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Change in the Soil Complex on Fallow Arable Land of the Boreal Zone of North-West Russia

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Abstract. Changes in the agrochemical state of old arable soils on two-membered sediments under the formed mature stands of pine and spruce in the Leningrad region of Russia are considered. It is noted that different pH and organic substances content of soil profile is observed depending on rock composition and granulometric condition of soils. The greatest acidification of all horizons along the soil profile occurs in stands with spruce predominance. At all objects studied the humus content is higher in the horizon of formed forest soil. The largest organic substances stock in the former arable horizon is found in areas dominated by pine. In general, in the investigated sites with spruce and pine stands in the soil complex, the amount of mobile phosphorus (P₂O₅) decreases as the pH value increases along the genetic horizons. As for mobile forms of potassium (K₂O), the dependence of its content reduction on the genetic horizons of the soil in the bottom profile from litter to loamy bedding is observed, where there is some increase in its content. High potassium content in postagrogenous soils under the forest indicates the ability of the soil to keep its level in equilibrium for a long time. The return of the former old arable soils and the native state has not yet happened.

1. Introduction

On unused agricultural land there is a natural process of succession of plant communities, which at the limit should lead to the restoration of original vegetation and to significant changes in the condition of old arable soils. This process should be considered as an important factor of modern evolution of Russian soils [1,2]. The arable land is transferred to the fallow and transformed under the influence mainly of natural processes due to changing factors of soil formation: infestation, overgrowth, swamping. Large areas of agricultural land, for a long period of time unused for its intended purpose, have been overgrown with woody and shrub vegetation and have already formed closed forests of different ages, up to middle-aged and adrift plantations. After cessation of active cultivation, agricultural land is renewed by natural vegetation and organic matter starts to accumulate in soil again [3,4]. There are significant differences in the length of time and rate of organic carbon accumulation in soil, which is related to productivity of reconstituted vegetation, physical and biological conditions in soil and past history of organic matter introduction and physical impact on soil [3-6]. The maximum rates of accumulation of organic substances are observed during the initial stage of the renewal of



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perennial vegetation. Previous land use is the main factor contributing to soil changes in C_{org} after reforestation [7-11]. In boreal zone of Russia the most significant transformation of studied soil properties in conditions of changing vegetation was revealed for poor sandy soils of southern taiga [3,12]. The regional climate has the greatest impact on carbon storage. It was noted that primary productivity, biomass and soil C content were associated with a warm, humid climate and limited in warm, dry climate, while warm temperatures were also associated with higher decomposition rates and reduced soil C storage. The degree of change in organic C content and stocks, nitrogen enrichment of humus and acidity in the soil layer from 0 to 20 cm during postagrogenic evolution decreases from north to south. Study of soils in postagrogenous ecosystems is an urgent problem of modern soil science, because of the global reduction of agricultural land in the world. [2,3,8,7]. At the end of agricultural use on anthropogenically transformed soils the process of soil formation occurs naturally and the territory is first overgrown with herbaceous, then bushy and woody vegetation [2,4,11,13,14]. The natural regeneration of coniferous wood vegetation in old growth areas that have come out of active agricultural use remains an under-researched issue, and the main regularities of this process have not been studied. In some areas, especially the boreal zone, forest cover has increased significantly [1,2]. For the North-West zone of Russia, the solution of the problem of growing forest plantations on lands not used in agricultural production is reflected in the specially developed Concept of Creation of Target Forest Plantations (2008) [15]. Studying the differences and composition of plant species among trees with different land-use history and at different stages of succession can improve understanding of the impacts of past land use on communities in these forests. The knowledge gained will serve as a basis for predicting the responses of plant communities to future environmental changes. In turn, plants are more or less selective with respect to soil properties and regimes. The question of the relationship between woody vegetation and postagrogenous soils has long attracted the attention of researchers in different regions of the world. In connection with the relevance of this topic, the purpose of the study was to analyze the processes of transformation of soils in postagrogenous lands under mature stands of pine and spruce in the North-Western region of Russia, to establish the rate of transition of these soils in the native state.

