Diversity of the vegetation cover of the zone of potential influence of the Nizhneboguchanskaya HPP (Lower Angara region)

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Abstract. Active economic development of the Lower Angara zone requires the creation of a scientific basis for long-term monitoring of the state of natural ecosystems. The paper gives an assessment of the diversity of vegetation cover in the zone of potential influence of the Nizhneboguchanskaya HPP. An analysis of its typological structure on a landscape-ecological basis is given. The results of the DCA ordination and the interpretation of the leading axes of variation demonstrated the presence of four distinct groups of forest types that form ecological series according to the leading factors - the richness and hydrothermal regimes of soils. The dendrogram of forest types in the study area reflects the floristic integrity of the identified groups of forest types and the floristic relationships between them.

1 Introduction

The forest ecosystems prevailing in the valley of the Angara River and its adjacent slopes, terraces and tributary valleys are largely disturbed by various natural and anthropogenic impacts, mainly logging and fires. Forest cuttings were carried out here systematically and in various ways (solid, selective) for at least two centuries, especially intensively in the middle of the 20th century. Selective logging is still ongoing. Over the past two centuries, almost the entire territory under consideration has been covered by fires of varying frequency and intensity. The light coniferous forests of the Lower Angara region are characterized by a high natural fire hazard [1, 2]. The frequency of burning of the most common pine formation in the study area varies from 25 to 40 years [3]. In recent decades, an increase in the frequency of fires has been observed, which is associated with an increase in anthropogenic pressures, a decrease in the quality of forest protection from fires, and climate change [4, 5]. The vegetation cover is influenced by a relatively developed economic infrastructure in the form of roads, power lines, settlements, forest warehouses, as well as agricultural land (mainly hayfields).

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At present the vegetation of the lower reaches of the Angara River is of great interest, since the natural ecosystems in this area should be partially flooded and impacted in connection with the construction of the Nizhneboguchanskaya HPP. Information about the current state of the vegetation cover is important for its monitoring and assessment of possible changes during the creation of a reservoir.

In this regard, the aim of the work was to assess the diversity of the vegetation cover of the potential influence zone of the Nizhneboguchanskaya HPP and its ecological characteristics.

2 Materials and methods

The study area is located in the lower reaches of the Angara River (from 58°22'N, 97°44'E to 58°42'N, 99°07'E) in a Central Siberian Plateau with absolute heights of watersheds 350–400 (up to 500 m).

The survey area of 185 thousand hectares is a buffer zone located along the riverbed Angara, 20 km wide. The projected flood zone during the construction of the Nizhneboguchanskaya HPP will occupy a area of the river with a length of about 100 km, with a maximum width of up to 7 km (Figure 1).

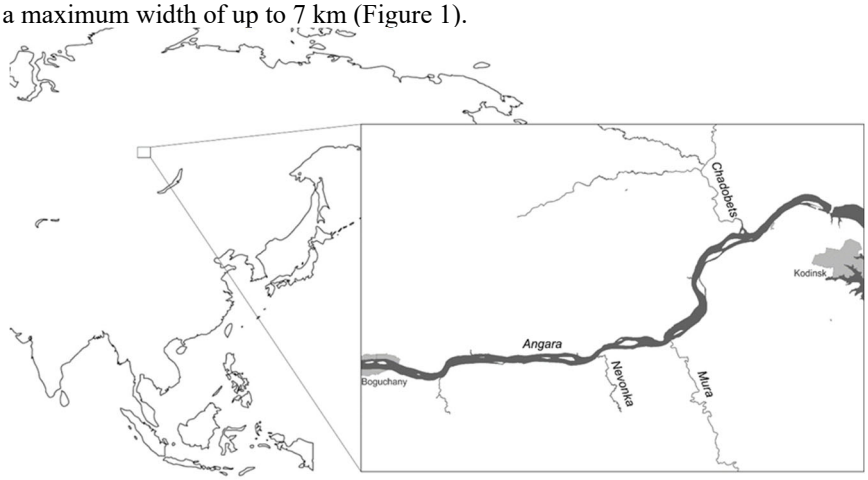

Fig. 1. Investigation area.

