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VARIABILITY PROPERTIES OF *Pinus sylvestris* L. WOOD IN GROWING STOCK UNDER TECHNOGENIC IMPACT

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The issues of variability of pinewood (*Pinus sylvestris* L.) properties in growing stock located in the vicinity of operating industrial facilities is still relevant. The paper aims to assess the technogenic impact on the radial increment as well as the physical and mechanical properties of pinewood in the conditions of Northern Taiga. The impact of the distance from the source of emissions on variability of the radial increment and the volume and technical properties of wood were determined. Distribution maps of the conventional wood density and its compressive strength along the fibers inside the trunk were formed. It is found that with a decrease in the distance from the source of emissions, the average value of the radial increment of trees occurs. It is revealed that there is a decrease in wood density from the butt to the top, and from the pith to the sapwood. Also, it is determined that wood density increases as the distance to the source of emissions decreases. However, there were obtained no valid differences of the indicator of wood resistance to compression along the fibers at various distances from to the source of emissions.
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Introduction

The issue of studying heterogeneity of the pine trunk (*Pinus sylvestris L.*) in terms of the physical and mechanical properties of wood is still of practical interest. Such studies help to better understand the process of wood formation at various age stages of tree growth and depending on the growing conditions [14, 15]. In tandem with the study of growth, wood density indices also make it possible to evaluate the intensity of tree cambium activity in various trunk zones [19, 34]. Uniformity of wood density inside the trunk appears to be its advantage in terms of wood processing, whereas sharp fluctuations of strength characteristics of wood inside the trunk up and down its section are unfavourable for most product ranges [12].

It is obvious that within a single forest stand, the physical and mechanical wood properties of individual trees can vary significantly. Typically, the variability of these properties occurs at a low level of variability. For example, specific wood density of pine in an air-dry state fluctuates within the range from 0.41 to 0.60 g/cm^3. Trees of the same age class, similar in development and growing in the identical conditions are supposed to form wood with similar properties [3, 13, 22, 25, 26, 32].

With the advancement to the south from the northern areas, pine shows an expected decrease in the technical properties of wood. Our data shows [3, 16, 28, 33] that the average value of the compressive strength along the fibers of pine, which grows in the Northern European conditions, is 450–500; in the Central European regions – 439; within the territory of Ukraine and Białowieża Forest – 384 and 377 kgf/cm^2, respectively (measurement units are given in accordance with the data sources). Moreover, there is a functional dependence of the technical and bulk properties on the structure of annual growth. It should also be taken into account that the data on the high variability of the physical and mechanical properties of wood from individual trees that can be found in scholarly literature is substantially influenced by differences in research objects and varying methodological approaches used by the authors [20].

The studies show [4, 5, 21, 30, 33] that due to the impact of industrial emissions, in particular the wood processing industry, a decrease in the period of cambial activity of conifers was observed, as a result the number of early wood tracheids declined in the annual ring of the wood trunk, while the share of late wood grew alongside the deterioration of the growing conditions. Also, there is an upward trend in the percentage of late tracheids in the structure of the annual ring as long as the distance to the sources of pollution decreases. As the distance to them gets shorter, a consistent decrease in the total value of the radial increment is noted. The impact of the anthropogenic load is more vividly reflected in low-productive forest stands, in particular, in forest stands of the sphagnum group.

The study purpose is an analysis of the technogenic impact on the radial increment as well as the physical and mechanical properties of pine wood in Northern Taiga.

Research objects and methods

The research was carried out on 11 sample plots (trial areas) in the ripe pine stands of the 5th quality class of the fruticulose-sphagnum forest type in the Northern Taiga zone (the area of the Northern Dvina River estuary). Establishment of the sample plots was done at various distances from the nearest source of aerotechnogenic emissions (Arkhangelsk Pulp and Paper Mill; Arkhangelsk Thermal Power Plant) in accordance with the procedures, recommendations and regulatory reference materials adopted from the forest management practice [2, 8, 18, 23]. The distance towards the source of emissions reflects the degree of aerotechnogenic pollution [29].

