

Features of Remote Determination of Humus Content in Arable Soils

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Abstract—The paper considers the influence of different covers, such as crop residues, soil crust, etc. on the remote determination of humus content in soils of agricultural land. It is shown that in laboratory conditions with dry soil there is a close relationship between the humus content and spectral reflective properties. When soil is moistened, the spectral brightness coefficient decreases, which gives a false idea of a higher humus content. The presence of naturally occurring crop residues in the form of straw, on the contrary, gives an idea of a lower content. The formation of seasonal thin soil crusts on the surface of arable soils with different humus content is even more difficult for remote determination of humus. In order to identify the impact of different covers on remote definition of humus, the complex of laboratory and field observations which showed that *in vivo* continuously there are processes as a result of which the same soil on the spectral reflective properties can be carried on the maintenance of a humus to various taxonomical groups was carried out.

Keywords—*humus content; spectral brightness coefficient decreases; soil crust; taxonomic group; remote sensing*

I. INTRODUCTION

V.V. Dokuchaev in his works drew attention to the relationship of soil color with humus content. However, he pointed out that the search for quantitative dependences of soil reflective properties on humus is justified only for soils of the same type. It is now known that in addition to humus, the spectral reflective properties of soils depend on a number of factors [1–5].

For carefully prepared soil samples of the same type, it is possible to obtain an unambiguous and fairly clear dependence of the spectral reflective properties on the humus content, which

gives grounds to determine the humus content up to a fraction of a percent [6].

V.V. Kuznetsov and V. Bochkov offered a method for determining the content of humus in arable soils to improve the accuracy and acceleration of determining the content of humus in agrogenic soils. The method consists in surveying the spectral reflection of the soil, measuring the spectral brightness coefficients, determining the shape of the spectral curve, determining the inflection point of the spectral curve in the wavelength range 560–600 nm. The humus content is judged by the difference between the measured values of the spectral brightness coefficients, which correspond to the inflection point of the spectral curve and the wavelength of 400 nm for this spectral curve. This method is remote; hence, the mistake in determining the content of humus does not exceed 10% of the Turin method [7].

The method of remote measurements of the coefficient of spectral brightness of soils and exposures by means of spectrometers (Ion-mobility spectrometers IMS-2, IMS-74) installed on the aircraft carrier was also presented by L.I. Chapursky [8].

Bondur V.G. and others have developed a method for remote determination of soil degradation. The method includes [9]:

- sensing of the underlying surface containing test areas by a multi-channel spectrometer mounted on an aerospace carrier with simultaneous acquisition of images on each channel;
- calculation method for the zonal relations of the amplitudes of the signals in channels of the partial indices of degradation, namely the percentage content of humus (H), salinity index (NSI) and the index of moisture loss (W);

- definition of the integral indicator of the degradation D for multivariable regression.

Research and experiments to develop scientific-methodical bases of application of remote sensing techniques in the study of soil condition and soil cover was carried out by V.M. Mazikov. The analysis of remote measurements of the brightness of plowed soils in local areas within the areas of the spatial-structural model in the Kursk region (autumn and spring) showed a sufficiently high stability of the revealed regularities of the ratio between the values of the spectral density of the energy brightness (SDEB) of different soils of cultivator inter-row cultivation (CIRC). This allowed him to simulate the spatial distribution of spectral brightness characteristics of the plowed surface, assuming their close connection with the actual state of the soil, including the humus content [10].

However, such clear picture is observed mainly in the laboratory, where it is easy to maintain the constancy of all factors except one - the implementation of the basic conditions of the experiment. Under natural conditions, the influence of extraneous factors on the spectral reflective properties of the soil can be so great that two fields or areas of soil with the same content of humus can be classified as fields or areas with significantly different content.