2. Methods and materials

2.1. Objects of study

The object of the study was a forest area on a placard elevation of the Oredezh Plateau adjoining the Oredezh River in the Gatchina district of the Leningrad region, which had been used for a long time for arable land. Previous agricultural use was indicated by piles of stones at the edges of former arable fields, as well as cartographic data from the times of the Russian Empire in the early twentieth century. Six plots of mixed spruce and pine stands were surveyed in the former old growth land. Soils are degraded agrosol on top, which formed a layer of humus horizon with traces of podzolization capacity of 10-12 cm during the formation of forest phytocenosis. The underlying agroforestry is a two-member rock, with a sandy loamy horizon on top and a red-coloured moraine loam below. Growth conditions correspond to the I-Ia class of bonitas for the research region.

2.2. Experimental part

Были Trial areas from 0.3-0.5 ha were laid out using portable GPSMAP 64 navigators, with boundary markings using measuring tapes. Variation in the size of the accounting area is due to the required number of trees on the sample of at least 250 trees. Taxation of the stand was carried out by methods generally accepted for forest research using measuring forks and altimeters Haglof.

Soil samples for agrochemical analysis were taken from genetic horizons. The mixed soil sample was composed of at least 25 individual samples. The weight of the sample is 250-300 grams. In selected samples of soil the content of organic matter, acid-base indexes were determined, granulometric composition was specified. The humus content was determined by the Tyurin method in the Nikitin modification. Determination of mobile phosphorus compounds (P_2O_5) on a photoelectric

colorimeter and potassium (K_2O) on a flame photometer using the Kirsanov method in a modification of Central Research Institute for Agrochemical Services of Agriculture. Determination of the particle size distribution is carried out with a pipette of N.A. Kachinsky. Measurement of soil pH was carried out using potentiometric method [16].

3. Results and discussion

Renewed tree pine and spruce stand has the age of 80-85 years, aspens and birches - 50-60 years. The biometric characteristics of the stands show that under these conditions, stands were formed with a different proportion of spruce and pine (table 1). Long-term soil cultivation is indicated by heaps of stones and a well-preserved profile of the former arable horizon of 15-20 cm under the formed 8-10 cm layer of forest soil and 3-5 cm layer of opal and forest litter. Beneath the former arable horizon, the sabulous-clayey and sandy loam, then a red-colored moraine loam with an infusion of boulders. With the weighting of the particle size distribution of binomial structure soils from sandy loams to light loams and the increase in physical clay content in genetic horizons, the share of spruce in the composition of planting increases. The conducted agrochemical analysis on genetic horizons on the laid six experimental plots showed the differences in the process of transformation of the soil complex depending on the prevalence of tree species and particle size distribution of soil. The analysis of soil profile of investigated soils testifies that transformations under a tree cover all postagrogenous thickness. Under pine dominated stands the arable horizon has soil density 0.6-0.7 g per cm^3 , under spruce soils 0.8-1.0 g per cm^3 , which is characteristic for forest soils of similar genesis. In the former arable soil, due to increased humus content, C:N ratio under pine stands is 8.5-8.7 and under spruce stands 10.2-11.6. In forest soils C:N indicator has a range from 6.5 to 11.2. It can be noted that: the old arable horizon begins to differentiate into humus horizon of forest soil and horizon of former arable land. It should be noted that woody vegetation, depending on its composition, has a different influence on changes in the structure of the upper soil thickness of the former arable horizon.

Table 1. Taxation characteristics of pine and spruce stands at experimental sites.

	Tree species	Stand composition, %	D_{avr} (cm)	H_{avr} (m)	N (trees per ha)	M , (m^3 per ha)
#1	Norway spruce	87	32,5	27,9	380	431
	Scots pine	11	35,7	30,2	50	55
	Aspen	0,5	17,4	21,7	7	2
	Birch	1,5		19,4	22	33
#2	Norway spruce	80	28.9	28.4	328	288
	Scots pine	18	39.6	28.8	46	64
	Aspen	1	27.9	25.5	4	3
	Birch	1	23.1	24.2	8	4
#3	Norway spruce	55	27,1	27,2	405	309
	Scots pine	38	35,2	28,8	197	215
	Aspen	5	29,3	25,7	34	27
	Birch	2	18,0	21,6	54	14
#4	Scots pine	59	31,2	27,4	316	269
	Norway spruce	32	21,8	25,4	316	148
	Aspen	4	33,8	26,2	16	18
	Birch	5	24,6	24,7	41	22

