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FOREST ECOSYSTEM AND ITS MANAGEMENT: TOWARDS UNDERSTANDING THE COMPLEXITY I

MEŽA EKOSISTĒMA UN TĀS APSAIMNIEKOŠANA: CEĻĀ UZ SAREŽĢĪTĪBAS SAPRATNI I

FOREST ECOSYSTEM AND ITS MANAGEMENT: TOWARDS UNDERSTANDING THE COMPLEXITY I
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„Forest ecosystem and its management: towards understanding the complexity”
15.10.2014.

10:00-10:20 – registration, coffee

10:20 Opening of the conference: Jurģis Jansons, Jānis Ozoliņš, **Āris Jansons**

10:30-10:45 Sucrose synthase and Aquaporine like gene expression and its dynamics during early and late wood formation in Scots pine (*Pinus sylvetris* L.) in relation to wood properties **Krista Kānberga-Siliņa**, Āris Jansons, Dainis Ruņģis

10:45-11:00 Productivity and quality of hybrid aspen at the age of 18 years **Martins Zeps**, Juris Kalnins, Janis Smilga, Aris Jansons

11:00-11:15 Preliminary results of hybrid aspen and poplar productivity in short rotation plantations **Toms Sarkanabols**, Dagnija Lazdina

11:15-11:30 Potential lands for short rotation coppice plantation establishment in Vidzeme region **Kristaps Makovskis**, Dagnija Lazdina

11:30-11:45 Biomass studies for four most common tree species in Latvia **Jānis Liepiņš**, Kaspars Liepiņš, Andis Lazdiņš

11:45-12:00 Decomposition of below-ground biomass in coniferous forest stands in Latvia **Sigita Mūrniece**, Andis Lazdiņš, Jānis Liepiņš

12:00-12:15 Impact of reconstruction of forest drainage systems on increase of living woody biomass in thinned middle-age coniferous stands **Ainārs Lupiķis**, Sigita Mūrniece, Andis Lazdiņš

12:30-13:00 LUNCH

13:00-13:15 Response reaction of European larch to climate change **Solveiga Luguza**, Mairis Stempers

13:15-13:30 Climate-growth relationships revealed from Norway spruce provenance trials **Juris Rieksts-Riekstiņš**, Arnis Gailis, Imants Baumanis, Āris Jansons

13:30-13:45 The effect of altered distribution of precipitation on growth of forest planting material in Central Latvia **Oskars Krišāns,** Līga Puriņa, Mārtiņš Puriņš, Āris Jansons

13:45-14:00 Needle cast damages in open-pollinated and control-crossed trials of Scots pine (*Pinus sylvestris* L.) **Kaspars Polmanis**, Una Neimane, Imants Baumanis, Dārta Kļaviņa, Tālis Gaitnieks, Āris Jansons

14:15-14:30 Height-growth dynamics of Scots pine (*Pinus sylvestris* L.) after forest fire in hemiboreal forests, Latvia **Mara Zadina**, Agris Pobiarzens, Juris Katrevics, Janis Jansons, Aris Jansons

14:30-14:45 Long-term natural fragmentation dynamics in semi-natural forest massif **Endijs Bāders**, Zane Lībiete, Māris Nartišs, Āris Jansons

15:00-15:30 coffee, poster session

Posters:

Regeneration of wet and drained forests by mounding in Latvia **Dagnija Lazdina**, Andis Lazdins, Andis Bardulis, Janis Liepins, Uldis Prindulis, Agris Zimelis, Kristaps Makovskis, Aris Jansons

Estimation of carbon accumulated in coarse dead wood in forest land using stock change method **Andis Lazdiņš**, Juris Zariņš, Dagnija Lazdiņa

Literature review on results of application of soil carbon model Yasso in forest, cropland and grassland **Andis Lazdiņš***,* Mihails Čugunovs, Dagnija Lazdiņa, Aldis Butlers

Formation of lammas growth for Norway spruce (*Picea abies* (L.) Karst.) **Una Neimane**, Juris Rieksts-Riekstins, Janis Jansons, Aris Jansons

Branch quality of Scots pine (*Pinus sylvestris* L.) plus-trees **Liga Purina**, Baiba Dzerina, Aris Jansons

Short-term prospects of mass outbreaks of most significant forest pests in Latvia **Ingars Siliņš**, Agnis Šmits, Āris Jansons, Didzis Elferts

15:30-15:45 Distance between strip roads on mechanical damages of remaining trees in deciduous stands thinned with ROTTNE H8 and John Deere 1070 harvesters **Uldis Prindulis,** Andis Lazdiņš, Santa Kalēja

15:45-16:00 Impact of forest machinery on soil compaction and forest regeneration in coniferous stands **Anna Liepiņa***,* Ainārs Lupiķis, Toms Sarkanābols, Andis Lazdiņš

16:00-16:15 Soil compaction using tracked and wheeled forest machines in early thinning **Santa Kalēja**, Ainārs Lupiķis, Andis Lazdiņš, Uldis Prindulis

16:15-16:30 Evaluation of chemical and physical properties of wood ash in Latvia **Modris Okmanis**, Kristaps Makovskis

16:30-16:45 Case study of soil carbon stock changes in drained and afforested transitional bog **Andis Lazdiņš***,* Ainārs Lupiķis, Aldis Butlers

17:00 closing remarks, coffee

SUCROSE SYNTHASE AND AQUAPORINE LIKE GENE EXPRESSION AND ITS DYNAMICS DURING EARLY AND LATE WOOD FORMATION IN SCOTS PINE (*PINUS SYLVETRIS* L.) IN RELATION WITH WOOD PROPERTIES DATA

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Information about gene expression involved in wood formation are mostly available for crop or model plants, for forest tree species there are still lot of knowledge to gain. For this study candidate genes were selected of which sucrose synthase gene (*Susy*) is involved in sucrose metabolism and provides precursors for cellulose biosynthesis (Nairn et al., 2007; Coleman et al., 2009). Aquaporin like gene (*Aqual*) which is involved in water transport across cell membranes and cell elongation was selected too (Johansson et al., 2000). These genes among others were selected in attempt to reveal whether link can be established between candidate gene expression and wood properties and to estimate natural gene expression variation in trees from open pollinated tree families growing in natural conditions.

Samples for gene expression analysis were collected from 50 29 years old trees with known wood density (measured using Pilodyn) during early and late wood formation. Gene expression analysis was performed using Real time PCR relative standard curve method. The wood physiological properties data were obtained using Silviscan instrumentation. Subset of these trees with correlations between gene expression data and wood properties were chosen for gene expression dynamics study.

There were important differences in gene transcript abundance displaying natural variation (Figure 1). Significant positive correlation was found between wood density and gene *SuSy* expression during early wood formation. For *Aqual* gene there was negative correlation between gene expression and wood density during early wood formation. No significant correlations were found for these two candidate genes expression during late wood formation and wood properties. *Susy* and *Aqual* expression during growth season varies significantly. The knowledge gained will be used to develop molecular tools directed toward improving wood properties of Scots pine.

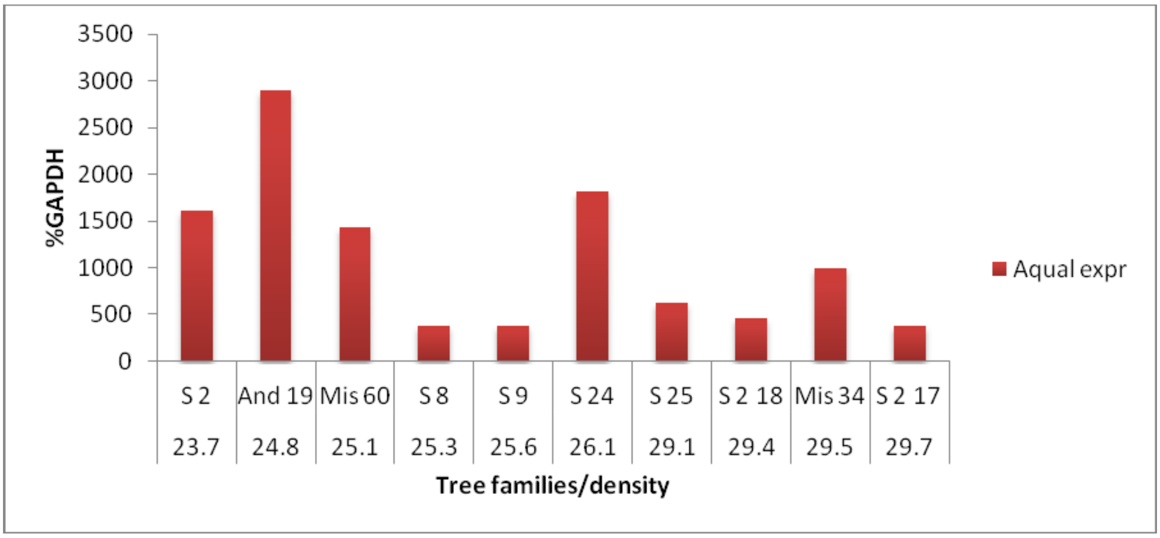

Figure 1 Gene Aqual expression variation during early wood formation in different tree families.

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Coleman HD, Yan J, Mansfield SD: Sucrose synthase affects carbon partitioning to increase cellulose production and altered cell wall ultrastructure. Proc Natl Acad Sci U S A 2009, 106:13118-13123.

Key words*: wood density, Scots pine, SuSy, Aqual.*

PRODUCTIVITY AND QUALITY OF HYBRID ASPEN AT THE AGE OF 18 YEARS

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Wood production is one of the goals of forest management and the sole purpose for establishment of short-rotation plantations. In Northern Europe *Populus* hybrids, among them hybrid aspen (*Populus tremuloides* × *P. tremula*), can be used in those plantations. Establishment of such areas require notable investment, therefore information on the potential revenue is crucial in the decision-making process. Therefore aim of our study is to assess productivity and quality of hybrid aspen at the end of predicted rotation period.

Data were collected in trial consisting of 24 hybrid aspen and 5 common aspen (*Populus tremuloides*) plus tress clones. Initial spacing 2×2 m. Systematic thinning was done at the age of 12 years, removing on average 78.3±12.9 m^3ha^{-1} (ranging between clones from 27 to 149 m^3ha^{-1}). Survival (before the thinning) was 82±6.0% for hybrid aspen and 68% for common aspen; after thinning on average 44±4.1% of trees were remaining.

Yield of hybrid aspen at the age of 18 years was 365 m^3ha^{-1} on average, ranging between clones from 117 to 608 m^3ha^{-1}. Man annual increment of hybrid aspen was 11.3±1.8 $m^3ha^{-1}year^{-1}$ at the age of 8 years, almost three-fold that of common aspen (4 $m^3ha^{-1}year^{-1}$). At the age of 12 years (before thinning) the figures reached 16.4±2.4 $m^3ha^{-1}year^{-1}$ and 7.3 $m^3ha^{-1}year^{-1}$, respectively, but at the age of 18 years: 20.3±3.3 $m^3ha^{-1}year^{-1}$ and 10.0 $m^3ha^{-1}year^{-1}$.

Quality of trees can be characterized as mean diameter and assortment structure. Mean diameter of trees reached 19.4±0.47 cm, ranging between clones from 14.2 cm to 22.9 cm. Major assortment was packing timber 43±4.86%, followed by saw logs 21±4.86% and pulp-wood 18±4.33%; energy wood was only 4±0.77%, but logging residues (small-diameter tops) 13±0.08%.

Results prove the high importance of selection of the best-growing clones for establishment of plantation and demonstrate the potential to obtain high proportion of timber, not only pulp- or energy wood in plantation of hybrid aspen.

