The composition and structure of mature aspen forests in Lisinsky Forestry Unit of the Leningrad region

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Abstract. The article addresses the structure of secondary aspen forests, which allows us to predict their productivity, as well as evaluate the features of the formation of the main types of taiga forests. We carried out an analysis of the vitality structure, which forms a basis for forest monitoring. All higher vascular plants, as well as ground, epiphytic and xylophytic species of mosses and lichens were also identified to assess the biological diversity of the stands studied. The study has established that the species diversity of the ground cover in aspen forests depends on the degree of the crown density.

1. Introduction

Logging have a significant impact on taiga ecosystems in the European part of Russia. This type of anthropogenic impact leads to serious changes and transformation of structural and functional relationships between all components of a biogeocenosis. Under the influence of man with his culture, the primary taiga melts “like wax in the face of fire” [1].

After deforestation of mature forests, a series of digressive-demutational changes of vegetation begins, leading to the formation of plant communities similar to the original ones. In the taiga zone, there are several stages of succession: herb stage followed by the formation of small-leaved (aspen, birch, gray alder) or pine stands, the sage of the spruce settle and the formation of a spruce forest [2]. As a rule, aspen (Populus tremula L.) plays a significant role in the composition of the leaved forest stage, forming both mono- and multi-dominant communities with the participation of birch and conifers. In the northern regions, aspen forests usually replace spruce stands of green-moss, bilberry, and wood sorrel types [3]. Recovery of spruce stands through aspen or birch stands often occurs on rather rich loamy or clay soils, while on sandy and sandy loam this process is more likely to occur with the participation of pine stands [4]. After felling of spruce forests, long-term secondary aspen forests (up to 5%) and stable secondary (up to 10%) of the prevailing type of forest conditions are often formed. In the European part of Russia, aspen forests occupy approximately 20% of the area and growing stock of all small-leaved forests [5].

Studying the dynamics of the structure of the secondary aspen forests allows us to predict their productivity during forest exploitation, as well as evaluate the features of the formation of the basic types of taiga forests. Assessment of the biological productivity of aspen forests is especially important for the rational management of forestry, as it provides better assessment and use of phytomass [6]. It is expected that in the near future the area and growing stock of aspen forests, which emerge in response to extensive clear cutting, will increase in the taiga zone of the European part of Russia. In this regard, there is a need to assess the productivity and accumulation of organic matter in...
aspen forests, with the aim of developing forestry measures and optimizing forestry, both in economic and environmental terms.

When considering the biogeocenotic functions of aspen phytocenoses, it is important to take into account the nature of the phyto environment which is different from the basic spruce forest types. The difference is largely due to the characteristics of the assimilation apparatus of edificators. In the course of restorative succession, a change in the structure and productivity of coenopopulations of many plant species is noted and entails a significant restructuring of other components of the biogeocenosis. Comparative studies in primary and secondary forest communities of vertical-fractional stratification of phytomass, as the main structural indicator that determines the environment-forming functions of the phytocenosis, are most important.

A number of researchers identified the following types of aspen forests for the north-west of Russia: dead-cover, green-moss (blueberry, fern, hornwort), long-moss (blueberry and lingonberry), herbaceous (common reed, stone bramble, wood sorrel, ground elder, aconite, meadowsweet, etc.) [7-9]. V I Vasilevich [10] distinguished cycles of associations of birch forests, aspen forests, and gray alder forests, similar in ecotope and composition of the lower layers: blueberry, wood sorrel, forest-reed, meadow-like, nemoral-herbaceous and wet-herbaceous.

According to Nitsenko [3], blueberry aspen forests belong to the group of mesophilic aspen forests on medium soils. They replace bilberry or wood sorrel coniferous forests. The blueberry aspen type [11] is widespread in flat areas and on gentle slopes with normal drainage on medium podzolic, sandy loamy and loamy soils. As a rule, other species (birch, spruce and less often pine) are also present. Aspen litter which is rich in ash elements, especially calcium, potassium and nitrogen, increases soil fertility. In addition, aspen litter has a high degree of decomposition, forms a litter with low acidity, which decomposes already by the middle of the following summer forming soft humus and contributing to the transition to sod type of soil [11]. The main associations are the following: bilberry–common reed, bilberry–wood sorrel, bilberry–stone bramble, bilberry-bracken and bilberry-lingonberry [11]. According to O G Chertov [12] on such forest lands, temporary associations are blueberry-birch or wood sorrel–aspen.

