EVEN-AGED SPRUCE STANDS IN LATVIA – KNOWLEDGE AT THE END OF THE SECOND DECADE OF THE 21ST CENTURY

Summary

Norway spruce is the second most widespread conifer tree species in Latvia. According to Latvian National Forest Inventory data (2013–2017), spruce stands comprise 597 thousand ha (±2.47 %) or 18.5 % of the total forest area (www.silava.lv; according to forest definition – at least 0.1 ha large area with at least 1000 trees ha^{-1}, able to reach the height of 5 m). The importance of spruce timber has been high during the recent past. Therefore, during the seventies and eighties of the previous century the establishment of spruce plantations was intensified in mesotrophic and eutrophic forests of Latvia. Spruce stands established by foresters differed significantly from the stands formed naturally in Latvia (in the southern part of the boreal zone). Even-aged spruce monocultures with fast juvenile growth rate are never formed naturally – for a prolonged time, spruce develops in the undergrowth, and afterwards – in the second layer, and only in the result of succession, it replaces the broadleaves as the dominant tree species of the stand.

Questions concerning the most rational management regime of initially highly productive but afterwards declining spruce stands have been raised repeatedly. Current Latvian legislation permits the final felling in Norway spruce stands where the trees of the dominant stand have reached the mean age of 81 years or the mean diameter of 31 cm. In cases of severe tree damage, the removal of the stand is possible in sanitary fellings, following certain procedures and criteria. In the beginning of this century, forest

scientists Pēteris Zālītis and Zane Lībiete developed and validated a methodology for the determination of the growth potential of Norway spruce, in order to identify problematic stands and enable their removal before the formal compliance with the sanitary felling criteria, thus facilitating efficient utilization of forest land and timber. This methodology was successfully integrated in the legislation.

When the proposal for 2014–2017 State Research Programme was prepared, the Latvian State Forest Research institute "Silava" (LSFRI Silava) offered to proceed with the development and clarification of knowledge concerning a topic still important for forest management – challenges and opportunities of even-aged spruce stand management. The proposal was supported by the forest sector, and a study within the of State Research Programme on even-aged spruce forests was started.

Within the scope of this study, we have attempted to clarify how the growth potential of Norway spruce has changed during 12 years, since the initial survey in the beginning of the century, and whether in 30–60 year old, initially overstocked spruce forests thinning may improve the growth of the residual stand.

The results of the repeated survey confirm further decline of the growth potential in young and middle-aged spruce monocultures. This decline is more pronounced in forests on dry mineral soils. In the Eastern part of Latvia the share of unpromising stands is considerably higher than in the western part of Latvia. The analysed compartments are mainly formed from overstocked young stands with overdue thinning, resulting in individual trees that are weakened by mutual competition for light, water and nutrients. In forests with this kind of management history the application of the current rotation age (81 years) will likely be a grave mistake; and the existing management regime should be altered, considering the ecological demands of Norway spruce as a shade tolerant tree species.

Historically, the technologies for establishment of even-aged spruce forests and their production forecasts were based on several assumptions. One of these was related to the prospect of obtaining additional wood resources from thinnings, and it was foreseen that thinning would improve the growth of the residual stand. Therefore, spruce stands were regenerated with high initial density – even 5–6 thousand trees ha^{-1}. In part of the area, mainly on drained sites, pulpwood plantations with especially high initial density were established, with a goal to supply raw material for the pulp industry, at that time operational in Latvia. Following the political changes as well as changes in the forest sector at the end of the 20th century, the code denoting compliance of the stand to the status of pulpwood plantation disappeared from the forest information systems, and these forests were included in the general management scheme.

Research on the structure of even-aged spruce stands and changes following thinning present evidence that a considerable part of the standing volume is contained within the suppressed stand – it is, on average, 16 %, and may reach even 70 $m^3 ha^{-1}$. To characterize the trees of thinned and unthinned stands across diameter classes, different parameter distributions were studied, and the *Weibul* 3-parameter distribution proved to be the most accurate. Also the normal distribution was found to sufficiently describe the actual distribution of trees in the diameter classes. In stands with overdue thinning, in cases when thinning intensity is below 25 %, no additional diameter increment is formed. Establishment of strip roads alone requires the thinning intensity of 20 %. Ten years after a high intensity thinning (more than 45 % of the standing volume), the stands have not yet reached the level of the previous standing volume, but their mean diameter is larger, thus ensuring the formation of additional increment in highly valuable individuals. In "risk free" environments, it is therefore possible to establish highly productive spruce forest even when performing overdue thinning in initially overstocked stands.

