mean yield over rotation could be expected to be roughly in the range of 10 to 25 % depending on the generation (selection background) and pollination status of the orchard. The associated economic benefits of the bred material for the land owner are likely to be even a magnitude higher.

GENETIC DETERMINATION OF NATURAL PRUNING OF SILVER BIRCH

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Stands dominated by birch (*Betula pendula* and *Betula pubescens*) cover almost one third of Latvia's forest area according to data of National forest inventory. Monetary value of birch stand is to a large extent determined by the amount (proportion) of veneer logs. Therefore not only productivity, but also quality traits has to be considered in birch breeding to increase the value of stands, planted by selected material. Branches create an important defect on the veneer sheet, therefore longer branch-free part of the tree ensures higher monetary value. To achieve this result, pruning can be carried out, but it is an expensive. Therefore aim of our study was to evaluate the potential to improve natural pruning in tree breeding process.

Tree height, diameter as well as branch angle (in mid-part of the stem) and crown height was measured and number of branches in first two meters of stem counted in 14 year old open-pollinated progeny trial of silver birch (containing 100 families). Since the branch traits could be affected by competition, distance-dependent competition index was calculated for every tree and used as covariate in the analysis.

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 $h^2 = 0.45 \pm 0.026$ (without competition as covariate: 0.20 ± 0.05), respectively. Tree diameter had positive and significant genetic correlation with height up to the first green branch ($r = 0.64$, $p < 0.001$) and negative but not significant – with number of branches in first two meters of stem ($r = -0.11$); respective correlation between tree height and branch traits was similar ($r = 0.56$, $p < 0.001$ and $r = -0.26$, $p < 0.01$). There was a high potential to improve natural pruning of trees and selection based on growth traits (height or diameter) would also result in better branch quality of silver birch.

Keywords: *stem quality, branch traits, Betula pendula.*

The study was carried out in Forest Sector Competence Centre (ERAF) project "Methods and technologies for increasing forest capital value" (No L-KC-11-0004).

SEED SOURCE DEPLOYMENT STRATEGIES IN A CHANGING CLIMATE

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The gains achieved in tree breeding programmes are utilized by forestry mainly through using improved forest regeneration material from seed orchards. Contemporary seed orchards of Norway spruce and Scots pine provide regeneration material, which are expected to have a 10–15 % higher areal production than unimproved local plants. However, the entire gain is only realized if the reaction of forest regeneration material to climate change is known. Recent studies have shown that climate change can increase forest production in northern Europe but at the same time this requires the use of well adapted regeneration material. In collaboration with other Nordic and Baltic countries we develop transfer functions for Scots pine and Norway spruce. The functions are based on state-of-the-art climatic variables considered important for the performance of boreal conifers, combined with information of growth and survival from provenance trials and other genetic trials with suitable design. For Scots pine, such functions have already been developed for Sweden and Finland and for Norway spruce a similar project has been running for more than two years involving Sweden, Finland, Norway, Estonia and Latvia. When such functions are available, climate adapted deployment recommendations of current seed sources can be developed using climate scenario data to predict their performance. Also, as the Scots pine functions are valid in both Sweden and Finland, this allows for common deployment recommendations and facilitates trade and use of improved material between countries. The deployment recommendations can be accessible for public use in different ways. One way, planned to be used in Sweden, is to develop a web-tool, where the user provides a regeneration site (with some local climatic background) and a climate scenario (several different will be available) and gets a list of seed orchards ranked according to their predicted per hectare production at that site. Per hectare production is calculated as the product of growth at mid-rotation (i.e. in a future climate) and survival at the current climate weighed by a function taking patchiness of mortality into account. A beta version of the web-tool will be demonstrated at the conference.

Keywords: *Scots pine, Norway spruce, climate change, deployment recommendations.*

SCOTS PINE (*PINUS SYLVESTRIS* L.) SEED ORIGINS RESPONSES TO ENVIRONMENTAL CONDITIONS ESTIMATED IN IUFRO 1982 EXPERIMENT

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We review data on the IUFRO 1982 Scots pine experiments and apply theory that allows us to mimicking climate change on provenance performance in the changed growth conditions. Regression approach were used to express survival, growth and quality traits of European populations of Scots pine (*Pinus sylvestris* L.) included in IUFRO 1982 experiment in relation to the differences in climate variables between the original location of a provenance and the location of a common garden experiment. Growth data were expressed in standard deviation units in order to compare results from different years. The result from available provenance plots showed that in Scots pine growth and survival exhibit a strong clinal variation and have a large potential for adaptation to changing climate. The analyses utilized the set of global climate data available at WordClim.org with a spatial resolution of a square kilometer. Regression models showed that the growth and survival generally decreased when population were transferred from the location of their provenance to a new distinct location in latitudinal gradient W–E. Strong relationships were found between volume and transfer distances measured as a difference of annual average air temperature of provenance origin and planting sites (Fig. 1). Local populations were not always among the best in particular location of the experiment. Artificial populations established by humans (17 Pornóapáti and 13 Ardennes) reacted in a different way than natural populations. Results indicate that provenance experiments can be applied to predict growth response reactions of forest reproductive material transferred in to new environmental conditions.

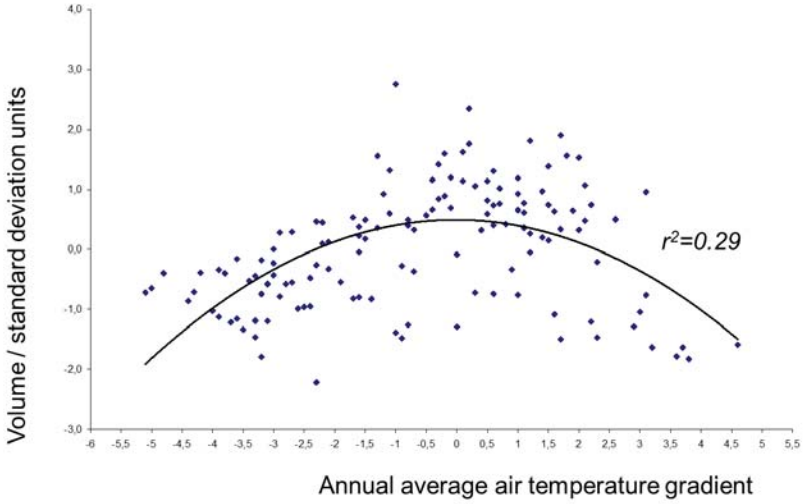

Figure 1. Regression models and observed volume of Scots pine populations plotted against transfer distance (planting site climate minus provenance climate) for the annual average air temperature.

Keywords: *Pinus sylvestris L., provenance experiments, climate, seed transfer.*

RELATIONSHIPS BETWEEN WOOD PROPERTIES AND GROWTH TRAITS IN SCOTS PINE (*PINUS SYLVESTRIS* L.)

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Trees are complex biological systems and wood formation is crucial for their existence. There are a lot of biotic and abiotic factors influencing processes within a tree. Information about wood properties and growth traits varies greatly between species belonging to the same taxonomic group or even within species. Scots pine as study object was chosen because of its global and local biological and economic importance and conflicting information available about its physiological traits and wood properties. Detailed characterization of Scots pine wood properties and growth traits was also necessary to incorporate into our research about expression of genes influencing wood formation.

Fifty 30 year old trees from a Scots pine breeding program progeny test site were selected according to relative wood density values measured with a Pilodyn instrument (25 with higher and 25 with lower relative wood density). To obtain detailed information about the wood properties and growth traits of these trees, 12 mm increment cores were gathered from these 50 trees and analyzed using Silviscan.

The average proportions of annual wood growth were 51 % early wood, 31 % transition wood and only 18 % late wood, with wood density average 346.8 kg m^{-3} for early wood and 826.6 kg m^{-3} for late wood. Significant correlations between Scots pine growth traits and wood properties were detected. Some differences between wood properties and growth traits were revealed for trees with higher and lower relative wood density. For example, a negative correlation was found between microfibril angle (MFA) and maximum wood density for trees with higher relative wood densities.

Keywords: *wood properties, growth traits, Scots pine, Silviscan.*

CHANGES IN LITTER COMPOSITION AFTER SURFACE FIRE IN THE DRY-MESIC PINE FOREST IN RUCAVA (LATVIA)

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Forest fire, a common occurrence around the world, is an important and typical disturbance factor in boreal forests of Europe. The statistics of forest fires in Latvia over last century shows occasional extreme events of fire. The most severe forest fires took place in 1963 when 12013 ha of forest area burned. In the 1992–2014 period, the most severe fires occurred in 1992 when 8412 ha of forest area burned; the area of burned forest in the other years of this period ranged from 90 ha in 2012 to 3790 ha in 2006. In Latvia, dry coniferous forest stands are subject to highest risk; 85 % of all forest fires occur in dry Scots pine forests. Scots pine (*Pinus sylvestris* L.) is a dominant tree species in 915000 ha of forest area in Latvia occupying ~29 % of all forest land.

The aim of this study was to assess the impact of low severity surface fire on chemical and biological composition of litter in 60 years old dry-mesic Scots pine (*Pinus sylvestris* L.) forest stand classified as *Vaccinio vitis-idaeo-Pinetum* community in Rucava, Peši site, SW Latvia. The fire took place in August 2014.

Analysis of total and partially decomposed litter layer indicated that litter layer thickness was reduced by 2 cm immediately after surface fire, the mean loss of organic matter mass was 8.0 t ha^{-1}. The fire also resulted in reduced carbon and nitrogen pools in litter layer. Properties of mineral topsoil (E horizon) below the litter layer were not affected by surface fire.

Keywords: *dry-mesic pine forest, surface fire, litter properties, carbon and nitrogen pools.*

Study was funded by the Forest Sector Competence Centre project "Methods and technologies for increasing forest capital value" (No L-KC-11-0004).

SPORE PRODUCTION OF *HETEROBASIDION ANNOSUM* S.L. FRUIT BODIES IN LATVIA: IMPACT OF SEASONAL AND METEOROLOGICAL FACTORS

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Heterobasidion root rot is the most serious problem in coniferous stands in Northern Europe, including Latvia. This fungus causes significant economic losses in spruce stands. Investigation of spore production was undertaken to understand sporulation biology of *H. annosum*, to optimize methods of controlling spread of the pathogen during forest management activities and to develop recommendations for forest management to reduce damages caused by *H. annosum*.

The study of *H. annosum* basidiospore production was carried out in the central part of Latvia in LLC "Riga Forests" forest stands dominated by *P. abies*. All *H. annosum* fruit bodies used in the investigation were located on stumps or logs of *P. abies*. Spores of *H. annosum* were collected in Petri dishes directly under fruit bodies over three years from 2012 to 2014 when diurnal temperatures were above 0°C. Spores were counted in 30 sight fields per Petri dish and then calculated as spores per dm^2 in one minute. Diurnal spore production was studied 7 times from July to November in 2012 and 2013. Spores were collected every 6 hours.