The studied territory belongs to the Angara River basin at the boundary of the southern taiga and subtaiga subzones of the Central Siberian taiga [6]. The climate is sharply continental with moderately warm summers and moderately severe snow winters [7]. The annual amount of precipitation varies from 300–400 mm at depressions to 500–600 mm at elevated relief elements. The average annual air temperature is -2.5°C. The period with negative temperatures lasts 195–200 days. The duration of the period with temperatures above 10°C is 95–105 days. The sum of temperatures during the growing season is 1600–1700, the average air temperature in July is +18°, in January –23°. The depth of the snow cover reaches 35–70 (up to 80) cm [8]. The territory is located in the region of the Angara-Chunsky (Priangarsky) low plateau of the province of the trap structural-denudation plateau of the Tunguska syneclise of the country of the Central Siberian plateau [9]. The channel facies is represented by sand and pebble formations. The floodplain terraces are composed of alluvium and deluvial deposits, represented by loams, sandy loams and pebbles with sands. On a significant part of the length of the coastline of the proposed reservoir, intrusive formations of the Siberian traps formation are observed, composed of dolerites in combination with deposits of sandstones, conglomerates and limestones of the Ii and Ust-Kut

suites. The trap bodies act as mesas, cone-shaped hills, steep ridges, loaf-shaped hills, and rocky remnants [6].

By soil-geographical zoning, the territory of the Lower Angara region is assigned to the Angara province of soddy-podzolic, soddy-calcareous and gray forest gleyed permafrost soils [10]. Zonal soils in the study area are podzolic and soddy-podzolic soils, different in texture, with a predominance of sandy and sandy loam.

According to the scheme of forest zoning of Russia and the republics of the former USSR [11], the region under consideration is located within the Central Siberian strongly continental sector and the Central Siberian plateau forest region represented in it. The study area is located in the southern part of the region within the Angara-Tunguska forest-growing province of taiga forests, and inside it is included in the Priangarsky district of southern taiga and subtaiga light coniferous forests.

Field studies were carried out in 2020-21: 1) by the method of topo-ecological profiling using standard methods of geobotanical descriptions [12, 13]; 2) methods of visual enumeration of forest stands [14] and accounting for renewal [15] in key areas (29 integrated forestry key plots) in the most common forest types. The work also used archival materials and previously published data [16–23].

The classification of vegetation was made according to the methodological approaches of V.N. Sukachev [24]. To identify forest types, forestry (forest-forming tree species, bonitet), floristic (dominants of all layers, floristic composition), soil-geomorphological (soil type, location in relief) criteria were used.

The ordination of forest communities in the study area was carried out using the Detrended Correspondence Analysis (DCA-ordination) [25]. Data processing and visualization during ordination and cluster analysis were performed by the TurboVeg [26] and Past [27] programs. As floristic lists compared with each other, non-geobotanical descriptions of specific phytocenoses were used, in coenofloras of forest types [28], that is, combined lists of types of descriptions reduced to one specific type of forest. The main weight parameter in the analysis of cenofloras was the occurrence of the species. Thus, the ranking of forest types and their groups along the main environmental gradients was freed from the influence of random local environmental factors.

The names of vascular plants are given according to the Synopsis of Siberian Flora [29], bryophytes - M.S. Ignatov, O.M. Afonina [30], lichens - according to the “Key to Lichens of the USSR”, Vol. 3 [31], “Key to Lichens of Russia”, Vol. 6 [32].

3 Results and discussion

The vegetation of the study area is a complex combination of communities of different formation composition. The main forest-forming species in the basin of the lower reaches of the Angara River is the Scotch pine (*Pinus sylvestris L.*), which forms forest stands in all major landscape types. Pine forests with an admixture of drooping birch (*Betula pendula Roth*) and Siberian larch (*Larix sibirica Ledeb.*) occupy the tops of small flat ridges and their slopes, leveled spaces between ridges. All surveyed areas at different times were covered by ground runaway fires, and some of them - repeatedly, and everywhere there are traces of selective logging. Small-leaved aspen (*Populus tremula L.*) and birch (*Betula pendula*) forests have a secondary character. Polydominant dark coniferous forests are not widespread. The predominance of spruce (*Picea obovata Ledeb.*) in the composition of forest stands in river floodplains, meso-depressions of relief and Siberian fir (*Abies sibirica Ledeb.*) on high upland areas is determined by their ecological and biological features. Fir rarely forms pure stands. Siberian cedar pine (*Pinus sibirica Du Tour.*) is growing in admixture and is relatively rare, it never forms pure forest stands due to soil and climatic conditions.

