RADIAL GROWTH OF NORWAY SPRUCE IN THE POLLUTED WESTERN PART OF LATVIA

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Abstract

Environmental pollution that has been one of the key issues for decades has still not lost any of its topicality. In order to study the impact of air pollution on the growth of Norway's spruce (*Picea abies* (L.) Karst.), 31 sample plots were established at different distances and directions from the pollution points in the Western part of Latvia. The plots were established starting from the year 2008 summer-autumn season and finishing with the spring of 2009. The selected stands were 32 - 171 year old and of different forest site types. The selection was used in the State Forest Service database and cartographic materials. Empirical data was obtained from each of the plots which reflected the environmental effects on the trees. To ascertain the effect of air pollution on the growth of Norway spruce, the algorithm based on additional increment to volume was used. Air pollution affects eating, regardless of age and the type of growing conditions. Pollution effects are closely related to the distance from the source.

Key words: air pollution, Norway spruce, dendrochronology, volume increment.

Introduction

If there were no anthropogenic effects, forest areas would be much greater. To the humanity, utilization of forest valuable products has brought their material well-being. At first, the forest was used in its primitive sense, but gradually human activity has considerably expanded. Nowadays, consequently, no direct use of the forest affects the physical and chemical factors that are especially dangerous because of their effects which are very difficult to discern visually.

The growth of industries and large urban agglomerations during the last half century has given a rise to significant changes in the natural environment, resulting in an adverse impact on many of its elements. Air pollution, especially taking into consideration its impact on a larger area, has become a very serious problem. This problem is quite evident in the environment. There has been a greater amount of emissions of pollutants into the atmosphere. Over the last decade the amount of damage to the forest to be investigated has increased not only at the local level but also at the regional level. Harmful compounds emitted into the air have severely impaired health status in many groves in Europe (Breymeyer, 1997; Kandler and Innes, 1995). Similar results have also been observed in Japan, where as a result of pollution and different climatic factors the growth of Norway spruce has decreased (Kobayashi, 1992).The Western part of Latvia should pay a particular attention to air pollution issue. In this part of the country, the focus is on steel and cement production companies, as well as there is an influence of cross-border pollution (Nikodemus et al., 2004; United Nations, 2006). Air pollution in developed countries started to decline already around 1980, while in the Central and Eastern Europe - around 1990 (Kupcinskiene et al., 2008). Although the level of pollution from industrial facilities has decreased, it still has a significant proportion of around 50% of the total pollution level (Pärn, 2006). Pollution from cement production can be neutral, stimulating or have toxic effects depending on the concentration (Pärn, 2006). Gaseous pollutants are expressed in phytotoxic effects particularly in terms of sulfur and nitrogen oxides (SO_x and NO_x), which lead to decreasing the physiological efficiency of foliage and defoliation (Bytnerowicz et al., 2004).

The aim of this study is to determine influence of air pollution on mature and medium Norway spruce stands in the Kurzeme region.

Materials and Methods

The installation of plots

The plots were established starting from the summer-autumn season 2008 and finishing with the spring of 2009. To cover the study area, two transects, each comprising 15 plots, were developed in the region of Kurzeme. So, the total number of plots was 31, and one control plot arranged in a potentially less contaminated area. The west side of transect was assigned the denotation 'Z' (a starting point N56^{0}31'26.05' E21^{0}2'13.08 end point E23^{0}4'51.031 N57^{0}21'18 .910''), but the eastern side of transect was granted the conditional designation 'D' (the starting point N56^{0}23'32 .185'' E22^{0}10'15.84'' end point ''E23^{0}16'02.984'' N57^{0}03'52 .90''). The sample plots' layout is displayed in (Figure 1). The geographical point of the notional line was placed in the plots. The researched middle-aged and mature stands of spruce were used in the selection of the forest register of the State Forest Service and cartographic materials. From the information obtained, equally spaced stands with no visible damage to bark beetle and use windfall effects were selected for the plots as possible areas of location.

