Forest growing conditions of chalk marl rocks in the Central forest steppe neo-landscapes

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Abstract. Monitoring of hydrophysical rocks features of the Kursk Magnet Anomaly (KMA) composing chalk marl dumps seems relevant for the evaluation of reliable information on the changes, assessment of the efficiency of reclamation works and for further anticipation of the growth and forest crops state. The object of the study is the Shchigrovsky phosphate rock deposit chalk marl dump planned in 1974 in Kursk region. The aim of the research is to study hydrophysical characteristics of chalk marl rocks and specific features of ontogenesis of Scots pine culture (Pinus sylvestris). It has been found that chalk marl rocks accumulate and retain moisture 2.1...2.3 times more than zonal humus carbonate soils. The hardness of chalk marl rocks in neo-landscapes increases with age. The preservation of Pinus sylvestris cultures in the first years reaches over 82%. This indicator decreases with age and is about 35% by the age of 40. 40-year old Pinus sylvestris culture grows according to V bonitet on chalk marl rocks. It is necessary to apply more fertile ameliorative layer to the surface, with better hydrophysical features in order to improve forest growing conditions of the root zone of the chalk marl dumps in neo-landscapes for forest reclamation.

1. Introduction

In the central forest steppe, the open-pit mining anthropogenic neo-landscapes have been formed since 1950s. At the same time, the issues of classification of anthropogenic complexes according to their content, depth of human impact on nature, genesis, purposefulness of their use, etc. become relevant. The works of such geographers and soil scientists as Milkov F.N., Akhtyrtsev N.I., Mikhno V.B. and others are devoted to the issues of theoretical and practical studies of anthropogenic neo-landscapes [1, 2].

The anthropogenic neo-landscapes belong to the industrial landscapes of the quarry-dump type. They are common for such mining regions as Ural, Kuzbass, Donbass, and Khibiny. Large industrial mining enterprises which operate on the basis of proven mineral raw materials are concentrated on the territory of the central forest steppe (Voronezh, Kursk and Belgorod regions).

The territory, disturbed by mining activities, currently occupies over 20 thousand hectares in the basin of the Kursk Magnet Anomaly. Along with clay loams and sandy deposits, up to 70% of the supraore stripping is represented by chalky and chalk marl rocks, which are most difficult for biological reclamation [3, 4]. They moved and lay in dumps during stripping works. As a result, chalk
landscape complexes appeared, where dumps afforestation is possible only with biologically resistant plant material due to tough forest growing conditions of rocks [5-9].

The aim of the study is to determine the forest growing potential of chalk marl rocks based on the monitoring of edaphic factors and the ontogenesis characteristics of Pinus sylvestris.

Monitoring of the hydrophysical features of the KMA rocks composing chalk marl dumps seems to be relevant for obtaining reliable information about the current changes, assessment of the reclamation works efficiency and further anticipation of growth and forest crops condition [10-12].

2. Materials and methods

2.1 Object Description and Sampling

The object of the research is mining complex on the example of Shchigrovsky phosphate rock deposit in Kursk region. Phosphate production was carried out in an open (trench) method to the depth of 8-10 m from 1953 to 1971. Previously, the technology did not provide fertile layer preservation. The disturbed lands of over 650 hectares were represented by ridges of cone-shaped dumps and trenches from chalk, marl and their technical mixtures.

In 1974, an experimental work was carried out on the area of more than 3 hectares. It consisted of mining and biological reclamation stage. The trenches were filled in and the dumps were leveled, followed by the creation of pilot production of Pinus sylvestris cultures.

Forest cultures of Pinus sylvestris were used on the territories of zonal humus-carbonate soils with close chalk deposits in Korotoyak forest district of Ostrogozhsk forest district in Voronezh Region and Shchigrovsky phosphate rock deposit to compare the biometric indicators of growth and state of crops in the recultivated area.

The granulometric composition, hardness and humidity were identified during the growing season to study the properties of the root layer of technogenic rocks.

108 measurements were carried out to identify the hardness index of chalk marl rocks and zonal humus-carbonate soils.

