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Determining the growth potential for even-aged stands of Norway spruce (*Picea abies* (L.) Karst.)

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Abstract

Under the forest growing conditions of Latvia the 30-40 year-old pure stands of spruce undergo abrupt changes. While in some stands an intensive volume growth in high quality stems continues, other stands decline, losing productivity and even breaking down. By using a method developed for this purpose, growth potential for even-aged pure stands of spruce in 355 forest compartments in eight regional forestries of Stock Company "Latvijas valsts me□i" was analysed. Out of the compartments analysed healthy and promising stands were 26%, hopeless unpromising stands 11%, and increased risk stands 63%. The loss of growth potential for spruce could only partially be explained by the impact of site type or regional differences. The results of the given study suggest that this process is related to the ecological demands of Norway spruce as a shade tolerant tree species.

Key words: young spruce stands, productivity, management regime, volume growth, growth potential

Introduction

Norway spruce (*Picea abies* (L.) Karst.) is shade-tolerant known to require as a minimum 1-3% of full daylight (Булыгин 1985). However, in some literature sources the spruce is held to be average shade tolerant species, which needs 3-4% of full daylight. It can be explained by the vast range of Norway spruce distribution and the variability of its ecological demands within it. For instance, the spruces of Baltic origin are found to be more shade tolerant than those of southern Poland (Schmidt-Vogt 1987).

Spruce has distinct early- and late-budding forms; over its natural range of distribution the time lag in bud bursting may be as high as several weeks. Late-budding forms dominate in Belarus while early-budding ones in Finland and Scandinavia. In Latvia, the spruce populations differing as to the time of budding are distributed symmetrically with early- and late-budding forms as marginal values of this distribution. It only proves that the climatic conditions of Latvia are especially suitable for the Norway spruce.

The earliest documented facts about the cultivation of spruce in Latvia refer to the first forest inventories carried out in the mid-19th c. As a result, uncontrolled selection cuttings were terminated and clear-cuttings introduced instead. At the first forest inventories the rotation age for spruce was set to be 120 years, which was later reduced to 100 years. Until WWI only narrow (50-60 m) felling coupes were planned and there was an invariable demand to retain the advance growth. The spruce stands were not thinned until the beginning of the 20th c. when the domestic market for spruce pulpwood emerged after pulp manufacturing was started. The value of spruce increased and the forest management planning envisaged artificial regeneration of spruce, initially by sowing.

After WWII the technologies of mechanized logging were introduced. The advance growth spruce was not retained any more as it was an obstacle in logging operations. The proportion of spruce forests decreased from 24.5% in 1928 to 15.7% in 1958 (Zviedris 1960).

After the year 1960 the areas under spruce increased rapidly; it was mainly at the expense of planting spruce on the sites suitable for pine. The reasoning behind it was both well grounded (excessively high elk population damaging young stands of pine) and groundless (less thinning expenses in spruce stands compared to pine) (Saliņš 2002).

In Latvia, the artificial regeneration of spruce was started quite late. As there was no knowledge about the optimal number of stems per unit of the stand area, the foresters believed the planting density should be like that for the advance growth in natural regeneration; and similar reasoning resulted in overstocked stands.

Until recently, overstocked stands of spruce were considered acceptable. However, it is proved that increased stand density neither reduces the wildlife damage nor improves the stem quality or enhances volume increment after thinning (Saliņš 2002). Swedish scientists have found that the risk of root rot *Heterobasidion annosum* (Fr.) Bref. infection is higher in denser stands (Venn, Solheim 1994). The research done by Zalitis and Spalte (2002) proves that in overstocked stands of the mean height above 10 thinning from below has no significant effect on the growth of the remaining trees.

In Latvia, the spruce can be a target species in fertile site types for the following forest growing conditions: 1) forests on dry mineral soils; 2) forests on drained mineral soils; 3) forests on drained peaty soils. On drained peaty soils the peak of the yield for spruce is at stand age 60-70 years, while in spruce forests on dry mineral soils a slight volume increment can be observed even at stand age 90 years. On drained peaty soils in the 80 year-old spruce stands the stock volume is approximately the same as in stands aged 50 years. It means that in at least a part of similar stands an intensive dieback of trees is under way, which cannot be compensated by the volume growth in healthy spruces or in some admixture species.

