Soil areas of the Novgorod region in the context of their agricultural use

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Abstract. The article considers the issues of establishing correspondence between soil-forming factors and soil properties. The aim is to determine the degree of natural soil fertility in the context of its agricultural use in the Novgorod region. The main soil-forming factors are the Quaternary mother rocks and modern sediments, in some areas they are represented by the Paleozoic indigenous deposits. Soil formation largely depends on climatic features, hypsometry, rugged terrain and vegetation, which are heterogeneous within the Novgorod region. These factors undermine the processes of podzol, peat and gley formation and sod process, which jointly determine the mosaic of the soil cover. The authors have examined the soil-geographical areas of the Novgorod region, given the characteristics of soils and identified measures connected with agricultural activities and special techniques aimed at improving the soil properties and increasing fertility.

1. Introduction
The soil layer of the Novgorod region is rather diverse, which is explained by various combinations of its formation and development conditions. The bases of soil formation are parent rocks, they affect many soil properties such as mechanical and mineralogical composition, water properties, density, content of chemical elements, etc. [2]. Soil-forming, or maternal, rocks of the Novgorod Region include sediments of the Quaternary period, modern sediments, and, less commonly, indigenous Paleozoic rocks.

Since the Novgorod region soils began to form after the Valdai glaciation, the Quaternary mother rocks became widespread. They are quite diverse in their genesis (glacial, water-glacial, lake-glacial) and mechanical composition (boulder and sandy loams, fluvioglacial sands with gravel and pebbles as well as lake-glacial sands and clays). Podzolic soils are formed mainly on these deposits, with humus fulvate composition, which reduces their fertility. Modern sediments are represented in the vast Ilmen-Volkhov floodplain and in river valleys. These are lake-alluvial and alluvial deposits of different mechanical composition (gravel, pebbles, clays, sands, loams, sandy loams composing both the floodplain and the first floodplain terrace).

Root Paleozoic age deposits hardly ever become directly parent rocks. These include the southwestern coast of Lake Ilmen (the Buregi – Korostyn section), where soils are formed on Devonian limestones and carbonate clays. Mother rocks in the form of limestones and dolomites are also found in the valleys of the Msta (Borovichi district), Shelon’, Kerest’, Mshaga and other rivers, where they form small sections of carbonate soils. Carbonates neutralize mobile organic and organo-mineral soil compounds, thereby slowing down or stopping the podzol-forming process and, accordingly, promoting soil fertility. These are the most productive soils of the region.
The Novgorod region belongs to the province of accumulative glacial and water-glacial relief. Its western part is characterized by the distribution of accumulative and abrasive lacustrine-glacial and glacial lowlands while its eastern part is characterized by hilly-ridged moraine, sandra, lake, and kama-lowland reliefs. The modern relief has a pronounced relict character and is only partially altered by relief-forming processes. The relief affects the redistribution of heat and moisture along with the development of characteristic soil-forming and erosion processes [4].

An equally important soil formation factor is the climate, which directly determines the energy level and soil hydrothermal regime, in addition it indirectly affects the soil formation process through vegetation, the vital activity of animals and microorganisms [3]. The leaching type of water regime of automorphic soils is formed due to the temperate-cold and humid climate of the region which is favorable for forest growth. Within the region, there is a border between southern taiga and mixed forests. Forests are characterized by low annual biomass growth and deep soil stratum wetting, as a result of which soluble forms of organic and mineral compounds are washed out of the soil. Moreover, the forest litter is decomposed very slowly by the fungal and bacterial flora, with the leading mushroom process, contributing to intense acid formation. Aggressive fulvic and low molecular weight organic acids predominate thus reducing soil fertility due to the destruction of the soil mineral part, the removal of some destruction products from the soil profile and, accordingly, the development of the podzolic process [4].

In addition to the widely developed podzol formation, the soils of the Novgorod region are characterized by a soddy process under grassy meadow vegetation on any rocks, and under grassy or mossy-grassy forests on carbonate rocks. A distinctive feature of this process is the accumulation of humus and nutrients and the formation of a water-resistant structure in the humus-accumulative horizon. It should also be noted that even with the long-term development of grassy vegetation under the forest canopy, a large amount of humus and nutrients do not usually accumulate, the podzolic process (along with sod-podzolic soils) is also opposed to the sod one.