The gentle upper rocky and middle parts of the slopes of eastern, northeastern, northwestern exposures are occupied by alder lingonberry- herb pine forests throughout the study area. The soils are sandy and loamy, often very stony - lithozems or coarse humus podburs. Stands of simple structure, quality class IV, up to 20 m high, canopy closeness 0.5-0.8, dominated by pine (*Pinus sylvestris*), sometimes with a significant admixture of aspen (*Populus tremula*), less often birch (*Betula pendula*) and larch (*Larix sibirica*). The undergrowth is usually well developed, 25-40% density, 0.5-4 m high, dominated by *Duschekia fruticosa* (Rupr.) Pouzar, mixed with undergrowth of all forest-forming species (almost no pine - which is typical), as well as *Sorbus sibirica Hedl., Rosa majalis Herrm ., Rosa acicularis Lindl. Salix taraikensis Kimura* and *Salix caprea L., Lonicera caerulea L., Spiraea media Schmidt, Swida alba (L.) Opiz, Padus avium Mill., Juniperus sibirica Burgsd.*, up to 14 species in total. In the herb-shrub layer with a protective cover of 20-25% and a height of 5-80 (20) cm, *Vaccinium vitis-idaea L.* usually dominates, *Pyrola rotundifolia L.,* co-dominate *Carex macroura Meinsh., Lathyrus humilis (Ser.) Spreng., Vaccinium myrtillus L., Maianthemum bifolium (L.) F.W. Schmidt, Linnaea borealis L.,* there are 26-34 species in total (average 30 species). The ground cover is usually poorly developed (5-10% of the projective cover), usually composed of 4-6 moss species with a predominance of *Pleurozium schreberi (Willd. ex Brid.) Mitt.* and *Hylocomium splendens (Hedw.) Bruch* et al.

Significant areas of the northwestern, western slopes of medium steepness, southern gentle slopes and plakors are occupied by alder *Carex macroura* -herb pine forests on stony loamy podburs and soddy-forest soils. The tree layer is usually two- layers, with a total density of 0.6-0.8, quality class IV. In the first layer, up to 25 m high and 0.15–0.4 closeness of the canopy, pine aged 100–200 years dominates, always with a small admixture of larch. In layer II, up to 15 m high and 0.3–0.7 closeness of the canopy, pine also predominates, but there is always a significant admixture of *Betula pendula or Populus tremula*. The undergrowth is well developed, with a protective cover of 15-35%, 0.5-4 m high, dominated by *Duschekia fruticosa*, sometimes together with undergrowth of *Picea obovata*, mixed with undergrowth of all species, as well as *Spiraea media, Sorbus sibirica, Rosa majalis, Lonicera caerulea, rarely Salix taraikensis and Cotoneaster melanocarpus Fisch. ex Blytt,* 9-10 species in total. The herb-shrub layer is also well developed, has a protective cover of 25-40%, height 5-100 (25) cm, always dominates in it *Carex macroura*, co-dominants - *Calamagrostis obtusata Trin., Vaccinium vitis-idaea, Rubus saxatilis L., Lathyrus humilis, Linnaea borealis, Iris ruthenica Ker Gawl., Orthilia secunda (L.) House, Pyrola rotundifolia*, total 34-41 (average 38) species. The moss-lichen layer, as a rule, is fragmentary, consisting of 4-7 species, both widespread boreal mosses, with a predominance, usually, of *Pleurozium schreberi and Hylocomium splendens,* and with an insignificant participation of fruticose lichens of the *genera Cladonia and Peltigera*.

On the slopes of shady exposures (northern, northeastern, northwestern), mixed herb-green-moss and lingonberry-green-moss pine forests are common on soddy-forest loamy sandy soils. Rarely there are larch forests similar to those in the composition and structure of the lower tiers herb-green moss.

Pine herb-green-moss forests, quality class IV, up to 20 m high and 0.6-0.75 canopy closeness, composed mainly of pine (*Pinus sylvestris*), there are significant proportions of *Picea obovata and Populus tremula* in the admixture, *Betula pendula and Larix sibirica* are sparsely present. Pine, spruce and larch are 100-200 years old, aspen is about 70 years old. The sparse undergrowth, density 10% and height 0.5-4 m, is dominated by undergrowth of *Picea obovata*, rarely *Abies sibirica* and *Betula pendula*, as well as *Rosa acicularis, Rosa majalis, Sorbus sibirica, Duschekia fruticosa, Crataegus sanguinea Pall*. In the herb-shrub layer with a projective cover of 20% and a height of 5-50 (15-20) cm, there are no dominants, typical boreal species are distinguished by abundance - *Orthilia secunda, Mitella nuda L., Linnaea borealis, Pyrola rotundifolia, Calamagrostis obtusata* and *Vaccinium myrtillus*,

total 42 species on average. The ground cover is well developed, up to 70% of the projective cover, it is composed of *Pleurozium schreberi* and *Hylocomium splendens* in equal proportions, with an admixture often of *Dicranum polysetum Sw.* and the *lichen Peltigera leucophlebia (Nyl.) Gyeln*.