The young stands of spruce go through a number of stages. Rather slow growth rate with annual increment in height about 10-20 cm prevails until the trees reach a height of approximately two metres. This stage is followed by a rapid increase in all the stand parameters with the difference in volume growth often as high as 20 $m^3ha^{-1}year^{-1}$.

Currently, the 30-50 year-old pure stands of spruce take up 38,800 ha, which in the state-owned forests accounts for about 40% of all pure stands of spruce. The highest amount (3,561 compartments or 6,177 ha) of the 30-50 year-old pure stands of spruce is in the Dienvidkurzeme Regional Forestry of the stock company "Latvijas valsts meži" (LVM), and the lowest in the neighbouring Ziemeļkurzeme Regional Forestry (1,337 compartments or 2,075 ha) (Fig. 1).

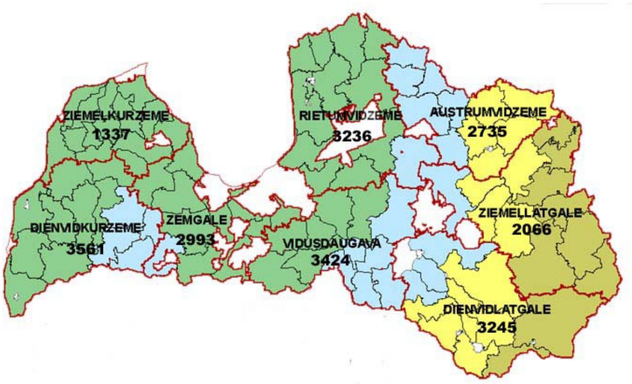

Figure 1. Total amount of the 30-50 year-old pure stands of spruce in the regional forestries of Stock Company "Latvijas valsts meži"

As it follows from the data of long-term observation plots, the rate of volume growth of purposefully formed even-aged young stands of spruce can be as high as 20 $m^3ha^{-1}year^{-1}$. (Zālītis, Lībiete 2003, 2005). However, abrupt changes in the development of some spruce stands are observed at the age of about 40 years. In some stands intensive volume growth in healthy stems continues, offering a yield close to 500 m^3ha^{-1} by the end of the rotation period (80 years). However, in other stands a notable reduction of the increment is observed at this age, accompanied in some cases by a collapse of the stand (Fig. 2).

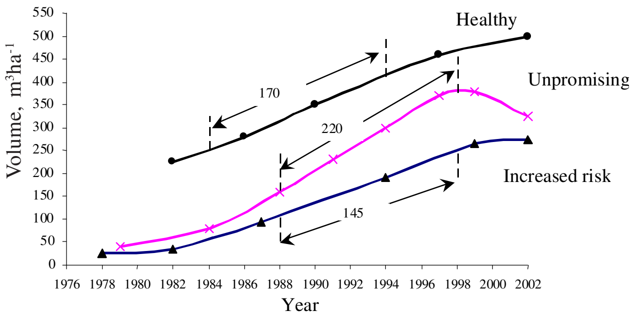

Figure 2. Volume growth trends in the 30-50 year-old pure stands of spruce

The major objectives of this study were to find the ways, how to identify unpromising and increased risk stands of spruce and draw a line of demarcation between vigorous and declining stands. Preliminary results of the given research project were presented in a poster session at the EFI Annual Conference in Sept. 2005.

Material and methods

The method was elaborated in 2002, by using the data on 22 permanent sample plots for identifying the indicators suitable for describing the growth potential of spruce stands. These plots have been measured 6-8 times every 3-5 years, recording the stand parameters and calculating the volume yield. Initially, all the stands were divided into three quality groups. The stands were evaluated following the curves of volume growth. The stands for which the recent volume difference was negative or close to zero were regarded as holding no promise. Of 22 sample plots 7 fell within this group. Increased risk stands (6 sample plots) were those showing a positive volume difference yet less than 10 $m^3ha^{-1}/year^{-1}$. These stands are believed to become unpromising in 20 years. The spruce stands where the volume growth reached or exceeded 10 $m^3ha^{-1}/year^{-1}$. were regarded as promising. In similar stands the yield at the end of the rotation period (80 years) is expected to be 500 m^3ha^{-1}.

