ARTICLES

The Productivity of Drained Pine Forests and Pinewood Quality

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Forest hydrotechnical amelioration as a measure to limit environmental degradation and increase forest productivity plays an important role in forest management in Latvia already for 150 years. The phenomenon of an abrupt increase in the annual growth after drainage, coupled with variations in the structure and mechanical properties of stemwood, is considered. The experimental data are collected from 115 stems of pine over a period of 4 years by analysing, by using the microscope, the annual growth layer formation during the growing season in undrained and drained stands. The quality indices of wood, depending on the hydrotechnical amelioration and the admixture of spruce and birch, are evaluated for 83 mature stands of pine. A close correlation of wood strength with the average height of the stand is pointed out.

Key words: forest productivity, forest hydrotechnical amelioration, stem quality, wood strength.

Historical background

Land paludification, involving a loss of the energy accumulated in an ecosystem and, consequently, environmental degradation, is an on-going process on the territory of Latvia over the whole post-glacial era, including the present period.

The early 19th c. was noted for a buoyant demand for wood on the international market, resulting in growing volumes of export and soaring prices for timber. Thus, economic preconditions were created for increasing the forest productivity by means of the hydrotechnical amelioration of forest lands. Though small-scale, but purpose-oriented forest hydrotechnical amelioration or drainage was started in Latvia in 1830 in the vicinity of Cēsis (Sivers, 1903), in Valmiera (1835), Valka, Kuldīga, Aizpute, Talsi and Ventspils (1840). The first forest drainage efforts in Estonia and in the St.Petersburg area (Russia) refer to the same period (Zālītis, Lazdiņš, 1990).

Latvia's earliest large-scale forest drainage projects carried out in the Riga municipal forests under the leadership of H.Fritsche, a professional forester, date from the period between 1847 and 1882. It amazed H.Fritsche (by Odiņš, 1971) that due to intensive paludification a lush forest could, within the man's lifetime, become a marshland of stunted trees. That is why he took the initiative to organize digging a forest ditch 11 km long.

A forest ditch of the total length 74 km, draining 13,200 ha of waterlogged forest lands and bogs, was laid out in 1866. Also E.Ostwald, a prominent scientist of that period, found the drainage effect surprising. It encouraged him to start investigating the impact of drainage on the stand performance, resulting in the first scientific publications on these problems (Ostwald, 1878).

During the first period of Latvia's independence a systematic drainage of forest lands was started in 1929 after the extremely rainy summer of 1928, when all the lowlands were inundated, causing forest dieback and pest outbursts. In the decade to follow 15,000 ha of waterlogged forest lands were drained annually by way of ditches, dug manually.

R. Markus was a direct follower of the research started by E.Ostwald. He analyzed (Markus, 1936) the variations in tree growth at different distances from the drainage ditch (440 sample stems on 77 sites). The research conducted by R. Markus convincingly proves the economic usefulness of forest drainage under the environmental conditions prevailing in Latvia.

By analysing the performance of the predominant trees, used as indicators (Kraft class 1), he suggested the following distances between ditches: in grass fens with sedge peat - ca 400 m; in transitional bogs with woody peat - 200 m; in moss fens with sphagnum peat - 70 to 120 m. As it turned out later, the response to drainage of other trees of the dominant stand, accounting for the bulk of stock volume, is so prompt that the distance between ditches had to be reduced, depending on the forest site type (Bušs, 1957, 1959, 1960, 1962 - in Russian). The principal argument advanced was that the site class index, should vary within the limits of one site class, so as to have the same forest type on the whole inter-ditch area.

When designing drainage systems, no strictly predetermined ditch spacing is possible due to the diversity of forest sites to be drained. Paludification causes, terrain inclination, soil permeability factor and the lay-out of forest compartments taken into account, the recommended distances between the ditches 1.0 to 1.2 m deep on the sites under pine are those shown in Table 1 (Bušs, 1968; Zālītis, 1968, 1983 - in Russian). These recommendations made the basis for the Methodological Guidelines for Designing Forest Drainage Systems (1986), and abiding by them normally resulted in a highly productive pine stand on the site drained.