Lingonberry -green moss pine forests of III-IV quality class, density 0.6-0.7. The height of the upper canopy is up to 23 m, composed of pine (*Pinus sylvestris*) with the participation of *Betula pendula, Larix sibirica*. Pine is 80-200 years old, birch is 50-80 years old. The undergrowth (coverage 20%, height 0.4-3.5 m) is formed by *Duschekia fruticosa*, with an admixture of *Sorbus sibirica, Vaccinium uliginosum L.* and *Ledum palustre L*. Undergrowth of dark coniferous species is noted: *Picea obovata* and *Abies sibirica*. In the herb-shrub layer projective cover - 60-70% is formed by *Vaccinium vitis-idaea* (40%), with the participation of *Gymnocarpium dryopteris (L.) Newman, Maianthemum bifolium, Pyrola rotundifolia, Arctostaphylos uva-ursi (L.) Spreng., Orthilia secunda, Linnaea borealis, Trientalis europaea L.* and other species (on average up to 30 species). The ground cover is well developed (70-80%) and is formed by *Pleurozium schreberi* and *Hylocomium splendens*, with an insignificant participation of *Dicranum polysetum*, species of the genus *Cladonia, Peltigera aphthosa (L.) Willd*.

On the slopes of shady exposures, bilberry-green-moss pine forests are relatively rare on poorly drained podzolic sandy soils. Mixed forest stand, quality class III, up to 23 m with *Larix sibirica, Betula pendula,* rarely *Populus tremula*. The age of pine and larch is 150-200 years. The undergrowth is poorly developed. *Duschekia fruticosa, Vaccinium uliginosum* and *Ledum palustre* are singly recorded. In the herb -shrub layer (projective cover 35%, height 5-20 cm), *Vaccinium myrtillus* dominates with the participation of *Maianthemum bifolium, Trientalis europaea, Vaccinium vitis-idaea, Empetrum nigrum* L., *Linnaea borealis*. The ground cover is developed (projective cover 30-50%), composed of *Pleurozium schreberi* and *Hylocomium splendens*, with the participation of *Dicranum polysetum*.

On the peaks and slopes of the southern exposure, lingonberry-lichen pine forests are rarely found. Soils are sandy podzolic. Single-layer stand, density 0.6-0.8, quality class III-IV, up to 20 m high, often pine, occasionally with a slight admixture of *Larix sibirica, Picea obovata* and *Betula pendula*. The age of pine is 90-160 years old, spruce - 40-60 years old. The undergrowth is poorly developed. *Duschekia fruticosa* and *Ledum palustre* are singly recorded. In the herb-shrub layer (projective cover 35%, height 5-20 cm), *Vaccinium vitis-idaea* dominates, *Linnaea borealis, Empetrum nigrum, Antennaria dioica* (L.) *Gaertn., Vaccinium myrtillus, Orthilia secunda* are found singly. The community is characterized by a depleted species composition. The ground cover is well developed, the projective cover is up to 80%. *Cladonia stellaris* (Opiz) Pouzar et Vězda dominates, with the participation of *Cladonia rangiferina* (L.) F. H. Wigg., *Cladonia gracilis* (L.) *Willd. polysetum*, single *Peltigera aphthosa*.

Steppe lingonberry-forb pine forests dominate on the slopes of the southern, eastern and southeastern exposures of small and medium steepness, on the sides of the ancient terraces of the Angara River. They grow on soddy-forest loamy or soddy-calcareous sandy loamy soils. The forest stands are single-tiered, IV-V quality class, up to 22 m high, always dominated by pine aged 70-200 years, birch and larch are sporadically found in the admixture. The undergrowth is usually sparse, 3-15%, 0.5-3 m high, *Rosa majalis* or *Cotoneaster melanocarpus* can dominate, more often there are no dominants, compose its rare undergrowth of *Pinus sylvestris, Betula pendula* and *Larix sibirica*, as well as *Salix taraikensis, Spiraea media* only 4-8 species. The herb -shrub layer is also sparse, 10-35%, 5-80 (20) cm high, *Vaccinium vitis-idaea* always dominates or co-dominates, *Lathyrus humilis, Pulsatilla orientali-sibirica Stepanov, Iris ruthenica, Rubus saxatilis* are also abundant, 19 in total -37 (average 27) species. The moss-lichen cover is absent or does not exceed 5% of the

projective cover; it is composed of 4-8 species of boreal mosses and fruticose lichens of the genera *Cladonia, Peltigera* and *Stereocaulon*.