The indicators for stand assessment were chosen by analysing the annual ring width for each of the three sets of spruce stands. The linear relationship between the d. b. h. and the width for the last five annual rings was used. It was described by regression equation i_5=ad+b, where i_5 is the total width of last five annual rings, mm; a and b are the regression coefficients; d stands for the tree d. b. h., cm. The following values were calculated for each stand:

• Mean stand diameter ***D*** as the arithmetical mean for the measured trees

• Regression coefficient ***a*** as the indicator of the stand structure

• Linear correlation coefficient ***r*** between i_5 and d of one stand as an indicator of the increment differences for the trees of the same diameter

• Mean width of the last five annual rings ***i*** as an indicator of the volume growth of the analysed stand.

Objective identification of unpromising stands (Group 3) is essential to justify their cutting down before the wood has lost its quality. The calculations show that the stand is to be included in Group 3 provided for the last five years (Fig. 3, C):

• At the mean stand diameter ***D*** the total annual rings width is less than 10 mm, *i.e.,* for the last five years the annual ring mean width was less than 2 mm

• The value of the regression coefficient a in the equation $\boldsymbol{i_5}$=**a*d*+b** is no greater than 0.30

• The linear correlation coefficient ***r*** between $\boldsymbol{i_5}$ and ***d*** is no higher than 0.60.

The following indicators describe highly productive and healthy stands (Group 1), which are likely to yield 500 m^3ha^{-1} at the main felling and should be managed according to the existing thinning regulations (Fig. 3, A):

• At mean stand diameter ***D*** the total annual ring width is greater than 10 mm

• Regression coefficient ***a*** in the equation $\boldsymbol{i_5}$=**a*d*+b** is greater than 0.60

• Linear correlation coefficient ***r*** between $\boldsymbol{i_5}$ and ***d*** is greater than 0.60.

The stand was included in one of the two groups provided the three parameters were within the limits defined. The stands other than those were included in the increased risk group (Group 2).

The measurements were made in the summer of 2003, 2004 and 2005. In each LVM forestry district according to the forest inventory data 10 pure stands of spruce of the age 30-50 years were surveyed. To evaluate the risks the cultivation of spruce may entail, it was decided to survey as many pure stands of