There was a complete inventory of trees carried out on the sample plots with the measurement step of 2-cm thickness. Based on the results of the measurement performed with the help of the methods adopted from forest inventory, the average diameter, height, sum of the trunk cross-sections, the overall stock, and the composition formula of the forest stand were determined. To determine the radial increment at the height of 1.3 m from the trunk base the cores of the pinewood were selected based on the method of random sampling (not less than 30 pine trees per each sample plot).

To determine the physical and mechanical wood properties beyond the area of the sample plots, 7 model trees were selected [10]. A sample of saw cuts and cores from each model tree was done at the following heights: 1.3 m from the root collar; at relative heights (*H*) of the trunk: 0, 1/4, 2/4, 3/4. At each height, up to 5 wood samples of 20×20×30 mm in size were selected: 3 samples in the core (center, middle and periphery) and 2 samples in the sapwood [7]. The zone of juvenile wood was excluded from the experiment. The value of the radial increment as well as the width of the zones of early and late tracheids was measured in wood cores using a stereoscopic microscope MBS-1 with an accuracy of ±0.01 mm. The percentage of late wood in the annual ring was calculated [24].

The basic wood density was determined based on the method of maximum sample humidity, which has a relatively small volume [9, 13, 31]. The basic wood density characterizes the dry basis of lignin in the volume unit of the fresh wood. In addition to it, an indicator of wood compressive strength along the fibers was chosen as a criterion of wood mechanical properties. Also, the validity of this choice is determined by the fact that wood structures, for the most part, while in operation appear to undergo a load precisely under compression and, to a lesser extent, structures undergo a load under bending and tension [16, 30]. Moreover, when conducting strength tests, it is enough to provide a load along the fibers, that is, along the trunk axis, while rotation around the axis does not affect the accuracy of the experiment in any way, which does not hold true, for example, when determining the wood's ultimate strength under compression across the fibers. This largely determines the low level of variability of this indicator [6, 13, 33]. The research test [11] was conducted with the help of a universal testing machine SHIMADZU, model AGS-100kNX, which was verified at the Arkhangelsk Center of Standardization and Metrology.

The processing of the experimental data is based on correlation analysis [17]. The findings and regularities are reliable at a significance level of 5 %. All measurement results were processed using MS Excel and developed to accelerate calculations of analytical programs in C++ using a specialized statistical analysis and forecasting package ALGLIB.

Results and discussion

As a result of this study, it was determined that the total value of the radial increment in pine stands of the fruticulose-sphagnum forest type decreased when approaching the source of emissions (Fig. 1). The approximation ratio of the obtained dependences increases from the center of the core to the sapwood. At the same time, in the central part of the core, the coefficient of determination (R^2) does not reach the value of 0.2. The lack of dependence is obviously associated with a low level of aerotechnogenic pollution in the 1940s. The detected dependence is marked at the heights (0*H*, 1/4*H*, 1.3 m) located in the trunk part cleared of wood knots. The difference in the radial increment of the sapwood and the core periphery between the forest stands growing at a distance of up to 8 km and farther from the source of emissions is noticed.

