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Effects of geo-ecological conditions on larch wood variations in the North European part of Russia (Arkhangelsk region)

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Abstract

Neverov N.A., Belyaev V.V., Chistova Z.B., Kutinov Y.G., Staritsyn V.V., Polyakova E.V., Mineev A.L. (2017): Effects of geo-ecological conditions on larch wood variations in the North European part of Russia (Arkhangelsk region). J. For. Sci., 63: 192–197.

The present study examines the macrostructure and density of larch wood and possible influences on the productivity of larch stands. The studies were conducted in the middle and sub-tundra taiga in the Arkhangelsk region. The selected trees were of the same age and diameter at breast height. In all sample plots the average annual ring width varied from 0.68 to 0.93 mm, the average content of latewood was about 29.7–35.1% and the average wood density of these old Siberian larch trees was 572 (500–698) kg·m^{-3}. There were no significant differences between sample plots in terms of the latewood content, density and annual ring width of the growth rings. Wood macrostructure of larch wood has the same values in forests growing in the sub-tundra and middle taiga. A possible explanation for this is the location of these stands in the karst landscape, which possesses abundant mineral nutrition. Geological factors are surpassing the influence of climatic factors and contribute to the formation of productive larch stands in the sub-tundra taiga in the European part of Russia.

Keywords: *Larix sibirica*; wood density; latewood content; ring width

The larch (*Larix* Miller) dominates the forests of Russia. Larch forests cover 278 million ha, corresponding to 40% of forested land. The total volume of larch timber is 25.2 billion m^3 or 34% of the Russian wood stock (Milyutin 2003).

Larches grow well and reach 20 to 50 m in height. Modern research shows that the larch wood in natural and artificial plantations has very good physical-mechanical properties (Vihrov 1949; Polubojarinov et al. 2000; Koizumi et al. 2003; Karlman et al. 2005; Topaloğlu, Ay 2010; Luostarinen 2011).

The main field of application for larch timber and lumber is wood construction. Larch wood is a suitable material for outdoor construction owing to its high mechanical strength and decay resistance. As a result of these properties, larch timber can substitute chemically treated wood, for instance for telephone or power line poles, bridges, fencing, noise protection walls, house panelling and so forth (Martinsson, Lesinski 2007).

In the Arkhangelsk region a subspecies of Siberian larch is growing, for example *Larix sibirica* var. *sukaczewii* (Dylis) Gorchakovsky & Shiyatov (Matveev, Semerikov 1995).

In the Arkhangelsk region 54,200 ha of the forest is predominated by larch, representing 0.24% of the forested land in this region. Of this total, 43,800 ha or 80.3% of the larch forest grows on the water-collecting areas of the Kulai, Pinega and Mezen rivers