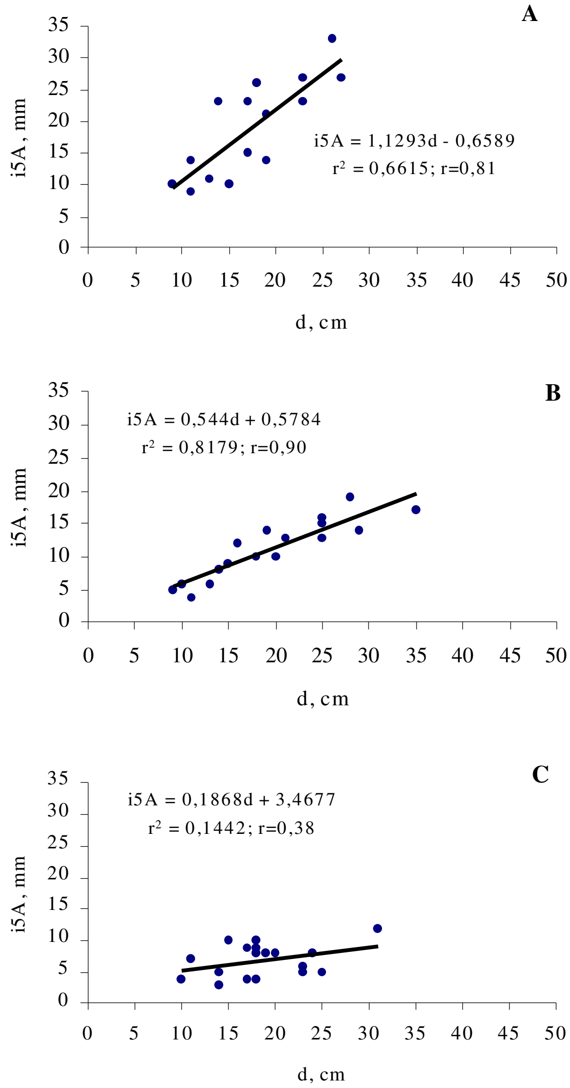

Figure 3. Relevance between total annual ring width of the last five years and the stem diameter: A – healthy stand; B – increased risk stand; C – non-promising stand

spruce as possible. A forest compartment was taken as the object of research. In each compartment a representative biogroup of spruce trees was chosen. For this biogroup the forest site type was defined and the basal area measured (Bitterlich method). The d. b. h. for 20 trees and the total annual ring width (using the increment borer) for the last five years were determined. Determined was also the height of the average tree within the biogroup.

No permanent sample plots were established and not all the trees within a stand were measured. We considered such a method excessively time-consuming and to a limited extent suitable for the problems under study. The information about the stand parameters derived from approximately 50 m wide belt was, perhaps, less accurate than that we would have obtained from larger sample plots by measuring all the trees in the compartment. The larger the compartment the higher is the probability that the biogroup would be less representative. Besides, it must be noted that the survey of spruce stands with this aim in view and by this method was done for the first time in Latvia with no data for comparison; that is why the verification of the conclusions of this study is to some extent complicated.

Altogether 355 stands were surveyed and the information about 7,100 individual trees was obtained.

Results and discussion

In the state-owned forests of Latvia there were totally 22,597 compartments of the 30-50 year-old pure stands of spruce with the standing volume 9.9 million m^3. As a result of the analysis, in 8 regional forestries of the LVM totally 2,508 stands of the total standing volume 1.25 million m^3 fell within the group of unpromising stands (Group 3). In these stands the rate of volume growth was less than 1 $m^3ha^{-1}/year^{-1}$. and it would be reasonable to cut them down in the near future. The average volume yield in this group was 291 m^3ha^{-1}. There were considerable differences in the distribution of three growth potential groups between the LVM regional forestries (Table 1).

Table 1. Growth potential in young spruce stands on the basis of LVM regional forestries

Regional forestry	Proportion of the stands, %			Average coefficient for the groups
	Group 1	Group 2	Group 3	
Ziemeļkurzeme	37.4	59.2	3.4	1.66
Dienvidkurzeme	33	50.9	16.1	1.83
Zemgale	42.9	51.4	5.7	1.63
Rietumvidzeme	21.2	71.0	7.8	1.87
Austrumvidzeme	13.1	66.0	20.9	2.08
Vidusdaugava	6.8	78.3	14.9	2.08
Ziemeļlatgale	20.6	66.7	12.7	1.92
Dienvidlatgale	35.9	60.3	3.8	1.68

The differences in the growth potential of spruce stands between the regional forestries were by no means accidental. If we divide the territory of Latvia along the line Riga-Bauska, which is widely practiced in ecological research, we obtain two distinct regions: one is Western Latvia (Ziemeļkurzeme, Dienvidkurzeme and Zemgale regional forestry), the other is Eastern Latvia (Rietumvidzeme, Austrumvidzeme, Vidusdaugava, Ziemeļlatgale and Dienvidlatgale regional forestry). The growth potential for the spruce stands differs significantly between the two parts of the country. In Western Latvia, 8% of all the stands analysed were considered unpromising; in Eastern Latvia this proportion was 14%. In Western Latvia 48% of all the compartments analysed were considered promising while for Eastern Latvia this indicator was 19% only.

The mean values of the stand parameters in different growth potential groups partly explain how these groups were delineated (Table. 2).