Ermilova V S [13] found that soils with temporary excess of moisture in the spring and with sufficient overall moisture with normal drainage are the best for aspen [14]. In addition, we consider soil with a proximity of groundwater favorable for growth of aspen (wood sorrel–grassy and transitional from wood sorrel–grassy to horsetail-meadowsweet types of forest).

Long-term secondary aspen forests are potential dark coniferous stands in which there is a tendency to spruce regeneration. The maximum age of long-term secondary aspen forests does not exceed 90 years [15].

Over the past 20 years, voluntary forest certification has become widespread not only in Western Europe, but throughout the world. For Russia, this is a relatively new phenomenon that is gradually transforming part of the national forest products market. It consists of documenting the conformity of the economic activities of an organization and/or a system for tracing the origin of forest products from the "harvester to the consumer" with the established requirements that ensure sustainable forest management and allow combining the economic, environmental and social needs of society.

2. Methods and Materials

As a basis for the research project, we used forest inventory materials of Lisinsky Educational and Experimental Forestry Unit. The following sites were selected for sampling plots: Lisinsky Forestry Unit, quarter No 15, sections 36, 37, 39, 41, 43, 46.

In this area there is a fairly wide variety of mature forests with spruce and the prevalence of old aspen. All communities are characterized by a significant amount of dead wood at different stages of decomposition which determines the abundance and diversity of wood-decay fungi. Most of them are indicator species of mature spruce forests. A stable microclimate, the presence of old trees of broad-leaved species and aspen determines the diversity of lichens and bryophytes, including Red Book listed species.
For carrying out forest inventory, geobotanical and floristic surveys we laid out four permanent sampling plots. Using a GPS navigator, we recorded the boundaries of these plots.

The following activities were carried out in each of the plots:
- all trees were tagged;
- density of crowns was determined for the whole stand and by species;
- the diameter and height of all trees were recorded;
- to determine the age and age structure of the stand, cores were taken from all trees using an increment borer;
- natural regeneration of all species was recorded in 10-fold repetition;
- at each plot, a geobotanical description was made taking into account the characteristics of each canopy layer (trees, undergrowth, grass-shrub layer, moss-lichen layer), such as density of crowns, projective cover, species composition [16];
- to identify the biological diversity and biological value of forests, all plant samples were identified and collected — vascular plants, ground, epiphytic and xylotrophic species of mosses and lichens;
- to assess the state of the stand, an analysis of its vitality structure, which is a necessary basis for monitoring forests, was carried out. This is required both for assessing the initial state of forest stands and its dynamics, as well as biological value, ecological role and resource potential of forest communities. When revealing the vitality structure of a stand, the ratio of the occurrence of trees of different categories of vitality (healthy, weakened, significantly weakened, dying and dead) was estimated. Names of forest types were assigned in accordance with the classification of forest conditions developed by Fedorchuk V N et al [17].

3. Results and Discussion

**Permanent sampling plot 1** (Size 25x30 m). The density of crowns of the stand was 80%. The stand formula (proportion of species timber volume): first layer: 8 Aspen 2 Spruce; second layer: 7 Spruce 2 Birch 1 Aspen. All aspen trees were described as healthy and were mainly in the first layer. The average diameter of aspen trees was 50 cm, and the average age was 70 years. The average age of spruce was 75-80 years, and the average diameter was 24–28 cm. The average age of birch was 70 years.

The vitality structure of the entire stand was the next: aspen: healthy, 6 pcs.; spruce: healthy, 21 pcs., weakened, 5 pcs., substantially weakened, 7 pcs., dead, 2 pcs.; total 35 pcs.; birch: healthy, 10 pcs. Total: healthy trees, 37 pcs., weakened, 5 pcs., substantially weakened, 7 pcs., dead, 2 pcs.

The natural regeneration of spruce had a density of crowns of 40%, and a density of 10,400 pcs./ha. The basal area of undergrowth was 25%. *Sorbus aucuparia* (15%) and *Frangula alnus* (10%) dominated. The grass-shrub layer had a projective cover of 55%. It was dominated by *Vaccinium myrtillus* and *V. vitis-idaea*, up to 10%. In addition, *Equisetum sylvatica*, *Rubus saxatilis*, *Dryopteris carthusiana*, *D. expansa*, *Trifolium pratense*, *Nardus stricta*, *Oxalis acetosella*, *Convallaria majalis* were found with a projective cover of up to 5%.

The projective cover of the moss-lichen layer was 25%. It was dominated by the green-moss group of moss species (16%): *Rhythydiadelphus triquestrus*, *Hylocomium splendens*, and *Dicranum polysetum*. Hypnous mosses (1%): *Rhodobrium roseum*, *Mnium cuspidatum* and *Sphagnum* mosses (10%): *S. angustifolium*, *S. squarrosum* were found.