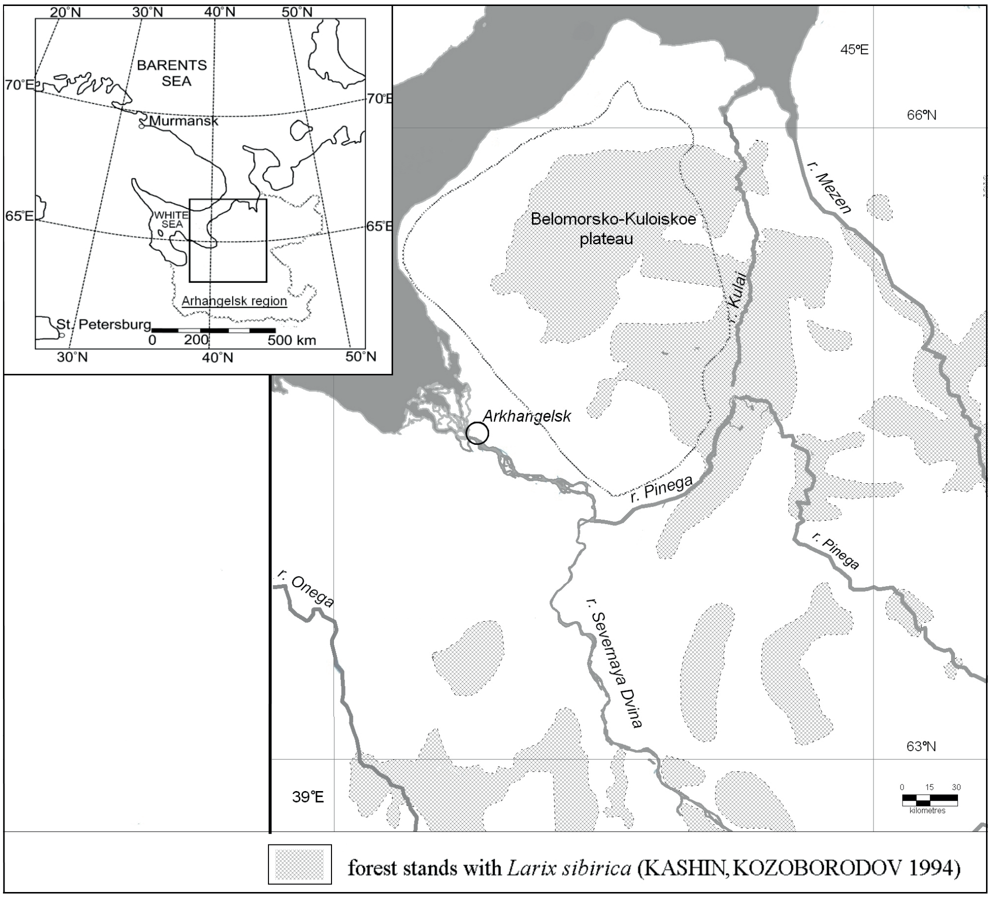

Fig. 1. Distribution of larch forests in the northern taiga subzone of the Arkhangelsk region

and the Belomorsko-Kuloiskoe plateau in the sub-tundra taiga (Gryaznov, Sokolov 2008) (Fig. 1).

According to data for 2008, from each 100 ha of forest stands with a predominance of larch, 85 ha represented overripe, 7 ha ripe, 1 ha of ripening and only 7 ha of young and middle-aged stands. Most of the young larch has an artificial origin; however, young larch mainly grows in the middle taiga in forest districts with extensive experiences of silviculture.

The goal of this study was to evaluate the microstructure and the density of larch wood growing in the sub-tundra taiga and assess the impact of geological factors on the productivity of larch stands in the Arkhangelsk region.

MATERIAL AND METHODS

The studies were conducted between 2008 and 2011. Seven sample plots were created in the natural boreal taiga forests where larch is predominant (Fig. 2). Each sample plot had a defined completeness and forest structure. The characteristics of the studied sample plots are shown in Table 1.

All sample plots are located in the Arkhangelsk region of the middle and sub-tundra subzone of the

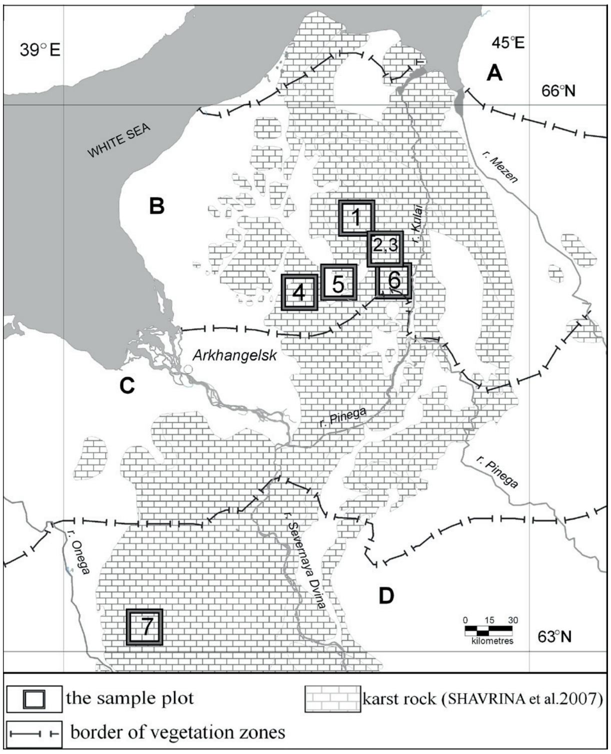

Fig 2. Geographical location of the seven plots for *Larix sibirica* Ledebour in the Arkhangelsk region

A – tundra-forest, B – sub-tundra-forest taiga, C – northern taiga, D – middle taiga

Table 1. Key characteristics: values (means) of the sampled stands

Sample plot	Stand composition	Age (yr)	DBH (cm)	Norm	Height (m)	Site index
1	6F:3L1:B	230	45	0.6	21	IV
2	6F:3L1:B	220	45	0.7	23	III
3	6F:3L1:B	220	44	0.7	21	IV
4	6F:3L1:B	200	48	0.6	23	III
5	5P:4L1:B	210	45	0.6	24	III
6	6F:3L1:B	210	43	0.6	23	III
7	5L:3F2:P	230	40	0.6	25	III

