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REMOTE SENSING OF THE AGROCHEMICAL PROPERTIES OF SOILS

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The idea of establishing the correlations between spectral reflectivities of soils and their humus content has long since been of great concern. So, as far back as 1929 a theoretical foundation of this problem was discussed in detail (Pokrovsky, 1929, pp.124-130). According to this theory, the dependence of the spectral reflectivity of soil, , on its humus content, , is exponential:

(1)

where , , and are the empirical constants; characterizes the spectral reflectivity of a soil-forming rock; is the reflectivity of humus; determines the dispersity of soil, i.e. the structure of the soil which may consist of either small-sized fractions (fine-grain fraction - clay soils) and/or large-sized fractions (rough-disperse fraction - sandy soils).

The experimental data obtained by Tolchelnikov (1960, pp.101-124) verify the conclusion drawn by Pokrovsky. Additional calculations have shown that such a correlation within the 5-6 per cent humus content range can be substituted for by linear correlation to the same accuracy:

(2)

where , , are the parameters characterizing, respectively, the spectral reflectivity of the soil-forming rock - humus system, the soil-forming rock, and the humus; is the weighting coefficient determining the humus content in the soil-forming rock - humus system.

Note that different characteristics can serve as the - values estimating quantitatively the spectral reflectivity of soils: the spectral brightness coefficient (SBC), the spectral reflection coefficient measured at one wavelength (Zyrin, Kuliev, 1967, pp.123-129; Mikhailova, Neunylov, Ivanov, 1967, pp.50-60), or the total reflection (Tolchelnikov, 1960, pp.101-124; Sorokina, 1967, pp.116-125). The sums of colour coordinates, the calculation technique for which has been described in detail, are used in our calculations as the -values (Kondratyev, Fedchenko,1982, pp.988-989; 1981,pp.52-57). To establish a quantitative correlation between of soils and their humus content, the following experiment was carried out.

A sample of the soil-forming rock from the Kiev region, dried and sifted through two sieves (with holes 0.5 and 1 mm in diameter) was carefully weighed on analytical scales, then photometered by the SF-18 spectrophotometer. Photometry and weighing done, small portions of a heavily humused soil with the humus percentage known were added to the sample. Upon every addition of soil to the soil-forming rock, the sample again was weighed and photometered. This procedure continued until the weight of the soil-forming rock was equal to that of the heavily humused soil. Then, the whole process of measurements was repeated in the reverse order, i.e. the heavily humused soil was supplemented with small portions of the soil-forming rock. An addition to a soil-forming rock of small portions of the heavily humused soil with the humus content known (or, vice versa, an addition of a soil-forming rock to soil) has enabled one to make a humused soil and calculate the amount of humus in each sample prepared for photometry. As a result of measurements, soil spectrograms were obtained with different amounts of humus, from which the colour coordinates and their sum were calculated. Then a graph was drawn (Fig.1), the axes of which were the sum of colour coordinates, , and the humus content percentage, . The same dependence was also obtained from ground-based measurements (Fig.1b) and used to estimate the humus content in soils from aircraft measurements.

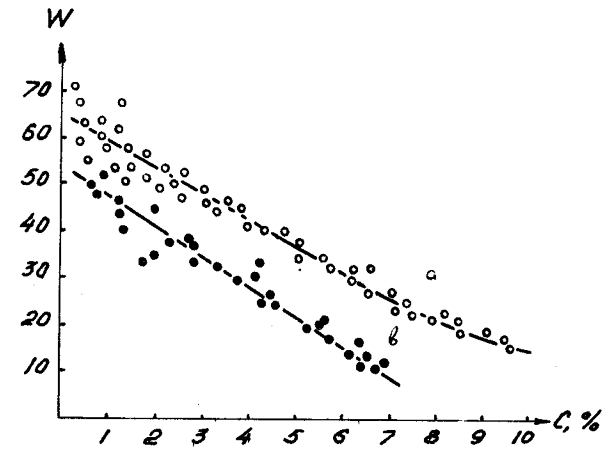

Figure 1. Colour Coordinates of Soils as a Function of Their Humus Content From Laboratory (a) and Ground-Based (b) Measurements.

The procedure of the experiment envisaged the selection of ploughed fields in the Cherkass and Kiev regions (Ukraine) as reference sites. Measurements of SBC's for these sites were made from the AN-22 aircraft with a fast-operating spectrometer in the visible and IR regions (Fedchenko, Kondratyev, 1981, 231 pp.). The flight altitude varied within 100-150m. The measured reference sites totalled 57. Observations were made in August, 1981 in the period of mass ploughing. In this period the factors affecting spectral reflectivities of soils can most completely be taken into account (Fedchenko, 1981, pp. 42-51).

The aircraft data processing consisted in re-calculation of the spectral reflection data into colour coordinates, from which, using the regression equations obtained from laboratory measurements, the humus content in the soils under investigation was determined.

A Meteor satellite obtained mid-resolution negative used in the experiment was processed in the following way: first, it was scanned with the R-100 densitometer with a 100- um aperture, then the numerical equivalents of images were recorded on the magnetic tape with discrete brightness levels from 0 to 255, the images being then displayed in false colours. Then the following information was presented on the display: (i) terminal points of the aircraft route; (ii) calculated optical dencities corresponding to the selected points on the route; (iii) the hystograms of relative frequences of occurrence of a given optical density within the images' fragments; (iv) the results of corresponding interactive classification of objects in the images.

The results of processing have shown that the maximum error in estimating the humus content from the optical densities of the satellite-obtained images does not exceed 6 per cent, and from the colour coordinates calculated on the basis of aircraft spectral measurements, it does not exceed 5 per cent for the learning set with the humus content within 3.8-5.8 per cent.

Then, the aircraft measurements were used to construct a learning set to estimate the humus content in the soils in the territory not measured from the aircraft but seen in the same picture obtained from space. This fragment of the picture was displayed, and in the interactive regime it was classified using the hystogram method. The results of classification were then compared to the humus content mapped from aircraft measurements made in 1973 in the Kherson region (Ukraine).

The data listed in Table 1 show a reasonable agreement between the aircraft and satellite-derived humus content in soils. So, for instance, in 9 of 14 cases the relative error in the results obtained do not exceed 10 per cent.

Table 1. The Results of Comparing the Humus Content (%) in Some Soils From Satellite (numerator) and Aircraft (denominator) Measurements.

Number of the point	Humus content	Number of the point	Humus content
1	5.4/4.9	8	5.1/5.3
2	5.2/5.1	9	4.9/5.3
3	4.2/4.8	10	3.9/4.9
4	5.0/4.9	11	5.0/5.5
5	4.8/4.6	12	4.9/5.2
6	4.9/5.0	13	5.1/5.1
7	4.6/5.0	14	5.3/5.0

A comparatively high agreement between the tabulated results can, probably, be explained by a low variability of the learning data set, and, apparently, by reliable classification of ploughed soils in the pictures. Both these reasons point to objective possibilities of combined solution of the problems of interactive processing of the satellite-obtained information and its sub-satellite referencing. Therefore, the use of the results obtained in estimating the soil's state from the satellite and aircraft measurements can be considered perspective.

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