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

Key words: *Populus tremuloides × P. tremula, mean annual increment, assortment structure.*

PRELIMINARY RESULTS OF HYBRID ASPEN AND POPLAR PRODUCTIVITY IN SHORT ROTATION PLANTATIONS

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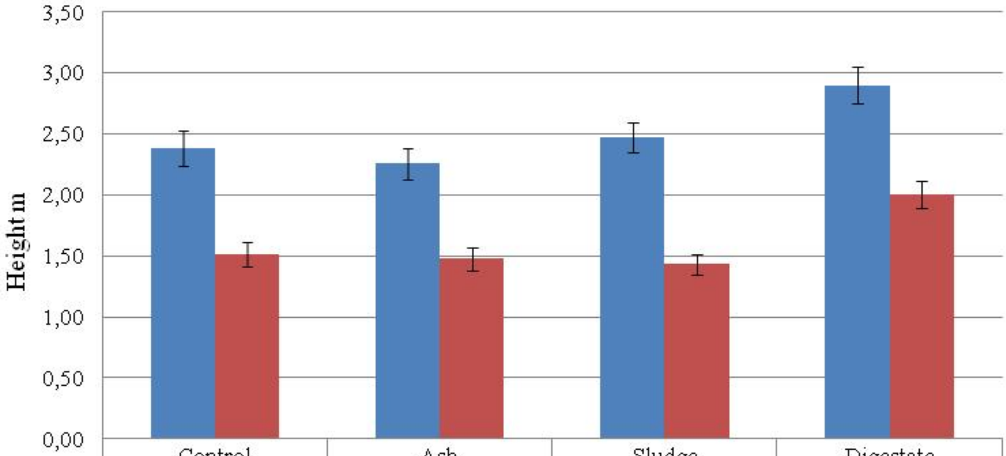
In order to diminish usage of fossil fuel and to increase usage of local renewable energy sources there is necessity for alternative energy sources. Biomass is considered as one of the most perspective in Latvia. Hybrid aspen and poplar are one of the fastest tree growing species used for biomass production in short rotation coppice cultures in Latvia. The aim of this study is to determine the most appropriate methods and the type of land use installing hybrid aspen and poplar plantations on agricultural land.

The experimental plot is located on drained mineral soil. During the work were measured heights, diameters and biomass to aspen clones No.4 and No.28 (*Populus tremula* × *tremuloides*) in three different design plantations 2m × 2m, 3m × 3m and 2,5m × 5m, each divided into four replicates with different fertilizers – digestate, sludge, ash and one replicate with no fertiliser – control. From poplar clones were measured AF2 (*Populus canadensis*), AF6 (*Populus generosa* × *nigra*), AF7 (*Populus generosa* × *Canadensis*) and AF8 (*Populus generosa* × *trichicarpa*) clones, which planted in 1.5m × 0.7m and like aspens, divided in four replicates with different fertilizers.

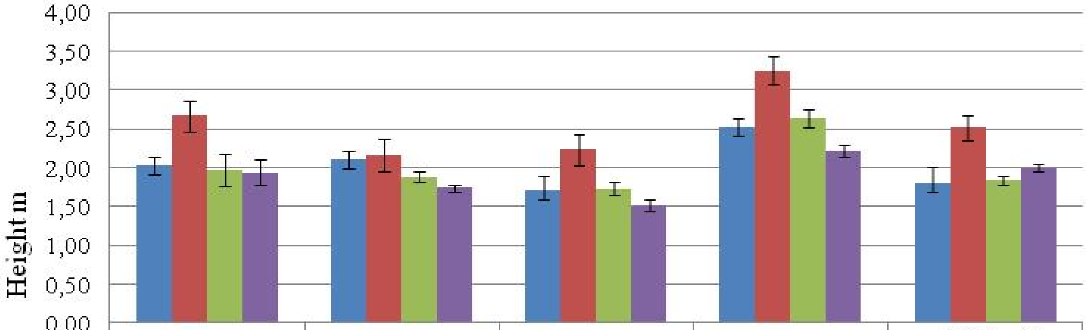
During the work was recognized that the best effect on the growth and only relevant difference among control to the aspen hybrids gives the digestate fertilizer especially planted 2m × 2m. Aspen clone No.4 is significantly more productive than No.28. After third vegetation period 4th clone heights ranged from 2.26 to 2.90 m while 28th clone heights ranged from 1.43 to 2.01 m. The most productive 28th clone plantations do not reach the height of unfertilized 4th clone plantations (*Figure 1*).



	Control	Ash	Sludge	Digestate
4.	2,38	2,26	2,47	2,90
28.	1,52	1,48	1,43	2,01

Figure 1 Average height of 4th and 28th aspen clones after third vegetation period.

Between planted ALASIA poplar clones the most productive one is AF6 clone. After third vegetation period average AF6 heights ranged from 2.17 to 3.25 m, while others ranged from 1.52 to 2.67 m (*Figure 2*).



	Control	Ash	Sludge	Minerals	Buffer of minerals
AF2	2,04	2,12	1,70	2,53	1,81
AF6	2,67	2,17	2,23	3,25	2,52
AF7	1,97	1,88	1,73	2,64	1,84
AF8	1,94	1,74	1,52	2,21	2,00

Figure 2 Average height of poplar clones after third vegetation period.

It is concluded that after first cycles in short rotation plantation at the same condition hybrid aspen clones are more productive than poplar. Biomass were determinate by formula $y = 0.0433x^{2,9528}$ with R^2 value – 0.8714 as only argument using tree height, although it might be determinate with even higher R^2 value – 0.9483 by using as argument tree diameter at 0 height. Comparatively most productive aspen clone in plantation with 2500 trees per ha gives 1.59 t of dry biomass, but most productive poplar clone 1.23 t (*Table 1*).

Table 1 Biomass comparison after third vegetation period

Clone	Wet biomass t	Moisture %	Dry biomass t
Aspen No.4	3.49	54.6	1.59
Aspen No. 28	1.24	53.7	0.58
Poplar AF2	1.68	58.5	0.70
Poplar AF6	2.66	53.7	1.23
Poplar AF7	1.84	56.7	0.80
Poplar AF8	1.05	54.2	0.48

Keywords: *Hybrid aspen, poplar, SRC.*

SRC+ www.srcplus.eu

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POTTENTIAL LANDS FOR SHORT ROTATION COPPICE PLANTATION ESTABLISHMENT IN VIDZEME REGION

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Vidzeme planning region is the biggest of the planning regions according to its territory. It covers 15 257 km^2 or 24% of the territory of Latvia. There are 25 local municipalities and one city – Valmiera. Vidzeme is rich in specially protected nature territories, which implies certain restrictions for entrepreneurial activity.

According to current legislations in Latvia, Short Rotation Coppice (SRC) plantations are agricultural crops or plantation forestry. No permission is needed to plant SRC as agricultural crops. In 2013 for EU subsidies in Latvia were applied 450 ha of short rotation coppice (SRC) plantations, from which around 230 ha were from Vidzeme region. Because of the rules that should be met to get subsidies, not all plantation owners applies and real the total plantation number is bigger.

The agriculture land quality in Latvia is expressed in quality units. Knowing the particular land quality unit allows better predict and evaluate the land productivity, value and make easier comparison. Conditions that are taken into account to measure the unit are particular soil type, relief, location, melioration systems and other field conditions. One quality unit is equal to 70 kg of rye or in money equal to 5.38 EUR. The average quality unit in Latvia is 38 units. According to studies, farming on lands that are below this quality unit could be unproductive. These lands could be used by growing herbaceous crops for bioenergy or SRC plantations, in cases when traditional agricultural crop growing in these areas could be disadvantageous.

In Vidzeme region are 501 880 ha of agriculture lands from which 206 574 ha (52%) are lands with quality assessment under 38 units (fig 1.)

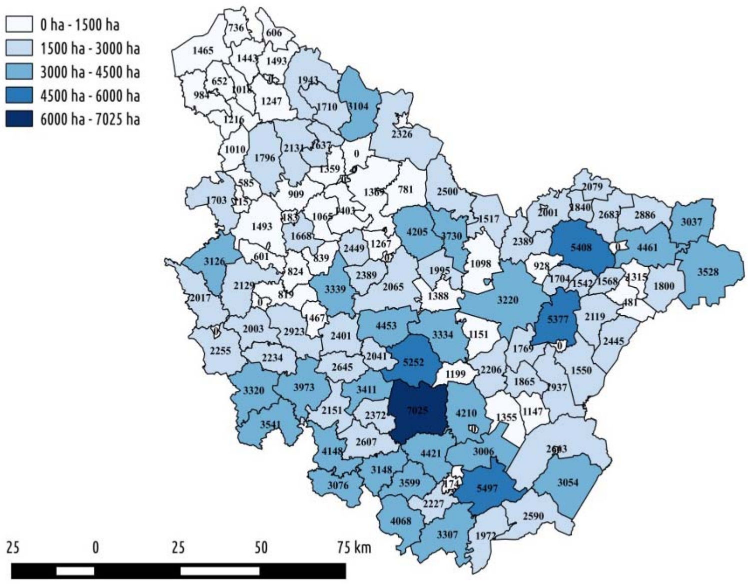

Fig.1 Agriculture lands in Vidzeme region with quality assessment under 38 units.

Large areas with agriculture land quality assessment under 38 units are in Liezeres parish (7025 ha), Alsviku parish (5408 ha), Belavas parish (5377 ha) and Jaunpiebalgas parish (5497 ha).

Not all of these areas are available or suitable for SRC plantations, in some cases, the areas that are slightly below 38 units are still used in traditional crop management, because of the closeness to existing crop fields. Some land owners thinks that lands under 38 quality units, still can be used in productive farming and the level, under which traditional farming is no more beneficial should be set under 25 quality units. There are 87 889 ha of agricultural lands under 25 quality units, which represents 18% from all agricultural lands in region.

To establish SRC plantations in poor soils (especially in lands with quality unit under 25), fertilization is recommended. Fertilizer that is easily accessible in the region, because of more then 200 enterprises that use wood as main resource for heat or electricity production is ash. Total amount of ashes, that were produced in 2013 from these enterprises were about 12 000 oven-dried tons. With that amount of ashes, it's possible to fertilize more then 2000 ha of agriculture land.

In good soils or with fertilization, average SRC plantation yields are about 7–10 oven-dried tons of wood chips per year. In poor soils under 38 quality units and specially under 25 quality units the average yields are about 5–6 oven-dried tons per year. Wood chips from SRC plantation could be used in regional market. In 2013, region has 43 enterprises that used wood chips, with total amount of 170 000 oven-dried tones per year. To meet the wood chip demand in the region, about 17 000–24 000 ha of agricultural lands with good soil conditions should be planted with SRC plantations. In poor soil conditions about 28 300–34 000 ha should be planted.

To fulfill the wood chip demand in region, about 31–39% from all lands under 25 quality units and 14–16% from all lands under 38 quality units should be planted. In good growing conditions the percentage will be 19–27% under 25 units and 8–12% under 38 units. About 6–12% from these plantations could be fertilized with ashes from this region.

Keywords: *SRC plantations, SRC in Vidzeme, SRC.*

The study is done by the scope of the Commission in the Intelligent Energy for Europe Programme project: "Short Rotation Woody Crops (SRC) for local supply chains and heat use" The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EASME no the European Commission are responsible for any use that may be made of the information contained therein. Contract number: IEE/13/574.

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BIOMASS STUDIES FOR FOUR MOST COMMON TREE SPECIES IN LATVIA

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Estimation of biomass of an individual tree and forest stand became the highest priority issue during the last decades since 1997, when developed countries adopted the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). At the present time reliable estimates of biomass of a tree and its components are needed for practical forestry as well for research purposes. A single tree and a stand biomass estimates are preconditions for assessment of energy wood potentials and carbon pools in forest land. Forest carbon sink is considered in the Kyoto Protocol as one of the mechanisms for climate change mitigation and it plays an important role in national and global greenhouse gas balances, especially in countries with considerable forest resources. Countries, which ratified the Kyoto Protocol, are obligated to report emissions of greenhouse gases (GHG) and removals of CO_2 in accordance with international reporting guidelines. Living biomass in forest land is the main source of carbon sink in Latvia. In accordance with guidelines for the GHG inventories, Latvia should develop a scientifically verified methodology for assessment of the carbon stock in all carbon pools in forest lands, including living biomass. Earlier studies on forest biomass and carbon stock in Latvia are fragmented and elaborated methods are not always compatible, therefore it is necessary to compile new biomass equations for above and below-ground tree components.

Empirical material for above and below-ground tree components of Norway spruce (*Picea abies [L.] Karst*), Scots pine (*Pinus sylvestris L*), silver birch (*Betula pendula Roth.)* and aspen (*Populus tremula L.*) were collected from 126 stands. These stands (27 Norway spruce, 34 Scots pine, 35 silver birch and 28 aspen stands) were located mainly on mineral and drained soils representing a large part of forest stand types in Latvia. In order to develop the above-ground biomass equations 372 trees were cut down and split into compartments. The total number of sample trees for below-ground biomass equations was 144. In each of the selected forest stand three sample trees representing the range of dimensions of the dominant stand (craft class I, II or III), were felled down. The selected stands were located in three regions of Latvia, representing different climatic regions and populations of trees. The tree biomass was estimated by individual tree components: stem wood, living and dead branches, stump, coarse roots (Ø >20 mm) and small roots (Ø< 20 mm). The biomass of living branch includes needles and cones but not leaves, except coniferous trees. Number of measured biomass components by tree species is not equally for all species (Table 1). Above-ground biomass measurements were done from autumn to spring, in period when deciduous trees don't have leaves and young shoots are mature.