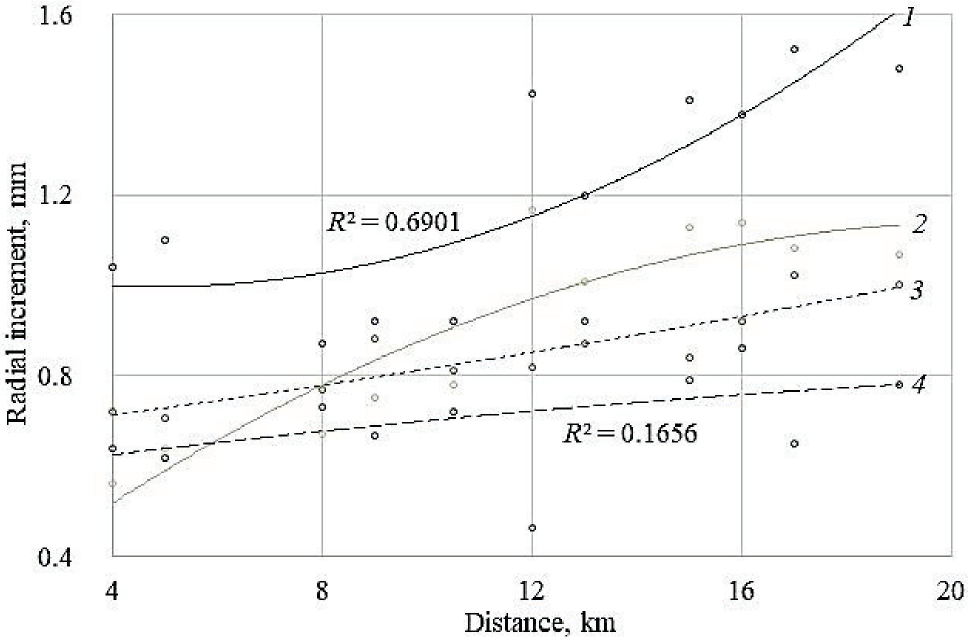

Fig. 1. Variability of the radial increment at the pine trunk bottom depending on the distance from the source of emissions: *1* – sapwood; *2* – core periphery; *3* – core middle; *4* – core center

Fluctuation of variability of the radial increment (all along the trunk radius) occurs within the range of 25–54 % with an increase in the basipetal direction inside the trunk and when approaching the emission source. A tight correlation between the value of growth in diameter and the width of the late wood zone (Table) is observed, which is very logical and consistent with conclusions of other authors [1, 4, 27, 29]. When evaluating growth only over the last 30 years, the correlation ratio significantly reduces. The result obtained requires additional studies to be conducted and applying measurements of the anatomical organization of individual elements in the radial increment such as the number of tracheids of the early and late wood zone, their linear sizes, etc.

Values of the correlation ratio between growth and width of the late wood zone

Distance, km	4	8	12	16	20
Correlation ratio (r)	0.815	0.836	0.797	0.781	0.823

The width of the late wood zone and the share of its participation in the formation of the annual ring are some of the most important indicators that characterize the technical properties of wood; the higher their value, the stronger the wood both at fracture and compression. Based on the research results, it becomes possible to talk about a downward trend in correlation between the percentage of the late wood and increment value as the distance from the source of pollution increases; the level of the environmental pollution decreases (Table).

Based on the results of laboratory measurements of basic wood density, a data set was formed, during the processing of which maps of the density distribution inside the trunk were designed separately for the experimental plots, and on the whole for the study area (Fig. 2). A decrease in the basic density was determined alongside an increase in the height of the wood sample with a slight levelling off in the crown area. This pattern seems quite logical, provided that the distribution of the main mechanical loads on the butt-log portion of the trunk is taken into account. The nature of the dynamics of wood density along the trunk radius for various heights of sample selection is described by the following dependences: *s*-shaped curve at the height of 0*H*, a hyperbolic curve at the breast height (1.3 m); and a parabolic curve or a straight line at the heights of 1/4*H* and 2/4*H*. The density changes between wood in the central part of the core and sapwood at the heights of 0*H* and 1.3 m are significant.

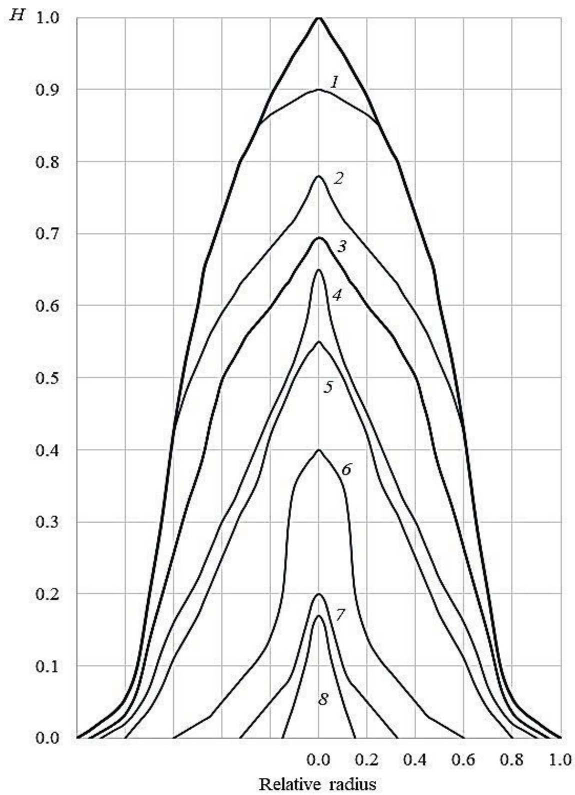

Fig. 2. Wood density distribution inside the pine trunk. Forest type – fruticulose-sphagnum; area – the Northern Dvina River estuary. Isolines, g/cm^3: *1* – 350; *2* – 375; *3* – 400; *4* – 425; *5* – 450; *6* – 475; *7* – 500; *8* – 525

It was found that pinewood density at the recorded heights (average radial value) of the sample increased whenever the distance to the source of emissions decreased (Fig. 3).