Tall herbs pine forests grow in small elongated areas along the valleys of small rivers and streams, in closed hollows, occupying gentle concave mesorelief forms. Evidences of a fire are usually not observed, the soil is gray forest heavy loamy. The forest stand is mixed, two-tiered, quality class III, with a total density of 0.6 and the age of the main layer is 150-300 years. In the first layer, with a canopy closeness of 0.4 and a height of up to 28 m, *Pinus sylvestris* predominates, with a significant admixture of *Populus tremula* and a small amount of *Betula pendula* and *Larix sibirica*. *Pinus sylvestris* also dominates in layer II with a density of 0.2 and a height of 10–18 m, with an admixture of *Betula pendula, Populus tremula, Larix sibirica*, and *Picea obovata*. In the undergrowth with a density of 10% and a height of 1-4 m, undergrowth of all canopy species occurs, as well as with a small abundance of *Sorbus sibirica, Duschekia fruticosa, Rosa majalis, Rosa acicularis Lindl., Lonicera caerulea, Cotoneaster melanocarpus* and *Salix jenisseensis* (F. Schmidt) Flod. The herb layer is polydominant (projective cover 60%) and up to 100 cm high (30-60 cm on average): *Crepis sibirica L., Parasenecio hastatus* (L.) *H. Koyama, Paeonia anomala* L., *Thalictrum minus* L., *Angelica sylvestris* L., *Heracleum dissectum Ledeb., Dryopteris expansa* (C. Presl) *Fraser-Jenk.* & *Jermy,* mesophilic herbs are also noted: *Vaccinium vitis-idaea, Linnaea borealis, Equisetum scirpoides Michx., Rubus saxatilis, Calamagrostis obtusata, Carex macroura, Pyrola rotundifolia, Mitella nuda,* 50 species in total. The ground cover is poorly developed, about 15% of the projective cover is composed of small patches of green mosses *Pleurozium schreberi, Hylocomium splendens, Ptilium crista-castrensis* (Hedw.) De Not. with small participation of *Rhytidiadelphus triquetrus* (Hedw.) Warnst.

Small-leaved forests of different composition are formed by birch (*Betula pendula*) and aspen (*Populus tremula L.*), stands often with pine. Secondary aspen forests of *Carex macroura-herb* are common on soddy-podzolic loamy, less often soddy-forest loamy sandy soils in the middle parts of the gentle slopes of the southeastern exposure, as well as in the middle parts of the steeper (5-10 °) slopes of the northern, northwestern exposure, in the middle and lower parts are the sides of the terrace of the Angara River. Almost all surveyed areas were repeatedly burned by fires, some have traces of selective logging. Forest stands are often two-layered, with a total coverage of 0.5-0.8, class quality III-IV. In the first layer up to 25 m high, *Populus tremula* always dominates with a large admixture of *Pinus sylvestris* and a single *Larix sibirica* and *Betula pendula*; in the second layer 8–20 m high, aspen, birch or spruce can dominate, always with an admixture of pine and larch, sometimes fir. Aspens are usually over 70 years old, pines are about 100-200 years old. The undergrowth is often also two- layered, 0.7-6 m high and 20-50% coverage, dominated by *Duschekia fruticosa, Rosa majalis, Rosa acicularis*, as well as undergrowth of *Populus tremula* or *Picea obovata*. Undergrowth of all species, as well as *Salix taraikensis, Sorbus sibirica, Cotoneaster melanocarpus, Spiraea media, Crataegus sanguinea, Rosa acicularis, Sambucus sibirica Nakai, Rubus matsumuranus H. Lev & Vaniot, Ribes rubrum L.* can be found in the admixture, 10-12 species in total. The herb-shrub layer is always well developed, 5-100 (30) cm high and with a protective cover of 30-50%. *Carex macroura* always dominates, *Lathyrus humilis, Rubus saxatilis, Calamagrostis obtusata, Maianthemum bifolium, Vaccinium vitis-idaea, Mitella nuda, Pyrola rotundifolia, Linnaea borealis, sometimes Equisetum pratense Ehrh*. The moss-lichen cover is distributed mainly on dead wood, on the soil it does not exceed 10% of the projective cover, it is composed of 3-7 species of ordinary boreal mosses and, sometimes, fruticose lichens.

Secondary *Calamagrostis obtusata-Carex macroura-herb* birch forests grow everywhere, in small areas in the lower parts of gentle (3-8 °) slopes of different, mainly light exposures, on gray forest heavy or medium loamy soils. A stand dominated by *Betula pendula* and *Picea obovata*, with an admixture of *Pinus sylvestris* and *Larix sibirica*, slightly

- *Populus tremula*, quality class III. The coverage is 0.6-0.7 and the height is up to 25 m. The age of birch is about 70 years, conifers - 100-150 years. The undergrowth with a density of 15% and a height of 0.5-5 m is dominated by the undergrowth of *Populus tremula* and *Picea obovata*, as well as *Spiraea media, Rosa acicularis*, a total of 11 species, including the undergrowth of other forest-forming species. The herb-shrub layer is relatively sparse, 30%, 5-80 (30) cm high, dominated by *Calamagrostis obtusata* and *Carex macroura*, *Equisetum pratense* and *Lathyrus humilis* co-dominate, 34 species in total. The ground cover is fragmentary, no more than 3-5%; it is composed of small patches of green boreal mosses and fruticose lichens, 8 species in total. The old deadwood is covered with mosses and lichens.