Forest type was *Populetum tremulae polytrichoso-myrtillosum on the insufficiently drained loams* [17]. Diagnostic features were the next: *Sphagnum* sp. cover >=10%, *Vaccinium myrtillus* and *V. vitis-idaea*, dominated.

**Permanent sampling plot 2** (Size 16x18 m). The total crown density of the stand was 85%. Tree stand formula: in the first layer, aspen dominated: 10 Aspen (18 pcs.). The average age of aspen was 72.5 years. The density was 625 pcs/ha in the first layer. The average diameter of aspens was 38.3 cm. All spruce trees were in the second layer: 10Spruce (11 pcs.). The average age of spruce was 82.8 years.
The vitality structure of the entire stand was the next: aspen: healthy, 37 pcs., weakened, 5 pcs., substantially weakened, 7 pcs., dead, 2 pcs.; spruce: healthy, 5 pcs., weakened, 3 pcs., substantially weakened, 2 pcs., dead, 1 pc.

The spruce natural regeneration had a density of crowns of 45%, and density of 18.800 pcs/ha. The undergrowth had a density of crowns of 15%. Sorbus aucuparia (10%), Padus avium (3%), and Frangula alnus (2%) occurred. The projective cover of the grass-dwarf-shrub layer was 60%. It was dominated by Vaccinium myrtillus and V. vitis-idaea, up to 10%. In addition, Equisetum sylvatica, Rubus saxatilis, Dryopteris carthusiana, D. expansa, Trientalis europaea, Oxalis acetosella, Convallaria majalis were found with a projective cover of up to 2-3%.

The projective cover of the moss-lichen layer was 15%. It was dominated by the green-moss group of moss species (12%): Rhytidiodelphus triquetrus, Hylocomium splendens, Dicranum polysetum, and Pleurostomum schreberii. Hypnous mosses (3%): Rhodobrium roseum, Mnium cuspidatum occurred.

Forest type was Populetum tremulae myrtillus on the normally drained loams [17]. Diagnostic features were the next: Sphagnum sp. cover <10%, subnemoral and nemoral species were absent, Vaccinium myrtillus and V. vitis-idaea, dominated.

Permanent sampling plot 3 (Size 30x25 m). The total density of crowns of the stand was 70%. The first layer was formed by birch and aspen, the stand formula was 7 Birch 3 Aspen. The second layer was formed by spruce (31 pcs.) and birch. The formula of the second layer was 8 Spruce 2 Birch. There were 586 spruce trees per 1 ha. There were 302 pcs. of birch per 1 ha. In total, there were 926 threes per 1 ha. The average age of birch was 70–75 years. The average age of spruce was 78 years, and the age of aspen was 65 years.

The vitality structure of the entire stand was characterized by the following data: spruce: healthy, 17 pcs., weakened, 1 pcs., substantially weakened, 9 pcs., dead, 4 pcs; birch: healthy, 13 pcs., weakened. 2 pcs., substantially weakened 0 pcs., dead, 1 pc. There were two healthy aspen trees with a diameter of 40 and 46 cm.

The total density of crowns of natural regeneration was 10%. Spruce density was 2,400 pcs/ha, and aspen density was 5,200 pcs/ha. The density of crowns of undergrowth was 10%. Sorbus aucuparia, Padus avium, Frangula alnus, Alnus incana, Lonicera xylosteum, Daphne mezereum, Ribes nigrum, Rosa majalis were present with a density of crowns of 1–3%. The grass-shrub layer had a projective cover of 85%. Rubus saxatilis, Oxalis acetosella, and the nemoral species Stellaria nemorum and Galeobdolon luteum dominated with a projective cover of up to 10–15%. In addition, Vaccinium myrtillus, V. vitis-idaea, Equisetum sylvatica, Dryopteris carthusiana, D. expansa, Trientalis europaea, Convallaria majalis were found in the grass-shrub layer with a projective cover of 2–5%.

The projective cover of the moss-lichen layer was 20%. It was dominated by the green-moss group of moss species (17%): Rhytidiodelphus triquetrus, Hylocomium splendens, Dicranum polysetum, and Pleurostomum schreberii. Hypnous mosses (3%): Rhodobrium roseum, Mnium cuspidatum occurred.

Forest type Betuletum oxalidosa on the normally drained loams [17]. Diagnostic features were the next: Sphagnum sp. cover <10%, Galeobdolon luteum (subnemoral species) dominated.

