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The Latitude-Zonal Variability of Hydrophysical and Energy Parameters of Soils of the East and the South of European Part of Russia.

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ABSTRACT

The soil cover of the east and the south of the European territory of Russia has been explored good enough and in various aspects. However, hydrophysical soil parameters are not well studied, despite the fact that they largely determine the crop yields of the cultivated plants. To this purpose, in 2010 during a field expedition by the route: Kazan-Cheboksary-Saratov-Volgograd-Elista-Caucasian Mineral water- Krasnodar-Rostov-on the Don-Voronezh- Tambov-Penza- Saransk-Kazan in July and August hydrophysical the parameters of the basic zonal soils of European Russia were estimated. Hydrophysical and soil-energy parameters of zonal soils were determined, the curves of the main hydrophysical characteristics of the studied soils to be the basis of water-reclamation and irrigation activities in the black earth, chestnut soil and gray-brown half-desert soils were calculated. The complex of hydro-studied and soil and energy parameters of soils east and the south of European Russia is an important step in understanding the links between the territory of the hydro-climatic conditions and the nature of the vegetation which grows in the area.

Keywords: hydrophysics of soils, the main hydrophysical characteristics of soils, black earth (chernozem), chestnut soils, grey-brown half-desert soils.

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INTRODUCTION

Theoretically substantiated determination of relationships between hydrophysical parameters of one of the most important landscape-forming systems “soil - plant – air” that meet the optimal conditions for plant development is a real condition for the solution of many geo-ecological, reclamation and agricultural problems. Since the soil hydrophysical parameters do vary spatially, for the purposes of their objective obtaining of significant indicators, one should be guided not only by the account and the analysis of natural-territorial complexes (PTC) and environmental characteristics of a particular region, but also by the results of quantitative and qualitative field stationary research.

Here a certain role, along with the existing classic ways and methods of stationary observations, can and should be played by fundamentally new methods for a more reliable determination of hydro-physical properties of the soil and the PTC as a whole. The latter are the basis for creating a database on the characteristics of the structural subdivisions of the landscape, including the system “soil - plant – air”. This, undoubtedly, will create information-analytical support for the organization of rational land use from the standpoint of applied geoecology.

PTC is relatively stable only for a certain period of time, although there matter and energy interchange constantly occur, i.e., movement or dynamic balance. The stability of the complex in relation to the landscape-destruction processes is determined by a complex of factors that characterize the state of its components. Here a special role belongs to hydrophysical parameters of the “soil” subsystem.

The soil covering of the European territory of Russia (ETR) has been rather good and thoroughly studied. The analysis of soil cover of the area under study began in the 19th century by V.V. Dokuchayev, N.M. Sibirtsev. Somewhat later, P. S. Kossovich, K. D. Glinka, G. N. Vysotsky, S. A. Zakharov, K. K. Gedroyts, V. R. Williams, V. A. Kovda, B. B. Polynov, I. P. Gerasimov and others went into the question in a varying degree.

Numerous and varied studies of soil cover resulted in the diversity of descriptions of morphological, physical, mechanical, chemical, hydrological, thermal, biotic and other properties of zonal soils. However, for the most part, in their description there is no or lack of information of hydro-physical and water-energy characteristics which are very important components of the soil properties.

A number of works by Soviet, Russian and foreign scientists (A. F. Ioffe [1]; S.V. Nerpin, A.F. Chudnovsky [2], A.M. Globus [3]; E. Childs [4], A.D. Voronin [5]; V.V. Sirotkin, V.M. Sirotkin [6], Ye. V. Shein, V.M. Goncharov [7]) point out the importance of studying these parameters.

The presence in the soil a sufficient amount of moisture is one of the most important factors determining the yield of crop plants. The information about these parameters is the basis for calculating the moistening of crops, time of irrigation, water for irrigation, time of planting and harvesting and other works in the area of water reclamation. The information given in the classification and description of zonal soils of the European part of Russia (EPR) relating to the water regime and physical properties of soils are inadequate for practical and sustainable use of soil and land resources of the country.