Table 2. Mean values of the stand parameters in compartments with differing growth potential

Stand parameters	Group 1	Group 2	Group 3
Number of compartments	118	207	30
Mean diameter, cm	16.4	17.4	19.2
Mean height, m	16	18.4	19.4
Mean age, years	33.8	37.7	40
Mean volume yield, m^3ha^{-1}	219	262	291
Mean basal area, m^2ha^{-1}	24.6	26.6	29
Current annual volume increment, $m^3ha^{-1}year^{-1}$	16.6	12.6	10.6
Current annual volume increment, m^3m^2 /year	0.69	0.47	0.36

The stands of Group 3 were somewhat older than these of Group 1. It is most likely that the former have originated from the overstocked increased risk stands of Group 2. The highest yield and the highest basal area were found in the stands of Group 3, confirming that once they had been highly productive. However, the current annual increment (it decreased from 16.9 $m^3ha^{-1}year^{-1}$ in Group 1 to 10.6 $m^3ha^{-1}year^{-1}$ in Group 3) implies that the period of high productivity is over. This trend is even more striking if we compare the current annual increment per 1 m^2 of the stand basal area: currently each square meter of the basal area in Group 1 produces twice as much wood as in Group 3.

In all the groups the stand density was rather high and the number of trees was approximately similar – around 1,100 trees per ha. The trees in Group 2 and 3 were more spindled as compared to the trees in Group 1 (Table 3). For example, at the same mean d. b. h., D=20 cm, in Group 2 the mean tree height was H=20.4 m, in Group 3, H=19.8 m, while in Group 1, H=17.9 m.

Table 3. Taper of the trees in the stands of different growth potential groups

Mean diameter, D, cm	Mean height, H, m			HD^{-1}		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
16	15.5	17.2	16.9	0.97	1.08	1.06
18	16.7	18.8	18.4	0.93	1.04	1.02
20	17.9	20.4	19.8	0.90	1.02	0.99
22	19.2	21.9	21.3	0.87	1.00	0.97
24	20.4	23.5	22.8	0.85	0.98	0.95

A similar trend is observed when comparing the tree taper ratio HD^{-1}. In Group 1 for all the diameter values this ratio was below 1 while in Groups 2 and 3 at diameter D<20 cm HD^{-1} is slightly above 1. Still, this difference cannot be considered as the indicator for the growth potential.

The division of stands into the growth potential groups could be treated as an indicator of stand quality as proved by the amount of healthy (Group 1), increased risk (Group 2) and unpromising (Group 3) stands in each regional forestry. The coefficients standing for an average group in each regional forestry indicate that the highest growth potential is for Zemgale (1.63), and the lowest for Austrumvidzeme and Vidusdaugava (2.08). The average coefficient 1.84 for all the compartments surveyed suggests that there are more Group 1 stands than Group 3 ones. These coefficients were calculated as the mean values of the group numeration figures and as such are unsuitable for more detailed analysis of the growth potential by using biometrical methods. Therefore it was necessary to propose a single integral indicator easy to calculate and describing as precisely as possible the growth potential of each compartment.

At first, the indicators already calculated as the annual ring mean width i, regression coefficient a, and linear correlation coefficient r were tested. The annual ring mean width evidently contained highly valuable information and was used as the basic indicator. It was possible to correct it by multiplying by coefficient a or r. The correlation between the two coefficients was close (r=0.81) and their values were higher for more promising stands. Consequently, at the same annual ring width a stand with a higher value of correlation coefficient scored a higher evaluation.

Coefficient a illustrates the gradient of the regression line only whereas coefficient r accounts also for the differences in the annual ring width for the trees of the same diameter. Therefore, correlation coefficient r is most suitable as a multiplier for the mean annual ring width i. As r<1.0 integral index i×r will always be less than i, and in unpromising stands, where r=0, also integral index i×r=0. The results show that a negative value of r is also possible, however seldom.

According to the defined limits, in Group 3 stands, where i<2.0 mm and r<0.60, index i×r cannot exceed 1.2 mm, while in Group 1 stands it will always be greater than 1.2 mm. It allows us to propose a single measure for the growth potential of a spruce stand – the higher the index i×r, the more productive and healthy the stand is.

