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Dynamic Trends of 100-year Anthropogenic Vegetation Cover under the Influence of the White Sea – Baltic Canal

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Dynamic Trends of 100-year Anthropogenic Vegetation Cover under the Influence of the White Sea–Baltic Canal

L B Vampilova^{1,2} ORCID 0000-0003-4813-6102

¹Pushkin Leningrad State University, Saint-Petersburg, Russia

²Belgorod State National Research University, Federal-regional centre of aerospace and surface monitoring of the objects and natural resources, Belgorod, Russia

E-mail: histgeolbv67@gmail.com

Abstract. The process of economic use of the White Sea region landscapes has historically impacted the vegetation cover trends. The reason lies in the intensity of development adjusted for time factor. We have provided a variety of events related with nature resource management of the Karelian Pomorye landscapes involved in iron production, salt making, sawmills construction, shipbuilding, building of railway and the White Sea–Baltic Canal (WBC), marshland reclamation, housing development and wood logging. These are the types of forest resources which did impact tree layer depletion. We have pre-conditioned to use a geobotanical map of the Shueretsko-Sorokskaya Forest Dacha, Kem Uyezd, the Karelian Autonomous Soviet Socialist Republic, which was compiled under the direction of K. F. Malyarevsky in 1925. An idea leaped into our mind to trace long-term influence made by the anthropogenic factor on differentiation, dynamics and stability processes experienced by swamp and forest geosystems. The research problem is the study of the duration and limitation of development, chronological researching role in landscape transformations. The original features of the study conducted to develop historical and geocological line of geography.

1. Introduction

As a study object we have chosen the White Sea rock-defended and marine accumulative northern taiga lowland with its landscapes having determined the nature of land use management and economic specialisation, which have both repeatedly changed over historical time. The landscapes of the White Sea lowland have specific features.

According to the nature of the Quaternary deposits these are recent and upper quaternary marine clays, loams and sands – biogenic and glaciomorphic [1]. The morphosculpture is represented by marine and glaciomorphic plains located at different levels from 0 to 100 metres. The terrain includes small-ridge-hilly plains, recent flat sea plains, flat-undulating or hilly plains. The sea terraces are well defined and nested along the river valleys at the level of 10 to 20 metres [1].

The terrain differentiating influence has affected the state of the landscapes. The flat areas are swampy and poorly dissected [1].

The area under study belongs to the Kemsk-Belomorsky geobotanical region [2] where shrubby lichen-green moss pine forests are common on the sandy moraine. The large-row terrain with acidic rocks is occupied by spruce-pine forests whereas the inter-row depressions with swampy spruce forests are located on gravelly primitive soils. The specified area is small-selgovo-marsh-plain and it is characterised by the predominance of swampy spruce forests on loamy and clay slopes of river valleys



and pine forest crow-cranberry landscapes [1]. It is dominated by seaside terraced landscapes heavily swamped with spruce forests and rare pine forests.

Our research on vegetation cover changes over 100 years was carried out on a key area of about 700 square kilometres located between the Kem and Vyg river valleys. This area coincides with the middle and lower part of the Shuya River valley and basin of brook called Lep Ruchei. As initial cartographic material to conduct the study we used the vegetation diagrams drawn up six years before the construction of the White Sea–Baltic Canal (WBC) and the schematic geobotanical map of the Shueretsko-Sorokskaya Forest Dacha located in the Kem Uyezd of the Karelian Autonomous Soviet Socialist Republic [3].

The landscapes of the Karelian Pomorye have a specific set of natural resources, determine the special nature use in the marginal, coastal strip where the coastal nature use prevailed. The landscapes have repeatedly become generic, accommodating for the inhabiting ethnic groups (Sami, Karelians, Russian Pomors). The landscapes have some traces left as a result of landscape and ethnos interaction which can be seen in specific historical land use management of each local ethnic group.