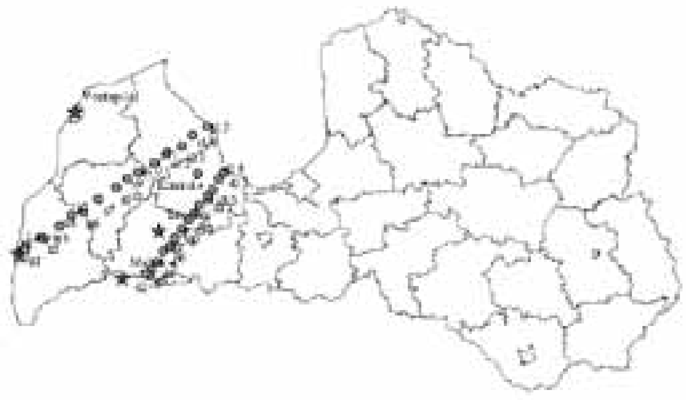

Figure 1. The location of sample plots.

Methods of sampling and measurements

Each plot was 400 m^2; the exact location of the plot was determined by the GPS receiver. Where possible, it was attempted to select Norway spruce stands of different age, about 32 – 171 year old, growing under similar site conditions. The trees that were sampled were either dominant or co-dominant. 20 samples were taken from each of 31 study sites. Increment cores were taken with the Pressler's increment borer at breast height, one core per tree (in the case of site K (Kontrole), samples were taken from 50 trees) on the southern or southwest side of the bole using a 4.3 mm increment corer. The prepared samples were placed in plastic material boxes with a diameter of 6 mm, labeled and prepared for transportation. In the laboratory, each core, when dry, was mounted onto a grooved holder, and the surface of the cores was cleaned and finished using sandpaper (No 80, 120 and 240). Afterwards, the tree ring width of each sample (655 cores in total) was measured with the accuracy of 0.01 mm. The measurement data was registered using the tree-ring measuring system 'Lintab 4' (RINNTECH Frank Rinn engineering distribution Hardtstrasse 20-22 D-69124 Heidelberg, Germany) that includes a stereomicroscope series 234 with the table and Electronic data collector. The measurement data was registered using the program 'T-tools Pro' (Mechanik Labor GmbH).

Data Processing

The method used in this work is based on the additional volume increment calculation algorithm. It is about growing stock increase or loss as a result of the factors under study. This method is based on the analysis of the characteristic years and abrupt changes in tree-ring width. The abrupt changes reflect severe changes in eco-physiological conditions, which lead to stimulation or impediment of cambium activity for several successive years (Schweingruber, 1986). By measuring the ring width, one can obtain the information on an individual tree or stand growth course of all specialties. Control is used to describe trends of changes without influence of pollutants of regional evaluation period. This should include the change in general climatic factors during the period under consideration in the environment where there is no exposure to the studied factors. The ring width is used for the adequate performance of the tree stand response. Environmental impact characterization informative is investigated in addition to the increase in growing stock (Liepa, 1996), as compared to other inventory data that shows the wood volume increase or decrease to a much complete extent.

Growing stock growth is divided in two parts - the growth of that breed that would be incurred in the previous growing conditions and in addition to growth caused by the factor studied. This increase may also be negative. In this case, it is an indication of the influence factor of harmful effects. The distinction is cumulative and refers to the current stock of additional increment. The parameters expressed are m^3 ha^{-1}, which facilitate the evaluation of economic aspects. Thanks to this method, it is possible to detect the specific years characterized by an abrupt increase in the number of trees with, for example, reduction in annual increment more clearly than by means of other methods (compare Kobayashi, 1997). In order to have a better comparison between stands of different density, the following figure calculates the reduced value, expressed in cubic meters per square meter -stand basal area.

Using the measurements of tree rings width, tree height and diameter at breast height, the stand's additional increment is calculated with the method of I. Liepa (Liepa, 1996).

$$Z_M^{kp} = 12732{,}4\Psi\left(GH^{\alpha}D^{\beta lgH+\varphi-2} - G_tH_t^{\alpha}D_t^{\beta lgH+\varphi-2}\right) \quad (1)$$

Where Z_M^{kp} – The cumulative additional increment
G; G_t – basal area at breast height
D; D_t – diameter at breast height
H; H_t – stand's height
Ψ; α; β; φ – coefficients

Results and Discussion

To see the stand's development during the particular time period, we use the additional increment. To display the course of the study accumulation factor, the reduced cumulative additional increment is used. The method can be used for the determination of the response of trees to various factors such as forest management activities, air pollution etc. via changes in their volume growth. The results of transects are shown in Table 1. and Table 2.