Rough estimates show forest hydrotechnical amelioration to result in an increase in the current increment: for pine - 3 fold, for spruce - 4, but for birch 2- fold only.

Sites investigated and the quality of pine stands

A thorough analysis of the impact of stand characteristics (forest type, site type class) on the technical properties of Latvian pinewood was conducted by A. Kalniņš in one of his pre-war monographs (Kalniņš, 1930.).

During the whole post-war period it became a standard practice to describe forest productivity in terms of quantitative indices only: m^3/ha, m^3/ha/yr. In market economy, the forest valuation in terms of stemwood quality, and the assortment yield in particular, is, informatively, equally important.

The proportion (%) of the first-grade saw logs (a branchless bottom log l > 3 m long, top diameter u.b. d > 26 cm) in the stock volume of a pine stand is chosen as an index describing pine stand quality. An evaluation, due collaborating to E. Špalte, *Dr. silv.*, of 83 mature pine stands on undrained wetlands as well as drained sites, found in North Vidzeme (North East) and North Kurzeme (North West of Latvia), is done. A comparison of variations in the stock volume and stem quality in the forests on peaty soil after drainage is made for two forest site types - Nd *Caricoso-phragmitosa* and the drained Nd or Ks *Myrtillosa turf. mel*; stock volume: Nd - 188 m^3/ha, Ks - 310 m^3/ha; the volume of the first-grade saw logs: Nd - 32 m^3/ha, Ks 60 m^3/ha; proportion of first -grade saw logs in the total stock volume: Nd - 17%, Ks - 19%; proportion of the first-grade saw logs in the stock volume of pine: Nd-27%, Ks - 30%.

For forests on hydromorphic mineral soils, a similar comparison is made between the stand data for Mrs *Vaccinioso-sphagnosa* and Am *Vacciniosa mel.* forest sites, stock volume: Mrs - 235 m^3/ha, Am - 285 m^3/ha; volume of the first -grade saw logs of pine: Mrs - 58 m^3/ha, Am - 68 m^3/ha; proportion of the first-grade saw logs in the total stock volume: Mrs - 25%, Am - 24%; proportion of the first-grade sawlogs in the stock volume of pine: Mrs - 28%, Am - 34%.

The above data show an increase in forest productivity due to drainage to go with better stemwood quality for pine, while the volume of top quality sawlogs (m^3/ha) is higher in more fertile forest site types. This is confirmed also by the statistically significant correlation coefficient (r= -0.52) between the volume of the first-grade saw logs and the site class index for the pine stand.

Forest management and the stemwood quality for pine

In the context of stemwood quality, two regularities, encountered in Latvia's wetland forests, deserve mention. One is the presence of birch in conifer stands. In waterlogged undrained forests, birch often acts as a "rescue" species for the forest ecosystem. Birch, actively transpiring water, creates a favourable ambience also for conifers, thus averting the transformation of forest into a bog. The impact of drainage on the growth of birch is less than that on conifers, yet in drained forests the admixture of birch impedes achieving a higher overall stock volume (m^3/ha).

Another regularity is the intensive encroachment of spruce on the drained pine forests, which is illustrative of both a higher ecological capacity of the former wetland, now less filled in, and the drained forest, becoming more eutrophic over time.

In drained forests of pine the two regularities show up as a constant component of birch and an increasing component of spruce. Obviously, the share of the tree species admixed will be higher in more fertile forest types, i.e. in forests having a higher site type index. For instance, in the stands of site type class V the admixture is no higher than 20% of the total stock volume, while for higher site type classes the same index may reach 60%. In the mature stands the site type class and the tree species admixed bear a significant correlation (r=-0.46; $r_{0.05}$ = 0.28) (Fig.1).