On the lower parts of gentle slopes along the valleys of rivers and streams, damp ravines with excessive moisture of a flowing nature, on peaty-humus, gley-podzolic soils, mixed fir-spruce forests of horsetail-green moss with are tall herbs. Quality class *of Picea obovata* and *Abies sibirica* is III. The stands include *Larix sibirica, Pinus sylvestris* and *Pinus sibirica*. The coverage of the forest stand is 0.7-0.8, up to 24 m high. The age of the forest stand is 70-210 years old. Single larches form the upper canopy of the stand and are older than other species. The undergrowth is well developed (coverage 10-20%, height 1.4-1.5 m), formed by *Spiraea salicifolia L., Spiraea media, Ribes nigrum L.* and *Ribes rubrum, Rosa majalis, Rosa acicularis, Sorbus sibirica*. The herb-shrub layer is mosaic, well developed (projective cover 60-80%) and is formed by: *Equisetum sylvaticum L., Equisetum pratense,* with the participation of *Calamagrostis langsdorffii (Link) Trin., Equisetum scirpoides, Aconitum septentrionale Koelle Angelica sylvestris, Oxalis acetosella L., Trientalis europaea, Maianthemum bifolium* and others. The moss cover is mosaic (projective cover 50-80%), green mosses dominate: *Hylocomium splendens, Pleurozium schreberi, Ptilium crista-castrensis, Rhytidiadelphus triquetrus with Climacium dendroides (Hedw.) F.Weber & D.Mohr, Rhodobryum roseum (Hedw.) Limpr.,* species of the genus *Mnium*.

Along with forest vegetation, meadow communities are found regularly in the study area, but in small areas. In the riverbed parts of floodplain and old floodplain river terraces on soddy-meadow soils, meadows with *Elytrigia repens* (L.) *Nevski* are found (*Elytrigia repens (L.*) *Nevski* dominates with the participation of *Poa pratensis L., Agrostis gigantea Roth, Dactylis glomerata L., Rumex thyrsiflorus Fingerh., Vicia cracca L., Trifolium pratense L., Taraxacum officinale F.H. Wigg., Equisetum pratense Ehrh., Thalictrum simplex L., Stellaria graminea L*. and other species) and giant field meadows dominated by *Agrostis gigantea*. The herbage consists of *Festuca pratensis Huds., Phleum pratense L., Agrostis tenuis Sibth., Trifolium repens L., Astragalus danicus Retz., Carum carvi L., Trifolium pratense, Potentilla anserina L., Vicia cracca, Juncus compressus Jacq.* and other types.

Meadows dominated by *Alopecurus pratensis L.* and wet herb meadow communities of *Filipendula ulmaria (L.) Maxim., Bistorta officinalis Delarbre, Sanguisorba officinalis L., Leucanthemum vulgare Lam., Rumex thyrsiflorus, Equisetum arvense L., Carex acuta L.* and other species often develop along shallow floodplain depressions and shallow river valleys on soddy-meadow slightly gleyed soils.On well-warmed parts of the floodplains, meadows with the dominance of *Calamagrostis epigeios (L.) Roth* grow. Meadow dominated by *Festuca pratensis Huds.* along flat elevations of shallow river valleys and depression on soddy-meadow soils are widespread.

In swampy depressions of river valleys, under conditions of flowing excessive moisture, swampy meadows are common on soddy-meadow gleyed or silty-gleyic soils. They are distinguished by the predominance of hygrophilous herbaceous plants (primarily sedges and grasses) growing on supersaturated and even water-covered soil. Meadows dominated by *Phalaroides arundinacea (L.) Rauschert* and *Carex acuta* are widespread. Under conditions of stagnant moisture, meadows dominated by *Calamagrostis langsdorffii* and *Carex cespitosa L.* are common on the flat bottoms of valleys in the upper reaches of rivers with

humus-gleyic slightly peaty soils. Hygromesophilic shrub communities of *Salix viminalis L.* and *Ribes nigrum* also grow here.

Due to the small amount of precipitation and the rather strong dissection of the relief, the areas of marsh vegetation are small in size [23]. Bogs are more often located in narrow strips along the valleys of small rivers, around small reservoirs, in forests along depressions in the relief and partly on burnt areas and are associated with their swamping. Mosses are edificators and contribute to stagnant waterlogging of the soil - waterlogging.