Spore production increases in April when diurnal temperature exceeds 5°C. Maximum spore production (more than 65000 spores per dm^2 in 1 min) is reached in August and September. In late autumn, *H. annosum* spores were collected more often when the diurnal temperature was below 5°C in comparison to the same temperature in spring. It was found that season, temperature and relative air humidity have an effect on spore production of *H. annosum*.

Diurnal spore production varies in different seasons. From July to September the highest spore production was at midnight but the lowest at noon. In October and November differences in diurnal spore production were not significant. To control spread of *H. annosum* it is recommended to practice thinning when the diurnal temperature is below 5°C. If tree cutting is done in summer, it is recommended that thinning be done during the day instead of at night.

Keywords: *Heterobasidion spp., Picea abies, spore production, seasonality, meteorological factors.*

Report was funded by European Regional Development Fund project No L-KC-11-0004 "Methods and technologies for increasing forest capital value" and State research programme "Forest and earth entrails resources: research and sustainable utilization – new products and technologies" (ResProd) project "Even-age spruce stands cultivation potential in fertile forest ecosystem".

DISTURBANCE LEGACIES IN FOREST ECOSYSTEMS OF THE HEMIBOREAL ZONE: LESSONS FOR FOREST MANAGEMENT

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Forest disturbance legacy is relatively long-lasting biological or physical structure in the forest ecosystem the condition or the environment of which was changed and it was caused by disturbance occurrence (agent) of varying scale. Forest disturbance legacy can be imported if those become a functional part of the ecosystem. Forest disturbance legacies determine the naturalness of the forest ecosystem. If no legacies are found on the site the forest ecosystem is regarded as semi-natural or novel. Tree harvest or legacy manipulation (removal) is the frequent case for semi-natural forest. Forest spontaneously regenerating or restored after temporary deforestation (changed land use leading to the loss of legacies) are novel ecosystems. Novel ecosystems appear under conditions where historical path of development is altered. The novel forest ecosystem may converge with higher naturalness when legacy components are created by natural processes or restoration. The ecosystem stays on novel trajectory when manipulations or other causes prevent the legacy formation and further function.

Forest dynamics depends on the condition and type of disturbance legacies. Shifting mosaic and steady state at the landscape scale are caused by forest gap dynamics Stand replacing disturbances result in forests of different stand development phases at the landscape scale. Biotic and abiotic legacies after stand replacing disturbances determine the dynamic properties of forest ecosystems and vary according to forest conditions and disturbance agent.

Different management strategies are feasible in regard of forest disturbance legacies when planning forestry. The three main scenarios involving anthropogenic drivers from the East-Baltic Sea area that substantially change successional trajectories via legacies are these: disturbance manipulation, common forest management practice and temporal agricultural deforestation. Novel trajectories are created when altered legacy conditions occur or the artificial legacies are involved.

Keywords: *disturbance legacy, forest, naturalness.*

BUILDING-UP UNDERSTANDING OF LONG-TERM NATURAL DYNAMICS IN FOREST LANDSCAPE: CASES STUDIES FROM SLITERE NATIONAL PARK, LATVIA

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Long-term changes of forest cover are notably affected by anthropogenic and natural disturbances. Major natural disturbance, impacting large forest areas in Northern Europe, is storm. Forest fires are efficiently suppressed and therefore usually affect only small areas in our region. Impact of both these disturbances is predicted to rise in future due to climatic changes, causing increase in frequency of storms and maximal wind-speed as well as increase in temperature and prolonged periods without precipitation. Usually after the large natural disturbance salvage logging is carried out to minimize both the financial losses and risks to remaining (neighbouring) stands, for example, due to expansion of bark beetle populations in damaged (weakened) trees.

Slitere national park, located in north-western part of Latvia (57°38' N, 22°17'E) provides a unique opportunity to study natural dynamics of hemiboreal forest ecosystem after large-scale disturbances.

Part of its territory (unmanaged since 1923) was affected by storm in November of 1969. Supervised classification of Corona and Landsat 5 images of the area (in total 1646 ha) from years before and after the storm (1966–2010) were carried out and parameters characterizing the fragmentation calculated for 3 land-cover classes: forest, areas with low woody biomass and non-forest areas.

Influence of windthrow on forest landscape was considerable: areas characterized as "forests" (dominant age exceeds that of young stands) were reduced by 53.3 % in year 1972 in comparison to 1966. Statistically significant influence of storm in land-cover classes were found to mean patch size, mean shape index and mean weighted Euclidean distance. Major part of the analysed un-managed landscape had returned to land-cover class "forest" already 19 years after the storm. However, changes in Shannon's diversity index demonstrated, that fragmentation of forest landscape had returned to pre-storm state only 30 years after the event. Therefore, if storms are predicted to occur in a frequency less than 30 years, their impact on un-managed (natural) forest landscape could be notable and permanent, changing also the habitat structure. Immediately after the storm mean weighted Euclidean distance between forest patches increased by 45 m. If such situation remains for a long time in future it can influence organisms with small dispersal distances, shaping the composition of species in natural forests.

Large-scale forest fire (total area 3200 ha, forest area 1032 ha) occurred in another part

of Slitere national park in 1992. Affected forest areas were Scots pine dominated (98 %) and mostly forest types on poor, sandy soils – *Cladinoso-callunosa* and *Vacciniosa* (55 %). In order to allow cross-dating sample plots were located only on these forest types, selecting the compartments systematically based on location to cover the burned area with the grid of similar distances between the plots. In total 70 trees were sampled (46 used in analysis) from 14 plots (5 trees per plot), choosing the trees with visible fire scars or, if no present, with largest diameters within the compartment.

Results revealed that age (at stump height) of sample trees ranged from 43 to 496 years. Number of fire scares (not counting the latest in year 1992) ranged from 0 to 4, fires with the intensity strong enough to leave visible scares were found to be happening in 36 separate years. Majority of the fire scares (24) were detected only on tree, but two of them – in 4 trees from 2 different plots, possibly indicating larger fire.

Results provide a sound basis for future studies of natural dynamics of forest ecosystem after large-scale natural disturbances. We acknowledge the permission of Nature Conservation Agency to collect the material for the studies.

Keywords: *windthrow, forest fire, hemiboreal forest, natural succession.*

Reference: Baders, E., Purina, L., Libiete, Z., Nartiss, M., and Jansons, A., 2014. Fragmentācijas ilgtermiņa dinamika meža ainavā bez cilvēka saimnieciskās darbības ietekmes (Long-term fragmentation dynamics in semi-natural forest landscape). *Mezzinatne* 28, 91–107. (in Latvian with English summary).

ESTABLISHMENT OF *POPULUS* SPECIES IN THE SECOND GENERATION

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The interest for woody biomass is increasing due to, among other things, the Nordic vision to become independent of fossil fuel by 2050. One way to approach this vision is to cultivate and harvest fast-growing tree species.

This investigation consisted of three study parts on how hybrid aspen and poplar perform in the second generation. In the first study, initial growth of root suckers between 1- and 4-years-old was studied at four sites. In the second part, growth effects following three different thinning treatments was studied for 12 years at one site. The thinning treatments in study 2 were 1) no thinning; 2) corridor thinning, where 2 m broad corridors were cut with a distance of 1 m; and 3) cross-corridor thinning, where 2 m corridors were cut in two directions, with a distance of 1 m. In the third part, one-year-old stump sprouts of 23 poplar clones were examined and survival, sprout straightness and growth were recorded.

In study 1, the four sites had a mean stand density of 63500 living stems ha^{-1} after two growing seasons. The range among the sites was 46800 to 72900 stems ha^{-1}. At this age the mean standing biomass, including dead stems, was 14.5 tons dry weight (DW) ha^{-1} (ranged between 8.8 and 21.7 tons DW ha^{-1}). The mean annual increment was after two years 7.2 tons DW ha^{-1}.

Even though biomass had been harvested after 2 years in study 2, the density of living stems did no longer differ between the treatments at the end of the 12-year period. The stem diameter was largest for cross-corridor thinning, while the height development was not affected by thinning strategy. The obtainable biomass (included living, dead and harvested biomass) and mean annual increment did not differ between the treatments during the study period. After 12 years, the mean annual increment had started to decrease and was 8.5 tons DW ha^{-1} yr^{-1} in unthinned treatment, 10.9 tons DW ha^{-1} yr^{-1} in corridor thinning, and 9.7 tons DW ha^{-1} yr^{-1} in cross-corridor thinning.

In study 3 it was shown that the capacity to produce new sprouts from the stumps differed among clones. In addition, clonal differences in sprout straightness were found.

This investigation showed that the second generation of hybrid aspen can contribute significantly to the biomass supply, and that the strength of early thinning has a large effect on the continuing growth. The importance of early thinning, when striving for large fast-growing trees, is highlighted. It was also shown that it is important to know the sprouting ability and

performance of poplar clones when striving for a second generation based on stump sprouts.

Keywords: *vegetative regeneration, root sprouting, biomass production, growth dynamics, thinning strategies.*

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ECONOMICAL ASSESSMENT OF WOOD ASH SPREADING IN FOREST

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TDue to increase of biomass consumption in energy production and increasing problem of wood ash landfilling, many studies analyse wood ash chemical properties and utilization ways. As wood ash is acceptable for soil amendment, economical assessment for following action is required. For that reason trial of forest fertilization was carried out using newly built spreading trailer which was connected with tractor Valtra 6350 equipped with wheel loader.

Experiment was held in end of November of 2014. Forest stands are distributed at Joint Stock Company "Latvijas valsts mezi" Viesite forest district. Experiment of wood ash spreading was made in four (two *Hylocomiosa* and two *Oxalidosa* turf. mel.) Norway spruce *Picea abies* (L.) Karst. stands from age of 43 to 48 years which were thinned in last two years. Total area treated with wood ash was 10 ha and total amount of wood ash – 20 t (treatment dose 2 t ha^{-1}) was scattered. Time for all work elements in total productive time consumption were received.

Costs for one hour implements services was 25.00 EUR. Total time consumed for fertilization was 17 hours and 29 minutes which makes 437.13 EUR or 43.71 EUR ha^{-1} costs. Assuming that average costs of landfilling are 36.00 EUR t^{-1} and transport costs in both cases are the same, gain of wood ash use in forest fertilization when treatment dose is only 2 t ha^{-1} is about 28.30 EUR ha^{-1}. Income of potential tree increments was not included.

Keywords: *wood ash, forest fertilization, economical assessment.*

IMPACT OF FOREST FERTILIZATION ON CARBON STOCK IN SPRUCE STANDS ON MINERAL SOILS

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Studies on impact of forest fertilization on the greenhouse gas (GHG) balances are done in several European countries. In the large scale study on forest productivity project (*Future Forest*) Swedish researchers estimated, what impact would have fertilization of 10 % of forests in Sweden (2.3 mill. ha). According to their results it would raise annual increment by 7.4 mill. m^3, including 41 % of the increment in large dimensions' timber. 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 which corresponds, respectively, to 18 % or 28 % the GHG emissions in Sweden in 2007 (Sathre *et al.*, 2010; Nordicforestry, 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 533611 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.). 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. Round sampling plots (area 500 m^2) 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 m^2; litter was collected from the same place by cutting samples to the whole depth of the litter layer (area of sampler is 100 cm^2); soil samples were taken with undisturbed soil samplers from 0–10, 10–20, 20–40 and 40–80 cm depth. Two sample sets were collected from each plot.