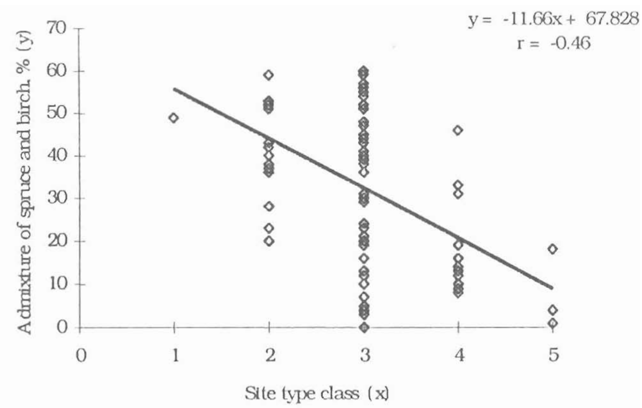

Figure 1. Interdependence between the site type class and species admixed in drained wetland forests of pine.

Opinions differ as to the impact of deciduous and spruce on the pine stemwood quality. The very differences in opinions point to the fact that this impact is not unambiguous, and within a single forest site no prediction of the variations in pinewood quality, depending on the availability or removal of the admixed species, is possible. Selective averaged data on pinewood quality show higher values, depending on both a higher site class index and a higher proportion of admixed species. The impact of the two factors on pinewood quality is 27%, where 20% account for the site class index, 7% - for the admixture. It implies that in drained forests of the cutting age each 10% of the admixture reduces the stock volume of pine by 19 m³/ha and increases the pinewood quality by 0.2%. For example, in drained pure stands of pine the average stock volume is 253 m³/ha (Fig. 2) with 22% or 56 m³/ha (Fig. 3) representing the first-grade sawlogs. In drained pine forests with the admixture of other species 40%, the stock volume of pine is 178 m³/ha with 34% or 60 m³/ha standing for the first-grade sawlogs. Statistical evaluation of the data show a higher site class index (higher fertility) to account for ca 1.3 m³/ha increase in the volume of the first-grade sawlogs, while the differences with regard to admixed species account for 0.5 m³/ha only, which is fully within the calculation error.

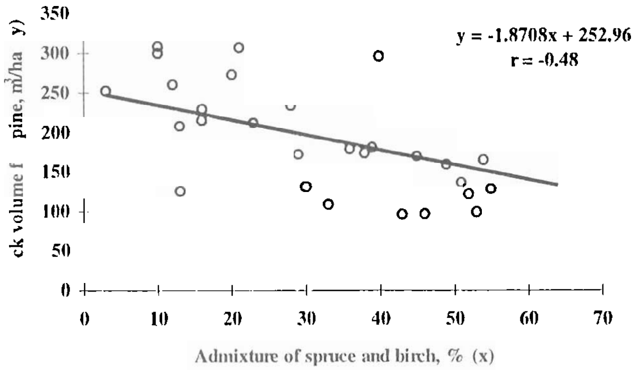

Figure 2. Stock volume of pine in drained forests depending on the admixture of other species.

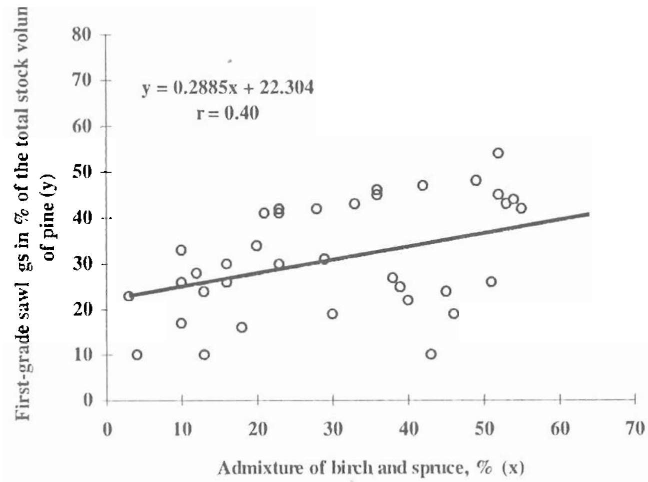

Figure 3. Pine quality on the drained forest sites depending on the admixture of other species.

Striving for a higher site class index and increased average diameter just by means of hydrotechnical amelioration will have a real positive effect on the quality of wetland forests of pine at the national level and that of regional forest districts (but not on the level of individual sites). The average diameter, closely correlating with the stand quality index (r=+0.82), i.e. the percent of top quality sawlogs, is a useful indicator for describing the success of hydrotechnical amelioration. For instance, an increase in the average diameter from 24 to 34 cm results in an increase in the proportion of the first-grade sawlogs from 21 to 46%.