#5	Scots pine	50	31.1	30.0	315	268
	Norway spruce	48	25.1	27.0	488	258
	Aspen	1	33.8	24.0	18	7
	Birch	1	24.6	28.0	9	4
#6	Scots pine	61	31.5	30.0	284	266
	Norway spruce	38	25.5	27.0	211	167
	Aspen	1	11.0	24.0	25	5

On all trial areas of old arable soils there is an increase in the pH value of the soil profile, which indicates the presence of carbonate rocks in the underlying horizons (figure 1). Under spruce-dominated stands a lighter humus horizon of small forest soil power is formed, the boundary is expressed by intricacies and tongues, and the eluvial horizon is characterized by a lighter coloration. The pH level of soil is lower in spruce-dominated areas, which is more the result of the action on the soil more acidic needles than pine [17,18]. A darker humus horizon is formed under pine dominated stands; the eluvial horizon is also darker than under spruce-dominated stands. Under these conditions, the stand is a mediating factor affecting the soil complex of former agricultural lands.

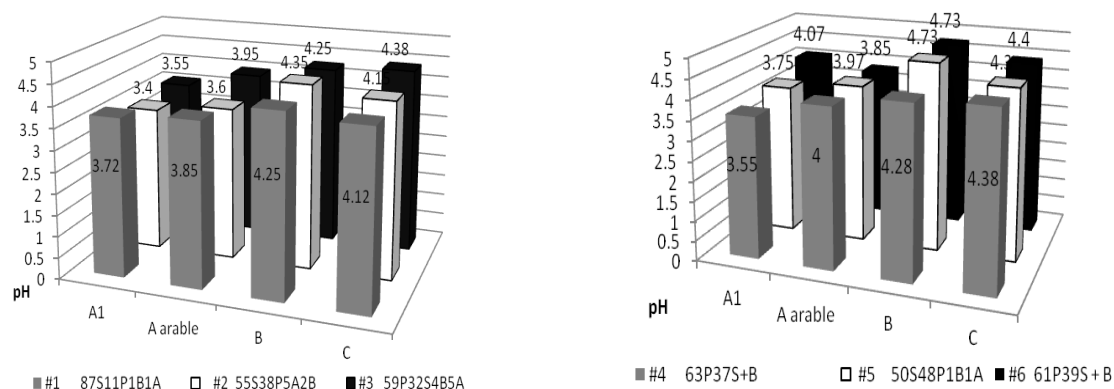


Figure 1. Change of pH indicator on genetic soil horizons on experimental objects with spruce and pine dominance in the structure of planting.

^a Where S – Scots pine (*P. silvestris* L.); S – Norway spruce (*P. abies* Kr.); B – Birch (*B. pendula* Rott.); A – Aspen (*Populus tremula* L.)

In general, in the investigated sites with spruce and pine stands in the soil complex, the amount of mobile phosphorus (P_2O_5) decreases as the pH value increases along the genetic horizons. As for mobile forms of potassium (K_2O), the dependence of its content reduction on the genetic horizons of the soil in the bottom profile from litter to loamy bedding is observed, where there is some increase in its content. Different content of mobile forms of potassium and phosphorus by genetic horizons under stands with different participation shares of rocks is noted. In plantings with a predominance of pine $P_2O_5 = 14.0 - 0.4$ mg per 100g and K_2O mg per 100g. In tree stand with a larger share of spruce the number of mobile forms is less than $P_2O_5 = 4.50 - 0.85$ mg per 100g, and $K_2O = 14.28.74 - 10.42$ mg per 100g is slightly higher. In contrast to spruce, where the surface root system primarily uses a 20-30 cm layer of soil, a pine with a core root system uses deeper horizons of the soil profile. In the former arable horizon the level of elements is also different, depending on the composition of the planting. Under spruce-dominated stands, the content of mobile forms of potassium and phosphorus is lower than in stands dominated by pine.