Table 1

Forest stands Changes in transect 'Z'20-year period

Code of sample plots	Volume increment m^3 ha^{-1}	Reduced volume increment m^3 m^{-2}	Basal area m^2 ha^{-1}
Z15	9.57	0.26	36
Z14	37.26	1.19	31
Z13	13.8	0.49	28
Z12	12.81	0.24	55
Z11	12.01	0.4	30
Z10	47.62	0.97	49
Z9	24.12	0.44	55
Z8	12.11	0.45	27
Z7	15.98	0.31	51
Z6	13.28	0.29	22
Z5	24.79	0.54	45
Z4	30.55	0.89	34
Z3	7.56	0.25	31
Z2	16.54	0.43	39
Z1	19.47	0.65	30

Table 2

Forest stands changes in transect 'D'20-year period

Code of sample plots	Volume increment m^3 ha^{-1}	Reduced volume increment m^3 m^{-2}	Basal area m^2 ha^{-1}
D15	19.07	0.49	39
D14	25.99	0.34	75
D13	10.91	0.33	33
D12	18.22	0.73	24
D11	31.05	1.14	27
D10	22.65	0.53	43
D9	11.46	0.57	20
D8	14.74	0.51	29
D7	14.48	0.36	40
D6	24.53	0.69	35
D5	17.53	0.46	38
D4	33.94	0.92	37
D3	22.70	0.57	40
D2	24.49	0.61	47
D1	17.11	0.39	43

Normalized additional growth can be assessed with stand development over the period. The environmental situation can be observed if the time period is known, as well as it is possible to observe whether the latter contributed to or restricted the studied factor or factor group effects in the stands.

Dendrochronological techniques were used to investigate the influence of climatic factors on the radial growth of Scots pine (*Pinus sylvestris* L.) under the impact of dust pollution in the industrial region of Northeast Estonia. The cement dust emissions had a minor negative effect on the radial growth of spruce (Pärn, 2006).

There is normalized increase in debt in addition to all the trees of the overall trend during the period of the individual intervals.

The stand is formed during the period that can be used in additional increment. Further, to show the effect of the accumulation process under study (the impact trend), taking the reduced volume increment. Using a reduced cumulative additional increment, different age, composition and density stands can be compared. This additional increase is expressed in the stands square cross-section; thus, we can compare different trees in different growing conditions by having only those indicators. This process makes it easier to evaluate the development of trees over a given period of time presuming the that ecological situation observed affected the studied factor on the forest stand. Normalized cumulative increase of debt influences stand development without distinguishing between the overall trends over a period.

Table 3

Analysis of Variance for increment in 2003 (5-th year period)

Source	*P-Value*
Liepāja	0.0088
Mažeikai	0.0089

Implementing the additional multi-factor analysis of variance, one can verify the interaction of specific factors on the stand. In this case, the additional analysis of the additional increases for the 5-year intervals mathematically confirms the relationship between the contamination points Mažeikai, Liepaja and stands response. In these periods, p-value is <0.05, which confirms the statistical relationship between growth and distance from the source of contamination.

To exclude additional unknown factors to the spruce stands in Kurzeme, in addition analysis on source of pollution area should be carried out. In addition, attention to the pollution of chemical composition and its changes over time should be paid. They help foster understanding of the development time and improve the outlook, particularly if major polluters are changing their production technology.

Conclusions

1. The reduced additional increment is not related to stand age and forest site types, because they act on the stand basal units.
2. The pollution in Liepaja and Mažeikai affected Norway spruce stands, which has been statistically proven. The confirmed relationship between additional increment and distance to Liepaja at the 95% confidence test is conducted with the multi-factor variance.
3. To rule out random checks, additional tests were carried out with a view to examine other factors which may significantly affect the growth of spruce stands in Kurzeme.

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