In laboratory 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. 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 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. Considerable increase of carbon stock due to fertilization is found in all soil layers (Table 1); however, due to high level of uncertainty the difference is statistically significant only at 10–20 cm depth.

Table 1. 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 2).

Table 2. 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 significantly higher in fertilized plots (by 29 % of carbon stock in living biomass in the control plots). Summarizing the carbon pools in Table 3, 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 3. 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 CO_2)	9.4	0.2	0.1	3.0	12.6

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 ranges from 29–30 % in living biomass and litter to 84–98 % in dead wood and soil. The average additional removals of CO_2 in all carbon pools in fertilized plots equals to 12.6 tons CO_2 per year. The project results approves, that fertilization of forest stands during the regeneration stage can be one of the most efficient climate change mitigation measures in Latvia.

The study is done within the scope of the National forest competence center project "Methods and technologies to increase forest value" (No L-KC-11-0004).

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EVALUATION OF THE IMPACT OF DIFFERENT TYPES OF TRACKS ON PRODUCTIVITY AND COST COMPARISON OF DIFFERENTLY EQUIPPED FORWARDERS IN THINNING

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Forwarding of round wood assortments to a roadside is one of the basic operations of logging technological process. Machinery corresponding to the Joint Stock Company "*Latvijas valsts mezi*" (further JSC LSF) technical requirements for harvesting equipment are used in forwarding in JSC LSF forests. The main factor influencing forwarding conditions is bearing capacity of soil. Forwarding conditions are classified as good, medium, bad and extreme depending on forest stand and skid road characteristics out of stand. Forwarding conditions are one of the factors affecting work productivity and cost of forwarding. Aim of study is to find out cost of forwarding of round wood assortments obtained in first in thinning using different forwarders with different tracks, including the assessment of environmental impact. Four forwarders were compared in the study: medium class forwarder John Deere 810 D without special equipment; Forwarder John Deere 810 D equipped with plastic tracks; forwarder John Deere 810 D equipped with steel tracks; ProSilva 15-4ST forwarder.

The study was implemented in three coniferous stands nearby Ugāle of JSC LSF forest areas in November, 2014.

In total 56 forwarder loads were extracted (about 407.9 tons, or 489.5 m^3). In average 36 minutes (John Deere 810 D equipped with plastic chains) to 46 minutes (ProSilva 15-4ST) of effective work time is spent to transport 1 forwarder load. In average 4.7 (John Deere 810 D without special equipment) to 6.1 minutes (John Deere 810 D equipped with plastic chains) of effective work time are spent to transport 1 m^3 of round wood assortments. Use of plastic tracks shows better productivity characteristics in comparison to the same forwarder with steel tracks. However, under the particular circumstances the best results are reached by using forwarder without tracks. Comparison of prime cost of forwarding shows the best results for the John Deere 810 D forwarder without tracks (2.38 EUR m^{-3}). The worst results are obtained with ProSilva 15-4ST (3.91 EUR m^{-3}) forwarder. Relatively high prime cost of forwarding with ProSilva 15-4ST relates to inefficient use of the load capacity as well as by incorrect measured fuel consumption high operational cost of the machine. Transportation of full loads would significantly reduce cost of forwarding. It is also important to estimate actual fuel consumption under different forwarding conditions, comparing tracked and wheeled machines. Additional study is necessary for estimation of forwarding prime cost calculation of the ProSilva 15-4ST

forwarder in compare to others in bad and extreme conditions, including weighing of forwarded material and real time estimation of fuel consumption. The evaluation of the environmental impact demonstrates that ProSilva 15-4ST forwarder, in spite of it's size, has the best results. Ruts after forwarding were found in 1.7 % of the skid roads length. Forwarding with ProSilva 15-4ST also resulted in relatively small number of root damages (2.8 trees ha^{-1}). The longest ruts (10.1 %) were found in skid roads, where forwarding was carried out by John Deere 810 D without tracks. While most damaged trees were found in the skid roads, where forwarding were carried out by John Deere 810 D equipped with plastic tracks (7.8 trees ha^{-1}). Quality indicators of environmental impact demonstrated by John Deere 810 D without special tracks are comparably the worst, but they meet the quality requirements of JSC LSF. The plastic tracks did not demonstrated considerable reduction of number of damages of roots or decrease of area of ruts.

It was not possible to completely evaluate the benefit of tracks and, especially, of tracked forwarder in this study, because forwarding conditions were optimal and suitable for wheeled forwarders without special equipment. Benefits of plastic tracks are reduced vibration, slightly reduced fuel consumption in compare to steel tracks and improved working condition for operator (no need to remove tracks to cross asphalted roads). However, in comparison with standard steel tracks, the tested plastic tracks cause significantly larger impact on environment and can significantly increase cost of forwarding. The study results show that plastic tracks have no significant advantages over currently used steel tracks. The study results point to the need to reconsider restrictions on the use of large tracked forwarders in thinning because their impact on environment in comparison with medium class forwarders can be even smaller; however additional studies are necessary to improve performance of tracked machines in thinning.

Keywords: *forwarding, work productivity, prim cost.*

The study is done within the scope of the Forest Sector Competence Centre project "Methods and technologies to increase forest value" (L-KC-11-0004).

IMPACT OF TRACKED AND WHEELED FOREST MACHINES ON SOIL PENETRATION RESISTANCE IN EARLY THINNING

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The aim of the study is to evaluate impact of small-sized wheeled and tracked machines on soil penetration resistance and rut formation during harvesting and forwarding operations in early thinning. The study was conducted in 7 forest stands growing on mineral soils. Wheeled John Deere 1070E (4 wheels) and wheeled Rottne H8 (6 wheels) harvester and tracked Timbear harwarder were used in harvesting. Wheeled John Deere 810E and wheeled Rottne H8 forwarder and tracked Timbear harwarder were used in forwarding. Forest machines were combined into 4 different combinations and work methods: 1) John Deere 1070 and John Deere 810E (JD-JD, no residues in skid trails); 2) Rottne H8 and Rottne F10B (R-R, residues in skid trails); 3)John Deere 1070 and Timbear (JD-T, no residues in skid trails); 4) Timbear harvarder both in harvesting and forwarding (T-T, residues in skid trails).

Mechanized thinning resulted in significantly ($p < 0.05$) increased soil penetration resistance on strip roads with all combinations of forest vehicles used in trials. The maximum increase on penetration resistance reached 106 %, 95 %, 85 % and 83 % for R-R, T-T, JD-T and JD-JD in a depth of 15 cm, 6 cm, 6 cm and 17 cm. If the tracked machines were used in forwarding (T-T, JD-T) soil was compacted down to 30 cm while significant increase on penetration resistance was found down to 60 cm (R-R) and 80 cm (JD-JD) if the wheeled machines were applied. With R-R and JD-JD ruts formed on 16 % and 6 % of total length of skid trails while after JD-T and T-T ruts were less than 1 %. The results shows that the most intensive soil compaction was found with R-R what can be explained with the number of wheels. However, the deepest impact was found with JD-JD, perhaps it can be attributed to the fact that this working method produced no residues to put in skid trails. Depth of soil compaction and rut formation can be reduced if the tracked machines are used in forest operations.

Keywords: *soil compaction, thinning, tracked, wheeled.*

IMPACT OF UNDERGROWTH REMOVAL ON DAMAGES OF REMAINING TREES DURING MECHANIZED THINNING OF YOUNG DECIDIOUS STANDS

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The aim of thinning is to improve growth conditions, where the suitable species are left for each stand and density is in accordance with the best forestry management practices. Nowadays the main attention in thinning is focused on ecological aspects, like forest health, considering under this term reduction of tree and soil damages. In order to evaluate impact of forest machinery in young stand thinning and to be able to provide recommendations for proper implementation of mechanized thinning, we need new research data about this topic, covering different aspects of quality requirement and technical capabilities of the machines employed in thinning.

The main attention in this study is focused on situation in a stand after thinning, if the undergrowth trees are extracted manually or left untouched before thinning. Hypothesis is raised of this study: if the undergrowth is left untouched before mechanized thinning, the remaining tree got more damages during thinning in compare to the case, where undergrowth trees are extracted.

Materials and methods. Data were collected in one forest stand (total area 3.8 hectares), which is located approximately 10 kilometer to North from Skriveri village. Approximately 5000 trees were extracted during the study. Before thinning the main stand characteristics, like diameter and height of trees, were determined in the field and other stand characteristics (basal area, growing stock, biomass, species composition) were later calculated in office. According to the measurement data the average diameter of trees at breast height is 7.7 cm, tree height is 10.9 m and stand density is more than 2900 trees per hectare. Only trees with diameter above 4 cm at breast height are accounted. Average tree volume is 0.0204 m^3. Area of the stand is regular shape and the area of plots, where different methods are applied is similar. Stand is divided into twelve parts or strip-roads and each working method is implemented in four strip-roads with average length of 155 m.

Working methods:

1. Undergrowth trees with diameter below 3 cm at diameter breast height are removed;
2. Undergrowth trees with diameter below 5 cm at diameter breast height are removed;
3. Undergrowth trees are left untouched.

Rectangular sample plots, including strip-roads and remaining stand, were established after

thinning for evaluation of quality of thinning and accounting of damaged trees. Width of the sample plots is equal to width of area thinned from one strip-road, length of sample plots is 20 m (Figure 1).

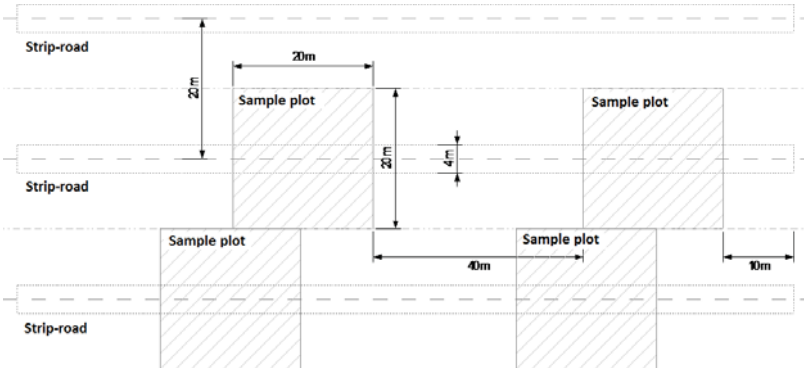

Figure 1. Technological scheme of established sample plots.