Eutrophic (*Hypnum*) bogs are located in relief depressions near rivers, oxbow lakes and groundwater outlets on humus peaty-gley soils. Such bogs often border on swampy meadows; they are characterized by the predominance of hypnum mosses *Tomentypnum nitens (Hedw.) Loeske* in the moss layer, often together with *Hamatocaulis vernicosus (Mitt.) Hedenäs*. In the tree layer, *Betula pubescens Ehrh., Pinus sylvestris,* and *Picea obovata* occur singly. The herb-shrub layer is represented mainly by *Carex lasiocarpa Ehrh., Carex diandra Schrank*, and also with the participation of *Carex rostrata Stokes, Carex rhynchophysa C.A. Mey., Menyanthes trifoliata L., Epilobium palustre L., Naumburgia thyrsiflora (L.) Rchb., Filipendula ulmaria (L.) Maxim.* and other types.

On steep rocky slopes of southern, southeastern exposure, along rocky cliffs, xeromesophilic shrub communities of *Cotoneaster melanocarpus* grow. On the rocky-gravelly slopes of the floodplain terraces of the riversteppe communities represented by steppes with *Festuca ovina L., Phleum phleoides (L.) H. Karst., Agropyron cristatum (L.) Gaertn., Carex pediformis C.A. Mey., Veronica incana L., Kitagawia baicalensis* (*I. Redowsky ex Willd.*) Pimenov, *Youngia tenuifolia (Willd.) Babc.* & *Stebbins*) fragmentarily in the Angara of southern exposure. and petrophytic groups of real steppes on the most stony and eroded soils (*Potentilla acaulis L., Orostachys spinosa (L.) C.A. Mey., Poa angustifolia L., Carex pediformis, Patrinia rupestris (Pall.) Dufr., Ephedra monosperma C.A. Mey., Saxifraga spinulosa Adams.* and other species.

The typological classification of forests in the study area was carried out in close connection with their ordination. This made it possible to reveal the ecological originality of forest plant communities and their groups, as well as to construct a regional ecological series of forest types under the influence of leading environmental factors. Ordination was performed only for forest communities, since forests prevail in this area and are distinguished by the greatest diversity of community types, while other types of phytocenoses (meadows, steppes, swamps, petrophytic and ruderal communities) are represented in the area by small areas, fragmentary and clearly do not represent the full diversity of these types of vegetation in the described region.

As a result of DCA ordination (Figure 2), four distinct groups of forest types were identified: herb, green moss, secondary *Carex macroura*-herb, and lichen. The results of the analysis showed clear differences between groups of forest types along axis 2, which can be interpreted as a soil richness gradient. On the poorest sandy and stony soils in the study area, lingonberry-lichen pine forests are common, and birch forests and *Carex macroura*-herb aspen forests stand out as the richest gray forest soils. An intermediate, approximately identical position on the considered axis is occupied by herb and green moss groups of forest types. Axis 1 can be interpreted as the gradient of the soil hydrothermal regime. Since the area under consideration is small in area, forest phytocenoses are located in approximately equal climatic conditions, therefore, herb and lichen groups of forest types occupy approximately the same position here. But on this axis, green-moss forest types are clearly distinguished, which, due to the development of the moss-lichen layer, are characterized by colder and more humid soils. An exception is the bilberry-green-moss pine forest, which is closer to forb types. This is probably due to the relatively weak development of the moss layer (from 30 to 50% in various descriptions) and significant participation in the composition of herb, especially *Carex macroura* Meinsh.