On average, the region under study reveals a consistent positive correlation of the basic density and wood compressive strength along the fibers, both in the core and in the sapwood of the trunk (0.767 and 0.547, respectively). The different nature of the dynamics of the indicator under consideration along the radius depending on the height of the sample was determined (Fig. 4). In the butt-log portion of the trunk (0*H* and 1.3 m), the indicator of wood resistance to compression decreases incrementally with the advancement along the radius from the center of the trunk. In contrast, at heights above 1/2 *H* and 1/4*H* it increases.

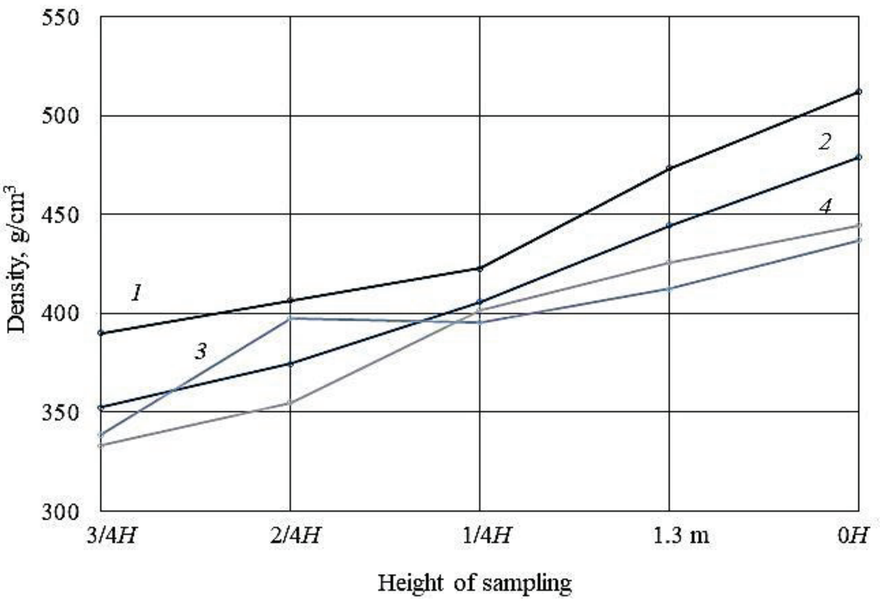

Fig. 3. Wood density distribution inside the pine trunk at different distances from the source of emissions, km: *1* – 4; *2* – 8; *3* – 12; *4* – 16