The distance between sample plots on each strip road depends of strip road length. If the strip road is longer than 160 m, then distance between sample plots is 40 m, but if the strip road is shorter than 160 m, then distance between sample plots is 20 m. Sample plots are located in parallel with strip roads in a way that it's mid-axis be in one line with column mid-axis, but sample plot side borders converge in one line with column side lines (Figure 1). At each strip road the first sample plot is about 10 m from edge of the stand to reduce effect of edge. All trees in each sample plot were measured if its diameter of breast height is equal to or more than 4 cm. Measured parameters are species, diameter of breast height and distance between tree and center of strip-road in 90° angle. Tree height after thinning was determined using logarithmic regression trendline elaborated on the base of measurements that was done before thinning. All damaged trees were counted, separating damages caused by harvester and forwarder, as well as location and type of damage. Qualifiers for damages were borrowed from JSC "Latvijas valsts mezi" quality requirements (Table 1).

Table 1. Qualifiers for mechanically damaged trees in thinning

Damage location	*Form of damage*	*Description of damage*
Crown	Broken top	Broken off top
	Broken branches	More than 60 % from crown
Stem	Stem part without bark	The area without bark is more than 25 % from stem girth at damage height
Roots	Broken root	Root that is thicker than 2 cm broken till 70 cm from stem

Used groups of tree damages:
1. Damage above 0.5 m;
2. Damage below 0.5 m;
3. Damages of roots;
4. Damages by chainsaw.

Results and discussion. According to the study results the undergrowth left untouched before thinning performs protective function from mechanical tree damages, respectively number of damages of remaining trees is smaller in compare to plots, where undergrowth is extracted before thinning. Undergrowth trees are acting as amortization material making moves of harvester head and crane slower.

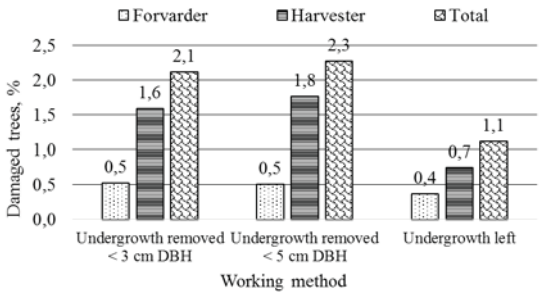

Figure 2. Percentage of damaged trees depends of group of used working method.

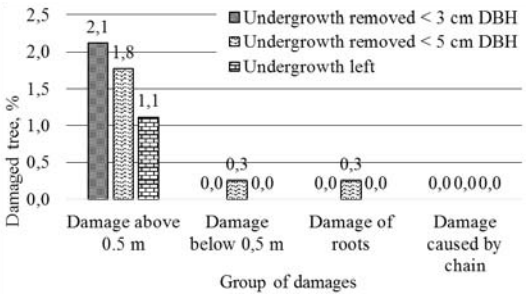

Figure 3. Percentage of damaged trees depends of group of damages.

Figure 2 shows, that the smallest number of damages is detected in working method where undergrowth trees are left untouched before thinning, but the most of tree damages are detected in working method, where undergrowth trees having diameter at breast height 3 cm or less are extracted before thinning. But Figure 3 shows distribution in groups of damage where the most of damages detected in group "damage above 0.5 m", but in other group "damage caused by chain" is not detected any damage. In groups "damage below 0.5 m" and "damage of roots" detected equal percentage of damages using working method where undergrowth removed below 5 cm at diameter breast height. Therefore in both of figures shows that less of damages detected in working method where undergrowth is left untouched. The study results approves that in contrast to a common opinion that undergrowth trees increases amount of damages during thinning, the undergrowth actually acts as buffer reducing damages of target trees. However, undergrowth may hamper to some extend productivity of thinning and forwarding. Pros and cons of different thinning methods should be evaluated further.

Keywords: *thinning, tree damages.*

BIOMASS EQUATIONS FOR THE 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 December 11, 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.

$$y = aD^b; \quad (1)$$

$$y = aH^b D^c; \quad (2)$$

$$y = a * e^{-\frac{1}{2}\left(\frac{H-b}{c}\right)^2 + \left(\frac{D-d}{e}\right)^2}; \quad (3)$$

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				*Height, m*			
	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 modeling 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*	R^2	*RMSE, kg*
Aspen	1	0.980	18.56	0.985	3.74
	2	0.991	14.34	0.986	3.71
	3	0.991	14.19	0.986	3.69
Birch	1	0.957	35.15	0.976	4.75
	2	0.985	20.92	0.976	4.73
	3	0.986	20.34	0.978	4.50
Spruce	1	0.979	31.08	0.961	8.97
	2	0.989	23.03	0.961	8.97
	3	0.990	21.44	0.964	8.55
Pine	1	0.977	34.99	0.956	10.85
	2	0.988	24.88	0.963	9.87
	3	0.989	24.29	0.992	4.67

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.

Keywords: *biomass equations, pine, spruce, birch, aspen.*

The study is done within the scope of the National forest competence centre project "Methods and technologies to increase forest value" (No L-KC-11-0004).

NATURAL WILLOW STANDS AS A RESOURCE FOR HONEY: A REVIEW

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Natural willow stands usually are neglected in Latvia. Natural willow stands on agricultural lands are usually harvested by completely removing the canopy. However, willow species have high ecological potential and can be used in several sectors of the economy, including beekeeping/transhumance. Bee care industry has rich traditions in Latvia and is a modern agricultural industry (Latvijas biškopības biedrība, 2011). The current weather conditions of Latvia ensure a large number of pollen and nectar producing plants in the early spring and the first half of summer. Willow species are found in different habitats in Latvia: forest, brushwood, swamp, roadside and river and lake shore (Evarts-Bunders, 2005). Willow species bloom one after another from the end of Mart till the middle of May and has very good nectar and pollen yield potential (Baltijas koks, 2014).

Willow species are valuable sources of pollen in many parts of the world (Ciesla, 2002; McIvor, 2013; Lindegaard, 2014). "Pollen collection is practiced in European willow breeding programs" (Kopp *et al.*, 2002). In the spring, willows are one of the first honey plants, thereby important source of energy for the bees (Хохлов, 2009) and other flower visitor's species after winter (Kay, 1985; Reddersen, 2001; Farkas, Zajácz, 2007; Dimitriou *et al.*, 2011).

For example, in Hungary, first flowering willows are *Salix daphnoides* Vill, which catkins appear in February. *Salix viminalis* L., *Salix caprea* L., *Salix alba* L., *Salix fragilis* L. and *Salix purpurea* L. blooming from March till April, *Salix repens* L. bloom in early April. *Salix triandra* L. bloom in April–May (Farkas, Zajácz, 2007).

Willows can yield up to 150–180 kilograms of honey per hectare in Latvia (Biškopis, 1999), 120 kg per hectare in Russia (Хохлов, 2009). Information gathered shows that areas dominated by *Salix* spp. shrubs occupies about 21 thousand hectares in Latvia (Lazdiņš, 2008), and *Salix* spp. natural stand (forest) area occupies about 2765 hectares in 2014 (Latvian State Forest service, 2015). Consequently, total honey yield, in appropriate weather conditions, could reach several thousand kilograms.

Daily nectar volume from *Salix caprea* may reach several kilograms and from *Salix alba* 1–2 kg. The estimated amount of honey per hectare of *Salix caprea* stands for one bee family was 26–120 kg per hectare (Farkas, Zajácz, 2007).

Overall, the yield of honey in flowering period of willow is evaluated to be about 2–3 kilograms per day per bee colony, in some cases up to 5 kilograms. Honey production during the willow flowering season (25.04–10.05) from one hectare is evaluated to be about

125 kilograms (Цебро, 1991).

One bee colony can pick up pollen and produce about 10–15 kilograms honey per flowering season in appropriate climate conditions in northern Russia (Правдин, 1952.)

Weather conditions (temperature, rainfall) may have significant effects on honey yield and on nectar release intensity (Latvijas biškopības biedrība, 2014; Hamdan, 2015).

In order to improve the ecological role of plantations, it is need to take into account certain principles. For example, it is needed to ensure balanced sex ratio with male and female specimens: to produce both nectar and pollen. Use willow species with different flowering times, to extend honey harvest time (Reddersen, 2001). Bee colony must be prepared to build up to full strength in time for the start of the bloom (for example feeding colonies with sugar syrup) to get more honey from willows in early spring (Hamdan, 2015). Otherwise, a large part of the spring honey will be eaten to get energy.

Keywords: *natural willow stands, bees, pollen, nectar, honey.*

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BIOMASS AND GROWTH PARAMETERS OF WILLOW CLONES FROM THE FIRST ROTATION – RESEARCH DATA FROM INDUSTRIAL EXPERIMENTAL PLANTATIONS IN LATVIA

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Energy resources are one of most influential political instrument in international relations and it plays important aspect of national safety for countries. Alternative to fossil fuel energy materials are wood chips from short rotation coppice stands. Willow short-rotation coppice is one of the most promising bioenergy-cropping system and it is suitable for growing in northern climate. Willow plantation could be grown on agriculture lands which are not used in traditional farming. Establishment of plantations could help to reach targets of renewable energy resource consumption of 40 % in 2020. Aim of the study is to evaluate the growth and biomass parameters of willow clones in 3 years old experimental plantation under different fertilization. Shoot height and sprouting point diameter of willow shoots were measured, fresh shoots were weighted, and moisture and density of stems with bark were determinate. Number of sprouted shoots from cutting was counted. Data from unfertilized plots – control, were compared with results from waste water sludge and wood ash fertilized plots. The average stem height in sampling plots without fertilization (*Control*) varied from 77.43 cm (*Biminalis*) to 188.71 cm (*Tordis*). Average stem height in sampling plots with ash fertilization varied from 115.10 cm (*Biminalis*) to 209.81 cm (*Klara*). Best average heights were in plots with water sludge fertilization, where height varied from 140.00 cm (*Burjatica*) to 260.65 cm (*Inger*). Average stem diameter in sampling plots without fertilization (*Control*) varied from 7.12 mm (*Burjatica*) to 12.43 mm (*Tordis*). Average diameter in plots with water ash fertilization varied from 8.59 mm (*Purpurea*) to 15.97 mm (*Inger*). Best average diameters were in plots with water sludge fertilization, where stem diameter varied from 12.17 mm (*Burjatica*) to 26.15 mm (*Inger*). Average moisture just after cutting for different species varied from 51.54 % to 63.08 % and absolutely dry wood average density varied from 0.29 g cm^{-3} to 0.41 g cm^{-3}. Fresh biomass from one cutting for different species varied from 0.2 kg to 2.15 kg.

Keywords: *SRC plantations, willows, growth parameters, biomass.*

The experimental plots were established as part of ERDF project No 2010/0268/2DP/2.1.1.2.0/10/APIA/VIAA/118 and research work is continuing in scope of ERDF project No 2013/0049/2DP/2.1.1.10/13/APIA/VIAA/031.