Such processes as peat and gley formation are also typical for the soils of the region. The first is observed under conditions of excessive atmospheric or groundwater humidification in the presence of moisture-loving vegetation which leads to its incomplete decomposition in obstructed aeration conditions. The second occurs under conditions of relatively stable overmoistening and leads to the oxidation of iron oxide affected by decomposing organic substances under restricted oxygen access with the help of anaerobic microorganisms and its transformation into acidic compounds with their subsequent leaching into the lower part of the soil profile. Thus, soil fertility is largely determined by the conditions of soil formation, which are diverse in the region. The study of the current state of the soil layer, the identification of soil morphological features, properties and fertility at the present stage of agricultural industry development is becoming an urgent task [1]. Considering everything, we can conclude that the soil-geographical zoning of the Novgorod region, which takes into account the structure of the soil cover and its formation factors, is of great practical importance in the context of further agricultural use.

2. Objects and methods of research
The object of the study was the soil-geographical areas of the Novgorod region. Field studies and observations over a twenty-year-long period, generalization and comparative analysis of the data obtained with the research results from the 60s, soil and landscape profiling techniques, and the analysis of theoretical and cartographic materials were used as research methods.

3. Results and discussion
Our territory is called the “Non-Black Earth Region”, as well as the “risky farming zone”, thereby determining the low favorable agricultural climate. If we examine the territory of the Novgorod region in more detail, it becomes clear that within its borders there can be found a rather variegated soil pattern.

The Luga-Shelon’ district is characterized by a complex soil cover structure. Deposits of Devonian limestones and dolomites are blocked here by moraine loam 10–15 meters thick. The rugged topography
determines the moisture unevenness. The relief is composed of carbonate gravelly moraine. On the surface of the plain, individual ozas composed of carbonate sands are found. Due to its high density, bottom carbonate moraine has insufficient water permeability. In the north-east of the region, thin lake-glacial sand spots lie on top of the carbonate moraine. A continuous strip of sand layer stretches along the Shelon’ river. Such conditions lead to a variety of soils in the area. Among automorphic soils there prevail sod-podzolic residual-carbonate and sod-carbonate podzolized, less often leached; the latter stretch as a strip along the channel of the upper reaches of the river Luga. Soils with normal moisture, not requiring any moisture control measures, are located in riverside strips and various hills. Arable sod-podzolic and cultivated meadow soils are often interspersed with poorly saturated and secondarily saturated ones. The share of automorphic soils is increasing in the western and southern parts of the region along the Shelon’ basin, where the plain is slightly better drained. In general, automorphic soils are inferior in covered area to semi-hydromorphic and hydromorphic soils throughout the region. Soddy-gley saturated and podzolized soils are very characteristic and widespread in flat undrained areas with close hard waters. Mainly in the northeast and east of the region soddy and peaty-podzolic-gley soils are found.

High natural fertility soils are widespread in this territory; there is a large stock of agricultural land. However, these territories need drainage reclamation and stone cleaning. The soils of the Soltsy and Batetskaya regions have high carbonate content, an increased supply of phosphorus and organic matter so the need for liming is insignificant.

All arable and meadow soils of the region are still insufficiently cultivated. Depending on their genetic properties, they need various systematic land reclamation measures as well as special crop rotations and farming techniques (improving the water-air regime, removing weed vegetation). Given the long-term use of various land reclamation and soil cultivation methods, the Luga-Shelon’ soil region may become one of the most productive in soil-agronomic terms.