At the present time, with consideration for the actual global climate changes of the Earth, particularly relevant become the issues related to the availability of soil moisture for cultivated and natural vegetation in ecosystems. The ongoing regional landscape-geophysical forecasts which are based on non-equilibrium prediction model GISS of Goddard Institute for Space Research (USA), one can calculate that in the near future (until 2050) quite significant changes of hydrothermal conditions will occur in the European territory of Russia towards aridity. As a result, issues connected with the motion and availability of soil moisture for the plant will be a limiting condition for the functioning of the existing habitual above-ground ecosystems within their current borders in the EPR. The information about zonal features of hydrophysical and soil-energy parameters in these conditions will be exceptional, valuable, since the rational and optimal artificial improvement of water and physical conditions of the improved soil will be possible if based on it. Hydrothermal conditions of the summer season in 2010 in the territory of European Russia demonstrated one of the most negative scenarios of such forecasts.

In connection with the foregoing, we have undertaken an investigation of hydrophysical and water-energy properties of a number of zonal soils in the European part of Russia.

METHODS

Hydrophysical parameters of basic zonal soils of the European territory of Russia were determined during a field expedition by route: Kazan- Cheboksary-Saratov-Volgograd-Elista-the Caucasian Mineral waters-Krasnodar-Rostov-on the Don-Voronezh-Tambov-Penza-Saransk-Kazan in July-August 2010. The field research was based on the aerodynamic method for determining the specific surface of the solid phase, the specific surface of the condensed phase, hydraulic conductivity coefficient, potential of moisture for homogeneous porous materials and devices for its realization [8, 9,10,11,12,13].

It should be noted that during the period of soil sampling in the territory of the European part of Russia the maximum drought was being observed. Therefore, differences in the characteristics of soils cannot simply be explained by the difference in soil moistening, which is indicative of the distribution of volumetric soil moisture (it is approximately the same for the northern and southern soils and amounts to 6-7%).

The following zonal soils were investigated during the expedition: leached black soils, podzolic chernozem, typical chernozem soils, pure black earth, southern black soils, chestnut soils, grey-brown half-desert Caspian soils.

The field and cameral treatment of the data obtained has resulted in the whole range of soil characteristics: volume density (g/cm^3), gravimetric moisture (expressed as a decimal fraction), volume of moisture (g), volume humidity (expressed as a decimal fraction), the density of the solid phase (g / cm^3), porosity (expressed as a decimal fraction), solid volume (cm^3), filtration factor (cm^3/s), volumetric specific surface of the solid phase (cm^2/cm^3) and soil moisture potential (atm), which enabled to determine hydrophysical and water-energy properties of some zonal soils [9,10,11] in the territory of European part of Russia.

Processing of the material obtained by the methods of mathematical statistics allowed to make the curves of basic hydrophysical characteristics of soils.

RESULTS

An analysis of the field data has shown that there is a appreciable variability of soil hydrophysical parameters in the direction from the north to the south of the European territory of Russia. And if not to take into account the humidity parameters of soils, as they are the most dynamic and very rarely remain unchanged for a long time, the picture of changes of hydrophysical parameters in the latitudinal direction becomes even more visible.

The tested soils have substantially the same density of the solid phase (except for the light-chestnut soils), which is indicative of the fact that the soils have the same soil-forming conditions (in terms of soil physics). Furthermore, close enough are porosity indices. The other analyzed parameters are quite different, suggesting the interesting features of the different types of soil.

Comparison of filtration factor has showen that this indicator in the explored territory varies greatly: the maximum values are reached in the black soils of forest-steppe and steppe (leached black soils, podzolic black soils, typical black soils), significantly reduced in soils of dry steppes and semi-deserts (ordinary chernozem and southern black soils, chestnut soils , brown semidesert black soils).

Distribution of the specific volume surface of the solid phase is also uneven: there is an increase in this indicator from the north to the south. Its value in the brown semidesert, chestnut, typical and southern black soils is significantly greater than in those soils of forest-steppe and steppe. In proportion to the previous parameter, potential soil moisture changes, it is highest possible in the soils of dry steppes and semideserts.

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The marked change of characteristics of zonal soils of European Russia shows latitudinal variability of hydrophysical parameters, which is due to the peculiarities of the functioning of terrestrial ecosystems and the difference in the character of the flow of the main soil-forming processes in soils.

For all soils studied above, we have made the curves of the basic hydrophysical characteristic (BHC) of soil on the basis of data obtained above. The curves of BHC - isothermal equilibrium relationship between the capillary-sorption (matrix) pressure of soil moisture and humidity (usually volume). The form of BHC is specific for each soil sample and describes the structure of the pore space of the soil, granulometric and mineralogical composition [14, 15, 16].