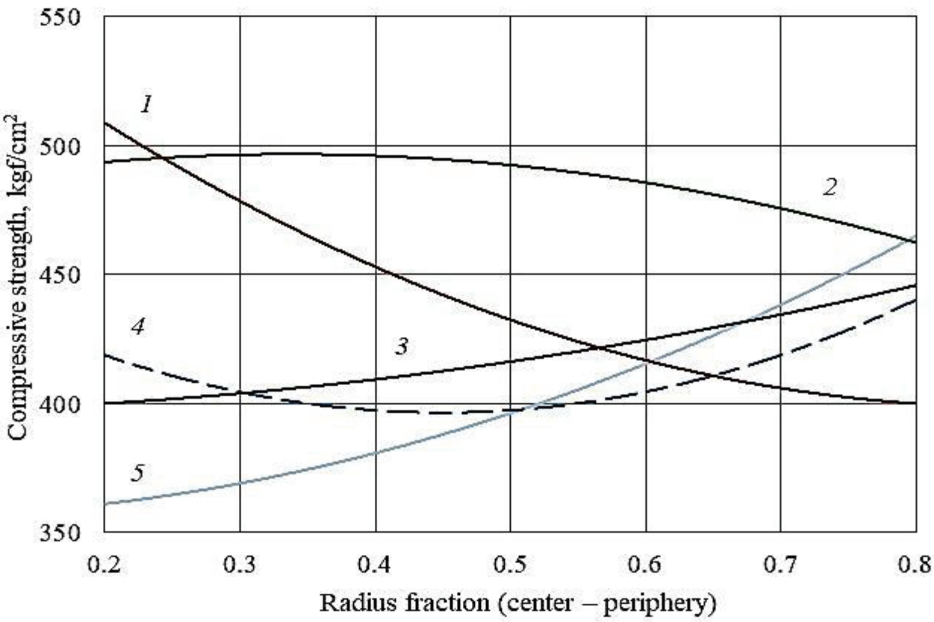

Fig. 4. Dynamics of wood resistance to compression along the fibers inside the pine trunk: 1 – 0*H*; 2 – 1.3 m; 3 – 1/4*H*; 4 – 2/4*H*; 5 – 3/4*H* (height)

The level of variability of the indicator of wood compressive strength along the fibers does not exceed 20 %. When comparing the values of the indicator under consideration at different distances from the source of emissions, no valid differences were registered.

Conclusions

1. As the distance from the source of emissions decreases, the value of the radial increment of the fruticulose-sphagnum pine stands in the northern Taiga subzone decreases, while the density of pine wood increases.

2. Inside the trunk of a growing tree wood density decreases from the butt log to the top and from the center of the trunk to the sapwood.

3. A positive correlation between indicators of the relative wood density and its resistance to compression along the fibers was determined. No significant differences of this indicator at various distances from the source of emissions were revealed.

REFERENCES

1. *Алексеев А.С.* Радиальный прирост деревьев и древостоев в условиях атмосферного загрязнения // Лесоведение. 1993. № 4. С. 66–71. [Alekseev A.S. Radial Increment of Trees and Stands under Ambient Conditions. *Lesovedenie* [Russian Journal of Forest Science], 1993, no. 4, pp. 66–71].

2. *Анучин Н.П.* Лесная таксация. 5-е изд. М.: Лесн. пром-ть, 1982. 552 с. [Anuchin N.P. *Forest Inventory*. Moscow, Lesnaya promyshlennost' Publ., 1982. 552 p.].

3. *Бабич Н.А., Мелехов В.И., Антонов А.М., Клевцов Д.Н., Коновалов Д.Ю.* Влияние условий местопроизрастания на качество древесины сосны (*Pinus sylvestris* L.) в посевах // Хвойные бореальной зоны. 2007. Т. XXIV, № 1. С. 54−58. [Babich N.A., Melekhov V.I., Antonov A.M., Klevtsov D.N., Konovalov D.Yu. Impact of Habitat Conditions on the Quality of Pinewood (*Pinus sylvestris* L.) in Plantings. *Hvojnye boreal'noj zony* [Conifers of the boreal area], 2007, vol. 24, no. 1, pp. 54−58].

4. *Белов А.А.* Особенности радиального прироста древесины в ослабленных сосняках-черничниках Брянской области, загрязненных радионуклидами // Лесохоз. информ. 2017. № 1. С. 42–51. [Belov A.A. Features of the Radial Wood Growth in the Weakened Pine-Bilberries of Bryansk Region Contaminated with Radionuclides. *Lesokhozyaystvennaya informatsiya* [Forestry information], 2017, no. 1, pp. 42–51].

5. *Вахнина И.Л.* Радиальный прирост сосны обыкновенной (*Pinus sylvestris* L.) в зеленой зоне г. Читы во второй половине прошлого столетия // География и природные ресурсы. 2011. № 1. С. 180–182. [Vakhnina I.L. Radial Increment in Scots Pine (*Pinus sylvestris* L.) in the Greenbelt of the City of Chita in the Latter Half of the Last Century. *Geografiya i prirodnyye resursy* [Geography and Natural Resources], 2011, no. 1, pp. 180–182].

6. *Вихров В.Е., Лобасенок А.К.* Технические свойства древесины в связи с типами леса. Минск: Изд-во М-ва высш., сред. спец. и проф. образования БССР, 1963. 72 с. [Vikhrov V.E., Lobasenok A.K. *Technical Properties of Wood in Relation to Forest Types*. Minsk, MVSSPO BSSR Publ., 1963. 72 p.].