The objective of the study: to show the differences in the impact produced by natural and anthropogenic factors on changes in the vegetation cover of the studied lowland area located in close proximity to the WBC.

We have analysed paleogeographic data on changing degree of waterlogging and rotation of species composition of woody vegetation within the studied region from the past to the present. It is established what natural trends are traced in the vegetation cover under the influence of the time factor [4].

Retrospective analysis of landscape development history has shown that since antiquity there has been a repeated change in archaeological cultures and types of economic activities. The historical and geocological periodisation is given here for the entire Karelian Region, so the history of White Sea region development can be divided into the following epochs: Ancient, Medieval, Imperial, Soviet, Modern (post-perestroika).

The historical and geocological periodisation is based on a set of land use management types subject to landscape specifics and the ethnic group living in these landscapes. Using the example of the landscapes of the White Sea region we consider the types of activities which have affected vegetation cover change. So, for example, the Ancient era was noted for the process of harvesting wood to produce charcoal in coal pits. Charcoal was used to smelt cast iron with primitive “blast furnace” method. The products of coal burners were sold to blacksmith and metallurgical industries. Currently, the reconnaissance studies conducted by archaeologists have shown that some traces of the earlier existed coal-burning pits are fixed in the current relief and belong not only to the Iron Age, but also to the beginning of the Middle Ages. However, coal-burning objects are currently identified as the most common type of archaeological sites because this business became really widespread in a certain period of history (the 18th–19th centuries) [5]. Currently, coal burning objects are often identified as a type of archaeological monuments, since in a certain period of history (the 18th–19th centuries) this craft became really massive [5]. There is no methodology for calculating the wood consumed per pit, by means of which it is possible to find out the area of forest felling.

The second type of activity associated with the destruction of forest resources is large-scale deforestation in the vicinity of settlements, when salt mining begins in the Middle Ages in the White Sea region. For the organisation of saltworks process wood was harvested for several centuries, and the restored forests were frequently subjected to repeated felling. Information on the start of salt industry on the White Sea coast is associated with the early monastic development, roughly from the end of the 14th century to the early 15th century. Saltworks were initially founded by monastery households and only later, as individual farms for salt production. One saltworks was capable of producing up to 500 kg of salt per day. The forests on the White Sea coast were thinning due to the huge consumption of firewood, given that in the best times of the late 16th century there were about 180 saltworks operating on the coast [6]. Although the peak of salt production falls on the 17–18th centuries some publications have references to salt production in the 19th century. According to H.

Kirkinen [7] there were about 30 saltworks within our key area, which means that the surrounding forests were repeatedly cut down. Along with salt-making, the iron-making industry was developed, in particular, the production of tsrenov, i.e. large boilers for salt-making. This iron production in primitive charcoal blast furnaces, smelters and foundries required a lot of wood.

These types of businesses were partially continued in the imperial times. Wood harvesting in the development of forestry activities – sawmills and shipbuilding; construction of buildings, gatehouses, household facilities and public wood procurement. It should be noted that these time slices with active human influence on forest resources were accompanied by a slow recovery of tree species due to harsh climatic conditions and they were characterised by weak renewal due to low forest productivity. During repeated long-term use forests lose many of their qualities, in particular, coniferous trees are replaced by small-leaved ones. A change of many forest “generations” (successions) leads to the loss or decrease of regenerative capacity: coniferous trees are replaced by small-leaved ones. The reason is that saltworks are located in constant places, they have been used in the same places for dozens and sometimes hundreds of years. The forests have lost their ability to recover for salt industries where saltworks have existed in the same places for many years. There is a need to conduct special studies to determine how the resistance of forest and meadow landscapes to anthropogenic factors has changed as a result of economic activity, especially since such methods already exist [8, 9].