F – fir-tree, L – larch-tree, B – birch-tree, P – pine-tree

Table 2. Climatic characteristics of the sample plots

Subzone of taiga	Temperature (°C)		Period with temperature > 10°C (days)	Annual precipitation (mm)
	annual mean	average July		
Sub-tundra taiga*	0.0	14.6	75–85	649
Middle taiga**	1.1	17.3	88–108	576

*according to Semenov et al. (2003), **according to Kurnaev (1973)

taiga (Fig. 2). The studied areas are located in territories with different compositions of karst rock.

Sample plots 1–6 are located in the sub-tundra taiga. This region is characterised by harsh climatic conditions (Table 2).

Sample plot 7 is located in the middle taiga. The sampled larch wood was studied in terms of its physical and mechanical properties according to GSSSD 69–84 (Vihrov 1949; Karlman et al. 2005).

Wood tissue was extracted and examined in terms of its macrostructure and density only for old trees. Core samples were taken using an increment borer perpendicularly to the tree trunk at a height of 1.3 m from the ground surface. In total, 15 cores were selected from each of the seven plots, following a south to north transect. The drying of timber samples was carried out for a month at room temperature in order to reach 8–10% moisture content (Melehov et al. 2003). To measure the tree ring width and the share of latewood an MBS-1 binocular microscope (LOMO, USSR) equipped with a micrometre measuring to the nearest 0.01 mm was used. The density of the timber (ρ) was measured by the method of maximum moisture in the middle part of core samples (Polubojarinov 1976). The level of density under room conditions (ρ_{12} – 12% relative humidity) was calculated according to Polubojarinov (1976) as Eq. 1:

$$\rho_{12} = \frac{\rho}{0.802} \quad (1)$$

All core sample measurements were then averaged in terms of the value of the annual ring width, share of latewood content and wood density.

Soil capabilities were evaluated by the content of mobile K and P and were assessed by the Kirsanova method with modification by the Central Institute of Agrochemical Service of Agriculture (GOST 26207-91, 1992). The method is based on the extraction of mobile P and K compounds from the soil using a solution of hydrochloric acid (extraction solution), with a molar concentration of 0.2 mol·dm^{-3}. Quantification of mobile P is done on a photoelectric colorimeter (ZOMZ, USSR) and of mobile K on a flame photometer (ZOMZ, USSR).

Statistical analyses were performed using the Python (Version 2.7.12, 2016) package Sci Py (Version 0.18.1, 2016).

RESULTS

All sample plots display an average annual ring width of 0.68 to 0.93 mm, while the average content of latewood is 29.7 to 35.1%. Timber from sample plots 4 and 7 has an average density of 600 kg·m^{-3} and above, while in other sample plots the density varies from 540 to 576 kg·m^{-3} (Table 3). There was no significant difference between sample plots in these indicators: latewood content, density and annual ring width.

The analysis of the soil was conducted on plots 2–4, 7 and is presented in Table 4.

The results of the chemical analysis of soil samples show that the A_0 layers are rich in P and K, which is typical of soils with shallow carbonate moraine or limestone and gypsum. In most soils of spruce forests in the Northern taiga of the Arkhangelsk re-

Table 3. Mean values of annual ring width, wood density and latewood content of the sampled stands

Sample plot	Mean latewood content (%)	Mean annual ring width (mm)	Mean wood density ρ_{12} (min–max) ($kg \cdot m^{-3}$)
1	30.7 ± 0.9	0.74 ± 0.03	545.4 ± 16.8 (461–637)
2	33.6 ± 1.4	0.68 ± 0.02	564.1 ± 10.2 (502–698)
3	30.8 ± 0.8	0.78 ± 0.05	560.2 ± 11.4 (500–643)
4	35.1 ± 0.9	0.92 ± 0.11	619.2 ± 11.9 (558–669)
5	29.7 ± 1.5	0.77 ± 0.03	540.5 ± 12.5 (458–600)
6	31.0 ± 1.1	0.70 ± 0.07	576.9 ± 12.3 (510–639)
7	34.1 ± 0.7	0.93 ± 0.03	600.2 ± 8.8 (533–676)