7. *Гаузнер С.И., Кивилис С.С., Осокина А.П., Павловский А.Н.* Измерение массы, объема и плотности. М.: Изд-во стандартов, 1972. 624 с. [Gauzner S.I., Kivilis S.S., Osokina A.P., Pavlovskiy A.N. *Measurement of Mass, Volume and Density*. Moscow, Izdatel'stvo standartov, 1972. 624 p.].

8. ГОСТ 16128–70. Пробные площади лесоустроительные. Методы закладки. М.: Изд-во стандартов, 1971. 23 с. [*GOST 16128-70. Forest Management Sampling Plots. Methods of Laying out*. Moscow, Izdatel'stvo standartov, 1971. 23 p.].

9. ГОСТ 16483.1–84. Древесина. Метод определения плотности. М.: Изд-во стандартов, 1985. 6 с. [*GOST 16483.1-84. Wood. Methods for Definition of Density.* Moscow, Izdatel'stvo standartov, 1985. 6 p.].

10. ГОСТ 16483.6–80. Древесина. Методы отбора модельных деревьев и разделки их на кряжи для определения физико-механических свойств древесины насаждений. М.: Изд-во стандартов, 1980. 4 с. [*GOST 16483.6-80. Wood. Method of Selection of Model Trees and Logs for Determination of Physical and Mechanical Properties of Wood Plantations*. Moscow, Izdatel'stvo standartov, 1980. 4 p.].

11. ГОСТ 16483.10–73. Древесина. Методы определения предела прочности при сжатии вдоль волокон. М.: Изд-во стандартов, 1999. 7 с. [*GOST 16483.10–73. Wood. Methods for Determination of Ultimate Strength in Compression Parallel the Grain.* Moscow, Izdatel'stvo standartov, 1999. 7 p.].

12. *Гриб В.М.* Влияние хозяйственных мероприятий на качество древесины сосны обыкновенной // Совершенствование лесного хозяйства и защитного лесоразведения: сб. науч. тр. УСХА. Киев, 1987. С. 55–58. [Grib V.M. The Influence of Economic Measures on the Quality of Scots Pine Wood. *Improving Forestry and Protective Afforestation: Collection of Academic Papers of USKhA*. Kiev, 1987, pp. 55–58].

13. Древесина. Показатели физико-механических свойств. РТМ. М.: Ком. стандартов при СМ СССР, 1962. 48 с. [*Wood. Characteristics of Physical-Mechanical Properties. Technical Guides*. Moscow, Committee of Standards at the Council of Ministers of the USSR, 1962. 48 p.].

14. *Кищенко И.Т.* Формирование древесины ствола *Picea abies* (L.) Karst. в разных типах сообществ таежной зоны // Изв. вузов. Лесн. журн. 2019. № 1. С. 32–39. [Kishchenko I.T. Formation of *Picea abies* (L.) Karst. Trunk Wood in Different Taiga Zone Communities. *Lesnoy Zhurnal* [Russian Forestry Journal], 2019, no. 1, pp. 32–39]. DOI: 10.17238/issn0536-1036.2019.1.32, URL: http://lesnoizhurnal.ru/upload/iblock/f41/32_39.pdf

15. *Косиченко Н.Е.* Формирование структуры и плотности в онтогенезе // Строение, свойства и качество древесины-2000: материалы III межд. симп. Петрозаводск: ИЛ КарНЦ РАН, 2000. С. 58–61. [Kosichenko N.E. *Formation of Structure and Density in Ontogeny. Structure, Properties and Quality of Wood-2000: Proceedings of the 3rd International Symposium*. Petrozavodsk, IL KarRC RAS Publ., 2000, pp. 58–61].

16. *Леонтьев Н.Л.* Исследование физико-механических свойств кольской сосны // Физико-механические свойства древесины. М.; Л.: Гослесбумиздат, 1953. С. 122–141. [Leont'yev N.L. A Study of the Physical and Mechanical Properties of Kola Pine. *Physical and Mechanical Properties of Wood*. Moscow, Goslesbumizdat Publ., 1953, pp. 122–141].

17. *Леонтьев Н.Л.* Техника статистических вычислений. 2-е изд. М.: Лесн. пром-сть, 1966. 250 с. [Leont'yev N.L. *Technique of Statistical Computations*. Moscow, Lesnaya promyshlennost' Publ., 1966. 250 p.].