In the district adjoining Lake Ilmen, there are both terrain plots composed of lacustrine, light-weight alluvium, as well as alluvial soils of large lakeside deltas of the Lovat’ and Msta rivers, composed of fine-grained clay sands up to 8 m thick. The deltas’ relief is complex; few even surfaces, fine contouring and strong variegation in the soil layer are observed. Acid and weakly acidic soddy alluvial gleysous soils lie on the lake alluvium along the flood coast of Lake Ilmen. These areas are subject to regular flooding, in some places they have a stagnant regime, the grass stand is mainly represented by sedges, usually hummocky. The deltas adjacent to the lake are characterized by slightly acidic, more fertile meadow-alluvial layered soils with a pronounced gleysous process. The middle floodplain is mostly occupied by meadow-granular soils. Loamy varieties prevail everywhere, although the mechanical composition of soils is motley, as is the alluvium itself. At low levels there are many silty and peat-humus soils.

The soils of the Ilmen-basin territory are both poorly cultivated and developed. Their reclamation restructuring involves high costs of regulating the surface and ground waters regime. Provided a continuous and properly planned land reclamation is carried out, the Ilmen floodplain may be the basis for creating the largest forage base in the region.

The Chudovo-Novgorod district is characterized by dominating parent rocks of water-glacial and alluvial origin. The main parent rock in the western Ilmen basin part (except for the coast) and in the Volkovh River lowland are tape clays, sometimes covered by thin lake-glacial sand deposits. In the large Volkovh floodplain lies a river alluvium of loamy and even clayey mechanical composition. Sod-podzolic surface-gley and sod-podzolic-gley soils are formed on tape clay. These soils are characterized by a large supply of nutrients, in the subsoil they are often quite carbonate. In the past, the territory was well developed for agricultural purposes. In the Soviet times, it was widely engaged in land reclamation. A closed drainage system was created, which turned out to be ineffective, since it diverted only surface water. Currently, these soils still need reclamation and can become the basis of meadow cultivation, used for pasture.

Peaty and peaty-podzolic-gley semihydromorphic soils are characteristic of undrained interfluvies. A distinctive feature of the territory is the widespread upland peatlands. In the Volkovh floodplain where
there are fertile meadow-illuvial and boggy floodplain soils. It requires a comprehensive improvement of soils for land reclamation and agrochemical purposes. With proper soil care, the area described can become the main food and vegetable suburban base.

The Shelon’-Polist’ district is characterized by a moraine, relatively flattened and uniform terrain plain. To the south, the degree of water logged soils increases, which is explained by a decrease in the depth of the rivers. The most fertile agricultural soils are located in the northern part of the interfluve. These areas of the region are characterized by a high degree of agricultural development. Agriculture is carried out on sod-carbonate leached and podzolized soils. The mother rock is a low-power carbonate gravely moraine. On the Ilmen clay, a strip of equal width reveals very dense variegated, water-resistant Devonian clays. They served as a basis for sod-carbonate and sod-gley soils of heavy mechanical composition, difficult for cultivation and agricultural use. In the south of the interfluve, soddy-slightly podzolic- and soddy-medium-podzolic carbonate soils on low-carbonate loam prevail. In low parts, sod-podzolic-gley and gley soils and lowland peatlands are widespread. The described area is distinguished by favorable conditions for agriculture. The relief leveling and the comparative uniformity of the soil cover make it possible to cut relatively large arable land sites, which favor the mechanization of tillage. Flax grows well on the soils of this region as well as barley, wheat and high-yielding seeded grasses. In southern Ilmen basin part, on carbonate soils, cherry orchards and berry plants used to be of industrial importance. Even at the times before the reign of Peter the Great, Moscow tsars kept here gardens of the well-known local Korostyn cherry famous for its exquisite taste. This branch of the economy has now come to naught. Meanwhile, in terms of bioclimatic and soil conditions, this region is the most favorable in the entire Novgorod region.

The Low-Msta district is characterized by dominance of light mechanical composition soils. The area is a sandy lake-glacial plain, the surface of which in some places was subjected to aeolian processing (sandy mounds and dunes). Among non-swarmpy soils, podzolic and sod-podzolic soils prevail on thin, silty sandy loams and bicompartamental sediments; in areas of dune relief under moss-lichen soil cover, skinny and dry low-power glandular podzols developed.