The descriptive statistics of the integral index within each group confirm the validity of these considerations (Table 4). In Group 1 there was a relatively high left skewness (A=1.94), which indicates that the distribution curve is inclined to the left. In Group 3 there was a negative inclination to the right (A=-0.57), which confirms prevalence of higher values.

Table 4. Descriptive statistics of growth potential index i×r in all analysed regional forestries (355 compartments)

Descriptor	i×r			
	1st group	2nd group	3rd group	All groups
Mean	2.16	1.18	0.53	1.30
Standard error	0.07	0.03	0.04	0.03
Median	2.02	1.19	0.57	1.25
Standard deviation	0.52	0.34	0.23	0.55
Sample variance	0.27	0.12	0.06	0.30
Kurtosis ??	4.17	0.44	0.33	-0.03
Inclination	1.94	0.18	-0.57	0.42
Minimum	1.55	0.25	-0.06	0.09
Maximum	4.04	2.31	0.94	3.09
Credibility level(95.0%)	0.13	0.05	0.09	0.07

However, for Group 2 the data were distributed rather symmetrically (A=0.18) and the mean value (i×r=1.18 mm) practically coincided with the median (1.19 mm).

The numerical values for these regularities suggest that the three groups are parts of a single (normal) distribution with the values for Group 1 and 3 as marginal.

The empiric values of index i×r varied quite widely between the maximum value +4.04 (Group 1) and the minimum value -0.06 (Group 3). However, the cases with the deviation from the mean value too high must be considered exceptional. In Group 1 the data distribution was especially extended. It included some highly productive and healthy stands; and the deviation of index i×r from the mean value exceeded the interval of two standard deviations: i×r+2s =2.16+1.04=3.20 (mm). This positive deviation refers to exceptionally good stands and their growth potential does not present any problems in management.

The demarcation line between the groups was not strictly defined. In view of the aims of the given study the delineation between Group 1 and 2 was insignificant since the growth potential for the best stands of Group 2 was similar to that for the worst stands in Group 1; and it is advisable to manage them following the same management regime.

As the stands of Group 3 are hopeless and should be cut down in the near future, it was necessary to set a strict line of demarcation between the stands of Group 2 and 3 in order to forecast the extent of work and the amount of wood to be recovered. We assumed that the demarcation should be set at the maximum value 0.7 mm for index i×r in Group 3. An assumption that 4% of the stands of Group 2 will pass over to Group 3 is admissible because the weakest stands of Group 2 will anyway decline to the growth potential of Group 3. All our data prove that the growth potential of weaker spruce stands grows only weaker with the time and transition of stands from Group 3 to Group 2 infeasible.

Two-way ANOVA was performed to find out the impact of the forest growing conditions (forests on mineral soils, forests on drained mineral soils, and forests on drained peaty soils) and the locality where the stand is situated (eight regional forestries of the LVM) upon the variations of the integral growth index *i*×r. The following results were obtained:

1. Reciprocal influence of the two factors explained 30% of the variations of integral growth index *i*×r.
2. The locality the stand was situated accounted for 25% of the variations, and the forest growing conditions for 5%. The effect of the stand locality was significant at 99% of the confidence level while the effect of forest growing conditions – at 95% of the confidence level.
3. 70% of the variations of the integral growth potential index *i*×r remained unexplained and most likely were relevant to the ecological peculiarities of the Norway spruce as a tree species.

There is another important fact that deserves mention. When surveying 205 cutovers where spruce had been clear-cut, Arvids Zviedris (*1960*) found that none of the stands had been even-aged. As it follows from the forest inventory data of the previous epochs, in the 19th c. no artificial regeneration of spruce was practiced. These facts allow concluding that during the process of natural regeneration the spruce tends to form uneven-aged stands. However, this seems to be true only for the forest growing conditions of Latvia. The literature sources quote that in the Carpathian Mountains, for example, the spruce regenerates naturally by way of even-aged stands (Питикин 1972).

The calculation results for the agreement of integral growth index *i*×r with the normal distribution indices indicate that the stands with differing growth potential are natural for Latvia and the foresters must reckon with it in their practical work. The decrease in the growth potential and dieback of trees might be a natural phenomenon for uneven-aged multi-storey stands of spruce. Similar stands are natural for the Latvian conditions while the existing regulations for the inventory, management, and utilisation of spruce stands disregard this fact.