In natural biocoenoses, a closed cycle of biogenic elements is achieved. Decrease in organic substances content down the profile can be observed on genetic horizons (figure 2). The largest organic matter stock in the former arable horizon is observed in areas with dominant pine humus 2.57-2.66%. In spruce-dominated plantations, the humus content is 1.75-1.97%. For the newly formed horizon of forest soil in the investigated stands this direction is also preserved. The content of organic substances in litter and forest soil horizon is higher in pine stands than in spruce stands. An exception is stand # 1, where due to the presence of birch and aspen in the composition of the plantation more organic substance content in the horizon of forest soil is observed. Apparently, due to the more acidic litter of spruce needles, a more rapid mineralization of organogenic soil horizons in these plantations occurs.

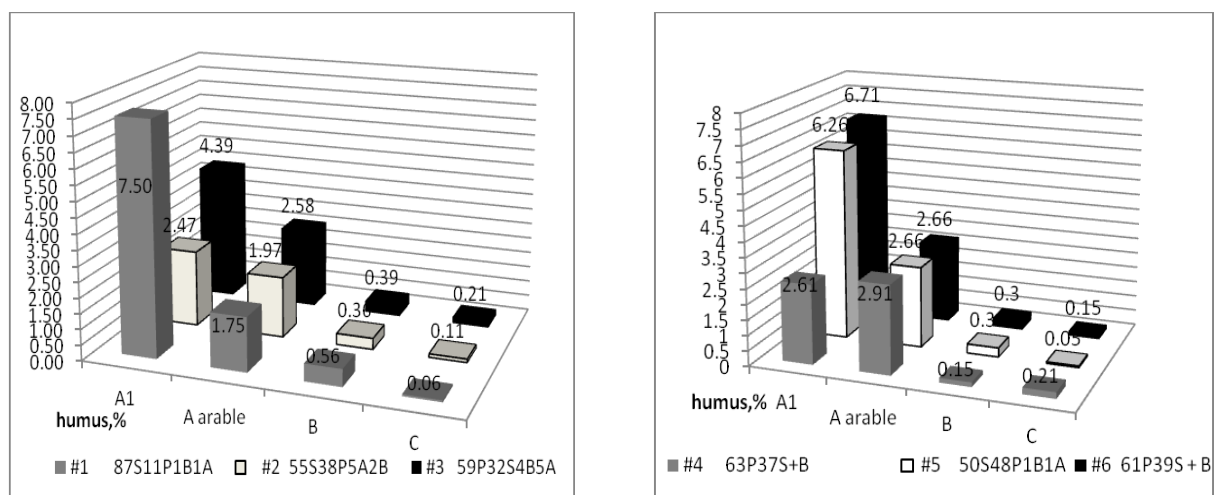


Figure 2. Change of humus content (%) by genetic soil horizons on experimental objects with spruce and pine dominance in the composition of the plantation.

^a Where S – Scots pine (*P. silvestris* L.); S – Norway spruce (*P. abies* Kr.); B – Birch (*B. pendula* Rott.); A – Aspen (*Populus tremula* L.)

In the last stages of succession on the former old plowing soils organic C accumulation is mainly due to the living ground cover characteristic of the forest, as well as coniferous and woody deposition. These stages are characterized by the formation and accumulation of forest litter with an acidic reaction of the environment.

4. Conclusion

On postagrogenous soils the profile of the former arable land is preserved, which is different from the formed horizon of forest soil in terms of agrochemical indicators. The influence of coniferous stands as a mediating factor on the soil depends on the share of spruce and pine. High potassium content in postagrogenous soils under the forest indicates the ability of the soil to keep its level in equilibrium for a long time. Postagrogenous soil by the content of mobile forms of phosphorus is close to the state of forest soil, which is associated with its removal and to a greater extent stands with a greater share of spruce. The greatest acidification of all horizons along the soil profile occurs in stands with spruce predominance. Content of organic substances in arable horizon is less than in newly formed horizon of forest soil. The return of the former old arable soils and the native condition under the formed forest at this age stage of the deposit has not yet occurred.

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