II. RESULTS AND DISCUSSION

Under natural conditions, the formation of spectral reflective properties of the surface of arable soils occurs under the influence of a number of natural and anthropogenic factors that give it a peculiar feature, often inadequately related to the genesis of the soil itself. These include agrotechnical processing, humidification of precipitation and irrigation water, etc. Agrotechnical treatments of the most significant adjustments to the spectral reflective image of the object, and therefore, the ability to remotely determine the content of humus. In case of soil tillage on the surface there is a large amount of crop residues, significantly increasing the spectral ratio of the radiance (SRR). After plowing with the turnover of the formation and harrowing, the SRR decreases due to the increase in the humidity of the surface of the freshly plowed soil. The determined spectral reflective properties of the dried soil surface are the closest to those measured in laboratory conditions [11, 12].

In order to identify the impact of different covers on the remote determination of humus, we conducted a set of laboratory and field observations.

Various organogenic and inorganic horizons or crusts influence spectral characteristics significantly, which are formed on the surface of the soil because of the development of a complex set of soil formation processes. These horizons can have extremely low power, only a few millimeters, but very significantly differ in their optical properties from the underlying arable horizon. V.A. Kovda and B.G. Rozanov, apparently, have identified the most significant impact on the optical characteristics of the cortical layers [13]:

1. Aal - Algal crust, the surface crust of algae and their residues, well exfoliating from the underlying soil, black in dry condition and green when moistened, with

a large admixture of mineral particles in the lower part, with a capacity of several millimeters, characteristic of dry-steppe, semi-desert and desert soils.

2. S - salt crust-white crust of salts or abundant fading of salts on the soil surface.
3. K-actually crust horizon-light and dark cellular crusts up to 5 cm thick on the soil surface often with polygonal cracking, easily separated from the underlying humus horizon.

N.G. Zborischuk with co-authors showed that crust horizon (K) is differentiated by properties for relief. They identified the following crust horizon of irrigated soils [13]:

1. Kg-formed in micro-depressions, where moisture is stagnated, enriched with humus-clay substances flowing down from elevated areas. It represents a black glossy crust with a thickness of 0.1-0.3 cm or more, depending on the size of the catchment. Such crusts occupy up to 10% of the surface.
2. Ke - whitish, strongly bleached cortical-spongy layer is common on rallies and develops due to the removal processes of humic and clay substances down through the soil profile and micro-depressions.

The horizons Kg and Ke differ significantly in their properties, both from each other and from the arable horizon. Thus, the content of soil organic matter in the horizon Kg (Table I) is 2.6 times higher than in An and 5.4 times higher than in Ke. At the same time, dark-colored humic acids predominate in the composition of humic substances of the Kg layer, which further reduces its spectral brightness.

The presence of a crust can distort the results of remote determination of the humus content in two directions. First, since the remote sensing tools study only a thin surface layer, they give an idea of the content of humus in the crust itself, and not in the arable horizon as a whole.

TABLE I. SOIL PROPERTIES

Horizon	Soil Properties		
	The content of physical clay (0.01 mm)	C gen, %	C h.a. (humic acid) C f.a. (fulvic acids)
K Kg	61.1	3.46	3.2
Ke	30.2	0.64	1.2
Ap	52.6	1.30	2.0

Second, the method of soil sampling for chemical-analytical determination of humus content is very important. If the sample is selected according to the agrochemical survey methods for the entire profile of the arable horizon, and not in the crust itself, the results of the thematic interpretation of remote sensing data will not be correct. These possible directions of distortion lead to the fact that it is possible to obtain the same spectral coefficients of energy brightness, but the humus content in the soil will be different and on the contrary [14].

At the time of the survey of territories by remote sensing, agricultural land is usually treated in different ways and at

different times, and may or may not have a crust, crop residues, be differentiated by humidity, so the soil with a similar content of organic matter will differ in spectral characteristics. Thus, the question arises about the degree of reliability of determination of humus content in agricultural land surveys based on remote methods.

The calculations show that the moistening of black soil up to 12% creates a false impression about the increase of humus content in it from 5 to 6%. If dry topsoil containing 5% humus covered 3.5% of the stalks of ripe corn, or 15% peel, it is by its spectral reflectance properties is related to the topsoil containing 4% of humus. The calculations used data on the spectral reflective properties of corn, crust and moist soil from the work (Fig. 1.) [6, 15].