Permanent sampling plot 4 (Size 27x24 m). The total density of crowns of the stand was 80%. Aspen (10 Aspen) dominated in the first layer, and spruce (10 Spruce), in the second. There were 288 pcs. of aspen and 576 of spruce per 1 ha. The average age of aspen was 80 years, and of spruce 78 years.

Vitality structure of the stand was the next: aspen: healthy, 12 pcs., weakened, 1 pc., substantially weakened, 5 pcs., dead, 0 pcs.; spruce: healthy, 20 pcs., weakened, 4 pcs., substantially weakened, 6 pcs., dead, 6 pcs.

The total density of crowns of natural regeneration was 25%. Spruce density was 4000 pcs/ha, aspen density was 3200 pcs/ha. The crown density of undergrowth was 35%. Sorbus aucuparia (33%) and Frangula alnus (2%). The grass-shrub layer had a projective cover of 65%. It was dominated by Vaccinium myrtillus and Rubus saxatilis, up to 10%. V. vitis-idaea, Equisetum sylvatica, Dryopteris carthusiana, D. expansa, Trientalis europaea, Oxalis acetosella, Convallaria majalis had a projective cover of up to 5%.
The projective cover of the moss-lichen layer was 30%. It was dominated by the green-moss group of moss species (20%): Rhytidiodendron triquetrus, Hylocomium splendens, Dicranum polysetum, and Pleurozium schreberi. Sphagnum mosses (10%): Sphagnum girgensohnii occurred.

Forest type was Populetum tremulae-polytrichoso-myrtillus on the unsufficiently drained loams [17]. Diagnostic features were the next: Sphagnum sp. cover >=10%, Vaccinium myrtillus and V. vitis-idaea, dominated.

An analysis of floristic diversity of mature aspen forests revealed rare and protected species of mosses and lichens (Table 1).

Table 1. Conservation status of rare and protected species recorded at sample plots: Cn is a specialized species, P is a rare species recommended for a new edition of the Red Book of the Leningrad Region [18]. The statuses of species are given according to the Category of status of species listed in the Red Book of the Leningrad Region [18]: 3 (R) - a rare species, 4 (I) - a species with an undefined status.

| Rare and protected species | Red Book of the Leningrad region [18] | Red Book of the Russian Federation [19] | Rare, indicator and specialized species |
|---------------------------|--------------------------------------|----------------------------------------|---------------------------------------|
| Nowellia curvifolia (Dicks.) | 3 (R) | | P |
| Plagiothecium latebricola | 3 (R) | | |
| B.S.G. | | | |
| Cetrelia olivetorum (Nyl.) WL Culb. et CF Culb | | R, Cn | |
| Lobaria pulmonaria (L.) Hoffm | 3 (R) | + R, Cn |
| Evernia divaricata (L.) Ach. | 3 (R) | | Cn |
| Nephroma resupinatum (L.) Ach. | 4 (I) | | Cn |

4. Conclusion

Forests rich with aspen were studied at Lisinsky Forestry Unit at three forest site types: Oxalis, Myrillus on the normally drained loams and at the Polytrichum-Myrillus on the insufficiently drained sites. According to [17] they are also common at Nemoriferbosum site types one on the normally drained loams and another on the normally drained loams rich with calcium carbonates.

In biologically mature and decaying aspen forests, spruce trees of the second layer had the strongest effect on the ground cover due to a strong shading and the formation of a large amount of coniferous litter. Fragments of vegetation consisting of grass and shrub species (Vaccinium vitis-idaea, Oxalis acetosella) and mosses (Dicranum scoparium, Hylocomium spentens, Plagiommum cuspidatum, etc.) were formed on the rised ground near the trunks of birch and aspen. Comparing the influence of environmental factors formed by the forest stand on the types of soil cover in aspen forests, it can be noted that the density of crowns plays the most important role.

In the stands studied, the shrub layer is clearly noticeable in sample plots 1 and 4. On plot 3, there was an increase in the projective cover of the grass-shrub layer up to 85% with a density of crowns of 70%. In all plots, aspen was abundant in the first layer, and spruce dominated in the second one. With age, the annual productivity of aspen stands decreased, at the same time there was an increase in the productivity of spruce in the undergrowth or in the second layer.

The results of this study can be used to maintain the sustainable development of forest territories, as well as to identify forest plots on the lease territory of forestry companies that are valuable from an environmental point of view and should not be subjected to deforestation. To study the dynamic changes in the structure, productivity and biodiversity, it is planned to study aspen forests of different
ages in order to develop optimal forestry measures to increase the productivity of forest stands, criteria and environmental protection in biologically valuable mature forests.

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