Currently, when economic principles are increasingly taken into account in forest planning, Norway spruce may be considered a cost-effective species for forest regeneration. Knowledge of the establishment of spruce stands is especially important in the light of the concept of the target diameter, included in Latvian forestry legislation and motivating forest owners to intensify management in order to gain profits earlier. Thus, the forest owner theoretically has an opportunity to plant spruce, grow valuable timber and perform the final felling in his stand within his lifetime, which is impossible if only the rotation age is considered. As Norway spruce is a fast-growing tree species in its youth, provided that it has optimal environmental parameters, currently in mesotrophic site types (*Myrtillosa, Hylocomiosa, Myrtillosa* mel. and *Myrtillosa* turf. mel.), forest regeneration with Norway spruce should be considered a better option than regeneration with Scots pine. Private forest owners, including forest management companies with foreign investors, increasingly prefer forest regeneration with Norway spruce.

Regardless of the advantages that cultivation of even-aged Norway spruce stands presents for contemporary forestry, there are certain associated risks as well. In scientific research forests, long-term sample plots have been established in the previous century, and these plots historically have served a dual purpose. Initially, they were used to demonstrate the outstanding growth and productivity of spruce plantations, including the effects of various thinning regimes. Currently, forest phytopathologists are occupied, striving to explain the loss of vitality and decline of these stands. In practical forest management, the question of the most suitable tree species for forest regeneration after sanitary clearfelling of even-aged spruce stands is increasingly pertinent.

Economic analysis of management alternatives for initially overstocked, even-aged Norway spruce forests has demonstrated that it is possible to establish productive stands if thinning is carried out, even though it is overdue. In "risk free" environments, both the standing volume of valuable timber and the financial indicators are higher in the case of thinning. Even in the case of root rot infection, even if the stand has to be removed in a sanitary felling later, thinning once or twice is a better alternative than no thinning at all.

In higher risk conditions, recommendations are less explicit, as the decision also depends on the risk perception of the decision maker. Moreover, owners of small forest areas have the opportunity to adapt to seasonal and yearly changes in prices, selling the timber when the prices are higher than the long-term average value.

Results of tree breeding experiments prove that the mean tree diameter and also the share of valuable timber is considerably higher in stands with very low initial density (400 trees ha^{-1}), compared to plantations with high initial density (3300 trees ha^{-1}) and mean values from the forest inventory data. Heredity (or clonal identity) has a statistically significant influence on radial growth, and individual stands may already reach target felling diameter at the age of 42 years. At the same time, the total standing volume in low-density plantations was considerably (by 34 %) lower than in dense plantations at the age of 50 years. Net present value in both plantations was similar if a 5 % interest rate was used for investments in regeneration and tending. The results of the study suggest that the currently recommended planting density could be reduced, and its optimal value calculated, based on developed growth models and risk forecasts. Resources should be allocated to the wider use of vegetatively propagated high quality genotypes of Norway spruce.

Historically, the planting of even-aged Norway spruce stands was promoted by the excessive population size of large herbivores, mainly elk. Damage to young spruce stands was lower, therefore pure spruce stands were established also in mesotrophic sites, where pure pine stands or at least mixed pine-spruce stands should have been planted.

After massive windthrows at the end of 1960's, large forest areas needed to be renewed, and there is a possibility that due to the lack of local spruce reproductive material some areas may have been regenerated using Norway spruce material, imported from the southern regions of the former USSR. Genetic analyses were applied to test whether this posible "import" influenced the low growth potential of spruce stands. It was, however, confirmed that imported genetic material has not been used in the stands that now are considered unpromising. We found that on average 7.2–7.8 % individuals originate from the refugia of Eastern Carpathians both in naturally regenerated (Moricsala and Rēzekne forest genetic resource stands) and in planted Norway spruce stands. There are no significant differences in genetic diversity between promising and unpromising stands, these differences comprise only 3 % and are related to the geographic location of the stands, rather than their vitality. Future use of spruce planting material from seed orchards for regeneration of even-aged stands will ensure high genetic diversity, and no differences in genetic diversity between seed or mast years were detected.

Within the scope of this study, an experimental plantation with different tree species and their combinations was established in an area where an even-aged Norway spruce stand was removed in sanitary felling, to serve as a research site and demonstration object for the challenges of forest regeneration in the future. The first evaluation and measurements have been carried out in this plantation. To provide the knowledge necessary for intensified forest management in the future and for promotion of Norway spruce in forest regeneration, a study on the growth of initially sparse stands was carried out, where the effects of tree breeding and genetics were also analysed. The best regeneration success was that of birch – high survival rates and stable height increments were observed during the first years of growth. The survival rate of Norway spruce was higher, when planted four years after felling, compared to the comparatively lower regeneration success if planting was carried out in the second year after felling.

Scientists at the LSFRI Silava continue to accumulate knowledge pertaining to the distribution of root rot in even-aged spruce forests on peat soils. The obtained information on the biology of the fungus will help to understand and to control root rot in the commercial forests. In case of infection, it is the duty of foresters to reduce the economic losses and to limit the spread of the infection and, most importantly, to prevent the development of new infection centres in previously healthy stands. In spruce stands with no *Heterobasidion* infection, it is necessary to prevent the primary infection via spores, treating fresh stems and also critically assessing the need for thinning. In already infected stands, the rotation age should be reduced, and regeneration with broadleaf species or removal of infected stumps should be considered.

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