The proportion of the significant influence of the two factors studied (25% and 5%) result in the following conclusions:

1. The proportion of unpromising stands of spruce cannot be expressed as a single percent for all the regional forestries; the area to be felled and the volume of timber to be recovered are to be calculated for each regional forestry separately.
2. There are no sufficient grounds to reject the hypothesis that the growth potential of spruce stands depends on the forest growing conditions (Fig. 4).

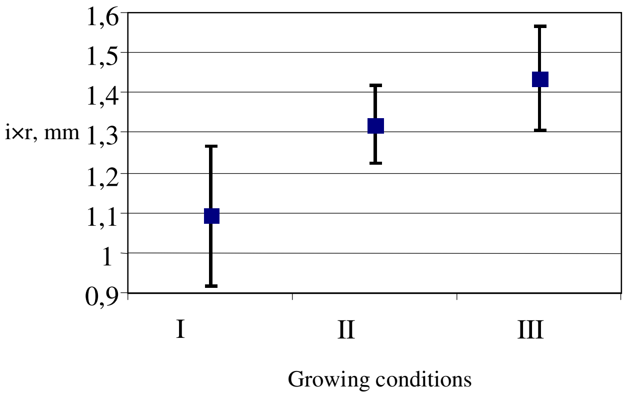

Figure 4. Differences and variations of the mean values of integral growth potential index *i*×r in different growing conditions (I – forests on drained peaty soils; II – forests on dry mineral soils; III – forests on drained mineral soils)

That is why the evaluation of the amount of unpromising stands of spruce in each regional forestry must be related to the existing forest growing conditions in the given forestry. The lowest growth potential is found for the stands on drained peaty soils. The largest statistical difference of the growth potential is between the forests on drained mineral soils and those on drained peaty soils.

The growth potential for initially overstocked stands declines with the time and after the age of 45 years no healthy and productive stands of Group 1 can be found in similar compartments (Fig. 5). On the other hand, there is no evidence that appropriately thinned and healthy stands, now 30-40 years old, would lose their productivity after the age of 45 years. It is also important to note that unpromising stands are found in all the age classes between 30 to 50 years. This fact once again confirms the suggestion that the spruce stands should be managed proceeding from

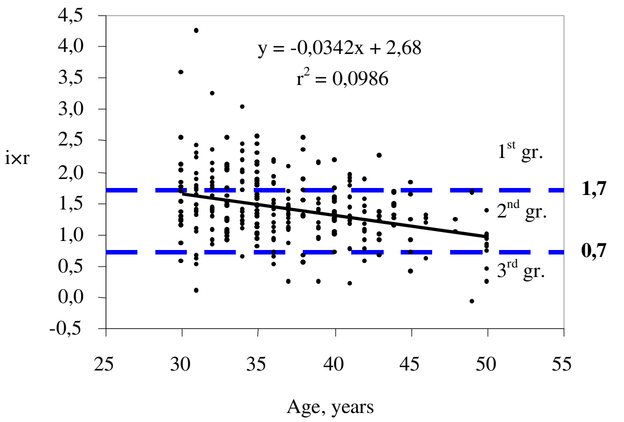

Figure 5. The growth potential for pure stands of spruce depending on the stand age

their actual growth potential rather than the stand age taken as an indicator for the management regime.

The even-aged spruce stands surveyed for this study cannot be considered natural for the Latvian forest growing conditions. As mentioned above, multi-storey stands with trees of different ages are the most natural form of spruce forest. By now it is only 100 years since the first even-aged spruce monocultures have been established in Latvia, and an extensive planting of such stands started only 40 years ago. A part of them are now considered unpromising. The existence of the spruce stand as the main component of the forest ecosystem is ensured by the survival of the shade-tolerant advance growth. Normally, the volume yield in a multi-storey spruce stand is no higher than 240 m^3ha^{-1}. The regime of selection cuttings, which implies removing the large-dimension stems, is the most appropriate way to manage similar stands. However, in drained forests because of the low bearing capacity of terrain, the establishment and long-term management of stable multi-storey stands are impossible.