The granulometric composition was identified by the Kachinsky pipette method on the basis of 63 specimens.

The rock humidity during the growing season was determined by taking soil specimens with Malkov auger to a depth of one meter with an interval of 10 cm in triplicate.

In 2015, in order to establish biometrics and study the growth course, 6 test plots with the selection of model trees were laid in pilot production forest cultures of Scots pine on chalk marl rock and humus-carbonate soils.

The works were carried out with Russian equipment.

2.2 Preparation and data processing

The surface layer of the edaphotopic horizon was analyzed to the depth of 50 cm (figure 1) in determining the granulometric composition [13].

The hardness of the arable layer was measured in the field using the Revyakin hardness tester with a tip - a flat disc with a diameter of 10 mm. The depth of measurement was 0-30 cm. The direction of immersion of the tip is vertical [14]. The final result of the determinations was a profile (1-D - one-dimensional) hardness diagram with a continuous distribution of hardness over the depth. The original data was received from the graph paper, and then transferred to kilograms in accordance with the predetermined calibration. One millimeter on the graph paper corresponded to 1 kg/cm² hardness.

Evaluation of technosol moisture content, total and productive moisture reserve was carried out by the thermostatic-weight method. The total and productive moisture reserve was calculated by generally accepted methods in soil science. Assessment of the condition of plant moisture supply with total and productive moisture was carried out according to the classification by A. F. Vadyunina [15].
Studies in forest plantations were carried out on permanent and temporary test plots [16]. The study of the current state and the growth course of artificially made plantings on carbonate soils were limited by chalky outcrops of Potudan river (tributary of the river Don) in Korotoyak forest district of Ostrogozhsk forestry in Voronezh region.

Statistical data processing was performed on the IBM-type computer using EXCEL, STATISTICA programs with the establishment of averages, errors of accuracy and test reliability.

3. Results and discussion
The granulometric composition is an important genetic and forest typological characteristic for the plant growth conditions in natural landscapes and artificially formed technosol soils.

It defines a number of important agronomical characteristics such as water and air regimes, and influences porosity, water-holding capacity, absorption capacity and many other indicators. Physical clay predominated (60.46%). in a 10 cm layer of chalk marl soil in the samples taken from the 1-year-old heap. The fraction of sand was 33.25%, sludge - 6.28%, what shows that the rock particle size is light clay with a predominance of the fine dust fraction according to the granulometric composition [17].

There is a high decrease in the clay fractions up to 11.04% or 5 times and an increase in the fractions of physical sand up to 83.25% or 2.5 times in the samples taken from 40 year-old leveled dumps (figure 1). The content of sludge particles slightly decreased. From our point of view, it is the result of physical and biochemical intensively proceeding weathering processes with following subsequent suspension removal of silt-sludge particles.

The granulometric composition in natural landscapes and artificially formed technosol soils:
- Physical fractions content in granulometric composition in%
- Application of the IBM computer and STATISTICA programs
- Establishment of averages, errors of accuracy, and test reliability.

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![Figure 1](image-url) The particle size change in distribution of the chalk marl soil.

The granulometric composition with close carbonate rocks occurrence in the form of chalk and marl in *Pinus sylvestris* cultures results show that there have been significant changes during forty years period in the surface edaphotic layer in the direction of the lighter grain size formation distribution (figure 2). The content of physical sand fractions has increased 1.7 times, the clay content has decreased 2.1 times and the clay fractions 7.5 times, this way the humus-carbonate soil with chalk deposits during the 40 years period is characterized as clay loam soil.
The content of physical fractions in granulometric composition in %

![Graph showing the content of physical fractions in granulometric composition in %](image)

**Figure 2.** Changes in the grain-size composition of humus calcareous soil with chalk stratification depth of 40-50 cm.

Technogenic and climatic soil types studies reveal genetic differences, which are considered as a nature diagnostic indicator and soil processes intensity.

Thus, after the forty-year period, the chalk marl embryo earth soil surface layer is characterized as a sandy loam. From our point of view, it is the result of physical and biochemical intensively proceeding weathering processes with following subsequent suspension removal of silt-sludge particles.