Table 1. Biomass equations and number of measured biomass components by tree species.

Tree species	Steam wood	Living branch	Dead branch	Stump	Coarse roots	Small roots	Above-ground biomass	Below-ground biomass
Scots pine	102	102	102	40	40	40	$y=0.244x^{2.4111}$	$y=0.0533x^{2.4178}$
Norway spruce	81	81	75	29	29	29	$y=0.4526x^{2.2459}$	$y=0.0499x^{2.5689}$
silver birch	105	105	89	42	42	42	$y=0.1341x^{2.6515}$	$y=0.0526x^{2.4606}$
aspen	84	84	78	33	33	33	$y=0.1356x^{2.606}$	$y=0.0538x^{2.4025}$

Biomass of stumps and roots was measured in summer. Stump biomass includes both above-ground and below-ground portions, and stump height is considered 1% of a tree height. Root system of each sample tree has been dug so that roots with diameter more than 2 mm are not lost. After excavation and transportation to laboratory the stump and root system was weighed with accuracy of 0.02 kg. Before weighing soil particles were separated with a high-pressure water pump.

In this study biomass equations for the fresh (naturally wet) above- and below-ground tree components of Norway spruce, Scots pine, silver birch and common aspen are developed (Table 1). Accuracy (R^2) of all biomass equations ranges from 0.9697 to 0.9958. Allocation of tree biomass varies by tree species, and the differences depend also from the tree age, which is demonstrated in Figure 1.

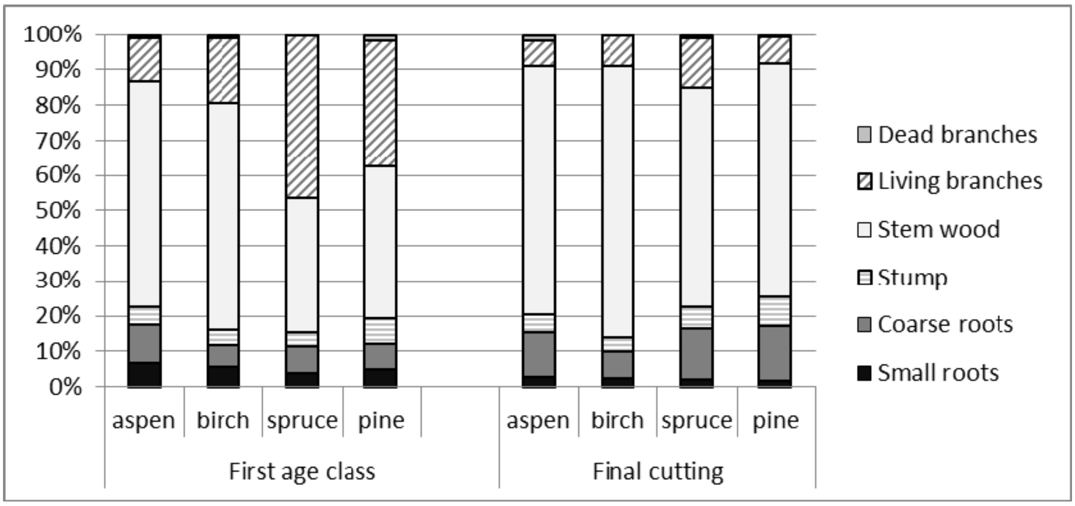

Figure 2. The biomass allocation of tree component at stage of first age class and final cutting.

(First age class aspen and birch is 1–10 years; spruce and pine 1–20 years. Final cutting: aspen-41, birch-71, spruce-81, pine-101 years).

At a given tree ages, except young spruce trees, the stem is the biggest biomass component, especially at the age of final cutting. The highest proportion of stem wood biomass is detected for birch, and the lowest – for spruce. The proportion of stem wood in young stands varies between 38 and 65%, but in mature stands varied between 62 and 77%. The highest proportion of crown biomass in compare to the total biomass (15–46%) is characteristic for spruce, in all ages. The proportion of crown for all tree species shows a decreasing tendency from first age class to final cut age. The proportion of below-ground biomass from the whole tree biomass is in average 19%. The biomass of stump and roots is significant proportion of the total tree biomass; it is larger in mature stands – 21%, and smaller in young stands – 18%.

The results are based on fresh cut tree measurements and after data processing will be updated to dry biomass and carbon content in the further studies. The study is done within the scope of the National forest competence centre project “Methods and technologies to increase forest value” (L-KC-11-0004).

Keywords: *biomass equations, biomass allocation, above and below-ground biomass.*

DECOMPOSITION OF BELOW-GROUND BIOMASS IN CONIFEROUS FOREST STANDS IN LATVIA

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The amount of carbon dioxide (CO_2) is constantly increasing in the atmosphere due to natural processes like volcanic eruption as well as due to human activities. The increasing concentration of CO_2 and other substances like methane (CH_4) and nitric oxide (N_2O) evokes greenhouse effect – heating up of the atmosphere, therefore these gasses, besides other less common gasses, are called greenhouse gases (GHG). Forest is a long-term carbon sink, which decreases the amount of CO_2 in the atmosphere through the photosynthesis process by immobilization of carbon in living biomass, then litter, dead wood, harvested wood products and soul carbon pools. Forests are also contribution to reduction of the GHG emissions by replacement effect – using biomass instead of fossil fuels and energy-intense construction materials. CO_2 is not immobilized forever in the forest carbon pools; decomposition of biomass during certain period returns CO_2 into atmosphere. Implementation of the climate change mitigation targeted forest management measures requires knowledge about the decomposition rate to adopt forest management planning, for instance, to decide, where stump extraction for bioenergy production will lead to the mitigation effect and where the impact might be opposite. The presented study focuses on evaluation of decomposition ate of the below-ground biomass of coniferous trees common in Latvian (Norway spruce and Scots pine) in forest stands of various age growing on dry mineral soils. In total 30 sample trees (stumps and roots of 16 pines and 14 spruces from the previous generation of trees harvested in clear-felling) were excavated and analysed. Age of stumps varied from 13 to 43 years.

Before excavation height and diameter of stumps was measured. All parts of stump and roots having diameter of more than 2 cm were collected, but those parts having diameter less than 2 cm were left, considering this biomass as a part of soil carbon pool.

Density, dry mass, moisture content of wood and carbon content were determined in the collected samples in laboratory – 3 samples of stump, 3 samples of coarse roots (diameter more than 5 cm) and 3 samples of small roots (diameter 4,9-2 cm). Carbon stock in below-ground dead biomass was calculated using density and carbon concentration values and compared with relevant values of living trees extracted and analysed using the same methodology.

It was found in the study that the density increases in pine roots, but remains constant in spruce and in pine stumps disregarding the age. Comparison of carbon stock in fresh and partly decomposed stumps of the previous generation of trees demonstrated, that for the pine decomposition rate can be described by the logarithmic regression equation (Figure 1). Based on this regression equation it is possible to make a conclusion that 50 % of the below-ground pine biomass, including fine roots accounted as decomposed material by default is decomposed within 10 years. Decomposition of the below-ground biomass of spruce can also be described by logarithmic regression equation, however, the uncertainty is considerably higher. Following to the regression curve of decomposition of spruce below-ground biomass, 50 % of the biomass is decomposed within 10 years. The values are similar for pine and spruce. The study results demonstrate that decomposition is fast at the beginning, but then it becomes considerably slower and it is heavily affected by the soil conditions.

The decomposition period of below-ground biomass for pine and spruce according to the study results is 60–70 years.

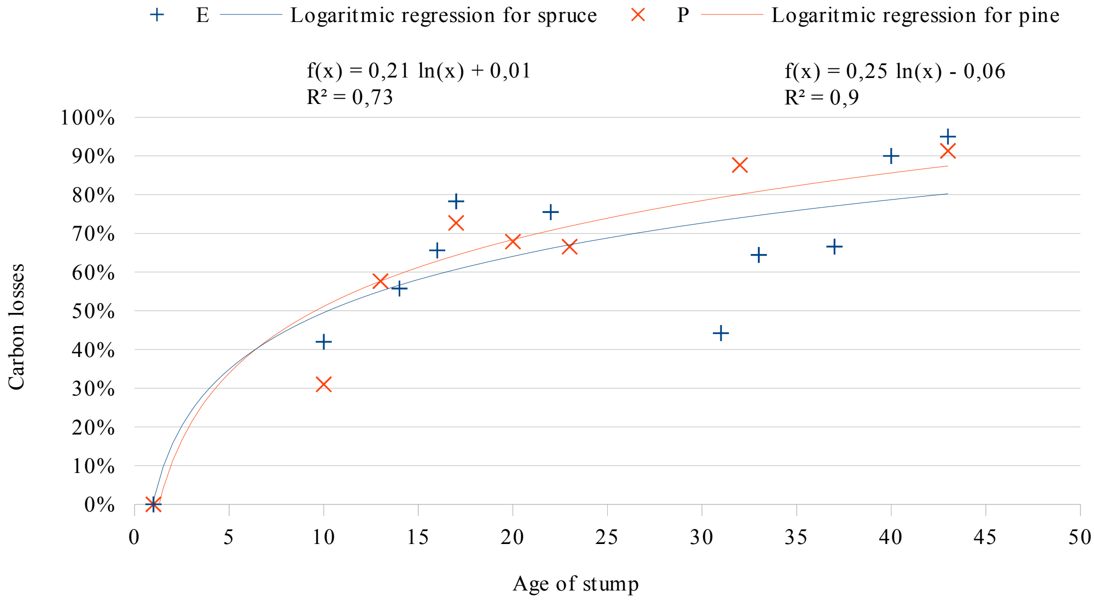

Figure 3. Regressing curves characterizing decomposition of pine and spruce stumps.

The results are similar with the findings obtained in Finland, where researchers concluded, that decomposition time of conifers is 60–80 years. (Mäkinen et al. 2006) Similarly in Swedish studies it is found that 50 % of conifers below-ground biomass is decomposed in 15 years. (Melin et al. 2009)

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Keywords: *below-ground biomass, dead wood, decomposition, carbon stock.*

IMPACT OF RECONSTRUCTION OF FOREST DRAINAGE SYSTEMS ON INCREASE OF LIVING WOODY BIOMASS IN THINNED MIDDLE-AGE CONIFEROUS STANDS

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Drainage can be considered as one of the most efficient forest management operations aimed to increase productivity and value of forest stands. Average growing stock in Latvian forests has been doubled since beginning of 20th century. Rapid increase in forest productivity coincides with distribution of drainage in 1930's till they stopped in the beginning of 1990's (Zālītis, Indriksons, 2009). Now 33 % of all forests are drained (FSI 2010). Functionality of drainage ditches is decreasing periodically and there is need for regular ditch cleaning (Zālītis et al., 2010). To understand impact of regular ditch cleaning on forest productivity and CO_2 removals, we set the aim to evaluate the impact of reconstruction of the drainage ditch networks on accumulation of above-ground biomass of trees and sequestration of carbon in living woody biomass.

Thirty six sample plots were established in the western and central part of Latvia to collect data for the study. Sample plots were established in 60...80 years old Scots pine (P) stands and in 40...60 old Norway spruce (E) stands, where thinning were carried out between 2006 and 2008. The stands were located on naturally wet mineral soils (P0, S0), on drained mineral soil, where ditch cleaning were carried out between 2006 and 2007 (P2, S2) and on drained mineral soil, where ditch cleaning is not carried out last 20 years, but is planned within the next decade (P1, S1). In each sample plot 10 radial increment core samples were taken for analysis of the annual radial increment.