Hydrotechnical amelioration and mechanical properties of wood

The indices describing the strength of wood positively correlate with the percent of latewood in the annual growth. It is relatively easy to determine this index by using Pressler's borer.

To better illustrate the hydrotechnical amelioration/ forest productivity interdepen-dence, it is deemed necessary to recall some of the conclusions made between 1962 and 1965, when investigating the course of pine growth over the vegetation season. A total of 18,370 samples of wood from 115 trees were collected using Pressler's borer.

The samples were collected within an interval of 10 days between May 15 and Sept. 25 in the forest stands intensively drained 25 years ago and also in those inadequately drained. The following indices were determined by using the microscope: the onset of wood formation, width of the new annual growth ring, number of tracheid rows in the growth ring, tracheid diameter in the radial direction, the onset and termination of the formation of latewood. The results allow us to objectively oppose the assumption that wider annual growth rings, resulting from the drainage, significantly affect the wood strength due to a lower proportion of latewood.

In spring, the diameter growth (on the sites studied, approximately on May 20) starts with an equal intensity at both 50 m (intensively drained part of the site) and at 100-150 m away from the ditch (inadequately drained part of the site) (Fig.4.). Approximately for a period of 3 weeks (on the average until June 10) the intensity of wood growth (mm^2/day) is the same for the two distances to the ditch. However, by the second half of June the intensity of wood growth in the less intensively drained part of the stand slows down, and by the moment the growth of wood is at its peak, reaching 11 mm^2/day around June 27, it starts falling behind. About 10 days later the growth of early wood is still

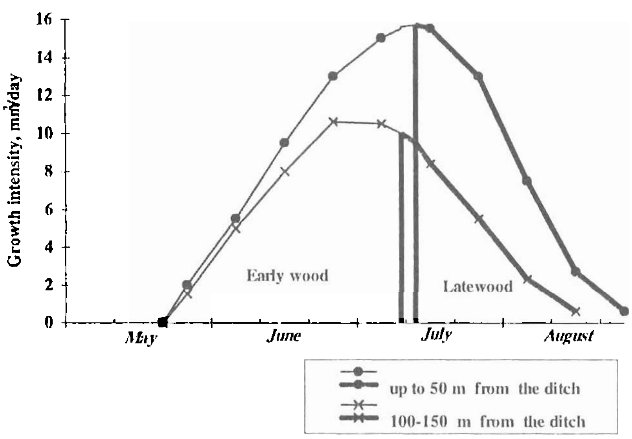

Figure 4. Intensity of wood growth over the vegetation period.

observed for the pine found on the inadequately drained part of the site under investigation.

In the intensively drained part of the site the wood growth is at its peak on the average around July 12, reaching by that time 16 mm^2/day. Normally, the peak of growth roughly coincides with the onset of latewood formation.

In the inadequately drained part of the site, the formation of new tracheids terminates around Aug. 15, on the intensively drained site - around Aug. 25.

There is quite a strong correlation between the intensity of latewood growth ($r= +0.95$) and the factor describing drainage intensity, i.e. the number of days over the growing season when the groundwater table is deeper than 30 çm. The intensity of early wood growth is to a lesser extent related to the factor, describing drainage intensity ($r= +0.58$). Both the simultaneous onset of the growth of early wood in the two cases considered and its relatively slight dependence on the soil hydrological regime appear to confirm the assumption, that the growth of early wood is predominantly at the expense of photosynthates of the previous growing season.

During the first 5 years after the drainage the percent of latewood in the annual growth ring somewhat reduces (on the average by 4%) or is the same as before the drainage, although the growth ring width has increased several times. During the years to come, the percent of latewood in the annual growth ring gradually increases, and by the time of 20 years after the drainage, the percent of latewood in the stem's outer periphery is significantly higher than in the wood that has grown before the drainage. For example, the average percent of latewood in the outer periphery of sample stems of the average height 9.8 m and the average diameter 12.6 cm found on the Nd *Caricoso-phragmitosa* site of pine, is 31%. For pine on the Ks *Myrtillosa turf. mel.* site (H=25.5 m, D = 27.0 cm), the average figure for the percent of latewood is 47.