Most marshes are located on the watershed in the Vishera river basin. Marshes are deep sphagnum peatlands. Many of them in this and in neighboring soil districts are characterized by high cranberry yield. Such bogs, if properly exploited, can yield no less than agricultural land. Agricultural land is limited to narrow riverside strips. Soils on dusty lake sandy loams with a properly developed agrochemical system can become quite valuable for potato growing. In the damp climate of the Novgorod region, not all soils are suitable for growing high-quality tasteful potatoes. Light soils on rich, unwashed sandy loams are most suitable. On such soils, the harmful effects of prolonged root layer wetting and nitrogen fertilizers overuse are excluded, as it spoils the taste of potato tubers.

The Beglovsky district is located on an abraded undulating moraine plain, composed of deep-carbonate and non-carbonate boulder loams. Bicomponent sediments are widespread in the region which is low-power sandy loam on a leached moraine. The soils developing on these rocks are characterized by the absence of podzolic formation signs or a weak manifestation of the podzolic horizon, but they are carbon-free and can be regarded as acidic, unsaturated bases. However, these soils are more fertile than typical podzolic soils. The most widespread in the region are typical sod-podzolic soils of medium and high podzolization degree. In lowlands, podzolic and bog soils prevail. Soils of the region in their natural state are low-productive, they need reclamation, moisture regulation and drainage. Yield grass stands, which make up a good forage base, are characteristic for areas with a closely occurring carbonate moraine. In other areas grass stand happens to be of poor quality.

The Polavsky district forms part of the vast Lovat’ River Lowland. The most common soil type is slightly humus sandy sod-podzolic illuvial-ferruginous soils, characterized by leaching regime. Here there are soils lacking a humus horizon, the so-called ferruginous podzols. In places of increased soil moisture, these soils are replaced by peat and peat-podzolic gley soils, and in those with constant excessive moisture, by peat. The most fertile are sod-podzolic soils on binomial sediments (thin sandy loamy clay loam) located on the periphery of the region. The problems of improving soils, agricultural reconstruction and land reclamation can only be correctly resolved having a plan for comprehensive
transformation and reconstruction of the entire lowland. Soils in large areas are waterlogged while sandy loam prevails in the mechanical composition. In general, they are slightly fertile and need to be drained. Polavsky district refers to territories with low agricultural development.

The vast Polysgrovsk-Lovat' region occupies the central part of the Lovat’ Lowland and is distinguished by the large swampliness of the watersheds, as well as the fact that its soil cover is most affected by water erosion. In the northwestern part of the territory lies a flat moraine plain, hardly dissected by a river network. The Kholm lowland is composed mainly of layered sandy-loamy deposits alternating with tape clays. On the interfluve, semi-bog and bog soils dominate. On the watersheds, peatlands of various types are combined with semi-hydromorphic soils on the slopes of river valleys and with sod-podzolic often gleyized ones near rivers. In the lake part of the Polist’ river basin the leafy lacustrine and boggy soil combinations are widespread: peat bog has a mineral boggy soil. Sod-podzolic soils have a second clarified horizon, usually fawn, of normal moisture and are located in narrow strips along the rivers. In these areas, there can also be found residual carbonate sod-podzolic soils.

The Lovat’ River Lowland, together with adjacent areas, is the largest reclamation site of the Novgorod region and the entire northwestern agricultural zone. Provided comprehensive land reclamation, including cultural development, special cultivation and land management of the soil stock, is carried out throughout the territory of the complex and developed according to a unified plan, a gigantic land mass of highly productive soils suitable for the large crop rotation fields and production sites similar to the ones in the chernozem zone can be obtained.

The Malaya Vishera district refers to the number of least developed in agricultural terms. Plowed lands occupy a little more than 5% of the area. This is largely due to the features of the soil cover. The area is composed mainly of moraine deposits, with the presence of weak drainage lowlands, runoff troughs, ravines, gullies, and is generally poorly drained. The most common parent rock is abraded, surface-sandy medium and heavy non-carbonate main moraine. In blurry areas, it is so overgrown that the soil is arable unsuitable. In the central parts of the interfluves there are significant massifs of upland bogs. Biennial deposits and dry riverbed sands in the floodplain of the rivers serve as the bases for the formation of infertile illuvial-humic and ferruginous podzols. The sand podzolic soils have two clarified horizons. The district is in dire need of planned land reclamation development and intensive cultivation.