Figures 1-6 demonstrate the relationship between potential soil moisture (decimal logarithm of the value of the potential) and volumetric moisture content (expressed as a decimal).

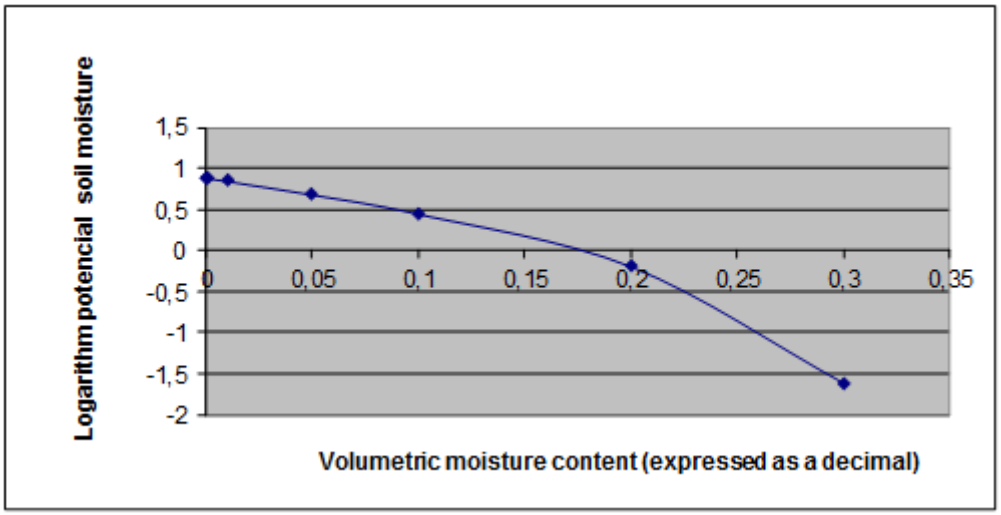

Figure 1. The curve of the BHC for podzolic black soil

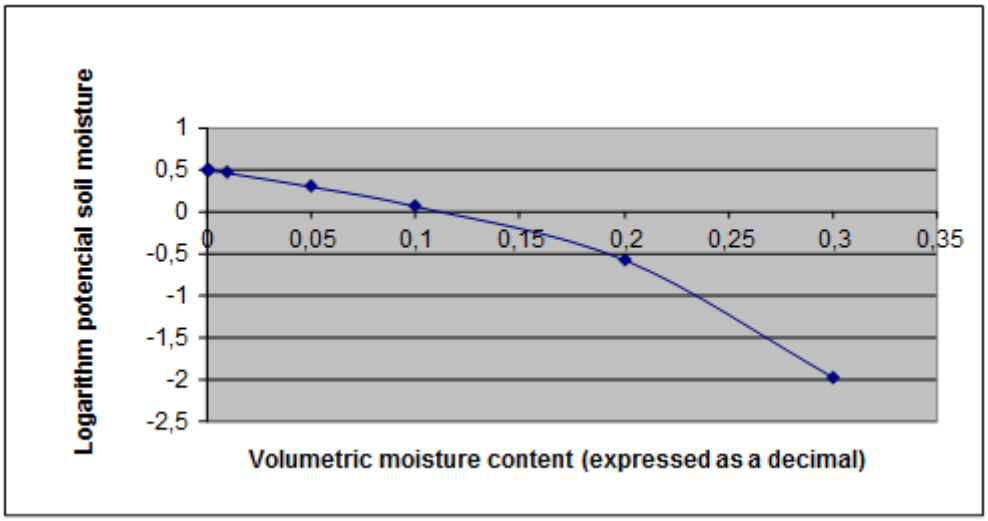

Figure 2. The curve of the BHC for leached black soil

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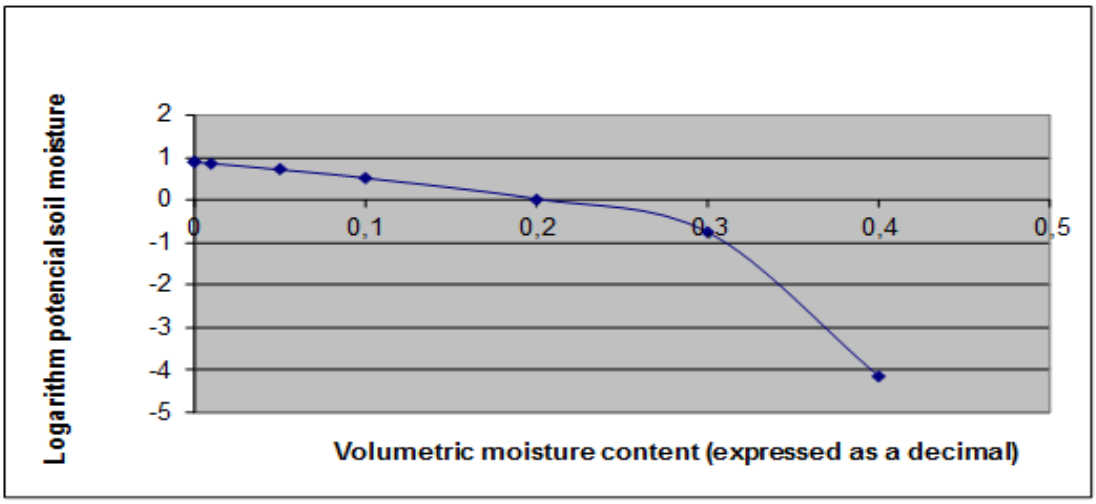

