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Principles and methods of complex agrophysical researches

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Abstract. The soil cover of the Vladimir Opole was investigated by the method of long (up to 40–50 meters long and 1.5 m deep) transects. Four Qualifiers of Phaeozem (PH) were morphologically identified: albic, gleyic densic, grayzemic and PH cambic with the 2nd humus horizon. Agrophysical studies of soils in transects included layer-by-layer determination (every 20–40 cm along the trench, and at depths 0, 20, 40, 60 and 100 cm) of soil density, water permeability, and penetration resistance. The soil compaction (up to 1.57 g cm⁻³) was observed, which was especially pronounced in a layer of 20–25 cm and connected with the agrotechnological impact. Simultaneously, friable (<1 g cm⁻³) and, therefore, zones with high moisture capacity confined to PH with 2nd humus horizon, showing that the change in agrophysical properties in the soil cover occurs gradually, continuously and regularly and is determined by both pedogenetic and agrotechnological factors.

1. Introduction
Modern soil science and adaptive-landscape farming pay great attention to the laws governing the distribution of soils and their properties at various scale levels. It is assumed that the agrophysical properties of the soil vary in space in accordance with the distribution of the soils in the soil cover. However, the physical properties, and, consequently, the most important regimes, such as water, heat and airdynamics, depend not only on the distribution of the soils in agrolandscape, but are also determined by anthropogenic factors, changing under external influence, above all agrotechnological operations. Quantitative information is needed on spatially distributed physical properties of the soil in the soil cover, landscape assessment and analysis of agrophysical conditions.

The works of many researchers are devoted to the fundamental physical properties of the soil and their classifications [1-3]. Simultaneously, insufficient attention to the development of the principles of spatial assessment, the analysis of the patterns of their distribution in space, and the peculiarities of their correspondence with the structure of the soil cover is given [4].

2. Object and methods
The heterogeneity of the soil cover, as well as the long-term agricultural use of the territory of Vladimir Opole are the main reasons for the significant variation of the physical properties of the soils [5, 6]. To study the lateral pedogenetic features and the spatial distribution of physical properties and possible agrophysical processes in the soil cover, methods of uniform grid testing and lengthy
transects (up to 50 m long) are proposed. In transects, the physical properties of soils were determined in increments of 40 cm. These studies require mass determination of properties, and, therefore, a set of simplified field rapid methods that characterize the conditions for plant growth and the need for development. These were in our experimental studies: soil density, soil penetration resistance (by penetrometer), soil water infiltration coefficient [4, 7] and some hydrological constants (soil moisture content close to field capacity, determined after infiltration experiments with the experimental square near 20 cm², named FC*). This method is not a complete analogue of the classically defined field soil water capacity (FC, experimental square near 1 m²), but reflects, first of all, the capillary water-holding capacity of the soil. This method allows to make a comparative assessment of the area under study in common characteristics.

In addition to traditional indicators of physical condition, we used the ratio of the logarithm of water permeability to soil porosity. It reflects the ability of the soil to conduct water flows: the higher it is, the more intense water flows in this area of soil. This made it possible to call it the “coefficient of potential conductivity”.

The proposed set of methods made it possible to conduct lateral studies and obtain spatially-distributed quantitative agrophysical information about the soil cover of the Vladimir Opolye, which is necessary for understanding the conditions for the formation and functioning of this agricultural landscape.

3. Results and discussion

The results indicate the variation of physical properties in a small area (less than 3 hectares) of the agricultural field (figure 1).

![Figure 1](image)

**Figure 1.** Topoisoplets of (I) soil density, g cm⁻³, (II) penetration resistance, MPa, (III) soil moisture content, %, in a layer of 10–15 cm of Vladimir Opolye Phaeozems.

It should be noted that the general agrophysical conditions are favorable, although in some parts of the investigated field the soil compaction (up to 1.57 g cm⁻³) is observed, which is especially pronounced in a layer of 20–25 cm. Simultaneously, friable (<1.0 g cm⁻³) and, therefore, zones with high moisture capacity, confined to Phaeozems (PH) [8] cambic with the 2nd humus horizon (figure 2). Probably the good aggregate structure increased content of humus – up to 6% is the reason for these
favorable agrophysical conditions. The differences remained even in the arable layer, subject to prolonged mixing and intense anthropogenic impact.