Table 4. P and K content of the soil horizons in the sample plots (Neverov et al. 2009)

Sample plot	Mobile K – K_2O ($mg \cdot kg^{-1}$)			Mobile P – P_2O_5 ($mg \cdot kg^{-1}$)		
	A_0	A_2	B_{Fe}	A_0	A_2	B_{Fe}
2	500 ± 7.7	26 ± 3.2	93 ± 3.7	1,130 ± 8.4	64 ± 2.9	90 ± 2.5
3	480 ± 5.4	22 ± 2.1	24 ± 2.4	1,830 ± 5.4	72 ± 2.5	58 ± 1.9
4	664 ± 4.3	29 ± 2.7	48 ± 3.1	1,559 ± 7.7	70 ± 2.8	76 ± 3.1
7	364 ± 4.3	38 ± 2.4	53 ± 7.2	1,170 ± 4.6	21 ± 1.8	20 ± 2.3
Middle taiga*	270	55	76	650	70	42

*according to Sklyarov and Sharova (1970), showing the values for the same type of soil

gion, the content of P_2O_5 is above the average data reported in comparable studies (Khmara 2008). In sample plot 3 the content of P_2O_5 in the A_0 horizon is the highest. The lowest content of P in the A_0 horizon is in sample plot 2. In sample plot 3 the average is twice as large and coincides with the value in the A_2 horizon. The K_2O also varies greatly by soil horizons: it reaches the highest value in the A_0 horizon in all sample plots and naturally decreases with depth to more than 10-times lower values. The lowest values of K_2O and P_2O_5 are detected in the A_0 horizon, as well as in the A_2 and B horizons of plot 7, where they reach values 2- to 4-times lower than in other plots.

Tables 5–7 show significant differences determined by ANOVA tests in the annual ring width, latewood content and wood density.

Statistical data processing enables us to establish the significance of differences in terms of density and microstructure of wood between the averages of the pre-tundra and the taiga. However, sample plots 5 and 6 have a false distinction to sample plot 7.

Fig. 3 shows a linear relationship between the wood density and the latewood content, as well as the annual ring width. Both relationships illustrate

Table 5. Significant differences in the one-way ANOVA test of latewood contents

Sample plot	1	2	3	4	5	6	7
1	–						
2	**0.16**	–					
3	**0.29**	**0.41**	–				
4	0.01	**0.27**	0.00	–			
5	0.00	**0.53**	0.05	**0.53**	–		
6	**0.55**	**0.07**	**0.14**	0.00	0.01	–	
7	0.00	**0.13**	0.00	**0.06**	**0.23**	0.00	–

differences at the significance level α = 0.05 are in bold

Table 6. Significant differences in the one-way ANOVA test of annual ring widths

Sample plot	1	2	3	4	5	6	7
1	–						
2	**0.29**	–					
3	**0.13**	0.00	–				
4	**0.5**	**0.96**	0.04	–			
5	**0.09**	0.00	**0.49**	**0.06**	–		
6	**0.07**	0.00	**0.47**	0.03	**0.47**	–	
7	0.00	**0.06**	0.01	0.00	**0.14**	**0.13**	–

differences at the significance level α = 0.05 are in bold

Table 7. Significant differences in the one-way ANOVA test of wood densities

Sample plot	1	2	3	4	5	6	7
1	–						
2	**0.43**	–					
3	**0.73**	**0.26**	–				
4	0.04	0.10	0.00	–			
5	0.05	0.03	**0.09**	0.04	–		
6	0.04	**0.06**	**0.08**	0.02	0.01	–	
7	0.05	**0.08**	0.05	0.04	**0.27**	**0.06**	–