18. Лесотаксационный справочник для северо-востока европейской части СССР: нормативные материалы для Архангельской, Вологодской областей и Коми АССР. Архангельск: Правда Севера, 1986. 358 с. [*Forest Inventory Handbook for the Northeast of the European Part of the USSR*: Guidance Materials for Arkhangelsk and Vologda Regions and the Komi ASSR. Arkhangelsk, Pravda Severa Publ., 1986. 358 p.].

19. *Лобжанидзе Э.Д., Гоциридзе Л.А., Цинцадзе М.С.* Биология образования древесины сосны // Современные проблемы древесиноведения. Красноярск, 1987. С. 64–65. [Lobzhanidze E.D., Gotsiridze L.A., Tsintsadze M.S. Biology of Pinewood Formation. *Modern Issues of Wood Science*. Krasnoyarsk, 1987, pp. 64–65].

20. *Мамаев С.А.* Формы внутривидовой изменчивости древесных растений (На примере семейства *Pinaceae* на Урале). М.: Наука, 1973. 284 с. [Mamayev S.A. *Forms of Intraspecies Variability in Woody Plants (Case Study of Pinaceae Family in the Urals*). Moscow, Nauka Publ., 1973. 284 p.].

21. *Мартынюк А.А.* Сосновые экосистемы в условиях аэротехногенного загрязнения. М.: ВНИИЛМ, 2004. 160 с. [Martynyuk A.A. *Pine Ecosystems in the Conditions of Aerotechnogenic Pollution*. Moscow, VNIILM Publ., 2004. 160 p.].

22. *Мелехов И.С.* Значение структуры годичных слоев и ее динамики в лесоводстве и дендроклиматологии // Изв. вузов. Лесн. журн. 1979. № 4. С. 6–14. [Melekhov V.I. The value of the structure of annual layers and its dynamics in forestry and dendroclimatology. *Lesnoy Zhurnal* [Russian Forestry Journal], 1979, no. 4, pp. 6–14]. URL: http://lesnoizhurnal.ru/apxiv/1979.pdf

23. Методические рекомендации по выделению групп типов леса в таежной зоне европейской части РСФСР. М.: ВНИИЛМ, 1979. 61 с. [*Instructional Guidelines for the Identification of Forest Type Groups in the Taiga Zone of the European Part of the RSFSR*. Moscow, VNIILM Publ., 1979. 61 p.].

24. *Молчанов А.А., Смирнов В.В.* Методика изучения прироста древесных растений. М.: Наука, 1967. 95 с. [Molchanov A.A., Smirnov V.V. *Methodology for Studying the Increment of Woody Plants*. Moscow, Nauka Publ., 1967. 95 p.].

25. *Москалева С.А., Чибисов Г.А., Крыжановская Л.Е., Белова Т.В.* Влияние рубок ухода на плотность древесины стволов сосны в продольном направлении // Материалы отчет. сессии по итогам НИР за 1987 г. Архангельск: АИЛИЛХ, 1988. С. 63–65. [Moskaleva S.A., Chibisov G.A., Kryzhanovskaya L.E., Belova T.V. The Influence of Cleaning Cutting on Wood Density of Pine Trunks along the Length. *Proceedings of the Reporting Session Summarizing the Research Results in 1987*. Arkhangelsk, AILILKh Publ., 1988, pp. 63–65].

26. *Перелыгин Л.М.* Строение древесины. М.: Изд-во АН СССР, 1954. 200 с. [Perelygin L.M. *Wood Structure*. Moscow, AN SSSR Publ., 1954. 200 p.].

27. *Пиндюра Б.С., Семенчук Е.С.* Изменение соотношения прироста ранней и поздней древесины у дефолиированных хвойных в эксперименте // Хвойные деревья и насекомые-дендрофаги. Иркутск: Сиб. ин-т физиологии и биохимии растений, 1978. С. 105–113. [Pindyura B.S., Semenchuk E.S. Change in the Growth Ratio of the Early and Late Wood in Defoliated Conifers in the Experiment. *Conifers and Dendrophagous Insects*. Irkutsk, SIFIBR Publ., 1978, pp. 105–113].