One of the principle concerns in forest recultivation at mining-engineering stage is properties optimization of the surface edaphotopic horizon to the tree and shrub species bioecological needs, that is, a decrease in the hardness of the arable horizon to optimal values of 6-12 kg/cm².

The hardness indicator of technogenic rocks varies over time. This process is influenced by the moisture content of the edaphotope layer, the change in the soil particle size distribution under the influence of physical and biological weathering in the soil formation process, consolidation and natural rocks compaction.

Depending on humidity the hardness of chalk marl leads to major fluctuations. The embryo soils in the dumps of the Shchigrovsky phosphoritic mine studies, carried out in 2016 showed that there was a hardness increase in the surface layer (0-5 cm) 2 times, at a depth of 10 cm - 1.6 times, at a depth of 20 cm - 1.4 times and at a depth of 30 cm - 1.3 times. The general feature of the decrease in hardness increase according to the edaphotopic layer depth profile is traced. However, the absolute indicators modify from 37.0 kg/cm² on the surface to 40.0 kg/cm² at 30 cm depth. Chalk and marl rocks accumulate and retain moisture 2.1-2.3 times more than zonal humus calcareous soils [18].

The total chalk marl soil moisture content is 409 mm, including the available moisture which reaches 314 mm, that is 76% of the total stock and is assessed as very good result according to water supply conditions (table 1).

| Table 1. Moisture dynamics content (%), productive moisture reserve (mm) of chalk-marl mountain rocks and zonal humus calcareous soil during the growing season |
|--------------------|------------|------------|------------|------------|------------|--------|--------|
| Location of the soil specimen | May 30 % | August 02 % | October 13 % | Average % | May 30 mm | August 02 mm | October 13 mm | Average mm |
| Zonal calcareous soils | 25.1 | 13.54 | 14.0 | 17.8 | 223.61 | 81.31 | 99.47 | 134.77 |
| Chalk and marl soil | 40.2 | 21.2 | 24.0 | 28.5 | 520.2 | 217.8 | 205.7 | 314.56 |
Chalk marl soils are alkaline rocks and practically do not overgrow with vegetation for many years. Pinus sylvestris refers to a low demanding species in terms of soil fertility and moisture. It has high survival rate and safety on various zonal soils. Growth and crops condition on humus-carbonate soils is determined by the depth stratification of chalk rocks. Scots pine plantations growth of I bonitet is possible on humus-carbonate soils with a capacity of 40 -50 cm; II bonitet - 30 40 cm; II - III bonitet - 15-20 cm.

According to Andryushchenko P.F. (1979) the safety of Scots pine trees on chalk marl soil was 82.6% at the age of 5, the average increase was 2.5 ± 0.2 cm [19]. Survivability of 35% was seen in 40 year old Scots pine plantations on chalk and marl rocks. The average height is 4.63 m, increment - 15.4 cm. Plantings grow according to V bonitet. The stock is 20.0 m²/ha. In this connection, plantations do not represent forestry value and should create only landscape-greening and erosion-resisting plantings.

4. Conclusion
1. Chalk and marl rocks have hard forest conditions and do not overgrow with natural vegetation for decades.
2. Chalk and marl rocks accumulate and retain moisture 2.1-2.3 times higher than zonal humus calcareous soils. The lower moisture content in the humus-carbonate soil is determined by the peculiarities of the water-physical properties of the upper humus-carbonate 30- 40 cm layer with a lighter grain size distribution, lower density and hardness.
3. With age the hardness of chalk and marl increases in neo landscapes.
4. The safety of Pinus sylvestris in the first years reaches over 82%. It decreases with age and is about 35% by the age of 40.
5. Pine cultures reach an average height of 4.6 m on the chalk marl rocks at the age of 40. Cultures grow according to V bonitet. They should be created in neo landscapes of the central forest-steppe as landscape-greening and erosion-resisting plantings.
6. In order to improve the vegetative conditions of the chalk and marl dumps root layer in neo landscapes for forest recultivation it is necessary to apply a more fertile meliorative layer to the surface, with better water-physical properties with a capacity of 20 to 50 cm.

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