Figure 3. The curve of the BHC for typical black soil

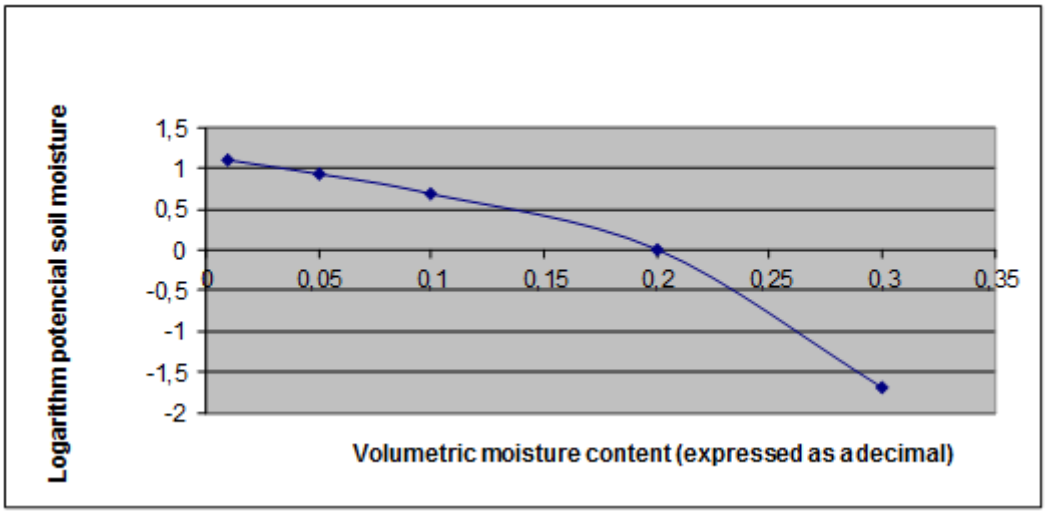

Figure 4. The curve of the BHC for southern black soil

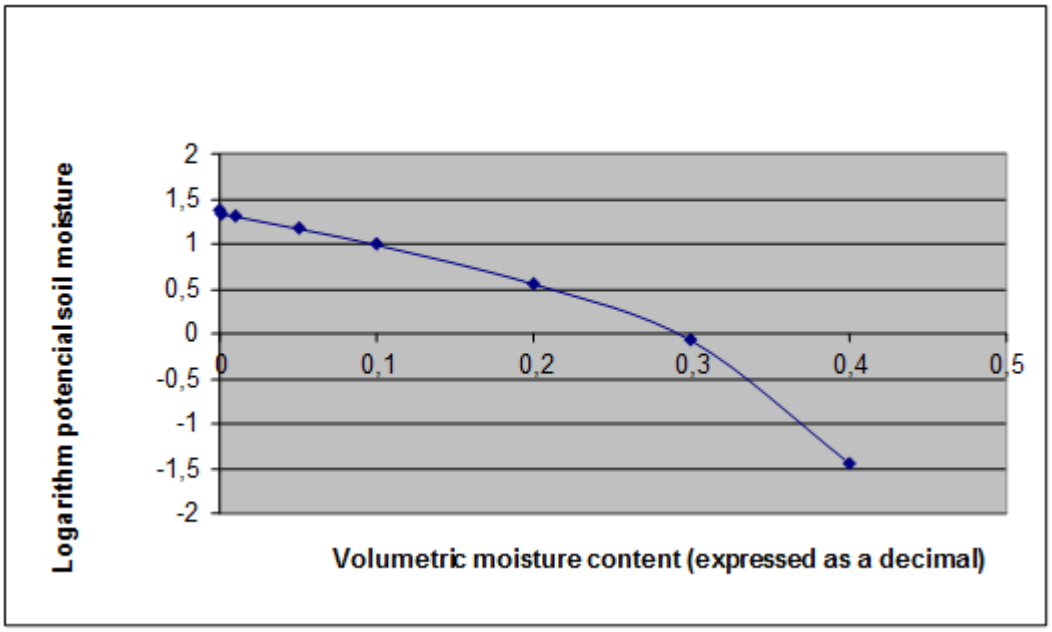

Figure 5. The curve of the BHC for light-brown soil

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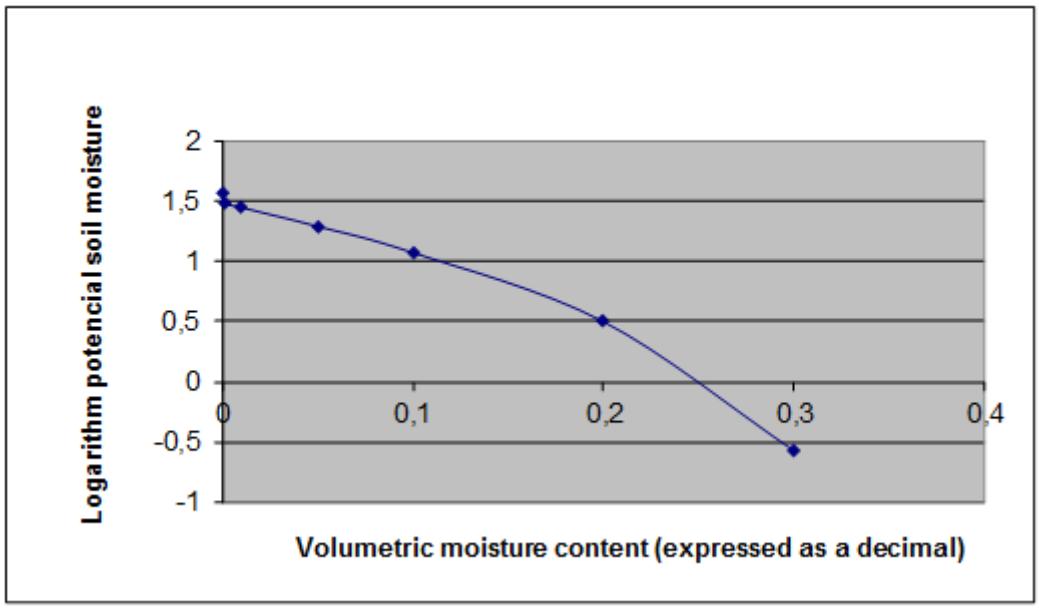

Figure 6. The curve of the BHC for gray-brown semidesert soils

SUMMARY

These BHC curves are unique for each particular zone of the soil and are in fact its soil-energy passport in terms of the availability of soil moisture to the plant. In fact, they can be used as a basis for artificial regulation of water regime of zonal soils in the territory of European Russia. It is known that the critical soil moisture range for most of the known cultivated plants whereby they are needed to be watered, varies in the range from decimal logarithm 0 to -0,796. Based on these values, it is easy to calculate at what moisture the regulation of water regime of the soil is needed. The character of change of the BHC curve points to its particular zonal variation. The flatter curve in the range of potential soil moisture values mentioned above is, the more favorable hydrophysical soil-energy parameters for the growth of vegetation (wider range borders of plant tolerance) are. They reach their maximum values in typical black soils (10-12%), and decrease in both the northern and southern direction, reaching 5-6% in the podzolic black soils and gray-brown semidesert chernozem, that actually proves the most favorable growing conditions especially for herbaceous vegetation.

CONCLUSION

The complex of hydrophysical and soil-energy parameters of the soils of the east and the south of European Russia is an important step in understanding the links between hydro-climatic conditions of the territory and character of the vegetation which grows in the area. In addition, it serves as a basis for irrigation activities on these soils in a predetermined range, based on the sustainable use of water and land resources.

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