Significant impact on the increase of biomass ($F < F_{crit}$, $\alpha = 0.05$) wasn't detected after ditch cleaning in 2006...2007. The study shows that the increase of biomass of sample trees in drained sample plots (E2 = 12.02 kg*a-1, E1 = 11.31 kg*a-1, P2 = 10.76 kg*a-1) was significantly higher ($F > F_{crit}$, $\alpha = 0.05$) in compare to the plots on naturally wet mineral soil (S0 = 9.34 kg*a-1, P0 = 8.44 kg*a-1). Five years after thinning in 2006...2008 drained spruce stands (S1,S2 = 14.4 t*ha-1) sequestered significantly more ($\alpha = 0.05$) carbon than spruce stands on wet mineral soil (S0 = 11.7 t*ha-1), and removals of CO_2 in living woody biomass can exceed potential greenhouse gas (GHG) emission due to the drainage. In pine stands there is no significant ($\alpha = 0.05$) difference between the plots on drained and naturally wet mineral soil. It can be explained by too intensive thinning and smaller stand density in pine stands on drained mineral soil. Although the results show significantly better biomass growth figures on drained soils, it is not caused by higher stand productivity but by the higher average diameter of trees in the drained stands. This assumption is approved by results demonstrating that trees with similar diameter produces similar accumulation of biomass in drained and non-drained stands. The reason for difference of the diameter in drained and non-drained stands of the same age can be found in early stages of stands development, when drainage triggered higher productivity in drained stands due to better growth conditions. Increasing stock of biomass triggers increase of evapotranspiration potential in forest stands (Sarkkola et al., 2013), which leads to decrease of water table and improvement of growth conditions in drained and non-drained stands (Ahti, Hökkä, 2006). To achieve the best growth rates and to boost sequestration of carbon in all forest carbon pools it is necessary to provide satisfactory drainage conditions in young stands. We suggest to do reconstruction and maintenance of the drainage ditch after final felling to secure the best conditions for the forest regeneration.

The study is done within the scope of the National forest competence center project "Methods and technologies to increase forest value" (L-KC-11-0004).

Keywords: *drainage, ditch maintenance, tree biomass growth, carbon.*

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CLIMATE-GROWTH RELATIONSHIPS REVEALED FROM NORWAY SPRUCE (*PICEA ABIES* (L.) KARST.) PROVENANCE TRIALS

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Climate in Latvia has become warmer in the last decades and such changes are predicted to continue, therefore it is important for forestry sector to understand how these climate changes might affect different tree traits. In order to assess climate suitability effect on Norway spruce (*Picea abies* (L.) Karst.) provenances in Latvia, height and survival data from a Norway spruce provenance trial located in Saldus, Latvia, were analysed together with several climatic indices. First site of the trial was established in 1974, second in 1976; both using two year old seedlings. Provenances originated from Latvia, Denmark, Germany, Russia, Lithuania, Norway, Romania, Slovakia, Finland, Sweden and Ukraine. Thirty year average climate data values from 1961 – 1990 for the 73 origins of provenances were acquired from the WorldClim project.

Correlation analysis confirms that there is a relation between provenance average values for height and survival and climate index values for the origins of the provenances, indicating that suitability of climate is an important factor affecting the results of provenance trials. Positive correlation between continentality index and survival rate ($r = 0.24$, $p < 0.05$) might indicate resistance of provenances against spring or autumn frosts, negative correlation between temperature and height ($r = -0.37$, $p < 0.01$) suggest that higher mean annual temperature in trial location than in the provenance origin has a positive effect on height increment. Negative correlation ($r = -0.24$, $p < 0.05$) between moisture deficit and height shows a weak tendency that provenances from origins with higher draught risk grow slower. Even though the relations are not strong, it is clear that information about climatic conditions in the provenance origins can help acquire a better understanding of causal relationships determining the results of provenance trials and thus ensuring a possibility to choose most suitable seed material for the predicted climatic conditions.

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

Key words: *spatial analysis, seed transfer, climate changes, height growth.*

THE EFFECT OF ALTERED DISTRIBUTION OF PRECIPITATION ON GROWTH OF FOREST PLANTING MATERIAL IN CENTRAL LATVIA

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Climatic changes are predicted to alter distribution of summer precipitation in Northern Europe. Higher frequency of longer periods without rain in combination with increased air temperature will increase the drought-stress for the trees, especially at sapling stage. Age (size) of the tree and parameters of its root system might be crucial in determining the actual impact of drought on its growth (increment) and survival. Therefore the aim of our study was to compare the effect of regular drought period on growth productivity of commonly used planting material in forest regeneration in Central Latvia. For this purpose facility with moving roof were constructed to cut off natural precipitation and irrigation of sample plots with withheld amount of water was done every 6 days. Open air plots were used as control. Experimental planting plots were established in sealed pits filled with substrates of poor sandy soil (*Caldinoso-callunosa* forest type), organic peat soil (*Myrtillosa turf.mel.* forest type) and fertile mineral soil (*Hylocomiosa* forest type). In each pit soil water potential was measured. Saplings of Norway spruce (bare rooted, containerized and saplings with improved root system), Scots pine (bare rooted and containerized), silver birch (bare rooted) and hybrid aspen (containerized) obtained from commercial nursery of JSC Latvia's state forests. Height growth and biomass (below- and above ground) of saplings were measured.

Altered distribution of precipitation did not have statistically significant effect on height increment and biomass, however, saplings from treatment plots had higher total area of fine roots compared to those from control plots (differences were especially pronounced for all types of Norway spruce saplings). Results indicate, that altered distribution of precipitation (weekly periods of drought) alone were not affecting growth and survival of saplings of species and planting material studied.

Height increment and biomass was significantly affected by between species, plant material and soil type. Containerized saplings showed better height increment. Better growth of all morphometric parameters was shown by plants in organic peat and fertile mineral soil.

Further studies should address longer periods without precipitation in combination of effect of increased temperature should be tested in a controlled environment.

Study was carried out in Latvian Council of Sciences project "Adaptive capacity of forest trees and possibilities to improve it" (No 454/2012).

Key words: *drought stress, height growth, biomass distribution.*

NEEDLE CAST DAMAGES IN OPEN-POLLINATED AND CONTROL-CROSSED TRIALS OF SCOTS PINE (*PINUS SYLVESTRIS* L.)

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The impact of climatic and genetic factors on needlecast damage, as well as relationship between degree of damage and survival and growth of trees has been evaluated. Two series of experiments were analysed: 1) open-pollinated Scots pine progeny trial that consists of 226 families from 13 provenances of Latvia, established in two localities (Tukums and Kalsnava). In these trials needlecast damage (in 5 grade scale) in the second growing season and survival of trees was assessed; 2) control-crossed progeny trial that consists of 72 crosses from 10 parent trees, established in two localities (Zvirgzde and Kalsnava). In these trials needlecast damage (in 5 grade scale) in the sixth growing season was assessed and tree height, height increment and diameter of root collar measured. Results reveal that degree of needlecast damage is influenced by the genetic as well as climatic factors and interaction between them. The average degree of needle cast damage in open- pollinated progeny trial was 4.7±0.01 in Tukums and 4.6±0.03 in Kalsnava; in control-crossed progeny trial it was 4.6±0.02 and 3.4±0.04 in Zvirgzde and Kalsnava, respectively. In both series of experiments statistically significantly ($p<0.001$) lower degree of needle cast damage is observed in experiments in eastern Latvia – Kalsnava, where the average daily air temperature in August was lower than in other sites. The impact of genetics (family, group of controlled crosses, provenance) on needle cast damage degree was statistically significant ($p<0.05$), and this effect remained also, when any of growth traits (diameter, height or height increment) is used as covariate in analysis.

Correlation between the family mean needlecast damage (grade) in different locations was significant ($r=0.40$-0.72, $p<0.001$). The correlation between the degree of needlecast damage and growth traits was negative and statistically significant both at provenance and family mean level: $r=-0.69$ and $r=-0.42$; $p<0.01$, respectively.

Increasing needle cast damages due to predicted rise of temperature can be foreseen in future therefore selection of less affected families and provenances for forest regeneration material is suggested.

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

Key words: *resistance, forest tree breeding, adaptation, genotype x environment interaction.*

HEIGHT-GROWTH DYNAMICS OF SCOTS PINE (*PINUS SYLVESTRIS* L.) AFTER FOREST FIRE IN HEMIBOREAL FORESTS, LATVIA

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Forest fires are part of natural disturbances in hemiboreal forest zone, however, nowadays majority of them are caused by human activities. It is reflected in spatial distribution of forest fires: majority of them occur in a vicinity of urban areas. According to the State Forest Service in year 2013 total number of fires was 422, affecting 217 ha of forests. In order to understand ecological role and the impacts of large-scale forest fires on forest ecosystems and the significance of these impacts over time we compare long-term growth dynamics of Scots pine (*Pinus sylvestris* L.) in burned and clearcuted areas.

The study sites are located in the northern and central parts of Latvia (56°45′- 57°40′N; 22°32′- 24°98′E). The data were collected in four Scots pine dominated forest stands burned in 1992, 2004 and 2006 in forest types *Vacciniosa* (Mr), *Vacciniosa mel* (Am) and *Myrtillosa mel* (As). Clearcuts of similar age and forest type, located as close as possible to burned areas, were used as a comparison. In each study site 100 m^2 and 25 m^2 circular plots were placed systematically and height of Scots pine, Silver birch, Norway spruce and Trembling aspen as well as height increment of Scots pine were measured.

The mean height of Scots pine at the age of 8 years was 168±4,37 cm (Mr) and 230±7,22 cm (As), at the age of 10 years 185±5,87 cm (Am) and at the age of 22 years 332±19,5 cm (Mr). The average density of Scots pine at 8 years was from 2828 to 3173 trees per hectare, at 10 years 2820 trees per hectare and at age 17 years 1872 trees per hectare. The average height of Scots pine at the age of 8 was significantly higher ($\alpha = 0{,}001$) in control areas than in burned areas, at age of 10 and 17 average height of Scots pine was still higher in control areas but difference was not statistically significant. Tree height was notably more variable in all burned areas in comparison to the control sites which could be a result of different fire intensity affecting the microenvironmental conditions. Distance from the forest edge didn't have a significant effect on mean height of Scots pine.

Acknowledgements

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

Keywords: *soil quality, forest type, height increment, tree species competition.*

LONG-TERM NATURAL FRAGMENTATION DYNAMICS IN SEMI-NATURAL FOREST MASSIVE

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Long-term changes of forest caver are notably affected by anthropogenic and natural disturbances. Major natural disturbance, impacting large forest areas in Northern Europe, are storms. Its impact is predicted to rise in future in our region due to climatic changes, causing increase in frequency of storms and maximum wind-speeds. Storms cause fragmentation of forest landscapes and stands, affecting their structure and composition. Aim of the study was to characterize long-term effect of such disturbance in un-managed forest landscape.

Study was conducted in north-eastern Latvia (57°38' N, 22°17'E): in a part of Slitere National Park that was un-managed since year 1923 and affected by large 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 (3 years after the storm) 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 has returned to land-cover class "forest" already 19 years after the storm. Further studies will include finer division of land-cover classes and resolution (size of area unit) to rafine the findings of this initial study and compare them with the trends in managed landscapes.

Research was carried out in Forest Competence Centre (ERAF) project «Methods and technologies for increasing forest capital value» (No. L-KC-11-0004). We acknowledge Nature Conservation Agency for permission to conduct the study.

Key words: *analysis of satellite images, windthrow, natural disturbance.*

REGENERATION OF WET AND DRAINED FORESTS BY MOUNDING IN LATVIA

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INTRODUCTION

Mounding is well known in Latvia but in last twenty years very rarely used soil preparation method (Bušs 1932, Katkevičs 1986, Mangalis 2004). Since disk trenchers started to operate in the country, application of mounding rapidly decreased. Fertile and wet forest sites with peat layer of more than 40 cm, such as *Myrtillosa* was left for natural regeneration more often as other, because it was impossible to prepare soil with disc trenchers due to low soil bearing capacity. Nowadays foresters can use improved planting material promising to reach by 20% higher increment, better stem quality, resistance to diseases and better adaptation to climate change, and so called "artificial regeneration" of stand coming actual again (Jansons 2008). Excavators are able to move on soft and wet soils, operators of these machines can choose discrete place to prepare soil for a single tree when prepare mounds, inverted humus layer, patch or just scarify the soil (Sutton 1993, Orlander et al. 1998, Saksa 2005).

MATERIALS AND METHODS

Mounding trials were done in Eastern part of Latvia, on drained forest sites (*Myrtillosa mel., Myrtillosa turf. mel.),* in spring and autumn in the second year after clear-cut. Soil preparation were done by three different buckets: conventional excavator bucket (110 cm wide), special mounding bucket Karl Oscar (50 cm wide) and specialized bucket MPV-600 (60 cm wide, produced by LSFRI Silava and engineering company Orvi). All three devices were mounted on New Holland E165 excavator. Time studies were done during soil preparation; site characteristic parameters and work elements used for comparison of productivity were: "weather conditions"; "amount of slash on field"; "moving in stand and out"; "moving looking for suitable place to make mound"; "removing of slash or overgrowth before making of mound", "making of mound"; "compression of mound", "other movements with crane"; "non work related operations". Number and dimensions of mounds, coverage of ground vegetation on mound and seedling surviving were evaluated in sampling plots in each stand in the next autumn after completion of time studies.