PRELIMINARY RESULTS OF COMPARISON OF CARBON STOCK IN SOIL IN GRASSLAND, CROPLAND AND FOREST LAND

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Land use changes, particularly, conversion of forest land to grassland and cropland and conversion of grassland to cropland in Latvia are key sources of greenhouse gas (GHG) emissions. Reporting of these GHG emissions should be based of scientifically verified methodology, using country specific and validated emissions' factors and data sources (Eggleston *et al.*, 2006).

The scope of the study is to evaluate carbon stock in soil in cropland and grassland in Latvia. The study is implemented in the National forest inventory plots, where no land use changes were fixed since 1990 (at least 20 years). Remote sensing methods were applied to identify the NFI plots on grassland and cropland, where no land use changes took place since 1990. Vegetation index was used as criteria to validate land use category. In total 120 plots on cropland and 120 plots on grassland were randomly selected (20 % of plots as reserve in case if some plots can't be used in the study, Figure 1). Soil sampling and analyses was started in autumn (September–November) of 2014 and will be completed in spring, 2015.

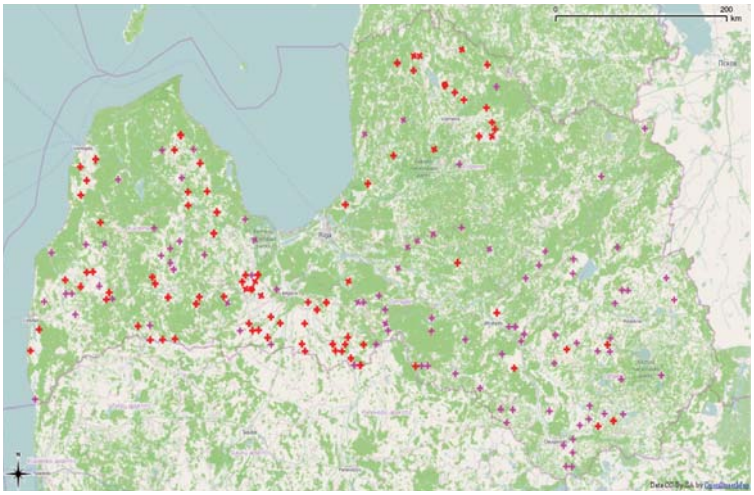

Figure 1. Location of sample plots in grasslands (violet) and croplands (red).

Four sample sets were collected in each sample plot, taking undisturbed soil samples (100 cm^3) at 0–10, 10–20, 20–40 and 40–80 cm depth. Soil samples at 20–40 and 40–80 cm layer were taken from different depths in each sample plot to represent characteristics of the

whole layer. Content of inorganic and total carbon and soil pH is determined in all samples; additional analyses are done to determine soil type.

Results of soil chemical analyses from 95 Level I forest monitoring plots (so called BioSoil plots, second cycle of sampling implemented in 2012) were used to estimate average carbon stock in mineral forest soil. Only *Hylocomiosa, Oxalidosa, Aegipodiosa, Myrtillosa mel.* and *Mercurialosa mel.* forest types were selected for evaluation considering that the most of afforested lands according to the NFI data represents these forest types.

The results of the study after completion will be used to estimate carbon stock changes in soil due to conversion of forest land to cropland or grassland, afforestation of grassland or cropland or conversion of grassland to cropland and vice versa. The calculation will be soil type specific, respectively, converted lands will be split into soil types and soil carbon stock changes will be calculated for each soil type separately. However, this approach requires comprehensive soil map, which is not digitalized yet in Latvia.

The presented results are based on data obtained in 80 plots in grassland and 70 plots in cropland. According to the study results average organic carbon stock in mineral soil at 0–30 cm depth in cropland is 63 ±2.4 tons ha^{-1} and in grassland – 74 ±5.6 tons ha^{-1}. These results are very similar to data obtained in earlier studies in 80 NFI plots; carbon stock in cropland at 0–30 cm depth is 62 ±2 tons ha^{-1} and in grassland – 87 ±7 tons ha^{-1} (Lazdiņš *et al.*, 2013). Maximal organic carbon stock in mineral soil at 0–30 cm depth in cropland according to the study data is 110 tons ha^{-1} and in grassland – 292 tons ha^{-1}; however, this result represents situation in heavily mineralized organic soil. The smallest organic carbon stock in mineral soil in cropland is 33 tons ha^{-1} and in grassland – 26 tons ha^{-1}.

According to the study results average losses of soil carbon due to conversion of grassland to cropland at 0–30 cm depth is 11 ±6.1 tons ha^{-1} and conversion of grassland to cropland contributes to sequestration of equal amount of carbon in soil. Uncertainty of the estimate is 56 %.

Carbon stock in litter layer on fertile mineral soils in forest according to forest soil monitoring data is 12 ±3 tons ha^{-1}. The average organic carbon stock in soil at 0–30 cm depth in forest on fertile mineral soils is 73.5 ±7.4 tons ha^{-1}. No statistically significant difference is found between mineral soil in forest land and grassland; respectively, afforestation of grassland according to the study result is not associated with carbon stock changes in soil, but sequestration of carbon still takes place in afforested grassland due to formation of litter layer (12 ±3 tons ha^{-1}). Deforestation to grassland is not associated with CO_2 emissions from soil, but losses of carbon stock equals to carbon stock in litter layer. Afforestation of cropland leads to accumulation of 10 ±7.8 tons C ha^{-1} in soil and 12 ±3 tons ha^{-1} in litter. The total carbon stock changes in soil ad litter due to afforestation of cropland are 22 ±8.3 tons ha^{-1}. Uncertainty of carbon stock changes in soil due to afforestation of cropland is 75 % and total uncertainty of carbon stock changes in soil and litter is 37 %.

The study is done within the scope of the EEA grants project "Evaluation of carbon stock in cropland and

grassland" (No 10942).

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INFLUENCE OF WORK METHOD ON HARVESTER PRODUCTIVITY IN THINNING OF CONIFEROUS STANDS

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Thinning is one of intermediate fellings, which can be done both, by machines and manually. Thinning is usually implemented in forest stands, where height of average tree is more than 9 m, to improve stand structure and growth conditions (http://www.likumi.lvforest/Forest law). Solid biofuel is fuel produced directly or indirectly from biomass. Woody biomass is produced from trees and bushes (Solid biofuels – Terminology, definitions and descriptions. LVS CEN/TS 14588). Harvesting residues and small trees can be collected in thinning for the solid biofuel production.

The aim of the study is to determine productivity of biofuel production from undergrowth trees and harvesting residues in thinning, depending from work method and the machine. The study is carried out in thinning with two harvesters: John Deere 1070 D and Ponsse Ergo. The study is implemented in JSC "*Latvijas valsts mezi*" Zemgales forestry near by Jelgava city (Table 1).

Table 1. Characteristics of thinned stands

Code	*Area, ha*	*Stand type*	*Dominant species*	*Average diameter, cm*
Stands thinned with John Deere 1070 D				
609-117-13	0.6	*Myrtilloso-sphagnosa*	Spruce	21.7
609-117-12, 17, 18, 19, 20, 24	18.3	*Myrtillosa. Hylocomiosa*	Black alder, spruce, pine	13.0
609-118-4	6	*Myrtillosa*	Spruce	8.5
Stands thinned with Ponsse Ergo				
609-82-8, 9, 15, 22, 18, 19, 20, 21, 14	13.7	*Myrtillosa. Hylocomiosa. Myrtilloso-sphagnosa*	Pine	18

Five work methods are compared in this study: The first work method (control) considers production of standard roundwood assortments; harvesting residues are packed on strip roads, undergrowth is removed with chainsaws before thinning, accumulating device of felling head is not used; The second work method (harvesting residues) considers production of standard roundwood assortments and extraction of harvesting residues for biofuel production; harvesting residues are piled behind or between piles of the roundwood assortments,, undergrowth is removed before thinning, accumulating device is not used; The third work method (small dimension biofuel) considers production of standard roundwood assortments and combined

biofuel assortment – firewood, partly delimbed tops of trees and undergrowth trees with diameter above 6 cm; harvesting residues are packed on strip roads, undergrowth trees are not extracted before thinning, accumulating device of the felling head is used to maximal extend to cut undergrowth trees and trees suitable only for a firewood assortment, a length of the biofuel assortments should not exceed 3 m; The forth work method (small dimension and harvesting residues biofuel) considers production of standard roundwood assortments and two biofuel assortments – firewood, partly delimbed tops and undergrowth trees with diameter above 6 cm in one pile and harvesting residues in other pile; harvesting residues are piled behind or between the roundwood assortments, accumulating device of the felling head is used to maximal extend to cut undergrowth trees and trees suitable only for a firewood assortment, length of the partly delimbed biofuel assortment should not exceed 3 m, undergrowth is not extracted before thinning; The fifth work method (combined biofuel assortment) considers production of standard roundwood assortments, including firewood, and separate piling of combined biofuel assortment consisting of undelimbed tops, undergrowth trees with diameter above 6 cm and harvesting residues; accumulating device of the felling head is used to maximal extend to cut undergrowth trees, length of biofuel assortments should not exceed 6 m, undergrowth not extracted before thinning.

The study approves, that John Deere 1070 D harvester can process 80 trees per productive work hour, but Ponsse Ergo harvester – 102 trees, which indicates higher productivity of the larger machine. In average Ponsse Ergo spends 26 % less direct work time (efficient time excluding driving into and out from the stand, as well as work cycles, which do not results in piled roundwood assortment or biofuel) to process a tree, than John Deere 1070 D. There is significant difference ($p = 0.03$) in time spent to process a single tree when John Deere 1070 D uses the first and the third work method, respectively, processing of trees takes less time if traditional method is used. No significant differences between work methods found for Ponsse Ergo harvester. Ponsse Ergo harvester in average needs 22 % less direct work time than John Deere 1070 D harvester to produce 1 m^3 of roundwood. Productivity rapidly decreases following to the power regression line, when small trees are processed (Figure 1).

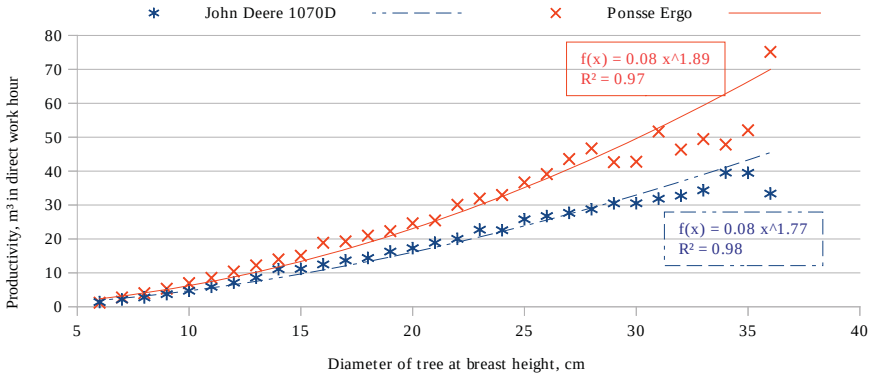

Figure 1. Productivity of John Deere 1070 D and Ponsse Ergo harvesters.