2. Statement of the problem

Space and time are two categories which are used to explain historical and geo-ecological events occurring within specific territory. Economic activity in White Sea region is quite active, it is characterised by constancy, frequent changes in the types of land use management and serious values of anthropogenic load, which causes response of landscapes and their natural components. A whole range of types of land use management and the duration of human use of forest resources have led to the transformation of the species composition of forests and weakened their resistance to anthropogenic influence. Studies were conducted using three time slices, with an interval of 30 and 65 years, despite the short time intervals, significant changes in the vegetation of the key site were revealed. The method of retrospective analysis for landscape changes and the obtained results will be used for the development of a new discipline – historical geo-ecology.

3. Models and Methods

The main approaches to the study are remote, historical-landscape and historical-geoecological, which allow for a retrospective analysis of changes in the natural environment and to trace the stages of interaction between the landscape and ethnic group, to study the problems of human interaction using the example of a specific key area. The initial cartographic material was a schematic geobotanical map of the Shueretsko-Sorokskaya forest dacha of the Kemsy district of the AKSSR, under the leadership of K.F. Malyarevsky in 1925 [3]. The named map was digitized, an analysis of quantitative indicators was carried out, a characteristic of vegetation was given, including various types of forests, a variety of bogs, sea meadows and meadows - tereba, of anthropogenic origin.

4. Results and Discussion

The key area is located at the mouth of the Shuya River, at its confluence with the White Sea, opposite the island of Shuy-Ostrov, approximately at an equal distance from Kem and Belomorsk. Geobotanical studies were conducted in 1925, almost 6 years before the construction of the White Sea–Baltic Canal. The key area occupies 697 square kilometres. The southern edge of the area is located along the lower course of the Vyg River, approaches the northern border of the city of Belomorsk and stretches along the lower part of the modern WBC highway. This is a fragment of a marine accumulative plain underlay by Lopian rocks: undifferentiated granitoid rocks and migmatites. Quaternary sediments are represented by marine clays, loams and sands, interspersed with modern biogenic (peat) sediments. The water content is 63.3 % (figure 1). Along the coastline it is often to see pre-quaternary rock exposures where the vegetation is represented by sparse pine forests.

Swamps are widespread, mainly sphagnum ones are 98.7 % of the total swampy area, including bogged marshes 73.6 %, sometimes with pines 19.8 %; one can meet transient swamps 1.25 % and herbal swamps 0.04 %.