RESULTS

Time studies and productivity

During spring the most important factor affecting productivity of mounding was skills of operator, because productivity of work increases constantly during the time studies and did not correlate with equipment used or work conditions. But in autumn there were some, but non-significant, differences between productivity of mounding and bucket used (Figure 1).

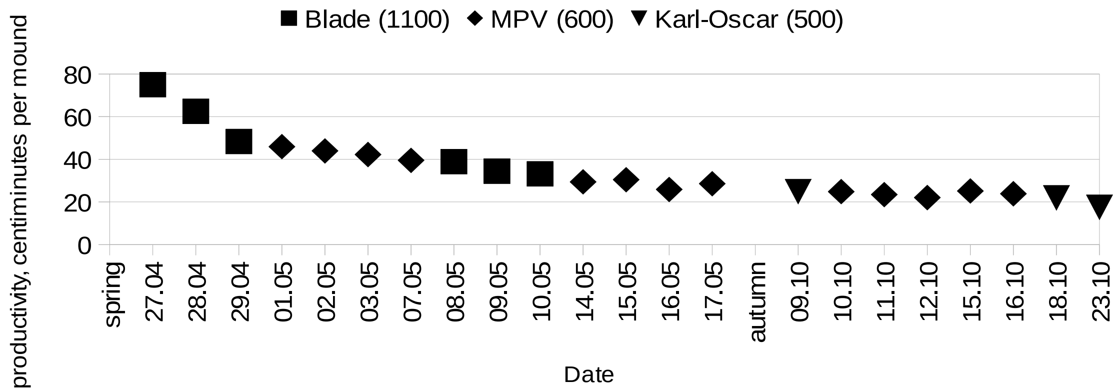

Figure 1 Growth of productivity of mounding during the trials.

Comparison of the work operations shows that proportion between them are approximately the same during the time and the most time consuming operations are crane movement and removal of slash & overgrowth (Figure 2). This result points to importance of leaving clean felling site with piled or extracted harvesting residues before soil preparation.

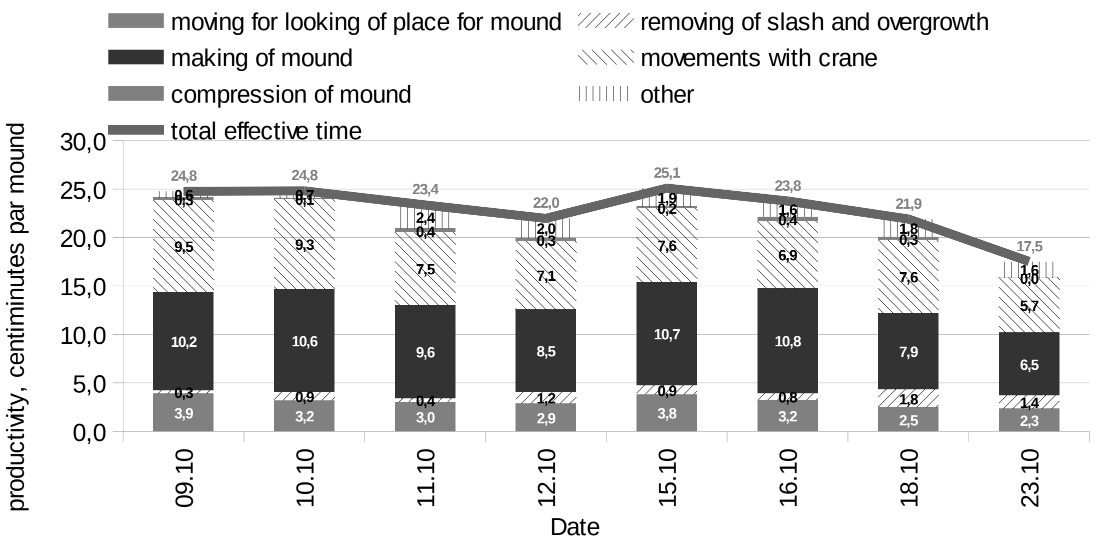

Figure 2 Distribution of effective time between work elements during mounding.

Average time spent to prepare one mound for trained operator at autumn was 22.9 centiminutes.

Ecological issues – level of scarification and growth conditions

According to FSC certification rules it is allowed to scarify no more than 30 % of the stand area. Rules of Cabinet of ministries No 308 determinate that in case of "artificial regeneration" it is necessary to plant at least 50% of trees and final number of trees should be at least 2000 for spruce or 3000 for pine. Figure 3 shows estimated percentage of scarified area depending from required number of planting spots using different mounding devices. For spruce stands preparation of 2000 planting spots wound not exceeds the FSC thresholds for all devices, except the excavator bucket (width 1100mm) but in pine stands only the narrow Karl-Oscar bucket is suitable –to prepare 3000 mounds per ha. Wider blade could be used only for reduced number of trees, when it is planned to plant only so called "future trees" considering certain amount of natural ingrowths in the regenerated stand.

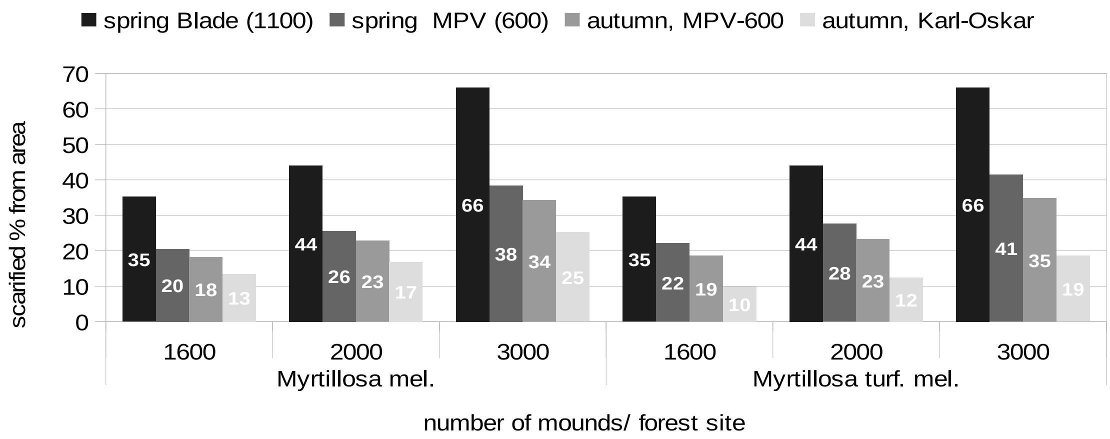

Figure 3 Estimated proportion of scarified area depending from proposed number of planting spots per ha using different buckets.

In Nordic conditions mounds are free from ground vegetation during two years, but in Latvia the situation is different, because of more fertile soils and climatic conditions, responsible for different balance between grasses, cereals and caulescent plants. In forest site type *Myrtillosa turf. mel.,* vegetation covered only 16-22% of the mounds' area after the first growing season, but in site type *Myrtillosa mel.* 39-41% of mounds' area were covered by caulescent vegetation. Percentage of area covered by vegetation was smaller on mounds prepared by wider buckets. In cases, when ground vegetation contained *Juncus sp.* it was necessary to make weed control already in of first growing season on *Myrtillosa mel.* stands.

CONCLUSIONS

Mounding is suitable and ecologically sustainable soil preparation method in artificial forest regeneration for planting up to 2000 trees for ha. Considering soil scarification thresholds and productivity of the operation optimal number of mounds is close 1600 trees per ha. Wider buckets are recommended in fertile site types with more aggressive vegetation, where it is enough to plant target trees considering certain percentage of natural ingrowths. In *Myrtillosa mel.* site type it is necessary to do weed control already during the first growing season.

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ESTIMATION OF CARBON ACCUMULATED IN COARSE DEAD WOOD IN FOREST LAND USING STOCK CHANGE METHOD

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The National forest inventory (NFI) provides the most comprehensive information about the dead wood in Latvian forests, which can be used in the national greenhouse gas (GHG) inventory to account carbon stock change in this carbon pool using stock change method or the increment method, if reliable data on decay of dead wood are available. The NFI separate dead wood into 3 quality classes (decay index): fresh residues, partly decomposed and heavily decomposed residues. The 1st class can be used in firewood production, 2nd class is transitional stage of dead wood and can be partially used as firewood and 3rd class is too decayed to be used as firewood.
The scope of the presented study is to elaborate factors of wood density and carbon content for the allometric biomass equations characterizing carbon stock in above-ground dead wood. Additional study was done to compare transition of dead wood from one decay fraction to another; however, preliminary results demonstrated, that 5 years period between site visits to the NFI plots is too short to obtain reliable data on transition between the dead wood quality classes. This exercise should be repeated every 10th year to reduce uncertainty of the evaluation and to provide reliable results on carbon stock in dead wood using stock change method.
The NFI sample plots for the study was selected so that only complete plots (500 m^2) are represented and up to 3 pieces of dead wood are measured in the plot so that they can be easily identified during the site visit. In total 400 plots were selected and 200 of them are visited until now. Samples for characterization of carbon content and density of dead wood were collected outside the sample plots by cutting complete 3 cm thick disc of stem near (50 cm) the thickest end of the dead wood piece. Only debris laying directly on the ground were sampled. Decay category, species and diameter of sampled dead trees had to be the same as inside the sample plot. Species, approximate diameter at breast height ($D_{1.3}$), thickness and diameter of the discs were measured in the field. Sawdust, bark and other pieces separated from the samples during cutting were collected in plastic bags and later mixed with the samples. Missing part of stems were considered as already decayed. Sampling was arranged so to cover whole range of dimensions of dead wood in all quality classes, starting from $D_{1.3}$ 6.1 cm.
In laboratory samples were photographed, weighed, air-drayed in room temperature, then drayed in oven at 105 ^{0}C temperature to absolutely dry condition, weighed again, crushed, sieved through 1 mm sieve and delivered to chemical analyses. Carbon content was determined using LECO CR-12 elemental analyser. Other parameters estimated in the laboratory are moisture content and bulk density (considering that the sample disc initially has shape of circle with specific thickness). Average stock of dead wood in different decomposition classes (Table 1) estimated in the 1st round of the NFI was used to calculate carbon stock in dead wood in Latvia.

Table 2 Dead wood stock in different decomposition classes in NFI plots with living trees, m^3 ha^{-1}

Land use	Fresh residues (1)	Partly decomposed (2)	Heavily decomposed (3)	All residues
Settlements	0.15	0.44	1.00	**1.60**
Forest land	5.89	7.15	3.74	**16.78**
Wetland	0.41	0.66	0.12	**1.19**
Grassland	0.01	0.02	-	**0.03**
All categories	**3.19**	**3.90**	**2.05**	**9.14**

No significant difference found in carbon concentration, but more decomposed materials has considerably smaller density resulting in reduction of carbon stock per cubic meter. Values provided in Table 2 were applied to calculated carbon stock in dead wood in Latvia. When data were not available, the value of the next quality class was used in calculation. According to the results (Table 3) total carbon stock in dead wood in the 1st round of the NFI in Latvia was nearly 9 mill. tons, mostly (99 %) located in forest land. If compared by dominant tree species, the most of carbon in dead wood is located in birch, pine and spruce forests, in spite the highest concentration is in aspen and black alder stands (Table 4).