![Figure 2](image.jpg)

**Figure 2.** Statistics of variation: A – density (g cm\(^{-3}\)), B – soil moisture (% by volume) in a layer of 30–35 cm. Legend of the soils: 1 – Phaeozem (PH) albic; 2 – PH gleyic densic; 3 – PH grayzemic; 4 – PH cambic pashic with the 2nd humus horizon.

Phaeozems (PH) [8] cambic with the 2nd humus horizon are less subjected to compaction, these soils are characteristic natural drains in the soil cover. High porosity, well-developed structure of the pore space, including large water-conducting pores, provide, on the one hand, high water-holding capacity, and, on the other hand, the rapid movement of water in this part of the profile. Their position contributes to the formation of a contrasting lateral structure of agrophysical conditions in the landscape of the Vladimir Opolye.

The method of lengthy transects (up to 50 m) was used for detailed study of pedogenetic features and spatial distribution of physical properties and possible processes in the soil cover. The soil horizons’ morphology, comprehensive testing of physical properties was carried out with a step of 20–40 cm along which, along the transects.

Figures 3 and 4 show the results of transect studies, where, above all, the position of PH [8] cambic with the 2nd humus horizon is noted. This soil is distinguished not only visually by morphological features, but also quite definitely by its physical properties: increased water permeability, low density.

This part of the transect is associated with an increased coefficient of potential conductivity – the ratio of the logarithm of permeability to total porosity (figure 4B), which has a pronounced direction in the depth of the soil profile. This distribution confirms a clear tendency for the vertical movement of moisture to occur precisely in this zone. Throughout the rest of the profile length at a depth of 20–25 cm, the formation of a compacted “plow pane” is noted, which has a low conductivity and play role of “screen” that prevents the flow of water into the underlying layers.

Consequently, the complexity of the soil cover determines the “mosaic” distribution of the physical properties responsible for the transfer of substances in the agrolandscape. The influence of long-term agricultural processing and the formation of a compacted subsurface layer lead to horizontal stratification of properties from the originally vertical organization of the soil profile.

Such layering in the distribution of soil physical properties is not continuous but is determined by the genetic origin of the soil cover. So, in the case of PH cambic with the 2nd humus horizon this compacted layer decreases or disappears completely. Vertical moisture fluxes are possible here [9], and these places can play the role of natural drains in the formation of the agrolandscape water regime.
Figure 3. Morphological features of soil horizons in soil profiles: transect studies of the complex of the Vladimir Opolye Phaeozems. The designations of the horizons: Ap – arable, Ah – humus, AEl – humus-eluvial, ElB – transitional, B – illuvial, Bca – carbonate. H_{boiling} – carbonate line.

Figure 4. Topoisoplets of (A) soil density (g·cm⁻³) and (B) ratios of the log permeability (mm·min⁻¹) to total porosity (cm³·cm⁻³).

Such a distribution of physical properties characterizes the soil cover, as a fairly “mosaic” in functioning, caused both by pedogenetic (presence of the second humus horizon, alternation of horizons, etc.) and agrotechnological reasons (peculiarities of agrotechnological processing, formation of artificial compacted layers and others).

The leveling of soil-physical conditions in the process of agricultural use in the arable soils takes place and the influence of the initial soil-genetic factors on the current agrophysical state decreases. However, in the agrophysical practice, it is the upper soil layer that is the most diagnosable [10]. Therefore, it is necessary to carry out not only the arable horizons but also an underlying layer.

The agrolandscape characteristic based on the results of soil genetic survey, especially with high heterogeneity of soil cover, becomes difficult because the patterns of lateral distribution of soils and
agrophysical properties can vary, and, we emphasize again, the agrophysical assessment based on soil contours can lead to significant errors.

To obtain a visual and quantitative picture of the laws of the spatial distribution of properties within soil contours, it is advisable to use GIS technologies in which graphic information is the basis for the integration of spatially distributed data. The advantages of this approach are obvious, since the combination of functional surfaces allows integrating data located in different thematic layers, analyzing, for example, the structure of the soil cover and the lateral variability of the physical properties of the soil. For example, it is possible to estimate the total susceptibility of each soil to the formation of a “plow pan” – zones with unfavorable density indices (> 1.3 g cm⁻³) in a layer of 20–25 cm, to calculate their specific area relative to the area of the defined soil contour (landfill).

