Journal of the Faculty of Forestry, Istanbul University 2010, 60 (1) 1-4

Influence of Anthropogenic Activity on Vital State and Productivity of Pine Stands

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Abstract

The purpose of this study was to analyze and to compare the data on the vital state and timber volume of primary weakly disturbed pine forests and of secondary pine forests formed under different kinds of anthropogenic impact, such as: selection cutting, clear cutting, aerotechnogenic pollution by wastes of timber, pulp and paper works. Objects were 137 permanent sample plots were launched in pine phytocenosises of different types (lichen, green-mossy) growing in taiga zone of the Komi Republic (European North-East of Russia). To estimate the vital state of tree stands, the index of stand disturbance was calculated by the formula for determining the weighted-mean class of damage to the trees comprising the stand. Primary and secondary pine forests formed under different kinds of anthropogenic impact were compared as to mean annual stems wood increment. It is shown the vital state of the secondary pine forests is inferior to that of the primary pine forests. Exposure to emissions from the pulp and paper industry leads to a decrease both in the vital state of stand and timber volume. Received during the first stage of researches results of plants biodiversity, structures, productivity and vital state condition of primary and secondary pine forests stands further will be used for assessment of a degree of various anthropogenic disturbances and ecological zoning of territory of the Komi Republic.

Keywords: Forest monitoring, forest felling, wood increment and volume.

1. Introduction

In a natural environment the vital condition of forest ecosystems depends on biological properties of trees species, site habitat conditions and influences natural abiotic (wilderness fires, windfalls and stormbreaks) and biotic (pests and rots disease) factors. Besides now forest ecosystems are under constantly increasing anthropogenic impact, connected as with increasing of volumes of clear-cuttings of different types, and increasing of air contamination by industrial releases. Therefore for collecting the detailed and comparable data on a degree of forests damages as a result of various kinds of pollution it is expedient to organize continuous monitoring.

Assessment of the vital condition of forest ecosystems under influence of aerotechnogenic emissions of various manufactures carry out on the permanent sample plots incorporated by deposition gradient and in "background" areas (Yarmishko, 1997). However it is rather frequently difficult to make the correct comparative analysis of received results. Therefore now forest lands in industrially advanced regions taking place on distance of 50-100 km from an emission source, it is necessary to belong to "conditionally background" areas. In them almost all forest areas were repeatedly exposed to various kinds of cutting, and researched secondary forests already have a certain degree of anthropogenic transformation.

The purpose of this study was to analyze and to compare the data on the vital state and timber volume of primary weakly disturbed pine forests and of secondary pine forests formed under different kinds of anthropogenic impact, such as: selection cutting, clear cutting, aerotechnogenic pollution by wastes of timber, pulp and paper works.

Received: 26.06.2008; accepted: 12.11.2009

2. Material and Methods

The region of study situated in the North-East of the European part of Russia. Pine forests (*Pinus sylvestris*) occupy 7.2 million ha (second place after spruce forests) in non-zonal habitats.

Objects were 137 permanent sample plots were launched in pine phytocenosises of different types (lichen, green-mossy), formed in anthropogenic unthreaded and threaded areas. Disturbed pine stands were influenced by forest felling ("slash-and-burn" agriculture, clear-cutting, clear-cutting with fire cleaning, and selection cutting), air pollution of pulp and paper mill.

Representative permanent sample plots have been chosen and valuated according to standard forest taxation methods. These plots are located in true moss pine forests (*Pinetum hylocomiosum*) and lichen pine forests (*Pinetum cladinosum*). Stem wood radial increment was measured and wood volume (gross, annual) was calculated according to classic methods. Distribution of trees after damage classes in stands are carried out according to international programme (ICP Forests Manual, 2006). To estimate the vital state of tree stands, the index of stand disturbance was calculated by the formula for determining the weighted-mean class of damage to the trees comprising the stand with the equation below (Alekseev, 1997):

$$I = \left(\sum_{i=0}^{4} i\, w_i \right) / W \qquad (1)$$

where I – index of stand disturbance, points; i – numbers of tree damage classes; points from 0 to 4; w – statistical share of trees belonging to i–the damage class (volume of trees, m^3); W – sum of statistical shares. According to the index wood stands were distinguished on degree of vital state: healthy (index 0 – 0.5), weakened (0.6 – 1.5), very weakened (1.6 – 2.5), dying (2.6 – 3.5) and dry woods (index > 3.6).