Table 3 Density and carbon stock in dead wood of different decomposition classes

Species	Density of biomass, kg L^{-1}			Carbon stock, kg m^{-3}		
	1	2	3	1	2	3
Aspen	0.31 ± 0.18	0.26 ± 0.11	0.19 ± 0.07	159 ± 95	129 ± 56	98 ± 31
Grey alder	0.41 ± 0.12	0.32 ± 0.05	0.19 ± 0.09	217 ± 64	171 ± 29	98 ± 35
Birch	-	0.25 ± 0.18	0.19 ± 0.06	-	144 ± 108	99 ± 28
Spruce	0.27 ± 0.28	0.31 ± 0.19	0.27 ± 0.04	143 ± 151	156 ± 90	151 ± 16
Black alder	-	0.3 ± 0.12	0.21 ± 0.24	-	151 ± 63	110 ± 125
Scots pine	0.37 ± 0.01	0.19 ± 0.08	0.4 ± 0.15	197 ± 15	104 ± 43	223 ± 74

Table 4 Carbon stock in dead wood of different decomposition classes and land use categories

Land use	Total carbon stock, 1000 tons				Average carbon stock, tons ha^{-1}			
	1	2	3	total	1	2	3	total
Settlements	3.0	7.3	24.8	**35.1**	0.01	0.03	0.10	**0.14**
Forest land	3 595.4	3 377.3	1 762.0	**8 734.7**	1.04	0.98	0.51	**2.53**
Wetland	29.6	12.0	3.3	**45.0**	0.06	0.02	0.01	**0.09**
Grassland	-	3.6	-	**3.6**	-	-	-	-
All categories	**3 628.1**	**3 400.3**	**1 790.1**	**8 818.5**	**0.56**	**0.53**	**0.28**	**1.37**

Table 5 Carbon stock in dead wood of different decomposition classes and dominant species in forests

Dominant species	Total carbon stock, 1000 tons				Average carbon stock, tons ha^{-1}			
	1	2	3	total	1	2	3	total
Aspen	318.4	399.2	124.6	**842.1**	1.31	1.64	0.51	**3.46**
Grey alder	328.2	472.0	98.7	**898.9**	0.95	1.37	0.29	**2.61**
Birch	1 007.1	991.9	358.7	**2 357.6**	1.04	1.03	0.37	**2.44**
Spruce	551.4	652.2	466.9	**1 670.5**	0.95	1.12	0.80	**2.87**
Black alder	147.6	223.2	101.8	**472.6**	0.93	1.41	0.64	**2.98**
Other species	136.1	97.7	32.2	**266.0**	1.22	0.88	0.29	**2.38**
Scots pine	1 106.6	541.2	579.2	**2 227.0**	1.21	0.59	0.63	**2.43**

The study approves that the most important parameter characterizing decomposition and carbon stock is density of dead wood, which can be determined using indirect measurement methods; hence, the uncertainty is high and alternative methods are necessary to approve the results. The elaborated stock change method should be applied in the national GHG inventory besides the gain and loss method considering certain period of decomposition of dead wood.

The study is done within the scope of the project (No. L-KC-11-0004) of the National Forest Competence Centre.

Keywords: *dead wood, carbon stock, biomass properties.*

LITERATURE REVIEW ON RESULTS OF APPLICATION OF SOIL CARBON MODEL YASSO IN FOREST, CROPLAND AND GRASSLAND

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The land use, land use change and forestry (LULUCF) sector is important in Latvia's greenhouse gas (GHG) balance because more than half of the country area is covered with forests and due to a long history of sustainable forest management. According to data provided by National statistical forest inventory (NFI) the total forest area in 2012 was 3 346 kha (52 % of total country area). The forest area in the annual GHG inventory is estimated using the NFI data; however, correction is applied to demonstrate impact of the land use changes since 1990. Twenty years transition period is considered for all land use changes.

The net emissions of aggregated GHG (CO_2, CH_4 and N_2O) in LULUCF sector in 2012 were – 12 301 Gg of CO_2 eq. The most important sink is carbon stock changes in living biomass. Aggregated net removals of the GHG reduced by 38 % in 2012 compared to 1990. Reduction of the CO_2 removals is associated with growth of the harvesting rate and increase of the age of forests. The recalculation in 2014 resulted in significant reduction of net removals of CO_2in living biomass, because of update of the harvesting rate and the natural mortality figures in forest on the base of the NFI data (Latvian Environment, Geology and Meteorology Centre, 2014).

GHG emissions from drained organic forest soil are accounted using factor 0.68 tons C ha^{-1} (Table 3.2.3 of the IPCC GPG LULUCF 2003) and 0.943 kg N_2O ha^{-1} annually. In drained mineral forest soils only N_2O emissions are accounted (factor 0.094 kg N_2O ha^{-1} annually, Penman, 2003). No CO_2 emissions are accounted from dry mineral soils, because the BioSoil data shows no losses of carbon in dry mineral soils between 2006 and 2012 (Lazdiņš *et al.*, 2012).

Emissions from organic soil in cropland are calculated using equation 3.3.5 of the IPCC guidelines. Factor of carbon stock change is estimated using the Equation 3.3.3 of the IPCC guidelines. Initial carbon stock in deforested areas was considered according to results of the BioSoil project – 124 tons C ha^{-1} at 0-30 cm depth. Factors for the carbon stock change calculations are taken from Table 3.3.4 – FLU 0.71 (Long-term cultivated, Temperate wet); FMG 1.00 (Full tillage, Temperate dry and wet); FI 1.00 (Medium input, Temperate dry and wet, Penman, 2003). The carbon stock in cropland after transition period is 88 tons C ha^{-1}; respectively net reduction of carbon stock in mineral soils is 36 tons ha^{-1} or 1.8 tons ha^{-1} annually. For organic soils in forest land converted to cropland the factor for cropland remaining cropland (3.7 tons C ha^{-1} annually) is applied (Latvian Environment, Geology and Meteorology Centre, 2014). The factor used to account carbon stock changes in drained organic soils in grassland is borrowed from the Swedish GHG inventory (1.6 tons C ha^{-1} annually). No carbon stock changes are accounted for grassland remaining grassland and for grassland converted to forest land. Removals of CO_2 are accounted for cropland converted to grassland using Equation 3.3.3 of the IPCC guidelines, factor for the carbon stock changes from Table 3.3.4 are used (Penman, 2003).

The need for modeling tool for estimation of carbon stock changes in soil in Latvia is identified long time ago. Previous consultations with institutions involved in the GHG inventories in other countries highlighted Yasso model, which can be applied, both, in agricultural and forest lands. However, drawbacks of the Yasso model are lack of ability to separate litter and soil layer and the model cannot be used on drained and naturally wet soils. The last issue is especially important, because about half of forest in Latvia is located on drained or naturally wet soils and, similarly, the most of agricultural lands are drained. Yasso model cannot be used directly to estimate non-CO_2 emissions; however, no other models either provides reasonable implementation of this function.

The most important benefit of Yasso model is use of productivity data instead of soil characteristics in calculations; respectively, in theory there is no need for soil map to calculate CO_2 emissions from soil. In practice, the information about organic soils is necessary to separate this source of emissions. Yasso is also the only open source application of this kind, which is tested in real world conditions.

The scope of the presented study was to evaluate possibilities to use dynamic soil carbon stock change models Yasso in the GHG accounting in Latvia in LULUCF sector. The evaluation was done on the base of the GHG inventory and literature review. Two versions of the model are used in practice: Yasso and Yasso07 (http://code.google.com/p/yasso07ui/). Yasso is the original version, which was used as a base for more updated version Yasso07. Yasso and Yasso07 are dynamic models of litter and soil carbon decomposition, which characterize cycle of decomposition of organic carbon in litter and soil layer, using morphomethrical and chemical parameters of litter and climate information as activity data. The output of Yasso model is total carbon stock in soil and distribution of soil carbon between different compounds (if the initial carbon stock in soil is set), carbon stock changes during the period split into the 5 categories of organic materials and release of carbon from soil (Liski *et al.*, 2005; Rantakari *et al.*, 2012).

According to the study results Yasso07 model can be used in Latvia to account carbon stock changes in soil in forest land, cropland and grassland; however the most beneficial is use of the model in cropland and grassland, where proportion of organic soils is small and the model can cover more than 90 % of these land use categories. Comprehensive study on elaboration and validation of the necessary calculation parameters should be implemented before broader use of the model, because earlier applications of Yasso on agricultural lands not always resulted with success.

Yasso can be applied also to dry and drained mineral soils in forest lands to estimate carbon stock changes in soil and dead biomass. However, there is urgent need to elaborate methodology for estimation of carbon stock changes and non-CO_2 emissions in drained and wet organic soils.

Implementation of modelling approach requires periodic field measurement information, which can be used for quality control purposes as well as to improve calculation parameters. Field measurement data can be obtained in permanent monitoring plots in forest land, grassland and cropland, which can be established on the base of existing monitoring systems.

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Keywords: *soil organic carbon, stock changes, Yasso.*

FORMATION OF LAMMAS GROWTH FOR NORWAY SPRUCE (*PICEA ABIES* (L.) KARST.)

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Trees are adapting and will have to adapt to the rapid climatic changes, including rise of temperature in increase of length of vegetation period. It might lead to shifts in phonological processes and increasing frequency of weather-related damages. It might also lead to increasingly frequent formation of lammas growth – additional height increment in second half of vegetation period. Lammas growth can lead to such negative consequences as higher number of branches per whorl and/or or per meter of tree stem, occurrence of spike knots and frost damages. Therefore aim of the study was assess proportion of trees with lammas growth and factors affecting it. Study was carried out in an open-pollinated progeny trials of Norway spruce plus trees, located in central part of Latvia (56°46`N, 24°48`E) on abandoned agricultural land in different soil conditions and elevation, but separated by distance of only approximately half kilometer. Average proportion of trees with lammas shoots in trials were from 1.2% to 15.2 % at the age of 10 years and from 13.1% to 29% at the age of 11 years. Differences between years were statistically significant, indicating impact of meteorological conditions, possibly the notably higher temperatures (on average by 3°C) during all August. As the temperatures are predicted to rise in future, higher frequency of trees with lammas shoots could be expected. Statistically significant difference between trials suggest, that also soil plays an important role in determination of proportion of trees with lammas shoots (soil differences being represented in notably different tree growth – mean height at the age of 10 years ranging from 190cm in trial 2 and 290cm in trial 3). It is suggested, that due to warmer climate also mineralization rate will increase, improving soil fertility. Our results suggest, that it will further contribute to increased frequency of lammas shoots.

Higher trees with longer height increments have also significantly higher frequency of lammas shoots. For those trees it is also more likely to have lammas growth several years in a row, indicating that quality of the best growing trees is at risk. At family mean level, however, correlation between height increment and proportion of trees with lammas shoots in the same year was $r=0.41$ ($p<0.01$). Notable variation in proportion of trees with lammas shoots was found among families (ranging from 0...42%) and genetic correlation for this trait among years was statistically significant ($r=0.39$, $p=0.01$). These results indicate, that selection of fast growing genotypes with low frequency of lammas shoots is possible, but rather high selection intensity might be required. Results suggest, that in conditions more favorable for formation of lammas shoots (as in trial 3) more families are affected not only the same families just with higher proportion of trees. That indicates, that for selection of least affected families trials shall be established on fertile soil and evaluation done in year with warm autumn. Family mean correlation among fields varies and average ($r=0.4$) in cases, where average proportion of trees with lammas shoots (and affected families) is similar.

Support for the initial study was provided by ESF project «Importance of Genetic Factors in Formation of Forest Stands with High Adaptability and Qualitative Wood Properties» (No. 2009/0200/1DP/1.1.1.2.0/09/APIA/VIAA/146), last year measurements and analysis was carried out in frames of Forest Competence Centre (ERAF) project «Methods and technologies for increasing forest capital value» (No. L-KC-11-0004).

DISTANCE BETWEEN STRIP ROADS AND DAMAGES OF REMAINING TREES IN DECIDUOUS STANDS THINNED WITH ROTTNE H8 AND JOHN DEERE 1070 HARVESTERS

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The aim of thinning, regardless of type, is to improve composition of the tree species and to maximize the value of the stand before final felling, while ensuring the implementation of the rest of forest ecosystem services. Nowadays thinning in Latvia mainly is performed by chainsaws, but heavy forest machines appear to replace manual operations. However, it doesn't mean that all of the available logging equipment is acceptable for thinning. The main priority of thinning is to secure improved growth of stand and production of wood, so the thinning must be done careful and mechanical damages to remaining trees and soil would be avoided. The assessment of applied techniques and work methods is necessary before broad implementation of mechanized early thinnings. The aim of the study is to determine, what is the impact of the distance between the strip-roads to remaining stand in terms of mechanical damages, using small and middle-class harvester (Rottne H8 and John Deere 1070D) with a different crane length, which are suitable for different distances between strip-roads (Table 1).

Table 1. Distance between stip-roads

Harvester and forwarder	Max. reach with harvester head, m	Distance between strip-roads, m
John Deere 1070 D harvester and John Deere 810 E forwarder	10	16; 18; 20
Rottne H8 harvester and Rottne F10B forwarder	7	15; 20; 30

Working with a small harvester and distance between strip-roads 20 m the machine made one extra road (further in the text "ghost-trial"), with 30 m distance between strip-roads the machine made 2 ghost-trials. Ghost-trials are not used for log transportation. At a 20 m distance between the strip-roads, ghost-trail is made and timber is put on the both sides at the edge of strip-roads but if the distance between strip-roads is 30 m, then two ghost-trails are made and the timber placed only on one side of each ghost trail, at the edge of strip-road. When working with John Deere 1070 D harvester, ghost-trials were not used, although there were difficulties to thin about 4 m wide zone located 8-10 m away from centre of strip-road, if the distance between strip roads was 20 m.