The results of landscape-agrophysical studies with GIS methods have shown that the categories of increased density in the subsoil layer are present in all soils of the agrolandscape, but their contribution to the formation of the “plow pan” in the agrolandscape is different. In the contours of PH cambic with the 2nd humus horizon, the compaction area is minimal – up to 20%. For other soils of the experimental field, the area of compacted plots reaches 30%.

These patterns in the spatial agrophysical organization of the soil cover play a special role in the redistribution of soil water, air and temperature in the profile of the studied soil and, accordingly, in providing optimal conditions for plant growth and development. Apparently, complex agrophysical studies, and not only the soil-morphological identification of boundaries, should become fundamental moments in the development of technologies.

4. Conclusions
The results of complex agrophysical studies of the soil cover of the Vladimir Opolye allowed us to draw the following conclusions:

Studies of the physical properties in lengthy trenches and over a spatially distributed grid of soil profiles showed that the change in agrophysical properties in the soil cover occurs gradually, continuously and regularly and is determined by both pedogenetic and agrotechnical factors.

Using the example of a complex of the Vladimir Oopolye’s Phaeozems, a method of sequential pedometric analysis of agrophysical properties under conditions of high heterogeneity was proposed, based on the use of GIS-technology. The categories of increased density in the subsoil layer are present in all soils of the agrolandscape, but their contribution to the formation of the “plow pan” in the agrolandscape is different: in the contours of PH cambic with the 2nd humus horizon, the compaction area is minimal – up to 20%. For other soils of the experimental field, the area of compacted plots reaches 30%.

The physical properties of the Phaeozems complex are characterized by high agrophysical variability, and the spatial position of the zones with different conditions does not correspond exactly to the boundaries of the soil contours.

In the arable layer, the regularities of the spatial distribution of physical properties are associated with the formation of compacted zones, and in the deeper, subsurface layers – with the heterogeneous structure of the Vladimir Opolye soil cover.

References
[1] Cambardella C A, Moorman T B, Novak J M, Parkin T B, Karlen D L, Turco R F and Konopka A E 1994 Field-scale variability of soil properties in central Iowa soils Soil Sci. Soc. Am. J. 58 1501–11
[2] Horn R, Hartge K H, Bachmann J and Kirkham M B 2007 Mechanical stresses in soils assessed from bulk-density and penetration-resistance data sets Soil Sci. Soc. Am. J. 71 1455–59
[3] Horn R and Smucker A 2005 Structure formation and its consequences for gas and water transport in unsaturated arable and forest soils Soil Till. Res. 82 5–14
[4] Hartge K H and Horn R 2016 Essential Soil Physics an Introduction to Soil Processes, Functions, Structure and Mechanics (Stuttgart: Schweizerbart Science Publishers) p 753
[5] Shein E V and Troshina O A 2012 Physical properties of soils and the simulation of the
hydrothermal regime for the complex soil cover of the Vladimir Opol’e region *Eurasian Soil Sci.* **45** (10) 968–76

[6] Shein E V, Kiryushin V I, Korchagin A A, Mazirov M A, Dembovetskii A V and Il’in L I 2017 Assessment of agronomic homogeneity and compatibility of soils in the Vladimir Opolie region *Eurasian Soil Sci.* **50** (10) 1166–72

[7] Blacke G R and Hartge K H 1986 Particle density In: Klute A Methods of Soil Analysis Part I- Physical and Mineralogical Methods 2nd Edition Agronomy Monograph (Baltimore: Am. Soc. of Agron.) pp 377-82

[8] World Reference Base for Soil Resources 2014 *International soil classification system for naming soils and creating legends for soil maps* World Soil Resources Reports IUSS Working Group (Rome: FAO) p 106

[9] Shein E V, Umarova A B, Kirdyashkin P I and Samoylov O A 2007 Preferential water flow in structured clay soils *Proc. Int. Conf. Soil Science—Base for sustainable Agriculture and Environment Protection* Part 1 (Sofia: PublishSaySet-Eko) pp 113–5

[10] Kilic K, Kilic S and Kocyigit R 2012 Assessment of spatial variability of soil properties in areas under different land use *Bulgarian J. Agr. Sci.* **18** 722–32