The Pre-Valdai district is characterized by the predominance of light mechanical composition soils and a variety of parent rock genesis. Moraine deposits are largely eroded by fluvialglacial accumulation processes. The deposits are predominantly sandy such as non-bouldery thin, thin-layered sands, heavily bouldery coarse-grained sandy loams. In the south of the region, sod-podzolic glandular soils are formed. Podzols are characterized by the presence of a glue process, which is very widely developed. The swamp massifs are not large, mainly of the upland or transitional type. The northern parts of the region are characterized by the spread of podzols, the predominance of illuvial-ferrous humus soils. Depending on the depth of the underlying deposits, podzolic soils with two clarified horizons (many fawn soils) or sod-podzolic glandular rocks were formed on the binomial rocks that are ubiquitous. The agricultural production properties of the district's soils are low, it is necessary to carry out measures to improve their water regime, increase the humus layer thickness and improve its structure. Soils are poor in nutrients and require large doses of a complete set of fertilizers. Organic fertilizers are especially important. Soil claying and the use of microelements can have a positive effect too. The southern part of this soil district, covering the territories of the Demyansk and Marevo administrative regions, may become the base for the production of early potatoes (the warmest sandy soils).

The territory of the Valdai district occupies the central elevated part of the Valdai Upland. This is the most dissected relief within the region. The area is notable for significant elevations, many moraine hills, ridges of different sizes, deep lowlands and runoff troughs formed by melt ice waters. The sandra and lake plains, the placer of kams, long ozas, deep beams result in a variegated soil layer. Soil-forming rocks are diverse in both origin and mechanical composition, medium, less often heavy reddish-brown loams prevail, initially carbonate, but currently leached from carbonates to a depth of 1–1.5 m. Sandy and sandy loam deposits occupy in separate parts from 15 to 30% of the area, however, they are rarely observed in the form of large massifs, meanwhile the change of rocks within a short distance, even on
the same relief elements, is more frequent. The small contour of agricultural land is determined by the relief cross-section. The advantage of this territory is good soil drainage and, consequently, low distribution of swamps and peaty soils. The area is rich in semi-hydmomorphic soils with a variety of reclamation properties. In the lowlands, sod-podzolic-gley and peaty-podzolic-gley soils are widespread. Indigenous spruce trees got rooted on sod-strongly podzolic soils. Under taiga type forests with small-leaved species, soddy-medium and slightly podzolic soils with a mechanical composition varying from loam to sandy loam are located. A special place is occupied by brown-podzolic soils, which are sub-pits on clay. These heavy soils are difficult to develop, but potentially very fertile. Soil fertility is not high, the difficulty lies in the application of agricultural technology in small contour areas and rough terrain.

On better developed slope lands, soil productivity significantly reduces erosion processes. Most of the developed soils need liming and applying mineral and organic fertilizers, systematic cultivation and the introduction of a proper farming system focused on dairy farming with grass sowing and cultivated pastures.

The Mid-Msta district covers terraced lacustrine-glacial and lacustrine-alluvial plains of the Msta Hollow, bordered by a strip of marginal formations. The parent rocks are variegated: they are represented by lake-glacial sands and sandy loams, occasionally loams and tape clays, in some places leached boulder loams come out to the surface (closer to the edges of the hollow). Biennial sediments are also widespread – lake-glacial or fluvioglacial low-power sands and sandy loam, on boulder loams. The largest area within this territory is occupied by sod-podzolic-gley and gley soils, and in the central part there are many upland and transitional peat bogs. The elevated sandy areas are represented by surface- and crypto-podzolic soils resembling the light brown soils of Karelia. In lower areas and on the periphery of the subarea, soils of upland and transitional bogs, as well as peat and peaty-podzolic-gley soils are found.

An extended soil stock needs land reclamation of various kinds. The problem of foraging in the area is complicated due to the low productivity of meadows on sandy lands. Within the territory of the Msta Hollow bottom, the conditions for agriculture are somewhat more favorable because of the peculiarity of the local climate.