Recently the foresters have started a purpose-oriented cooperation with the specialists of the Institute of Wood Chemistry. Under the supervision of J.Hrol, *Dr. h. chem.*, research on the microstructure of pinewood from different localities of Latvia is started. Sample stems are analysed in 6 forest districts (Fig. 5): Misa (Mi), Saule (Sa), Silene (Si), Spārni (Sp), Tome (To), Zalakas (Za). The results clearly show the percent of latewood in pine to depend functionally on the average stand height: 82% of the variations in the proportion of latewood in pine may be attributed to the differences in tree height.

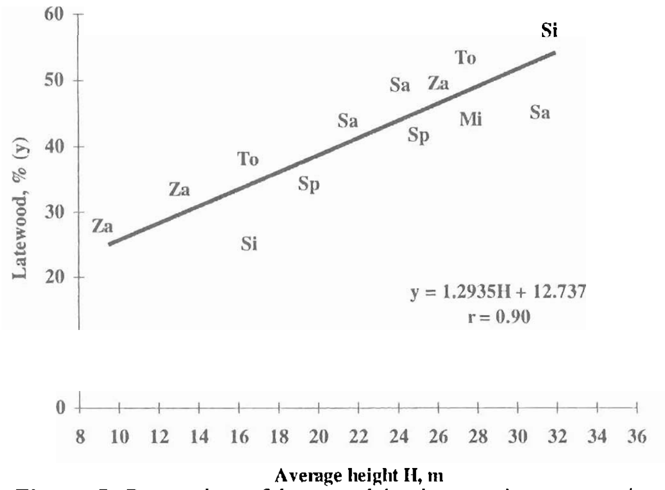

Figure 5. Proportion of latewood in the stem's outer periphery at the stump.

For wetland forests of pine, the stand quality evaluation in terms of the assortment structure, the growth of wood during the vegetation season and the close correlation of the percent of latewood with the stand's average height allow us to draw the following silviculturally **significant conclusions:**

1. During the first years after drainage the percent of latewood in the annual growth may decrease and the mechanical properties of wood deteriorate, resulting from a tenfold increase in the annual growth layer width as compared to the situation before drainage, and a slight increase in tree height. The annual growth layer width as a rough indicator of the mechanical properties of wood may be used only in cases the tree height is the same.

2. In pine stands the average tree height fairly closely correlates with (r = +0.91) the percent of latewood in the outer periphery of stem, and the tree height is indicative of the strength of branchless wood. With the average tree height increasing by 3 m, the proportion of latewood increases by ca 4%.

3. The quality of pinewood is higher in the stands where at the cutting age the number of large-dimension trees is larger. The average volume of the first-grade sawlogs (m^3/ha) may be calculated following the forest site type, the average diameter and the highest value of the average height. Accordingly, the forest management must be adjusted to maximize the above parameters.

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ПРОДУКТИВНОСТЬ И КАЧЕСТВО ОСУШЕННЫХ СОСНОВЫХ ЛЕСОВ

П. Залитис

Резюме

Гидротехническая мелиорация в течении уже полтора века в Латвии играет важную роль как мероприятие корренным образом повышающее продуктивность леса и препятствующее деградации лесной среды. Резкое возрастание текущего прироста ($м^3$/га год) стволовой древесины после мелиорации неизбежно влечет за собой изменения как в структуре древесины, так и в ее технических характеристиках, анализ и оценка которых проделаны в этой статье. Исходные данные собраны в течении вегетационного периода за 4 года и с помощью микроскопа у 115 сосен изучен ход сезонного формирования годичного кольца, его структура. В 83 насаждениях спелых сосен изучены показатели качества стволов в зависимости от интенсивности осушения и примеси деревьев ели и березы в составе древостоя; подчеркнута тесная зависимость показателей прочности стволовой древесины от средней высоты древостоя.

Ключевые слова: продуктивнось леса, мелиорация, качество ствола, прочность древесины.