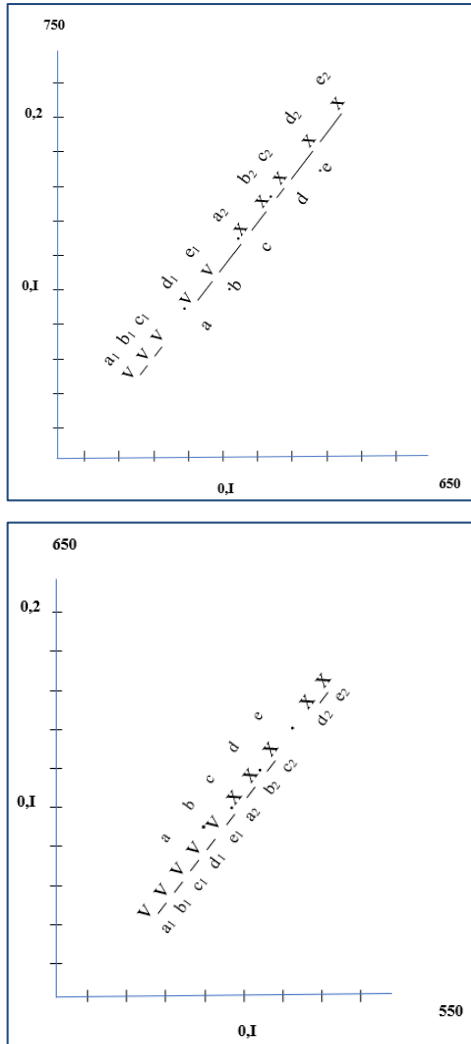


Fig.1. Location in two-dimensional spaces of spectral reflection coefficients of points corresponding to different humus content in dry, moistened and covered with stubble residues in Chernozem. Humus content, % - a, a1, a2 – 5.2; b, b1, b2 – 4.1; c, c1, c2 – 2.9; d, d1, d2 – 2.0; e, e1, e2 – 1.0. - «v» - dry soil, «x»- soil containing 25% moisture, «x»- dry soil, 8% of the area is covered with Mature corn stalks.

It is known that dry plowed soil after wetting by rain and subsequent drying due to smoothing of the surface increases its spectral reflectivity in the visible and near infrared regions of the spectrum by 10-15%. This is equivalent to the effect of

reducing the content of humus in it by 0.5-0.8 %. Repeated loss of rainfall increases the effect of seeming depletion of soil by humus [16]. Thus, for example, plowed southern chernozems containing 5.2% humus, covered with 30% clods with crust, have the same spectral reflective properties, which in their quantitative and qualitative indicators are inherent in plowed soil with humus content between 2 and 2.9% [6].

Thus, in natural conditions there are processes, as a result of which the same soil in its spectral reflective properties can be attributed to the content of humus of different taxonomic groups. This fact should be taken into account when assessing the humus content in soils by remote methods.

In connection with the above, it is very important to assess the reliability of the allocated contours of soil maps created on the basis of automated processing of remote information, where the spectral characteristics of the open surface of arable soils play an important role. In the contours selected according to the results of automated processing, in the process of ground surveys it is necessary to statistically reliably estimate the humus content. Deviations from the average values of humus content in the surveyed contours should not go beyond the gradations established by the classification of soils of the Russian Federation [17].

III. CONCLUSION

The remote determination of soils with different humus content significantly influenced by the presence of different covers: crop residues, soil crusts, etc. Thus, the coating of 8% of the dry black soil area with stems of ripe corn can reduce the humus content by 2% according to remote sensing data in the visible range of the spectrum.

Based on the results obtained, to collect information, it is necessary to choose a surface with a smooth treated soil without plant residues, crusts and without waterlogging, etc.

The use of medium-scale soil maps in combination with other methods of automated processing of scanner data allows obtaining reliable cartographic information. A ground-based study of the contours of the medium-scale map showed that they are relatively homogeneous in general, and their thematic content corresponds to that indicated on the map.

The average values of humus content in the surveyed contours correspond to what is highlighted on the soil map. Deviations from the average, basically, do not go beyond the gradations established by the classification of soils of the USSR for different types of chernozems. Soil areas with deviations from those indicated on the map are insignificant and in the process of mapping are subject to generalization.

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