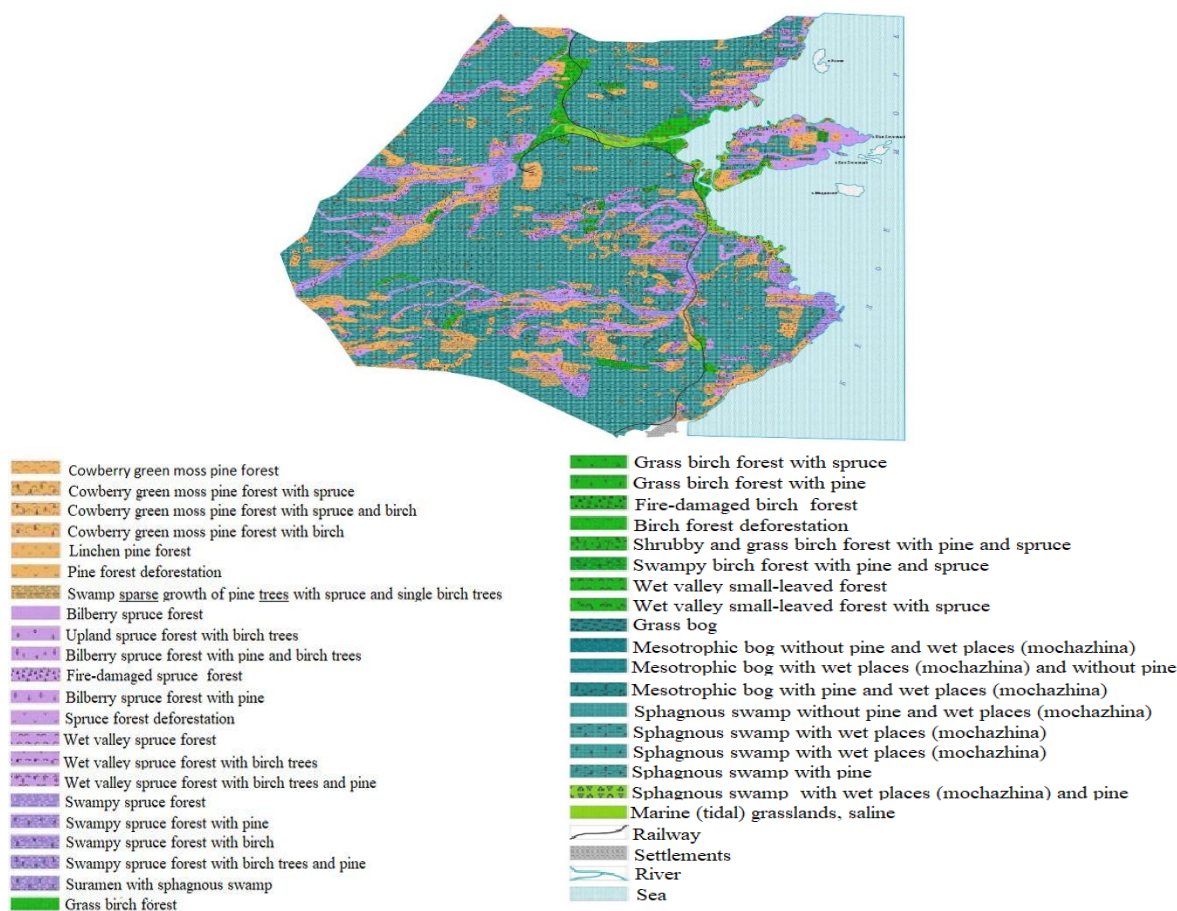


Figure 1. Vegetation of the key site-the mouth of the Shui River in 1925.

The results of the geobotanical study have shown that spruce forests were indigenous within the key area. As of 1925 the forested area covered 35 % of the territory of the key area. Among the timber complexes, coniferous forests prevailed – 90.28 % of the forested area: spruce forests occupied 47.99 %, and pine forests 42.29 %. In the structure of spruce forest, swampy spruce forests prevailed – 44.85 %, including birch and pine 15.25 %; subdominants were represented by spruce forests near the river – 28.8 %, including those with an admixture of birch and pine – 2.29 %. Blueberry spruce forests accounted for 23.19 % of all spruce forests, including 3.7 % with an admixture of pine and birch. All the forests had practically no traces of economic activity, with the exception of nearby settlements – the city of Belomorsk and the village of Shueretskoye.

The most drained areas of river terraces and water-glacial landforms were occupied by pine forests, mainly cranberry-green moss – 42.98 % of the total area of pine forests of the area as well as white moss 7.92 %. Pine forests included rare-coniferous swampy pine forests with spruce and a single birch which accounted to 45.15 % of all pine forests. Deforestation made up 3.95 % in the place of pine forests. By 1925 the territory was practically not involved in economic activity. Except for a small section (10 km) of the lower course of the Shuya River where the village of Shueretskoye is located, it is mentioned in historical documents since the 17th century and its population included about one and a half thousand inhabitants at the beginning of the 20th century. By 1925 secondary forest complexes were formed in the vicinity of the village, including small-leaved forests, areas of burns (0.43 %) and

deforestation (0.25 %), among which there were also meadow areas in place of tereba forests (2.08 % in relation to the forested area). Marine saline meadows are widespread within the key area and occupy 1.1 % of the entire territory of the area along the White Sea coast.