differences at the significance level α = 0.05 are in bold

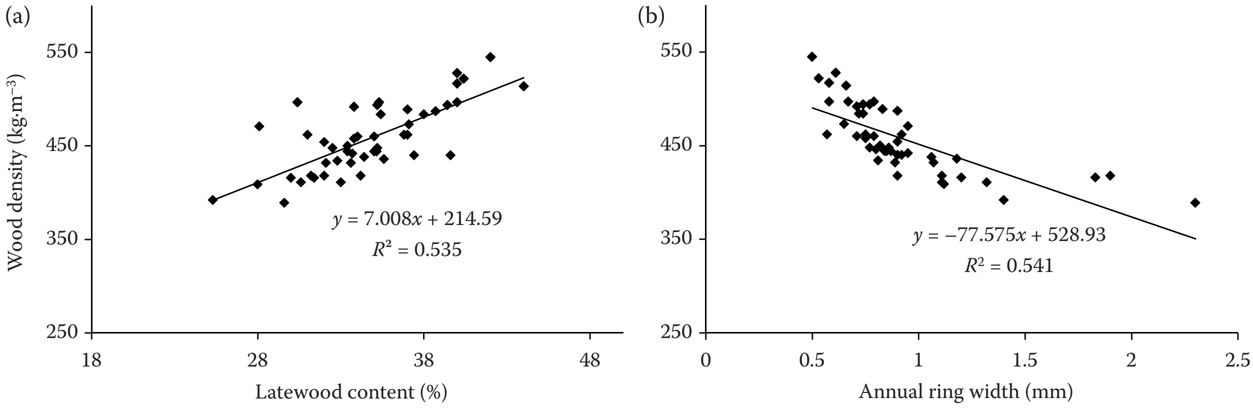

Fig. 3. The relationship between wood density (ρ_0) and latewood content (a), annual ring width (b)

the known mechanism between increasing ring width and decreasing wood density due to a decrease in the latewood amount.

DISCUSSION

Fig. 4 shows a direct correlation between latitude and yield class of the stand in different forest associations. This indicates a direct dependence of the growth rate of forest on changes in latitude.

The determined differences in growth between southern and northern plots, in spite of extreme differences in the temperature and the length of vegetation period, can be explained by the overlapping influences of compensating conditions in soil nutrients and soil water supply. However, missing gradients of several north-south plots along a wider catena and the low number of investigation plots in some climate regions limit identifying clear dependences between climate and growth, like those shown in a similar investigation of spruce in the region of the middle taiga and sub-tundra taiga (Lvov, Ipatov 1976).

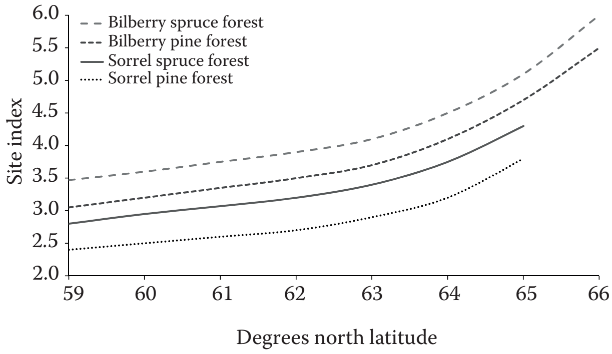

Fig. 4. Variability of the average site index and the latitude (Volosevich 1984)

Timber density values, as well as the maximum, minimum and average density for spruce, are generally lower in regions with low temperatures and high precipitation (van der Maaten-Theunissen et al. 2013), in accordance with the rule of lower latewood production in the case of decreased growth or ring width.

The difference in latitude between the larch test areas in the middle and sub-tundra taiga is 2°. The climate in the sub-tundra taiga is colder and more humid; however, the observed differences in the macrostructure are insignificant.

In the northern taiga, plant mineralisation occurs slowly due to low temperature. Soluble degradation products are quickly leached from the soil due to a high amount of precipitation. On top of the soil, raw humus and peat deposit are mainly accumulated. Aggressive soluble fulvic and humic acids provide mobile complexes with Fe and Al. Ca, Mg, K, P and Na, entering into the soil during the decomposition of plant residues are readily leached from the soil. However, they do not suffice to neutralise the organic acids, so strong acidic conditions are formed (about pH 4) in the top soil, resulting in a deficit of many elements, especially N, P, Ca, K, Na (Perelman, Kasimov 1999).

Increasing pH in the root horizons reflects the similar occurrence of a calcareous horizon in the underlying stratum with neutral and slightly medium alkaline reaction. The presence of additional sources of nutrient elements leads to improved site indices of the stand (Goryachkin et al. 2010).

CONCLUSIONS

This study found insignificant differences in density, latewood content and annual ring width in larch timber with latitude of the research site. The differences in the latewood content, annual ring width and timber density values are not more than 12, 20 and 10%, respectively, between plots located at latitudes of the sub-tundra and middle taiga. This can be explained by the advantages in the growth of these stands in the karst landscape, which possess abundant mineral nutrition. Geological (soil condition) factors can cover the influence of climatic factors and contribute to the formation of productive larch stands in the sub-tundra taiga in the European part of Russia.

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