The study focuses on conditions in stand after thinning, assessing mechanical damages of remaining trees. Thinning trials were performed in September – October, 2013. Empirical data were collected in 9 forest stands (dominant tree specie birch, number of trees per hectare before thinning 3-5 thousands, average tree diameter 7-10 cm, average tree height 10-16 m). Total area of the stands is 14.3 ha, including 9.1 ha thinned with John Deere 1070D and 5.2 ha – with Rottne H8. Undergrowth was left before thinning in all plots. The stands are located in Skrīveri region (Lat: 56.713834, Lon: 25.062916).

Before the trials centres of strip-roads in all stands were marked with colour. After thinning (separately after harvesting and forwarding) damages of remaining trees were accounted and divided in four groups: (1) damage above 0.5 m; (2) damage below 0.5 m; (3) root damage and (4) the cuts. Remaining stand and damages were measured in rectangular plots (length 20 m, width 15-30 m, depending from distance between strip-roads), including strip-road and both sides of thinned stand. Sample plots were placed on every strip-road, distance between borders of the plots

40 m. In the sample plots each tree with diameter above 4 cm was measured, including DBH, distance from tree to a centre of strip-road, tree species and damages (origin and type). According to study results considerably more damages was caused by middle-class harvester John Deere 1070D, if the distance between strip-roads is 16 and 20 m (Figure 1), where, respectively, the proportion of damaged trees is 10 and 12 %, while proportion of trees damaged during forwarding is relatively small. The smallest proportion of damaged trees was found, if the John Deere 1070D harvester worked at 18 m distance between strip roads. Operations with Rottne H8 harvester resulted in the smallest proportion of damage, if the distance between the strip-roads is 15 m, but increase of distance between strip-roads to 30 m raised proportion of damaged trees almost 2 times. Notably, that proportion of damaged trees increased considerably, if distance between strip-roads was 15 m.

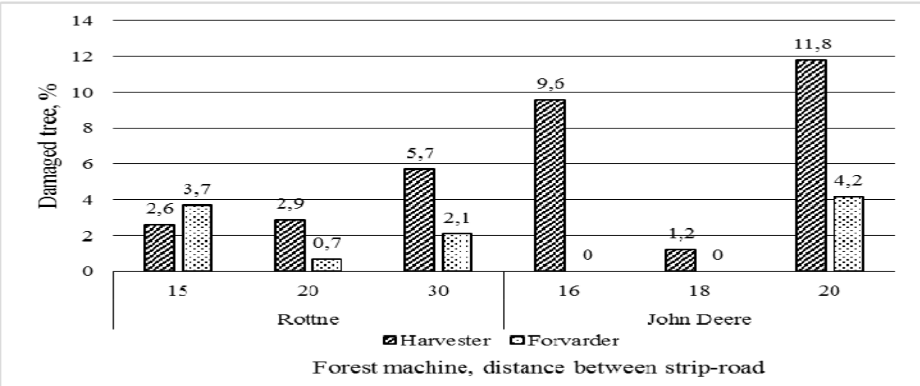

Figure 1. Proportion of damaged trees depending from harvester type and distance between strip-roads.

If small Rottne H8 harvester is used in thinning, the proportion of damaged trees is less than 5%, except for 30 m distance between strip-roads, where the proportion of damaged trees is approaching to 6 %.The study demonstrates, that regardless of the harvester type, if the distance between strip-roads is equal to the maximum reach length (15 m for Rottne and 20 m for John Deere), the total proportion of damaged tree is the highest.

The optimum distance between strip-roads for Rottne H8 according to the study results is 20 m with one ghost-trail between and for John Deere 1070 – 18 m, without ghost-trails. The results presented in this abstract are based on currently available data. Other factors influencing tree and soil damage during thinning will be analysed in further studies and recommendations for reducing the damages will be developed.

The study is done within the scope of the National forest competence centre project No L-KC-11-0004.

Keywords: *thinning, tree damages, striproads.*

IMPACT OF FOREST MACHINERY ON SOIL COMPACTION AND FOREST REGENERATION IN CONIFEROUS STANDS

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Forest regeneration on forest logging trails can be obstructed by the impact of, both, branch layer and soil compaction. It has been proved in Germany that stand productivity in long term decreases as a result of soil compaction (Gameda, Raghavan, McKyes et al. 1987). Soil compaction, which takes place during final felling, is correlating with the use of forest machinery. The level of soil compaction indicates the ability of plant roots penetrate through soil layers. The maximum soil penetration resistance, which can be considered as acceptable for optimal root development, is one 1 MPa, which corresponds to strength, with which growing roots force on soil particles. Significant disturbance in growth of roots are observed, if the soil penetration resistance is higher than 3 MPa (Bakker, 1990; Mullins, 1990).

The sample plots were set up in JSC Latvia State Forests (LSF) Zemgale and Vidusdaugava forestries, where clear-cuts were performed from 1997 to 2006. The felling was done either mechanically or manually (using chain saws), but the off-road transport of timber was done with forwarders. The logging season for each plot is known. The sample plots are rectangular-shaped and comprised of a logging trail and the adjacent forest stand. Measurements of the penetration resistance were done during July and August, 2013 to estimate, if there is significant difference of soil penetration resistance at the depth of 0-80 cm between the former skid-trials and untouched part of the stand. Measurements were done on logging trails and on control plots with the Eijkelkamp digital penetrologer. The soil penetration resistance describes soil compaction. Number of trees of economically important tree species was counted and their height was measured to determine the species composition, to calculate the average tree height and to determine the number of trees per unit of area on a strip roads and other part of the stand.

By evaluating the soil profile to the depth down to 25 cm, soil compaction on logging trails and soil control sample plots differs significant in stands, which are located on organic and drained soils; however, significant differences were not found on top soil down to 25 cm where the majority of tree roots are located. Significant difference in soil compaction can be observed only in the deepest soil layers of forests on naturally dry mineral soils. Permanent compaction in the deeper layers can be connected with a regular soil freeze-through down to approximately 50 cm depth. Compaction of the deepest soil layers is not influencing vitality of trees, however, it can have influence on hydrological regime of area, reduce tree resistance to wind, as well as inhibit the access to water and nutrient reserves in deeper soil layers. The study shows that compaction is not influenced by the choice of forest machinery, but it can be influenced by felling season.

When analysing the obtained data about forest regeneration, it has been concluded that in majority tree dimensions do not significantly differ between control and logging trails. Pine and spruce reach equally good height indicators, both on logging trails and control. Birch even grows better on forest logging trails in compare to control. Birch is the most widespread specie, both, in control areas and on the logging trails. Pine and spruce is following by the number of trees. There is no significant difference in species composition between the logging trails and control areas. The number of trees is significantly smaller on logging trails comparing with the rest of stand, but it is sufficient to ensure the minimum number of trees defined in forest regeneration regulations. It is most likely that the number of trees on forest logging trails is influenced by forest residues, which detains seeds from getting to soil. Soil compaction does not influence the growth of young trees at the moment.

However it does not exclude possibility that the negative impact of soil compaction can increase during the further stand development.

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Keywords: *soil penetration resistance, compaction, harvesting.*

SOIL COMPACTION USING TRACKED AND WHEELED FOREST MACHINES IN EARLY THINNING

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In order to increase efficiency and to secure deliveries of solid biofuel from forest it is necessary to start to use forest machinery in early thinning. However, such practice may affect the growth of forest adversely. The use of forest machinery in early thinning can lead to soil compaction and formation of ruts. Soil compaction may affect the water regime in soil, reduce stand resistance against wind, as well as restrict access to the existing water and nutrient reserves in deeper soil layers. Ruts left after forest machines can speed up distribution of root rot considerably. The aim of the study is to evaluate impact of different combinations of wheeled and tracked machines on soil penetration resistance and rut formation during harvesting and forwarding operations. In central part of Latvia nearby Skrīveri 7 deciduous stands representing fertile *Aegopodiosa* and *Dryopteriosa* site types were selected for the study. Soil penetration resistance was measured with Eijkelkamp penetrologger down to 80 cm depth or 3.5 MPa level (maximum limit for manual operation) in November 2013. The harvesting trials were done in August and September, 2013. Wheeled harvesters – John Deere 1070E and Rottne H8 and tracked harvester – Timbear where used in harvesting trials. Wheeled tractors – Rottne F10B and John Deere 810E and tracked machine – Timbear, were used as forwarders. Four different combinations of machines and working methods were compared: (1) John Deere 1070E harvester with Bracke C.16b felling head (full tree harvesting, no residues in corridors) and Timbear as forwarder (JD-T); (2) Timbear as harvester (residues in corridors) and as forwarder (T-T); (3) Rottne H8 (residues in corridors) in harvesting and Rottne F10B in forwarding (R-R); (4) John Deere 1070E harvester with Bracke C.16b felling head (no residues in corridors) and John Deere 810E forwarder (JD-JD).

The results show significant differences between corridors and remaining stand in all 4 combinations. But the depth of impact differs between combinations and harvesting methods (full tree or delimbed assortments). We found significant impact ($p < 0.05$) down to 25 cm with T-T, down to 35 cm with JD-T and down to the whole depth (80 cm) with JD-JD and R-R. The most intensive soil compaction was found in areas, where the combination JD-JD was applied, with relative difference of soil penetration resistance by 129% higher in corridors in compare to control spots indown to a 27 cm depth. With R-R the penetration resistance in corridors was up to 95 % higher in compare to control spots down to 15 cm depth, with T-T – up to 92 % down to 4 cm depth and with JD-T – up to 76 % down to 7 cm depth. Both combinations of wheeled harvesters and wheeled forwarders (JD-JD, R-R) resulted in rut formation in 46 % of total length of all corridors and only 2 % of ruts, if the tracked Timbear machine was used in forwarding (JD-T, T-T).

The study results demonstrate that forest machines can compact forest soil significantly and compaction takes place not only in upper soil layers, but also down to 80 cm depth, if wheeled machines are used, and there is significant difference between different types of machines and working methods. As it has been demonstrated in similar studies in Nordic countries the hydraulic conductivity in compacted forest soil decreases by up to 86 %, which might result in much more dramatical changes in young stands than in mature stands. Soil penetration resistance data obtained in forest stands (*Hylocomiosa* and *Myrtillosa*), where forestry activities carried out during the period from 2009 to 2011, shows that soil penetration resistance in corridors and remaining stand is still significantly different. The negative impact can be reduced by broader utilization of tracked forwarders and by use of forest residues in corridors. Although the penetration resistance significantly increased in corridors, it did not exceed critical level (3 MPa) for plants root formation in upper 40 cm soil layer.

The study is done within the scope of the National forest competence center project “Methods and technologies to increase forest value” (L-KC-11-0004).

Keywords: *soil penetration resistance, compaction, thinning, harvesting, forwarding.*

EVALUATION OF CHEMICAL AND PHYSICAL PROPERTIES OF WOOD ASH IN LATVIA

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Utilization of wood ash is growing issue in Latvia and the whole Europe, because increases use of biomass in energy production. Thanks to its low cost and favorable chemical composition wood ash can be more used as soil amendment. As a fertilizer ash has many advantages. Ash fertilization reduces soil acidity, which induces reduction of leaching toxic Al compounds. Ash significantly increase the effective cation exchange capacity and mineral saturation in soil overall. It has been shown that fertilization positively affects the increment of trees. But wood ash also contains elements that might pose environmental problems – heavy metals.

Physical and chemical properties of wood ash depends on many factors, for example, combustion systems and temperature, type of fuel (bark, leaves, hardwood or softwood) etc. These factors also affect content and distribution of heavy metals, which could limit ash application.

Samples of wood ash from 40 different companies were analyzed. Ash were sieved and divided into three fractions – fine, average and coarse. For each fraction composition of chemical elements, pH, moisture and density was determined.

Acidity of wood ash varied from pH 9.5 to pH 13.6. Mean density was 967 kg m^{-3}.