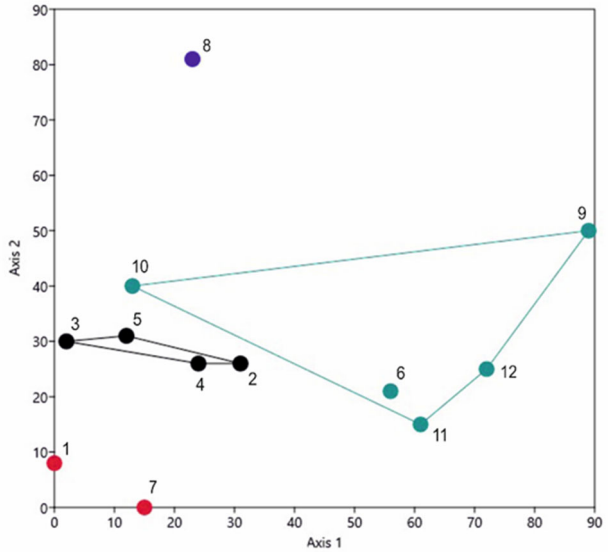

Fig. 2. DCA-ordination of forest types in the zone of potential influence of the Nizhneboguchanskaya HPP. Here and below, Arabic numerals designate forest types united into the following groups: herb group of types: 2 – lingonberry-herb pine forest; 3 – lingonberry-herb alder pine forest; 4 – alder pine forest with *Carex macroura*-herb; 5 - Tall herb pine forest; green moss group of types: 6 –herb-green moss pine forest; 9 - lingonberry-green moss pine forest; 10 - blueberry-green moss pine forest; 11 - fir-spruce forest with horsetail-green moss with tall herb; 12 - herb-green-moss larch forest; *Carex macroura*-herb derived group of types: 1 – birch forest *Calamagrostis obtusata- Carex macroura*-herb; 7 - aspen *Carex macroura*-herb; lichen group of types: 8 - lingonberry-lichen pine forest.

The dendrogram of forest types in the study area (Figure 3), in general, demonstrates the floristic integrity of the identified groups of forest types and the floristic relationships between them. One clear group is made up of green-moss forests, but from this group, as shown by ordination, the bilberry-green-moss pine forest stands out, which, in terms of floristic composition, is closer to herb forests, in the group of which it is located. Also, the floristically derived aspen *Carex macroura*-herb forests turned out to be close to the herb forests. At the same time, the lingonberry-lichen pine forest, and especially the *Calamagrostis obtusata- Carex macroura-herb* birch forest, showed significant floristic differences, both from all other types of forest, and among themselves.

Thus, most of the surveyed area is occupied by pine forests. The diversity of their composition and structure is explained both by the peculiarities of the variation of soil and hydrological conditions, and by changes associated with the influence of fires and logging. *Carex macroura*-herb pine forests are widely represented on soils of light mechanical composition. Under conditions of a sufficient leaching regime, forests of tall herb types grow, and on shady slopes, lingonberry-green-moss and herb-green-moss forests grow. In the series of decreasing moisture supply, small areas of slopes with southern exposures are occupied by lingonberry-lichen and steppe lingonberry-herb pine forests. Polydominant dark coniferous forests grow in low relief elements, along rivers and streams, on high uplands, occupying a row of flowing moisture. In addition to forest vegetation, there are thickets of shrubs, meadow swamps and steppe communities in the study area.

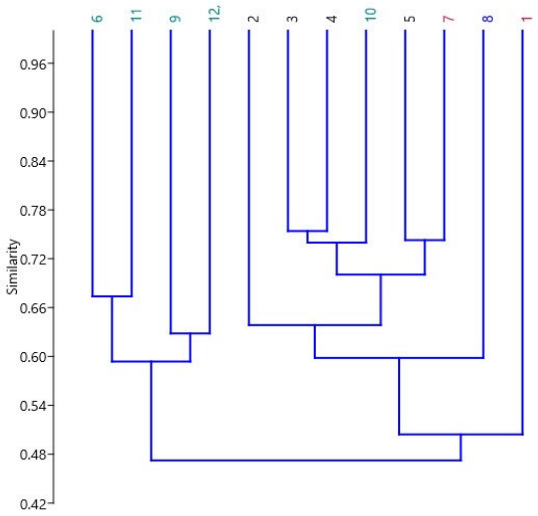

Fig. 3. Dendrogram of 12 forest types in the zone of potential influence of the Nizhneboguchanskaya HPP (Paired group, Bray-Curtis factor).

4 Conclusion

As a result of various types of anthropogenic impact, the vegetation of the Angara River basin in the flood zone of the Nizhneboguchanskaya hydroelectric power station has changed and continues to change - synanthropization of the plant world is taking place. This process can be defined as the adaptation of the plant world to environmental conditions changed under the influence of man [33]. Synanthropization can be divided into stages in accordance with the intensity (strength and duration) of the impact and, accordingly, a certain response of the flora and vegetation.

According to our estimates, at present, the degree of anthropogenic transformation of flora and vegetation corresponds to stage I or the transition from stage I to stage II. Significant depletion of the flora is not observed, on the contrary, there is an increase in the diversity of the floristic composition of forest, meadow, steppe, ruderal phytocenoses with synanthropic, both invasive and native plant species. The diversity of plant communities also does not show a significant decrease; on the contrary, the diversity of meadow phytocenoses has probably even increased (due to the influence of moderate grazing and haymaking). But, in forest phytocenoses, as a result of cuttings and fires, a convergence of forest types is observed, i.e. leveling differences in the composition and structure of communities. These changes, in the future, with an increase in anthropogenic pressure, will inevitably lead to the blurring of differences between forest types, i.e. to the unification of the floristic composition, including the tree canopy, to the simplification and homogenization of the structure of forest phytocenoses.

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