The work time for removal of undergrowth with harvester to clear space for assortments and maneuvers of the machine increase about twice working with both machines, if undergrowth trees are not extracted before thinning; however, the average time spent for undergrowth removal does not exceed 4 % of efficient work time. Remaining living trees are distributed evenly in stands, approving that that density of strip roads (20 m between trials) is sufficient to ensure even distribution of trees in thinned stand; although, there are difficulties for John Deere 1070 D harvester to reach and process bigger trees located more than 8 m away from strip road. Working with John Deere 1070 D, there are more damages of living trees due to harvester and crane maneuvers during reaching distant trees. Operations with Ponsse Ergo harvester results in 15 % less damaged trees in compare to John Deere 1070 D harvester. No statistically significant differences ($p > 0.05$) is found between work methods for both machines; however, John Deere 1070 D harvester makes more damages, if second or third work method is used; Ponsse Ergo harvester makes more damages, if third, forth and fifth work method. The first (conventional) work method for both harvesters is associated with smallest number of damaged trees. The project results approve that biofuel extraction in thinning increases amount of damages of remaining trees. The most visible technical solution for this issue is reduction of number of roundwood assortments, especially of those longer than 4.2 m to free up space for biofuel assortments between roundwood piles. The results obtained with Ponsse Ergo harvester approves, that all of the tested work methods can be recommended for practical use in thinning, but it is important to reduce time spent to cut and process small trees (diameter at breast height below 8 cm); therefore, the work methods needs to be improved (avoiding of extraction of undergrowth trees not affecting further development of dominant stand and not hampering other operations). Separate piling of harvesting residues (the second and fifth work method) is recommended primarily in a single species dominant stands with small admixture of other tree species and where relatively small number conventional roundwood assortments is expected, as well as in stands with relatively small yield is expected to be produced.

The study is implemented within the scope of the Forest Sector Competence Centre project No L–KC–11–0004.

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EVALUATION OF PROPERTIES OF SOIL SOLUTION DURING 2 YEARS PERIOD AFTER STUMP REMOVAL IN FERTILE FOREST SITES IN LATVIA

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Stump removal is a novel potential source of woody biomass for renewable energy production in the Baltic countries; however, stump harvesting might lead to several negative environmental impacts, including undesirable impact on water catchments. The ecological risks associated with the soil disturbance during the stump removal should be quantified and compared with the benefits gained by using stump and root biomass for renewable energy production and improvement of growth of the next generation of trees due to reduction of root rot distribution.

The aim of this study is to estimate the effect of stump extraction after clear-felling of spruce stands heavily affected by root rot on the soil solution properties in nutrient rich mineral soils in Latvia. Three Norway spruce (*Picea abies* (L.) H. Karst.) stands of similar forest site type (*Hylocomiosa*) were monitored using suction tube lysimeters to study changes in nutrient concentrations (pH, conductivity, total N, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $P\text{-}PO_4^{3-}$, K, Ca, Mg) in the soil solution following to stem only harvesting (SOH) and stems and stumps (D > 20 cm) extraction (SSH) during a period of two years after the treatments.

The preliminary data demonstrates that stump extraction in fertile forest sites in Latvia does not increase nutrient's leaching from the ecosystem or soil solution acidification over two years after the treatments. Concentration of nutrient in soil solution has site specific character and the affect of stump extraction is considerably smaller. However, the study period should be extended to at least 15 years to estimate long term impact of stump extraction.

Keywords: *stump removal, soil solution, nutrient cycling.*

This study was funded by the Forest Sector Competence Centre project No L-KC-11-0004 "Methods and technologies for increasing forest capital value".

CHEMICAL COMPOSITION AND PULPING CHARACTERISTICS OF WOOD USED FOR BIOENERGY

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In order to limit global warming and reduce CO_2 emission, the EU target is to limit fossil fuel consumption with a plan to achieve a share of 20 % renewable energy in 2020. Within this bioenergy category wood plays an important role worldwide and also in Latvia. Forestland's owners are well informed about the opportunities in short rotation forestry. Several plantations and short rotation experimental trials in Latvia were planted in former farmland. Most promising fast growing wood species for bioenergy in Latvian condition are willow, poplar, aspen, their hybrids and lodgepole pine. Nevertheless, every fibre of fast growing wood has value for its potential use as a material in pulp, paper and wood chemical industry. Aim of this study was to assess chemical composition and fibre properties of fast-growing wood in Latvia and to rate their potential of applications for wood products.

Keywords: *short rotation, fibres, pulp.*

INFLUENCE OF MECHANICAL PRE-TREATMENT ON THE PROPERTIES OF PINE FIBRES

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Pulp refining is a mechanical treatment for fibres by using a special equipment to change structural and electro kinetic characteristics. It improves bonding ability of the fibres and increases the mechanical properties of the product. The change in nature and intensity of the fibre depends on several factors, including wood species. Objective of this study was to compare properties of gradually refined fibres of lodgepole (*Pinus contorta*) and Scots pines (*Pinus sylvestris*). The tensile and burst index of paper handsheets was measured as well. Significant correlation was found between the time of refining and the properties of pulp. Higher beating degree and mechanical properties were found in the case of lodgepole pine.

Keywords: *pine, refining, paper properties.*

EFFECT OF INITIAL FERTILIZATION OF SEEDLINGS ON INCREMENT AND WOOD PROPERTIES OF NORWAY SPRUCE IN EXPERIMENTAL PLANTATION IN LATVIA

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Initial fertilization of coppices is applied to increase their productivity and hence to improve the yield from stands in future. However, higher growth rate caused by the addition of nutrients is also known to decrease the density of wood and hence the quality of timber. Therefore, the aim of the study was to assess the effect of initial fertilization on growth and tree-ring properties of Norway spruce in experimental plantation in Kalsnava, Latvia. The plantation was established on forest land in 1982. Four-year-old bare rooted saplings of Norway spruce from local provenance enclosed in peat containers "Brika" were planted with density of 4000 trees per ha. After the planting, each sapling received local fertilization in the equivalent of 14, 6 and 11 g of N, P and K, respectively. Chemical weed control was applied during the first year to facilitate the establishment of planted material. Trial inventory was conducted in February 2012. From 30 fertilized and 30 control trees that were healthy and undamaged by browsing, increment cores were collected at 1.3 m height. In the laboratory, increment cores were processed with LignoStation (RinnTECH) wood analysis system and high-resolution (50 μm) density profiles were obtained for each core. Tree-ring width, proportion of latewood, density of entire tree-rings and their parts were the obtained parameters.

As expected, initial fertilization increased the dimensions of trees (by ca. 3 and 7 % for height and diameter, respectively) and resulted in additional ca. 0.003 m^2 of basal area per tree at the age of 34 years. Amongst the tested tree-ring parameters, tree-ring width showed the strongest reaction to fertilization, while it was less apparent for the wood density parameters. Judging by tree-ring width, the effect of fertilization had been lasting up to 15 years. Generally, fertilization increased tree-ring width due to formation of wider earlywood, thus decreasing the proportion of latewood. However, during a few years directly after the plantation tree-ring width of fertilized trees was lower compared to control. Apparently, it took up to 6 years for trees to adjust for nutrient enrich conditions, but afterwards growth was released for eight consecutive years. Fertilization increased latewood and hence the maximum density but the earlywood density was not affected. Mean density of tree-rings was similar for both groups, as formation of denser latewood, apparently, was countervailed by the formation of wider earlywood. Thus initial fertilization increased structural heterogeneity of wood in the pith part of the stem.

We acknowledge the Nature Conservation Agency for permission conduct the study. Study was financed by European Social Fund project „Management of vital Norway spruce stands: ecological and technological aspects" (No. 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

PRODUCTIVITY OF NORWAY SPRUCE STANDS WITH LOW INITIAL DENSITY

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Sawlogs are the production goal for coniferous stands in Latvia. Recently collection of logging residues in clear cuts has increased due to rise of demand for chips for energy production – mainly in heating plants of municipalities. Minimal length of rotation period for trees in Latvia is determined by legislation; it is 81 year for Norway spruce. Cutting could be carried out earlier than that if stands reach certain target diameter (for Norway spruce: 27–31 cm depending on the site index). 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 and 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: *forest plantation, above-ground biomass, target diameter.*

Study was financed by European Social Fund project „Management of vital Norway spruce stands: ecological and technological aspects" (No 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

ABOVE-GROUND BIOMASS EQUATIONS OF *POPULUS* HYBRIDS IN LATVIA

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In the Baltic States several *Populus* hybrids, differing by a number of traits (e.g. costs of establishment and tending of plantations, soil requirements, resistance against different damages etc.) are suitable for establishment of short-rotation plantations. However, accurate and precise information on their biomass is required both for the landowners for financial calculations as well as for policy makers, developing support schemes to achieve renewable energy targets. Above-ground biomass equations are influenced by tree species (hybrid) and growing conditions, therefore the aim of our study was to develop them for Latvia for hybrid aspen (*Populus tremula* × *P. tremuloides*) and hybrid poplar (*Populus balsamifera* × *P. laurifolia*).

Sample trees for the study were collected during winter period in four stands located on mineral soil with normal moisture regime and similar fertility (corresponding to *Oxalidosa* forest type) in the central part of Latvia – hybrid aspen (diameter at breast height (DBH) 9–37 cm): 12 and 19 year old (67 and 13 trees, respectively), and hybrid poplar (DBH 23–57 cm): 62 and 64 years old (9 and 15 trees, respectively).

Tests of the fit of already published biomass equations for the empirical data demonstrated that they underestimate the real above-ground biomass significantly: by 8–24 % for hybrid aspen and as much as by 20–54 % for hybrid poplar. All acquired biomass estimation models were statistically significant ($p < 0.01$) and R-squared values ranged from 0.85 to 0.96 for hybrid poplar and from 0.96 to 0.98 for hybrid aspen, demonstrating very good explanatory power. There were no significant differences in above-ground biomass for both *Populus* hybrids for trees with similar dimensions, however, noticeable difference in biomass allocation was found: stem forms 69 % and 90 % of the above-ground biomass (in leaf-less state) for hybrid aspen and hybrid poplar, respectively.

Keywords: *hybrid aspen, hybrid poplar, above-ground biomass, biomass allocation.*

This research was conducted as a part of the European Regional Development Fund's Project "Fast-growing tree plantations: development of methods of establishment and management and assessment of suitability of wood for production of pellets" (No 2013/0049/2DP/2.1.1.1/13/APIA/VIAA/031).