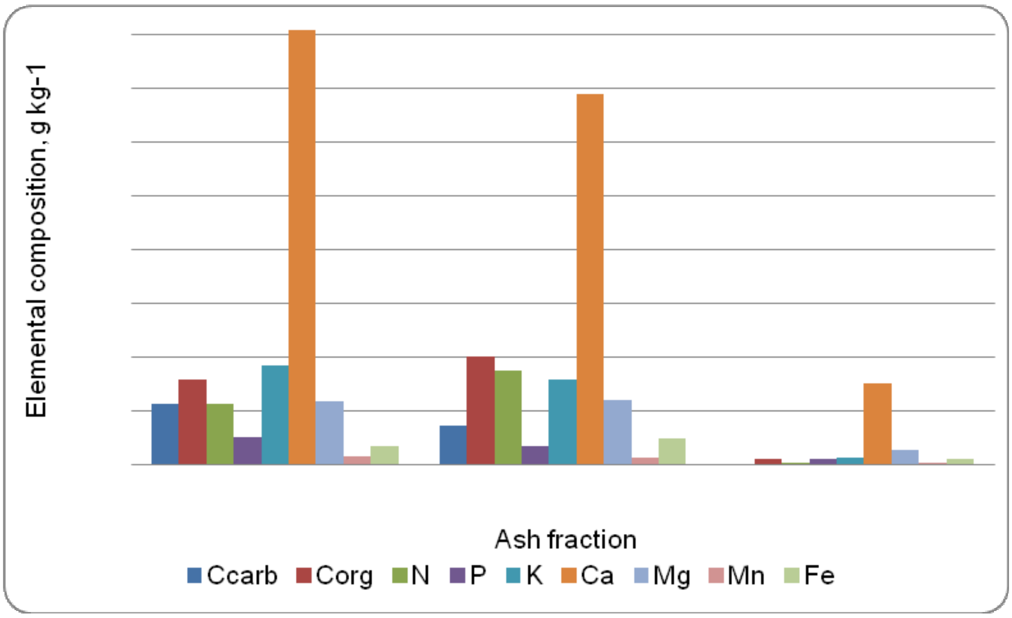

Figure 1 Major elemental composition in different ash fractions.

Coarse fraction has low content of the nutritional elements (Figure 1), which means that it consists mostly of SiO_2. It suggests to sieve ash before application to increase fertilization efficiency and reduce transport costs. Fine ash fraction has more elements required by plants such as calcium, potassium and phosphorus.

Wood ash mostly consists of fine particles (Figure 2). Higher share of coarse fraction (particles larger than 45 mm) is characteristic for wood ash from combustion systems with a capacity higher than 10 MW because of uneven combustion.

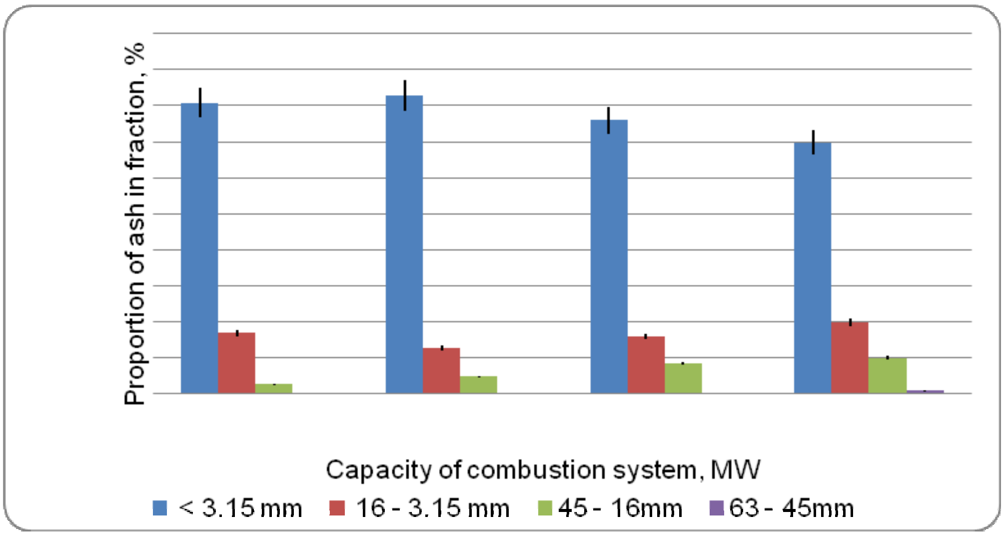

Figure 2 Ash fractions depending on capacity of combustion system.

Higher mineral content, but not significantly, was found in fine ash fraction (Table 1). Only for phosphorus (P) content significant difference between fine and average ash fraction was found in the study.

Table1 Chemical composition of wood ash

Capacity, MW	Fraction	Main elements, g kg^{-1}							
		C_{org}	C_{carb}	P	N	K	Ca	Mg	Mn
<1	Fine	21.29 ± 6.48	31.09 ± 8.35	10.75 ± 2.67	1.3 ± 0.61	46.34 ± 10.88	155.95 ± 25.67	28.11 ± 8.16	3.81 ± 0.93
	Average	94.9 ± 36.8	20.71 ± 6.87	6.64 ± 1.58	1.72 ± 0.58	42.5 ± 11.96	138.78 ± 24.12	27.63 ± 11.34	3.04 ± 0.86
1 - 5	Fine	46.01 ± 23.4	27.01 ± 4.25	11.61 ± 1.08	0.28 ± 0.07	46.22 ± 3.96	190.21 ± 13.96	26.69 ± 2.24	3.7 ± 0.37
	Average	33.73 ± 10.67	14.01 ± 3.3	8.12 ± 0.89	0.48 ± 0.14	41.51 ± 4.28	163.32 ± 13.12	26.56 ± 2.79	2.85 ± 0.38
5 - 10	Fine	28.84 ± 9.95	23.63 ± 3.56	12.8 ± 1.37	0.46 ± 0.1	41.64 ± 8.02	200.67 ± 19.65	25.14 ± 1.98	3.72 ± 1.1
	Average	113.58 ± 91.49	24.21 ± 12.8	8.85 ± 0.52	1.64 ± 0.79	31.96 ± 5.29	146.7 ± 27.47	22.85 ± 5.3	3.01 ± 1.17
>10	Fine	28.84 ± 9.95	23.63 ± 3.56	12.8 ± 1.37	0.46 ± 0.1	41.64 ± 8.02	200.67 ± 19.65	25.14 ± 1.98	3.72 ± 1.1
	Average	113.58 ± 91.49	24.21 ± 12.8	8.85 ± 0.52	1.64 ± 0.79	31.96 ± 5.29	146.7 ± 27.47	22.85 ± 5.3	3.01 ± 1.17

No correlation between the content of heavy metals in fine and average ash fractions and capacity of combustion system were found, except of chromium (Cr). Concentration of Cr is higher in average fraction of ash in combustion systems with higher capacity.

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Keywords: *wood ash, chemical properties, physical properties.*

CASE STUDY OF SOIL CARBON STOCK CHANGES IN DRAINED AND AFFORESTED TRANSITIONAL BOG

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Vesetnieki research station was established in 1963. The total area of the research station is 370 ha, including 31 % of forests on drained organic soil, which are located on a right bank of Veseta river in transitional bog. Forest drainage was done in 1960 (Zālītis, 2008). Initial depth of peat in transitional bog was 4.5 m. It consisted mostly of sedge peat (75-80 %) and woody peat (20-25 %). Down at 1.5-2 m depth reed peat was found. The sphagnum layer characteristic for transitional bog disappeared within 15 years. The decomposition rate of peat at 10 cm depth in 2008 was 55 %, in deeper layers – 33 % (Zālītis, 2008). Forest stands on drained organic soils correspond to fertile stand types. An important part of measurements in the Vesetnieki research station was regular leveling out of the ground surface. Repeated measurements were done in 1966, 1970, 1975, 1977 and 1982. A part of the transitional bog was left untouched, providing opportunity to compare 2 scenarios of carbon stock change – natural and drained land.

The national greenhouse gas (GHG) inventory uses default emission factor for all drained organic soils – 0.68 tons C ha^{-1} annually (Latvian Environment, Geology and Meteorology Centre, 2014). Total GHG emissions from drained organic soil in forest land according to the GHG inventory in 2012 was 1 069 Gg CO_2 and 124 Gg of CO_2 eq. of N_2O emissions. Organic soils in forest are one of the key sources of emissions in land use land use change and forestry (LULUCF) sector.

The scope of the study is to compare carbon stock changes in soil and other carbon pools after drainage of the transitional bog. The obtained data are supposed to be used in elaboration of the country specific factors of carbon stock changes in drained organic soil. Possible accumulation of carbon in peat in the untouched part of the transitional bog was ignored due to the fact, that visible height difference between land surface and tops of groundwater sampling wells was not found. Multiple data were collected in 30 sample plots, including stand characteristics, surface leveling, bulk density of soil and litter, carbon content in soil, litter and woody debris.

The surface leveling results demonstrated reduction of ground level by 25.7 cm during 51 year after drainage (Table 1), more significant reduction was found in spruce stands.

Table 6 Reduction of ground level after certain period of time (cm)

Dominant species	7	12	14	19	51
Norway spruce	11.8	11.5	15.9	13.9	28.6
Scots pine	-	13.7	15.6	6.8	21.4
Average	**11.8**	**12.0**	**15.8**	**11.8**	**25.7**

Carbon stock in living biomass in drained areas 51 year after drainage is 6 times higher than in transitional bog (Table 2). Carbon stock in dead wood and litter in drained plots is 34 times higher than in transitional bog. Peat in drained plots in layers located above groundwater level is considerably more compacted than in natural bog and contains more carbon (Table 4).

Table 7 Carbon stock in different fraction of living biomass, tons ha^{-1}

Growth conditions	Dominant species	Stem	Green branches	Dry branches	Coarse roots	Small roots	Stump	Total
Drained forest	Norway spruce	49.0	20.2	1.3	13.8	14.0	2.9	**101.3**
	Scots pine	60.3	10.2	1.5	8.9	9.0	1.9	**91.8**
	Average	**53.5**	**16.2**	**1.4**	**11.9**	**12.0**	**2.5**	**97.5**
Transitional bog	Norway spruce	3.8	8.5	0.1	1.5	1.5	1.0	**16.4**
	Scots pine	7.2	5.2	0.5	1.3	1.4	0.8	**16.4**
	Average	**6.1**	**6.3**	**0.4**	**1.4**	**1.4**	**0.9**	**16.4**

Table 8 Carbon stock in dead wood and litter, tons ha^{-1}

Growth conditions	Dominant species	Litter	Coarse debris	Fine debris	Total
Drained forest	Norway spruce	4.5	4.8	1.6	10.9
	Scots pine	6.1	1.8	1.4	9.3
	Average	**5.1**	**3.6**	**1.5**	**10.2**
Transitional bog	Norway spruce	0.0	0.0	0.6	0.6
	Scots pine	0.0	0.0	0.2	0.2
	Average	**0.0**	**0.0**	**0.3**	**0.3**

Table 9 Carbon stock in soil at 0-80 cm depth, tons ha^{-1}

Growth conditions	Dominant species	0-10 cm	10-20 cm	20-40 cm	40-80 cm	Total
Drained forest	Norway spruce	80.4	70.4	133.0	248.9	**537.0**
	Scots pine	65.5	63.1	116.9	226.0	**477.5**
	Average	**74.4**	**67.5**	**126.6**	**239.7**	**513.2**
Transitional bog	Norway spruce	35.3	31.7	61.0	174.6	**302.6**
	Scots pine	39.3	38.3	83.5	196.6	**357.6**
	Average	**38.0**	**36.1**	**76.0**	**189.3**	**339.3**

Carbon stock in soil increased significantly after drainage, even if upper 25.7 cm layer is considered to have zero carbon. The study results shows, that upper peat layers (down to 60 cm) are not decomposed, but compacted, when groundwater went down, and enriched with organic materials from forest floor. Total increase of carbon stock in the study area is 106 tons ha^{-1} (corresponding to removals of 7.6 tons CO_2 ha^{-1} annually). No significant difference was found in spruce and pine stands (Table 5).

Table 10 Corrected carbon stock changes in different carbon pools after drainage, tons ha^{-1}

Dominant species	Living biomass	Dead wood	Litter	Soil	Total
Norway spruce	84.9	6.0	4.5	15.6	**110.9**
Scots pine	75.4	2.8	6.1	11.5	**95.7**
Average	**81.1**	**4.7**	**5.1**	**15.0**	**105.8**

The study demonstrates considerable overestimation of CO_2 emissions due to drainage of organic forest soil in Latvia (0.97 tons C ha^{-1} or 1 524 Gg CO_2 annually, if obtained results are applied to all drained organic soils). However, the study also highlights need to extend the study to obtain more comprehensive results representing different stand types and initial conditions.

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Keywords: soil organic carbon, drainage, stock change.