Small-leaved forests within the area covered 9.74 % of the forest area. Birch forests are confined to the drained locations of river valleys, near settlements, mainly in place of primary spruce forests. Grass birch forests accounted for 50.26 % of all birch forests, including spruce ones – 15.68 % and pine ones – 7.44 %. Birch forests are shrubby and grassy with an admixture of spruce and pine – 4.03 %, swampy ones with an admixture of pine and spruce – 13.87 %. It should be noted that spruce took an active part in all stages of small-leaved forests recovery, which confirms the assumed wide distribution of spruce forests as a root land site. Small-leaved brook forests with a mixed composition of species, including birch, alder and aspen, made up 24.87 % of microphyllous forests. Burning and deforestation in place of birch forests were represented on the 6.97 % area.

Vegetation description made in 1954 for the same key area: 29 years after the first survey and 21 years after the construction of the White Sea–Baltic Canal. During the WBC construction (1931–1933) there were water reservoirs created. Although not being connected to a common system of channels, they formed conditions for water saturation, flooding and subsequent waterlogging of the surrounding areas. A significant role in the waterlogging of the eastern part of the territory of the key area was played by the construction of the railway (the section from Belomorskaya to the Shuya River valley): the highway was built in 1917 in the direction from south to north, almost parallel to the sea coastline 5–20 km from it, and actually blocked the natural flow to the White Sea. To prevent waterlogging processes there was a large-scale drainage of the territory carried out in the 30–40s, it affected two areas: the south-western (a watershed between the Hongaya and Shuya Rivers) and the central part of the White Sea coast to the west of the railway line.

According to the results of aerial photography data decoding and analysis of topographic maps M 1:100,000 swamps make up 47.4 % of the territory area. As compared to 1925 their area decreased by 15.7 % due to a large-scale drainage of the territory after the WBC construction as a measure against intensive swamp formation. Due to the drainage, there have been some changes in the structure of the swamps: the share of upper sphagnum bogs has decreased by 32 % , and the share of transitional and lowland bogs has increased by almost 6 % in total. The following swamps are mainly widespread: sphagnum, ridge-pool ones 65.94 % of swamps, and grass-sphagnum, transitional, sometimes with pine and birch 27.26 %, lowland grass and moss-grass swamps 6.8 %.

As a result of land reclamation measures the structure of the forests has also had some changes. In general, the forested area increased by 15 %: in 1954, 50.16 % of the key area was covered by forests, including coniferous ones – 39.1 % and small-leaved ones – 11.06 %. These are spruce forests that played the main role in forested area increase in the territory: their area increased by 15.9 % as compared to 1925.

Spruce forests are still structurally prevailed by wetlands with an admixture of pine and birch (52.79 % of all spruce), followed by riverain ones with admixture of birch and pine in the second place – 34.59 %. Drained and earlier water-logged forests take 8.18 %. These groups made up the main part of the newly emerged forests in place of swamps and marshy forests. Dry spruce forests with an admixture of birch occupy 2.71 %, burnt areas in place of spruce and blueberry 1.73 %.

As of 1954 the structure of coniferous forests had significant changes in the ratio of spruce and pine forests: if in 1925 they were approximately equal, in 1954 the picture looked different: 32.67 % of spruce forests against 6.43 % of pine forests. The change occurred not only due to a significant increase in spruce forests in the marsh drained areas; there was also a reduction in the area of pine forests – 8 % as compared to 1925, mainly because of deforestation and subsequent renewal of birch forests in their place with the use of pine. In the structure of pine there are reduced share of marshy forests (29.82 % in 1954 against 45.15 % in 1925) and relatively increased proportion of forests with cowberry and green mosses: (43.79 %, including approximately half of them mixed with pine and birch trees – 21.96 % in 1954 against 42.9 % in 1925); given the overall 8 % reduction in pine forests it can be concluded that *high-bonitat* pine forests with green mosses being the most valuable for

logging suffered most from wood-felling. Lichen trees occupy 19.68 %, felled lichen trees 4.38 %, pine renewal in place of felling sites 2.33 %. The total share of felling sites in place of pine forests has increased from 3.95 % in 1925 to 6.71 %. The total number of small-leaved forests has increased by 2.3 times, mainly due to the deforestation of spruce and pine forests. Birch and spruce forests have partially grown in places of drained swamps and marshy spruce forests with the use of birch. Tereba meadows occupy 0.37 % of the forest areas, which is five times less than in 1925 (2.08 %). This indicates a significant reduction in small-scale private farmlands unsuitable for processing with the use of equipment. Marine saline meadows – 2.3 % of the land area – remained unchanged (figure 2).