Still, it does not imply that spruce cannot be cultivated on drained sites but, no doubt, these stands require special attention. It is infeasible to keep declining and non-promising stands of spruce for a fixed number of years as the present regulations require. Even-aged spruce stands should be managed according to their growth potential and it should be legal to cut down hopeless stands starting with the age of 40 years. Then the volume yield in similar stands is close to 300 m^2ha^{-1}. Of course, such a management regime cannot be applied to all spruce stands. Perhaps, the existing spruce monocultures should be regarded as forest plantations, although for other situations this term is inappropriate. Planting spruce in woodlands means maintaining the integrity of forest ecosystems while its exploitable product, that is high quality timber, should be taken out when the stand has reached the technical maturity irrespective of its actual age.

Conclusions

1. Spruce monocultures on fertile forest site types are highly productive; the volume growth often exceeds 20 $m^3ha^{-1}year^{-1}$ with the volume yield in 40 year-old stands as high as 350 m^3ha^{-1}.

2. Approximately at the age of 40 years the growth of even-aged stands of spruce may change substantially; in part of the stands the volume increment still exceeds 10 $m^3ha^{-1}year^{-1}$ while in other stands it is even negative or close to zero.

3. In analysing the data for about 355 pure 30-50 year-old stands of spruce in eight regional forestries of the Stock Company "Latvijas valsts meži" the stands surveyed were divided into three groups: Group 1: healthy stands to be managed following the present thinning regulations; Group 2: increased risk stands, thinnings should be avoided there; Group 3: unpromising stands which should be cut down in the near future.

4. The stands were divided into groups according to the following indices: the total width of the last five annual rings; regression coefficient a in the equation i_5=ad+b, and linear correlation coefficient r between i_5 and d. The limiting values for these indices were defined for the stands of Group 1and 3 with the remainder counted as Group 2.

5. To conduct more precise mathematical analysis of the results and enable identifying the area of unpromising stands to be removed, and calculating the volume of the timber to be harvested and the forest regeneration measures to be taken, integral growth potential index i×r was proposed by multiplying the average annual ring width of the last five years with linear correlation coefficient r between i_5 and d. The statistics of this index for the groups indicates that the three groups are parts of one probability distribution with the values for Group1 and 3 as maximum and minimum.

6. Two-way ANOVA proved that the reciprocal effect of the locality the stand is situated and the forest growing conditions account for 30% of the variations of integral growth index i×r. The locality the stand was situated accounted for 25% of the variations, and the forest growing conditions for 5%. The effect of the stand locality was significant at 99% of the confidence level while the effect of forest growing conditions – at 95% of the confidence level. 70% of the variations of the growth potential index are attributed to the ecological demands of Norway spruce.

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ПРОДУКТИВНОСТЬ ОДНОВОЗРАСТНЫХ ЕЛОВЫХ НАСАЖДЕНИЙ И РЕЖИМ ИХ ВЫРАЩИВАНИЯ

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Резюме

Искусственно заложенные лесные культуры ели характеризуются очень высокой продуктивностью в возрасте 20-40 лет – темп накопления стволовой древесины нередко превышает 20 $м^3 га^{-1}$ в год. После этого возраста во многих насаждениях прирост древесины резко уменьшается и древостой постепенно разрушается.

На основе данных, полученных в результате долгосрочных наблюдений и активного эксперимента в лесу, разработана методика выявления потенциала роста каждого древостоя, в возрасте 30-50 лет, условно распределяя их на полноценные, повышенного риска и бесперспективные. Потенциал роста мало зависит от типа условий произрастания – леса на суходоле, на осушенных гидроморфных минеральных почвах и на осушенных торфяных почвах. В целом полноценные насаждения в лесах Латвии занимают 26%, насаждения повышенного риска – 63% и бесперспективные – 11% от одновозрастных еловых древостоев 30-50 летнего возраста.

Ключевые слова: еловый молодняк, запас древесины, потенциал роста