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POSSIBLE GROWTH OF SCOTS PINE IN LATVIA UNDER CHANGING CLIMATE CONDITIONS

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The climate in Latvia has been becoming warmer during the past decades and such trend is predicted to continue in most global climate model scenarios. Historical climate data shows that mean annual temperature has increased by approximately 1°C since 1960s and could increase by another 1–2°C by 2050s and by 3–5°C till the end of the century, according to different GCMs. In order to understand the possible impact of such changes on forest, different mathematical models have been developed. One of such models has been developed in Potsdam Institute for Climate Impact Research. The 4C model, which has been developed to describe long-term forest behaviour under changing environmental conditions, describes processes on tree and stand level basing on findings from eco-physiological experiments, long term observations and physiological modelling. The model includes descriptions of tree species composition, forest structure, and total ecosystem carbon content as well as leaf area index. Single tree data from 3 geographically distant Scots pine stands in Latvia were analysed together with historical climate data and three different climate projections from EURO-CORDEX datasets for the future using the 4C model. The results show that 4C model works well for the used Scots pine stands as the simulated forest values using historical climate data are very close to the real ones. The exact precision of simulated forest stand values using the future climate projections remains unknown, but a good overall impression can be established on how possible climate changes might affect the tree growth.

Keywords: *Scots pine, climate change, EURO-CORDEX, 4C, tree growth.*

REACTIVITY OF ADAPTATION OF THE CARPATHIAN SILVER FIR PROVENANCES AT THE EXPERIMENTAL PLOT IN THE WEJHEROWO FOREST DISTRICT

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The climatic changes, observed in recent decades, have a significant impact on the natural dynamics of forest ecosystems. Adverse weather conditions: extremely low or very mild temperatures in winter and drought in summer can contribute to a shift in the range borders and continuous changes in the habitat conditions. Consequently, threats for the spruce, pine and fir populations may occur. In Poland these main forest species are environmentally and economically important. The natural range boundary limits of these species are found in Poland. The provenance experimental plots have become very valuable areas for assessing the effect of climate change. Regular observation of the tested populations in remote locations has enabled an understanding of the ability of the provenance to adapt to be acquired. The choice of propagating material, consistent with the economic and breeding aims, is becoming more reliable. The selection based on the assessment of the breeding value and plasticity of introduced provenances will ensure the stability of formed stands.

The aim of this study was to investigate the adaptive reactivity of 33 provenances of fir from the Carpathian Mountains located outside their natural range, at plots located in the Baltic region of north Poland, which is subject to a marine climate. The assessment of the survival, height and height growth of the fir progeny indicated the possibility of transferring the provenances from the Carpathians to the Baltic areas. The fir provenances from the Carpathians Mountains showed high adaptation reactivity to the climatic and habitat conditions on the plots. The best adaptation of the fir was observed for Wojtkówka from the Przemyskie Foothill, Berest and Powroźnik from the Beskid Niski and Beskid Sądecki Mountains, respectively. The results indicated the possibility of inclusion of the fir into the breed mixture of cultivations for a fresh forest and a fresh mixed forest as well as the greater preference for this breed during the conducted research. The climatic conditions in the Baltic area of northern Poland, especially the high annual precipitation, are conducive to the good adaptation and growth of fir. The experimental plot of fir established outside the current limits of the natural range is an

excellent example of test cultivation promoting the development of the selection and breeding programme. It enables an indication of the provenances with an extended tolerance and greater resistance to stress to be obtained. This aspect is particularly valuable and important from the perspective of the impact of climate change on the habitats of forest tre+e populations.

Keywords: *Abies alba Mill., climate change, adaptive traits.*

SEASONAL GROWTH DYNAMICS OF NORWAY SPRUCE

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Earlier start of spring and later onset of autumn are forecasted for Northern Europe during next century. Prolonged vegetation period, however doesn't necessarily imply longer period of xylogenesis. Changes of stem circumference in early spring is not caused by wood formation but rehydration of xylem and phloem after winter dehydration; therefore, observation of sap flow is efficient tool to trace rehydration and hence to detect the onset of vegetation period. The aim of the study was to assess the seasonal processes of xylogenesis for Norway spruce in Latvia.

In this study we observed sap flow and fluctuations of stem circumference in two mature Norway spruces, located in western and central part of Latvia (two different Norway spruce provenance regions). Sap flow was monitored with two sensors, based on heat ratio method. Fluctuations of stem circumference were observed by band dendrometers. In order to describe seasonal dynamics of apical growth, height increment was measured on average once per week for seven years old trees in progeny trials of plus trees from different regions of Latvia.

In both sites onset of spring rehydration was three months earlier than increase of stem circumference (beginning of January and middle of April, respectively); however, fluctuations of stem circumference were detected throughout the winter period as a result of dehydration and rehydration of xylem and phloem due to processes of cold hardening or dehardening. Stem circumference didn't fluctuated two weeks before the onset of radial growth showing completion of rehydration before initiation of xylogenesis, although, during this period tree water use increased as a result of transpiration due to increased air temperatures. In western part of Latvia intensity of radial growth reached its peak in the end of June (0.65 mm day^{-1}) and formation of increment ceased in mid-July. In contrast, in central part, intensity of radial growth reached its peak twice – in the end of May (0.6 mm day^{-1}) and in the end of July (0.63 mm day^{-1}) and ceased in mid-August. Peaks of the height and radial increment were in similar time in western Latvia, reaching 1.5 mm day^{-1}. Development of height increment ceased earlier than radial growth in both locations.

***Keywords:** growth intensity, sap flow, wood increment.*

Study was supported by European Social Fund project "Management of vital Norway spruce stands: ecological and technological aspects" (No 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

STRUCTURE OF SEMI-NATURAL NORWAY SPRUCE (*PICEA ABIES* (L.) KARST.) STANDS IN *OXALIDOSA* FOREST SITE 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. In this approach diameter distribution of trees in combination with other parameters of stand (age structure, species composition, basal area) is an important source of information. It has been found, that diameter distribution of shade tolerant species can vary greatly: from a symmetric to unimodal form. In ecology and forestry different theoretical diameter distributions, like, beta, Weibull (2 and 3 parameters), Johnson`s SB functions have been widely used to characterize stand structure in a mathematical form. Since forest disturbances play a major role in shaping the forest structure they should be reflected in stem diameter distribution, however, there is very limited information of this characteristic of the stand long-time after the disturbance in hemiboreal forests. Therefore aim of our study was to quantify parameters of such stands forming after large-scale wind storm in absence of any management.

We conducted our study in Slitere nature reserve (SNR) – a forest landscape with total area 1100 ha, that has been excluded from management activities since year 1923 and is located in north-western part of Latvia (57°38'N, 22°17'E), in territory of Slitere national park. Most of SNR was affected by windthrow in November 2, 1969, no management have been taking place after the storm. Compartments for the study were randomly selected from those severely affected by the storm (based on post-storm inventory data). The sampling design consisted of stands with four different dominant tree species: aspen (9 plots), birch (5 plots), mixed (aspen, birch, black alder, spruce – 6 plots) and spruce (8 plots). Altogether 28 circular sample plots with radius 12.62 m (area 500 m^2) were established in winter of 2013/2014 in *Oxalidosa* forest type (fertile mineral soil with normal moisture regime). Dominant tree species before the storm in all selected compartments was Norway spruce. 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 (as much as it was possible to detect visually).

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 $m^2\ ha^{-1}$. In stands dominated by aspen or

birch or classified as mixed Norway spruce compiled 10 to 35 % of dominant trees and ~70 % of understory trees, indicating ongoing succession towards stands dominated by this shade tolerant tree species. 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 understory (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 ($\chi 2 = 350.6$, $p < 0.001$) from diameter distribution in stands dominated by other tree species. The theoretical three parameter Weibull distribution fitted the empirical diameter distributions (Fig. 1.) in stands dominated by Norway spruce, but not is stand dominated by other tree species (Kolmogorov-Smirnov test). Our results reveal statically significant ($p < 0.05$) differences of the mean values of the parameters of three-parameter Weibull distribution between stands in *Oxalidosa* forest type.

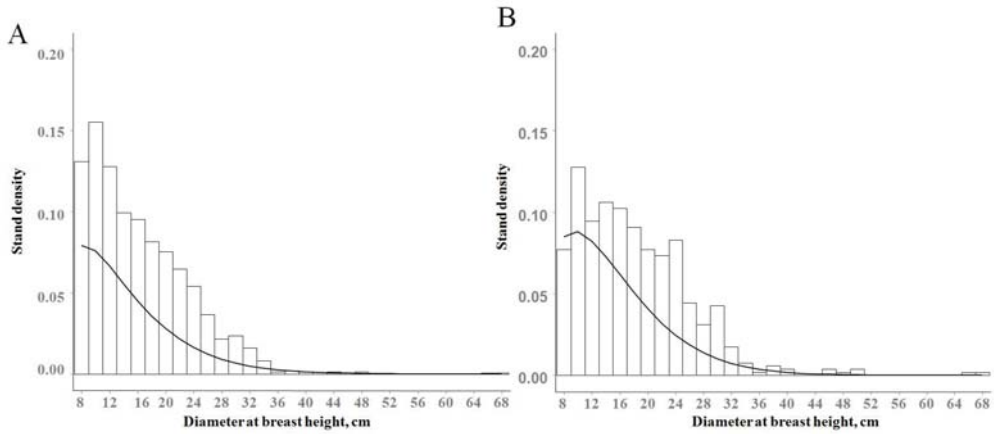

Figure 1. Theoretical three-parameter Weibull distribution fitted to diameter density distributions: A) for trees in all stands; B) focusing only for stands dominated by Norway spruce.

Keywords: *diameter distribution, wind storm, natural succession.*

We acknowledge the Nature Conservation Agency for permission conduct the study. Study was financed by European Social Fund project „Management of vital Norway spruce stands: ecological and technological aspects" (No 2013/0022/1DP/1.1.1.2.0/13/APIA/VIAA/052).

A 247-YEAR TREE-RING WIDTH CHRONOLOGY OF SCOTS PINE (*PINUS SYLVESTRIS* L.) FROM SLITERE NATIONAL PARK

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Tree ring data are widely used for multiple purposes, mainly to explore interactions between climate and growth of trees and to reconstruct historical disturbance regime at site or regional scale. Significance of certain climatic variable on growth pattern of tree varies between tree species and sites. Only in few areas in Latvia is possible to find more than 200 years old Scots pine forests. Tree ring chronology provides unique site specific information of temporal and spatial growth characteristics obtained data are useful for forest ecology and climatology research. We have built a Scots pine tree-ring chronology with the aim to serve as basis for historical forest fire regime reconstruction in the territory.

Study site with total area of 4 km^2 was located in Slitere National Park in Northern–Western part of Latvia (57°40′–57°42′N, 22°25′–22°36′E) and was affected by large forest fire in 1992. The sampling points were placed in approximately 500 m intervals in the site on forest types on dry sandy soil (*Cladinoso-callunosa* and *Vacciniosa*) that comprised approximately half of the study area. Two increment cores were taken from the oldest dominant Scots pine (*Pinus sylvestris* L.) tree in each sampling point at breast height (1.3 m). In total 126 cores were collected from 63 trees. The CooRecorder software was used to measure the width of tree rings. Data were cross-dated in CDendro 7.7 software. Quality of data was verified by COFECHA and graphical inspection. ARSTAN software was used to detrend all tree-ring series. Graphics were created in R software. Individual series were excluded from further data analysis if correlation between individual series and tree-ring master series in COEFCHA were lower than 0.5.