3. Results and Discussions

Analysis of stands taxation values of native northern taiga and middle taiga pine forests have shown that with advancing to the north their productivity decreases. So, the average class of site quality of mature and overmature lichen pine forests in middle subzone of taiga has made IV.4, true moss - III.7, in conditions of northern subzone - IV.6 and IV.0 accordingly. It is necessary to note, that the decreasing of relative density of tree stands with advancing to the north is marked only for lichen pine forests: 0.77 in middle subzone of taiga and 0.66 in northern. Relative density of tree stands of true moss pine forests in both subzones of taiga is averages 0.78.

Table 1 Index of stand disturbance different kind of pine forests

Anthro-pogenic impact type	Pine forest type	Generation	Age of generation, year	Index (I) of stand disturbance
Without impact (primary)	Pinetum cladinosum	I	200—350	0.85± 0.24
		II	100—120	0.56± 0.12
		III	60—100	0.18± 0.05
	P.hylocomiosum	I	200—350	0.90± 0.25
		II	100—120	0.47± 0.18
		III	60—100	0.25± 0.04
"Slash-and-burn" agriculture	P. cladinosum	I	70—100	0.14± 0.02
	P.hylocomiosum	I	60—100	0.29± 0.01
Selection cutting	P. cladinosum	I	100—140	0.35± 0.15
		II	60—105	0.75± 0.31
	P.hylocomiosum	I	95—200	0.64± 0.26
		II	65—120	0.94± 0.39
Clear cutting	P. cladinosum	I	70—120	0.39± 0.13
	P.hylocomiosum	I	60—120	0.45± 0.14
Aerotecho-genic pollution	P. cladinosum	I	100—165	0.62± 0.22
		II	70—120	0.78± 0.13
	P.hylocomiosum	I	95—100	0.56± 0.13
		II	60—90	0.68± 0.10

Primary pine forests have a certain degree of natural disturbance, which is explained mainly by the age of tree stands and the impact of forest fires (Table 1). This damage has an effect on the vital state of trees even after 40-50 years, increasing the degree of defoliation and the proportion of drybranches in the crown. Also primary pine forests of the "healthy stand" category were distinguished. Parameters of these stands make it possible to assess reliably damage level of pine forests growing in air pollution impact zone or after forest felling. The damage degree in 137 investigated pine stands in view of their age are: in 60…100-aged plantings 0.44 (0.10-0.96), 105…200-aged ones - 0.61 (0.23-1.27) and 210…350-aged ones - 0.94 (0.60-1.76).

For productivity assessment of tree stands used both yearly mean increment of wood in pre-mature, mature and overmature tree stands and yearly wood increment of one tree. Yearly mean wood increment of tree stands 100…200-aged native northern and middle taiga lichen pine forests appeared identical: 1.39±0.23 and 1.36±0.30 m^3/ha accordingly. However yearly mean wood increment of one tree (2.5-3.0 dm^3/year) in all inspected pine forests in middle subzone of taiga were higher than in northern taiga (1.9-2.4 dm^3/year). The wood increment of tree stands in middle taiga true moss pine forests 100…200-aged are: 1.91±0.32 m^3/ha yearly, in northern taiga - 1.50±0.17 m^3/ha yearly, an increment of wood of one tree - 3.9±0.6 dm^3/year and 2.9±0.4 dm^3/ year accordingly. A principal cause of decreasing of wood increment of trees in pine forests of northern taiga is decreasing of the season of active growth of their root systems, which connected with deterioration of thermal performances of soil. According to A.Y.Orlov and S.P.Koshelkov (1971), the low temperature of soil not only detains growth of roots, but also hampers a digestion of dissolved nutrients and decelerates process of an interchanging and transport of nutrients from root systems to above-ground organs. That eventually results in a decreasing of wood productivity.