The Sherekhovichy district is characterized by hilly moraine topography with large fluctuations in altitude in the northern and central parts of the region and an alternation of hilly moraine sections with moraine and sandra plains in the eastern and southern parts. The parent rocks in the territory are mainly represented by boulder red-brown loams (Kresty and Vepsovskaya moraines), binomial sediments and deep fluvioglacial sands.

The soil cover of the district is diverse. Under coniferous forests, podzolic soils dominate, under secondary forests and agricultural land sod-mid-podzolic soils prevail. There are few bog soils in the region, the largest masses of peat bogs are concentrated in the east, almost all the bogs are of the upper type. The interfluve of the region is poorly drained, composed of loamy, boned moraine. Here, similarly to any lowlands, sod-podzolic gley and gley soils are formed. Swamps with peaty-gley soils on the edges are common on the outskirts.

Forest poddebice (brown soil-podzolic deeply gleyous soils) were formed on the bell clays. Spots of soddy-carbonate soils are found both on loams and on sands with calcareous gravel. In the Soviet period, flax-growing and livestock breeding were the leading economy directions here.

The Khvoinaya-Pestovo district located in the northeast of the region in the southern taiga zone with pine and spruce forests domination has soils of mostly light texture. The Pre-Molog territory is distinguished by the presence of elongated sandy terraces with a wide distribution of pine along with spruce forests. The typical representatives here are soddy, medium, and strongly podzolic gley and gley soils. Small areas are covered by bogs. Within the Khvoinaya subarea, the typical soils are ferruginous and illuvial-humus podzols as well as sod-podzolic ferruginous soils formed on fluvioglacial sands. In the soil sections of the latter kind, a powerful humic horizon is observed. The mother rock is the sandra plain, which is hobbled in some areas with clay moraine. Meadow lands are non-productive, arable land
requires a large number of organic and mineral fertilizers, and somewhere even drainage. In terms of agriculture, this area is unpromising, though the pine forests are of great value.

The surface of the Meglinsky district is represented by abraded moraine plains interspersed with sections of hilly glacial relief. Moraine deposits here are characterized by significant fading, variegated mechanical composition and significant weathering; the carbonates in them are leached to a considerable depth. Acidic rocks of light and medium mechanical composition serve as the basis for the formation of medium- and strongly-sod-podzolic soils. Within the borders of the district, along with the upper swamps, lowland ones were also widespread. In hollows soddy and peat-podzolic-gley soils are common. The flat terrain and relatively good drainage of the territory favor the development of agricultural production. Further land reclamation in the area promises a significant increase in the stock of valuable productive land.

The Zamologsky district is located east of the strip of Pre-Molog boron sands (on the western spurs of the Ovinischenskaya Upland) and is an elevated wavy plain with smooth relief forms and areas of eroded marginal formations. In terms of soil, it is characterized by the distribution of soddy-medium-podzolic soils on a washed light loamy sandy moraine, sod-podzolic soils with a second clarified horizon on bicompartamental rocks (cover sandy loam on moraine loam). In general, the region is characterized by soils of light mechanical composition, mainly sandy loam. The soils of the region are of little value for agricultural production, but some of their sandy varieties are able to give good potato crops with high taste qualities [5].

4. Conclusion

Thus, the soil layer of the Novgorod region is very heterogeneous. Soil areas are identified on the basis of studying soil-forming conditions and dominant soil types. Each district has its own specific soil diversity and characteristics that should be considered when choosing farm machinery.

No significant changes in the location of soil differences were found. An increase in flooded territories and a longer period of non-drying were recorded. Changes connected with a decrease in the cultivated land, hayfields, and pastures area have led to the overgrowing of many areas with shrubs and the process of secondary forests formation. The process of flooding is actively ongoing on the territory of peat bogs. Arable land, abandoned for a period of 15–25 years, and reincluded in the crop rotation practically did not change its characteristics. Those farms that have restored reclamation facilities have the positive experience of growing crop yields. Provided land reclamation is not carried out, the most frequent consequence is soil waterlogging; the death of some crops, and in some cases the inability to harvest, as fields are inaccessible for farm machinery. If such a crop is harvested, then it is quickly lost during storage.

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