28. *Полубояринов О.И., Федоров Р.Б.* Изменчивость плотности древесины сосны и ели в Европейской части СССР // Лесоводство, лесные культуры и почвоведение. Л.: ЛТА, 1982. Вып. 11. С. 128–133. [Poluboyarinov O.I., Fedorov R.B. Variability in Wood Density of Pine and Spruce in the European Part of the USSR. *Forestry, Forest Crops and Soil Science*. Leningrad, LTA Publ., 1982, iss. 11, pp. 128–133].

29. *Тарханов С.Н., Прожерина Н.А., Коновалов В.Н.* Лесные экосистемы бассейна Северной Двины в условиях атмосферного загрязнения. Диагностика состояния. Екатеринбург: УрО РАН, 2004. 333 с. [Tarkhanov S.N., Prozherina N.A., Konovalov V.N. *Forest Ecosystems of the Northern Dvina Basin in the Conditions of Atmospheric Pollution. Diagnostics*. Yekaterinburg, UB RAN Publ., 2004. 333 p.].

30. *Тарханов С.Н., Щекалев Р.В.* Внутриорганизменная и внутрипопуляционная изменчивость количественных признаков *Pinus sylvestris* L. в северной тайге Северо-Двинского бассейна при атмосферном загрязнении // Лесн. вестн. 2007. № 5. С. 116–123. [Tarkhanov S.N., Schekalev R.V. Variability of Quantitative Attributes *Pinus sylvestris* L. at a Level of an Organism and Group in Northern Taiga at Atmospheric Pollution. *Lesnoy vestnik* [Forestry Bulletin], 2007, no. 5, pp. 116–123].

31. *Уголев Б.Н.* Испытания древесины и древесных материалов. М.: Лесн. пром-сть, 1965. 251 с. [Ugolev B.N. *Testing of Wood and Wood-Based Materials*. Moscow, Lesnaya promyshlennost' Publ., 1965. 251 p.].

32. *Чавчавадзе Е.С.* Древесина хвойных. Л.: Наука, 1979. 169 с. [Chavchavadze E.S. *Wood of Conifers*. Leningrad, Nauka Publ., 1979. 169 p.].

33. *Щекалев Р.В., Тарханов С.Н.* Радиальный прирост и качество древесины сосны обыкновенной в условиях атмосферного загрязнения. Екатеринбург: УрО РАН, 2006. 125 с. [Schekalev R.V., Tarhanov S.N. *Radial Increment and Quality of Scots Pine Wood in Terms of Atmospheric Pollution*. Yekaterinburg, UB RAS Publ., 2006. 125 p.].

34. Seth M.K., Chaman L., Madhu B. Effect of Several Variables on Specific Gravity in Different Zones of Blue Pine. *Indian Journal of Forestry*, 1988, vol. 11(1), pp. 42–47.

ИЗМЕНЧИВОСТЬ ХАРАКТЕРИСТИК ДРЕВЕСИНЫ *Pinus sylvestris* L. В ДРЕВОСТОЯХ ПРИ ТЕХНОГЕННОМ ВОЗДЕЙСТВИИ

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Вопросы изменчивости характеристик древесины сосны обыкновенной (*Pinus sylvestris* L.) в насаждениях, произрастающих в зонах влияния промышленных объектов, не теряют своей актуальности. Цель данной работы – оценка влияния техногенного воздействия на радиальный прирост и физико-механические характеристики древесины сосны в условиях северной тайги. Проанализировано влияние фактора расстояния от источника промышленных выбросов на изменчивость радиального прироста, объемных и технических характеристик древесины. Сформированы карты распределения условной плотности древесины и ее сопротивления сжатию вдоль волокон внутри ствола. Выявлено, что с сокращением расстояния до источника выбросов происходит уменьшение средней величины радиального прироста деревьев. Установлено снижение плотности древесины от основания к верхней части дерева и от сердцевины ствола к его заболони. Определена тенденция повышения плотности древесины с сокращением расстояния до источника эмиссий. Достоверных различий показателя сопротивления древесины сжатию вдоль волокон на разном расстоянии от источника эмиссий не выявлено.
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Ключевые слова: сосна, древесина, радиальный прирост, плотность древесины, сопротивление древесины сжатию вдоль волокон, расстояние до источника выбросов.

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