We have developed 247-year tree-ring chronology based on 33 cores from 18 trees. 93 cores were rejected due to low correlation with tree-ring master series suggesting the need for development of a new master series, presumably, based on even larger number of sample trees. The quality of chronology for detrended data: signal-to-noise ratio (SNR) which indicates explained variation of data by climate or other factors was 8.45; expressed population signal (EPS) was 0.89. Obtained high EPS value suggested high reliability of chronology as it was above accepted quality threshold of 0.85. Notable radial growth declines observed in 1829, 1847, 1918, 1940. After large fire in 1992 longer period of growth decline was observed (Fig. 1) despite the fact that the sample trees didn't have any visible wounds from the fire.

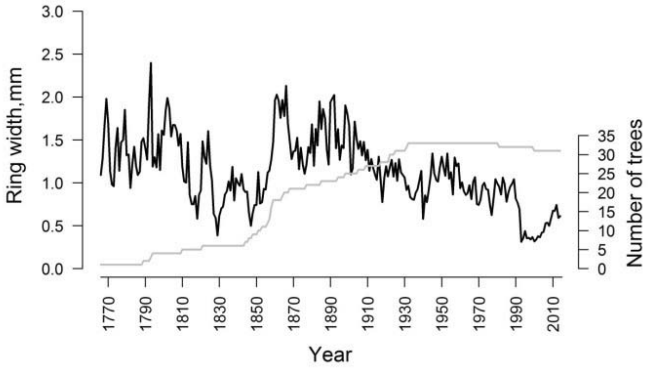

Figure 1. Mean ring width (mm) of Scots pine from 1770–2014 sampled in Slitere National Park. Black line – mean ring widths (mm) per year, grey line – sample size (number of trees).

Keywords: *dendrochronology, tree-rings, age structure.*

The study was supported by Forest Competence Centre (ERAF, L-KC-11-0004) project "Ecological risk in management of forest capital value – methods of assessment and recommendations of their minimization".

EVALUATING EDGE EFFECT ON THE SURVIVAL AND GROWTH OF SCOTS PINE (*PINUS SYLVESTRIS* L.) AND NORWAY SPRUCE (*PICEA ABIES* (L.) H. KARST.) 3 YEARS AFTER PLANTING IN DIFFERENT SIZE GAPS IN SHELTERWOOD

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Continuous cover forestry is one of possibilities for adaption of management of forest ecosystems. Issue of the optimum size of gaps made in forest stand in group shelterwood or selection cuttings has assumed to be important for foresters working with continuous cover forestry methods. In Latvia, shelterwood and selection cuttings are usually practiced in forests where clear-fells are forbidden or there is a high proportion of mature stands, as well as in private holdings.

The study was carried out on two test sites in about a 100-year-old mixed stands dominated by pine in *Hylocomiosa* forest type. Rectangular gaps of different sizes – 10×10 m; 20×20 m; 20×40 m (with the longest side arranged in the N–S or E–W direction), and 40×40 m were made. In these gaps were planted pine and spruce arranged in a square pattern, so the distance from the gap edge was known for each tree planted.

For performance analysis of planted trees the survival and sum of the tree growth in height over a period of three years are used. The test site, initial tree height, gap size and distance from the closest gap edge as the factors affecting the results of multifactor ANOVA were checked.

Survival rate of pine 3 years after planting is quite different regarding test site (66 % and 24 %), but does not differ regarding gap size and distance from the closest gap edge. Survival rate of spruce 3 years after planting is at least 86 % regarding gap size and at least 80 % regarding within-gap position.

Gap size has significant ($p < 0.05$) influence on the growth in height for both species. But distance to the closest gap edge has significant ($p < 0.05$) influence on the growth only for spruce, which could be explained by the adverse impact of competing vegetation at greater distances from gap edge on the growth of pine as shade intolerant species.

Based on results we can say that gap size must be greater than 10×10 m to ensure acceptable growth in the first years after planting for both species.

Keywords: *gap, edge effect, survival, growth, pine, spruce.*

AN ASSESSMENT OF EDGE EFFECT ON FENNOSCANDIAN DECIDUOUS SWAMP WOODS IN SOUTHERN LATVIA

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Fennoscandian swamp woods in Europe have experienced dramatic changes and decreases in forest landscape during last centuries. In Fennoscandian and Baltic forests the woodland key habitat (WKH) concept has been created to preserve small forest parcels in production forests for conservation of biodiversity. However, these parcels are strongly affected by fragmentation, edge influence, isolation and habitat depletion. Few empirical studies have assessed how different taxonomic groups respond to the establishment of edges as the result of forest management activities. We tested the influence of human-induced edges on vegetation, stand structural characteristics and occurrence of lichen indicator species in 30 unmanaged woodland key habitats of black alder *Alnus glutinosa* (L.) Gaertn. in southern Latvia. Additionally we investigated the persistence of edge effect in these stands. For this we compared swamp woods adjacent to young, middle-aged and mature stands within the distance of 0–50 m from edge to forest stand interior. We revealed the most pronounced differences in species composition, the amount of dead wood and the occurrence of epiphytic lichen indicators between swamp woods adjacent to young and mature forests. Our results show that unmanaged black alder woodland key habitats adjacent to young stands are strongly influenced by anthropogenic activities and therefore could not facilitate the survival of habitat focal species.

Keywords: *Fennoscandian swamp woods, Alnus glutinosa, woodland key habitat, edge effect.*

HETEROBASIDION ANNOSUM IN NORWAY SPRUCE STEMS ON DRAINED PEATLAND SITES

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Heterobasidion annosum s.l. is one of the most important pathogens of Norway spruce (*Picea abies* (L.) Karst.) forests in the Northern hemisphere and spread of rot in tree stems decreases timber yield from infected trees. There are some studies on the spread of *H. annosum* in spruce stems, but information about the spread of root rot in spruce stems growing in drained peatland forests is scarce. Therefore the aim of this study was to evaluate the spread of *H. annosum* root rot in spruce stems growing on drained peatland sites. Data for this study was obtained from 41–111 years old spruce stands managed by LSFRI Silava and the LUA National Research Forest Agency 'Forest Research Station' (located in Kalsnava, and Smiltene) and JSC 'Latvijas valsts mezi' (located in Plakanciems and Ogre). Presence of *H. annosum* s.l. in stems was detected in the laboratory from previously obtained bore cores at stump height. A total of 60 *H. annosum* infected trees with signs of root rot in the stem were chosen for analysis and data about tree height, spread of root rot, diameters of tree with bark and without bark, root rot diameters at stump and breast heights were measured. Diameter of tree without bark at breast height for all analysed trees ranged from 16.3 cm to 48.3 cm (average 28.0 ±1.0 cm) and tree height from15.1 m to 38.9 m (average 24.6 ±0.7 m). Results show that spread of decay column ranged from 0.8 m to 12.6 m (average 5.9 ±0.3 m), but rot diameter at stump height from 13.4 cm to 60.6 cm (average 29.9 ±1.4 cm) and on average constitutes 86.1 ±1.1 % of stump diameter without bark.

Diameter of root rot at breast height is 23.9 ±1.1 cm, and it is 5.9 ±0.5 cm (19.4 ±1.4 %) smaller than at stump height. The ratio between diameter of *Heterobasidion* spp. rot at stump height and length of decay column in drained peatland forests is 1:20.3 ±1.0 and has a significant ($p < 0.01$) medium ($r = 0.579$) linear correlation between parameters. Results of this study show that *H. annosum* spread (rot; height, diameter at stump and breast height) in spruce stems on drained peatland sites increases with dimensions and age of the tree.

Keywords: *Heterobasidion decay column, Norway spruce, drained peatland.*

IMPACT OF WIND ON YIELD OF MATURE SPRUCE, BIRCH AND PINE STANDS IN LATVIA

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Strong winds are one of the most important natural disturbance agents in Latvia. On one hand they creates new habitats for species dependent of dead wood, on other hand they creates risks to timber production. We had the hypothesis that wind disturbance contributes to reduction of standing volume in mature stands as well as to reduction of quality of timber. Goals of the research was to evaluate character of wind damage in mature stands dominated by commercially most important forest tree species – spruce, pine and birch, as well as to find out relationships between windiness and proportion of sawlogs.

To assess long term wind disturbance regime we elaborated wind hazard score map based on approach used in UK. Wind hazard assessment takes into account regional windiness, elevation, topographic exposure, aspect and soil.

Standing volume of mature spruce, birch and pine stands by regions was assessed based on National forest inventory sample plots. Impact on timber quality was assessed based proportion of sawlogs in total standing volume based on JSC data.

We find out negative correlation between wind hazard class and standing volume of mature spruce stands as well as negative correlation between wind hazard class and proportion of sawlogs outcome. For pine and birch reduction in timber volume and proportion of sawlog outcome was not significant.

Keywords: *wind, damage, mature stands.*

WILDFIRE IN SPAIN

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This project talks about the wildfire in Spanish forest. Spain is a country situated in the South of Europe, where the majority of the territory has a Mediterranean clime (warm winters, hottest and driest summers, and a few days raining), as Spain is a Mediterranean country also he has a Mediterranean forest where the main families consist about *Pinus* sp. and *Quercus* sp.

The first question that we must think is why happen this wildfires? Which are the cause of this wildfires? In this part we speak about the reasons by start a wildfire, as economic profit, growth grassland, etc. The second point we will see the quantity the damages induced by wildfires, as the amount burnt land every year, unprotected soil, die animals, etc. The last point is about the adaptation solutions for fight against the wildfires and how we can help prevent the wildfire in the Spanish forest.

Keywords: *Wildfire, anthropogenic disturbances, Mediterranean clime, Spanish forest.*

A REVIEW OF SOCIO-ECOLOGICAL TRIGGERS, DRIVERS & RESPONSES TO THE MOUNTAIN PINE BEETLE EPIDEMIC IN BOREAL FORESTS OF CANADA

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The mountain pine beetle epidemic of lodgepole pine in the boreal forests of western Canada is now entering its third decade and thus far, has impacted over 18 million hectares of forest, resulting in a loss of 723 million cubic metres (53 %) of the merchantable wood volume. The beetle's range is continually expanding eastwards into more commercial forests, and now colonising the forests' dominant species – jack pine. The nature, intensity and frequency of such natural disturbances may be exacerbated in response to projected climatic changes – not only in Canada, but globally. It is therefore important to examine these case studies to gain early insight into the socio-ecological strategies, processes and principles which can assist the forest sector in mitigating impacts and adapting to these new circumstances. Accordingly, I present a review of the management of the mountain pine beetle epidemic in Canada, including the: pest's ecological behaviour, triggers and drivers (e.g. fire suppression, warming trend), suite of short- and long-term in-field containment strategies (e.g., modelling, pheromone baiting and trapping, removal of colonised trees, etc.) and governance responses (i.e., policy and institutional/actor innovations).

Keywords: *mountain pine beetle, boreal forest, Canada, adaptation, governance innovation.*