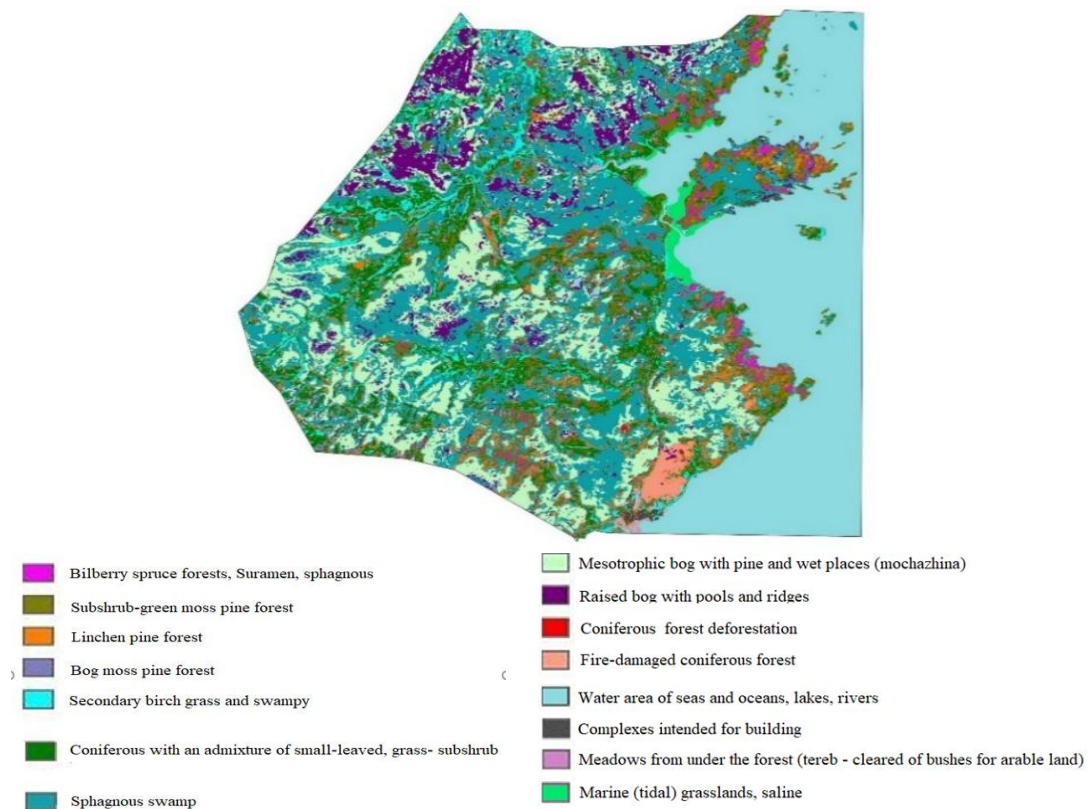


Figure 2. Vegetation of the key site—the mouth of the Shui River in 2018.

