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SOIL PHYSICS

Reflective Capacity of Coastal Soils of the Russian Far East

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Abstract—The reflectance of coastal soils in the Russian Far East is considered. The correlation between the integral reflectance of the investigated soils and the electrical conductivity of water extracts from them is estimated.

INTRODUCTION

The transformation of luminous energy by soil structures is a poorly investigated issue, two aspects of which are usually considered by soil science: (1) morphopedogenetic and (2) physicochemical [4, 12, 19]. It was found that the proportion of the light reflected back by the soil cover displays a normal distribution. Basic soil types differ from one another by their reflecting power, which increases in the following sequence: tundra, soddy-meadow, meadow-boggy, soddy-podzolic, and light gray forest soils; it falls to minimum in chernozems [15, 16]. Soils of southern arid territories have a specific composition of the reflected light. It was shown that the light-transforming ability of soils is determined by the presence of light-absorbing substances (organic matter together with iron and manganese compounds); a certain role is played by aluminum–silica and other light-colored compounds. Humus was found to be the leading factor in the process of light transformation by soils; the proportion of reflected energy is determined primarily by the quantitative and qualitative parameters of humus. The dependence of soil reflectance on the humus content obeys an exponential function and is manifested differently by geographic regions [1, 13, 18]. Previous publications suggest that it is possible to use soil reflectance as an important diagnostic index in soil morphological, pedogenetic, and ecological studies, environmental monitoring, etc. This approach seems to have even better prospects if a comprehensive spectrophotometric database on different soil types is developed.

This work considers the reflective capacity of plain soils in the coastal areas of Peter the Great Bay and Sakhalin Island. The soils located in this relatively narrow coastal belt have specific morphological and physicochemical features [3, 5–8, 14]. That is why it was suggested that all these soils be grouped into a separate taxon called thalassic soils (thalassosols).

This study is aimed at differentiating this large and diverse group using objective spectrophotometric data.

OBJECTS AND METHODS

Specific coastal soils are exposed to the strong climatic and geochemical impacts of the ocean. Ambiguous pedogenetic factors determine a range of unique features and lead to a wide variation in the properties of thalassosols [2]. The genesis of these soils depends primarily on their location in relation to the ocean. The soils of the tidal zone experience conditions accumulation of sediments (synlithogenous soils); they are most strongly influenced by the ocean. Unlike tidal soils, the so-called postlithogenic thalassosols above the tidal zone are less affected by the ocean; they develop under hydromorphic, mesomorphic, or even automorphic pedogenetic conditions. The genesis of thalassosols is always accompanied by peat formation, gley processes, and salinization.

Spectrophotometric data are considered in this work in accordance with the classification approach to thalassic soils developed by the Soil Division of the Soil-Biological Institute in the Far East Division of the Russian Academy of Sciences. A general group of thalassosols is represented by three subgroups: marsh, maritime boggy, and maritime meadow soils. Each of the subgroups is subdivided into two substantially different types: (1) organic soils composed of organic matter (peat, muck) and (2) marsh, maritime meadow-boggy, and maritime meadow soils composed of both organic and mineral material. All organic types include mucky–peaty, peaty-mucky, and mucky varieties. The marsh type is represented by typical marsh and alluvial marsh varieties. Maritime meadow-boggy soils are subdivided into peat, peaty, and typical varieties (subtypes). The maritime meadow type includes typical and gley subtypes [21].