It is considered, that for the lack of natural spontaneous factors (fires, windfalls, insect invasions, etc.) primary forest stands produce the greatest possible quantity of wood per ha. Comparison of mean annual stems wood increment of pre-mature primary
and secondary mossy pine forests has not revealed authentic distinctions between them (Table 2). It descends because on more humidified and rich soils volume and annual increment of wood of stands secondary mossy pine forests because of higher trees density the subsequent generation not only does not concede, but also in many events exceeds productivity of climax tree stands of the same age. However in primary lichen pine forests mean annual stems wood increment has appeared at 1.2-1.6 times above than in pre-mature secondary stands. It testifies that any anthropogenic breaking of the pine ecosystems growing in ecologically extreme site conditions (low fertility of soils, deficiency of a moisture, etc.) result to significant reduction of volume of secondary stands

For assessment of annual loss of wood volumes because of releases influence of pulp-and-paper works on secondary pine forests have carried out comparison yearly means of one tree wood increment with ones from pine stands formed after clear-cutting. It is shown, that yearly mean wood increment of one tree from polluted area in lichen pine forests is less on 1.1 dm^3, in true moss pine forests on 1.6 dm^3, than in other secondary pine forests. Taking into account, that average number of tree in middle-aged lichen pine forests from polluted area are 900 tree per ha, it is calculated, that annual loss of wood reaches up to 1 m^3/ha. In true moss pine forests it is even more loss of wood - up to 1.9 m^3/ha per year. It is calculated, that wood losses of pine stands from forested area around the timber industry complex, have consist from 30 up to 60 m^3 on each hectare within last 30 years.

For comparison of growth intensity of tree stands the method of an evaluation of their average diameter in the age of 60 years (minimum age among the investigated pine forests) has been approved. Reducing of diameters of uneven-age pine forests to 60-age stand has allowed us to lead correct comparative analysis of their growth(Table 3).

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Table 2 Mean annual stems wood increment in middle-aged and ripening stands of primary and secondary pine forests in middle taiga (x± m)

Mean annual stems wood increment	Pine forest type	Primary	Secondary, after:			
			"Slash-and-burn" agriculture	Selection cutting	Clear cutting	Aerotechnogenic pollution
Stand, m^3/ha	Pinetum cladinosum	2.49±0. 48	2.08± 0.25	1.53±0. 34	1.41± 0.40	1.37± 0.28
	P.hylocomiosum	2.67± 0.23	3.61± 0.79	1.54± 0.32	3.42± 0.55	2.09± 0.83
1 tree, dm^3	P. cladinosum	3.3± 0.5	4.8± 0.3	2.8± 0.7	2.8± 0.5	1.7± 0.4
	P.hylocomiosum	3.7± 0.7	4.8± 0.3	2.6± 0.8	3.8± 1.5	2.2± 0.6

Table 3 Mean DBH (cm) approximated for 60-ages Pine trees in primary and secondary pine forests in middle taiga

Pine forest type	Primary	Secondary, after:			
		"Slash-and-burn" agriculture	Selection cutting	Clear cutting	Aerotechnogenic pollution
Pinetum cladinosum	19.1	18.9	15.4	14.6	12.7
Pinetum hylocomiosum	17.4	16.4	15.7	14.3	13.7

4. Conclusions

The results of this work allow us to make the following conclusions:

1) Primary pine forests have a certain degree of natural disturbance, which is explained mainly by the age of tree stands and the impact of forest fires.

2) The vital state of the secondary pine forests is inferior to that of the primary pine forests, which is a consequence of cutting performed by various methods in the past.

3) Exposure to emissions from the pulp and paper industry leads to a decrease both in the vital state of stand and timber volume.

4) The data on the vital state and wood volume of natural pine forests applied to the inspection of a secondary pine stand makes it possible to determine the degree ("norm") of its spontaneous disturbance (accounted for by natural factors) and the degree of anthropogenic disturbance caused by various kinds of cutting or industrial pollution.

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