A current vegetation map for the historical and geocological Pomeranian province as of 2018 was compiled using the following materials: 1:2,000,000 scale vegetation map of Karelia, 1:50,000–1:200,000 scale topographic maps, 30 m spatial resolution Landsat-TM satellite images. Survey measurement decoding and subsequent map operations were carried out using software packages Erdas Imagine 8.0 and ArcGIS 10. To facilitate recognition of plant community areas, two colour combinations of image channels were developed. Finally, we obtained 15 plant community areas with the decoding accuracy being 85 % (figure 3). Based on the results of geobotanical mapping in three sections (1925, 1954, 2018), diagrams are presented that show changes in vegetation types within the key site (figure 3). In particular, the areas of bogs are shrinking by 1954 due to the introduction of drainage reclamation systems. At the same time, drainage affected the structure of the tree cover: the area of distribution of pine increased twice and reached 32.7%, and spruce forests three times - from 3.5 to 11.0%. Small-leaved areas are shrinking due to drainage and then more than doubling by 2018. The reasons for such modifications of the breed composition are associated exclusively with human activities.

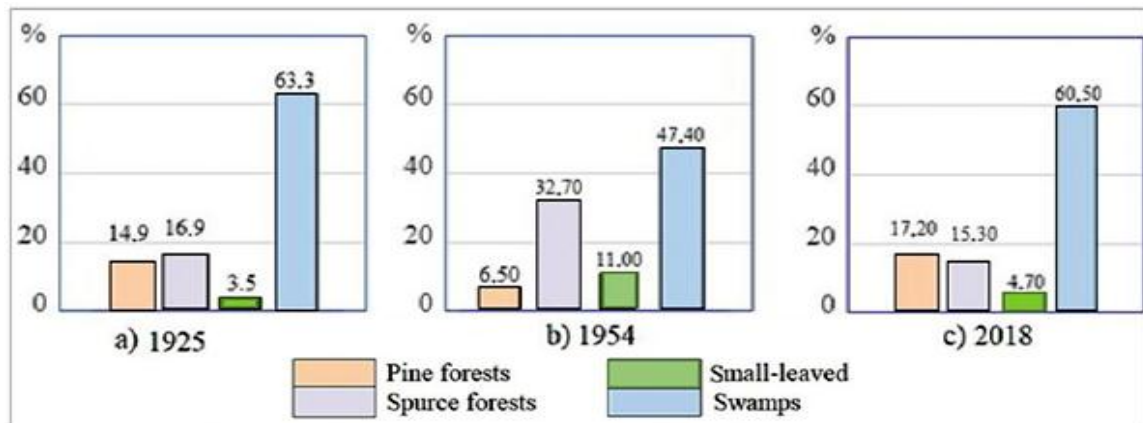


Figure 3. Diagrams of changes in vegetation types of the key site for three-time section.

The diagrams presented (figure 3) indicate a certain dynamics of swamping processes within the key area for three time slices. The natural swamping processes characteristic of 1925 were subsequently disrupted by the creation of drainage systems associated with the hydrological problems associated with the creation of the railroad embankment. After 1970, the drainage operation ceased due to the abandonment of the reclamation system. Flooding from the White Sea-Baltic Canal was added to natural processes and the area of bogs increased to the initial level - 60.5%.

Historical and geocological studies envisage taking into account the results of spatio-temporal zoning [10, 11], where the ethnic component would be designated and an assessment of the current state of the population [12, 13] was carried out to objectively determine the magnitude of anthropogenic load.

5. Conclusion

At different spatio-temporal scales of active nature management within the key section of the Shuya River valley, spatio-temporal differentiation of the vegetation cover is traced, which indicates a weak degree of stability and functioning of natural geosystems of various genesis, depending on the duration and intensity of development. The results of the study showed a quick response of the geosystem to human intervention, and fast modification variability. It should be emphasized that the landscapes of the key site are characterized by self-organization, accompanied by both complication and simplification of the horizontal structure. For the morphological units of the valley landscape and the watershed plain, polychronism is noted - different temporal states, which allows us to make an assumption about ergodicity. According to the change in the states of geosystems within the valley landscape, it is possible to recommend the use of a synergetic approach to solving the problem of a sharp change in space-time boundaries, due to the frequent and rapid change of states.

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