The diffusive reflection spectra of soil samples were obtained using the laboratory spectrophotometer SF-18. The interpretation of the spectra was made by the methods described in our earlier publications [9–11]. Data on the integral reflection (R) and $\Delta\rho$ index (the difference between spectral coefficients at 740 and 420 nm) were obtained. In addition, a new coefficient (r) is used. It displays the dependence of the spectral reflection on the wavelength and characterizes the qualitative and quantitative specifics of the energy distribution by the spectrum. The *r* coefficient is calculated as the product of the integral reflection and the sum of the ratios of spectral coefficients at certain wavelengths:

$$r = R\left(\frac{\rho_{420}}{\rho_{460}} + \frac{\rho_{460}}{\rho_{500}} + \frac{\rho_{500}}{\rho_{540}} + \frac{\rho_{540}}{\rho_{660}} + \frac{\rho_{660}}{\rho_{700}} + \frac{\rho_{700}}{\rho_{740}}\right).$$

The wavelengths for measuring spectral coefficients were chosen with due account for the specifics of spectrophotometric soil characteristics. The indices R_{pr}, $\Delta\rho_{pr}$, and r_{pr} obtained for different genetic horizons were averaged for the entire profile of every soil type.

RESULTS AND DISCUSSION

A set of spectral curves describing the soil reflectance is characterized by rather low indices of the reflecting power and their high variability. The degree of the ordinate increment varies in the spectrum from 1 to 31% with the average slope of spectrum curves at 14%. The increase in spectral coefficients in the basic and middle parts of the spectrum (usual for most soils) is especially manifested in the shape of differential characteristics (Fig. 1). The curves can be grouped into two distinct types: (a) with low-variable ordinates over the entire spectrum and (b) with weakly manifested extremes at 460–480 nm (minimum) and 520–560 nm (maximum). The first group primarily describes the humus and peat horizons, whereas the second group is constituted by the spectrograms of gley and organomineral horizons.

Most soil variations are well differentiated by their reflecting power, and the distribution of this index down the soil profile varies depending on the soil type (Fig. 2). Marsh and maritime organic soils with the screening effect of the organic matter are more homogenous by their reflective properties and are characterized by low reflectance. The profile is most differentiated in the alluvial-marsh subtype, which is due to the lithological specificity of these soils. Shallow marsh soils exhibit some decrease in the integral reflecting power in their upper layers. The latter is not characteristic for primitive marsh soils, since differentiation of their profile by color does not depend on the pedogenesis. Some decrease in the integral reflecting power is characteristic for the upper horizons of typical marsh soils. Maximum values of this index are observed in the middle part of their profiles. The profiles of maritime meadow-boggy soils are weakly differentiated by the reflecting power. The distribution of this index by the horizons is similar to that in organic soils. Typical maritime meadow soils are characterized by high values of reflecting power and manifested differentiation of the profile by this index. The buried organic horizon in these soils corresponds to the second minimum of reflecting power. It should be mentioned that some thalassosols do not exhibit any minimum of reflecting power in their superficial horizons.

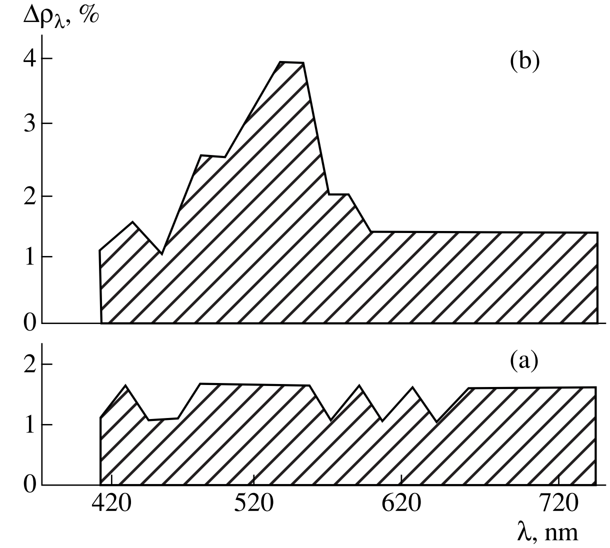

Fig. 1. The variation range of the spectral reflection coefficients ($\Delta\rho_\lambda$): (a) soils with almost stable ρ_λ over the entire spectrum, (b) soils with changing ρ_λ.

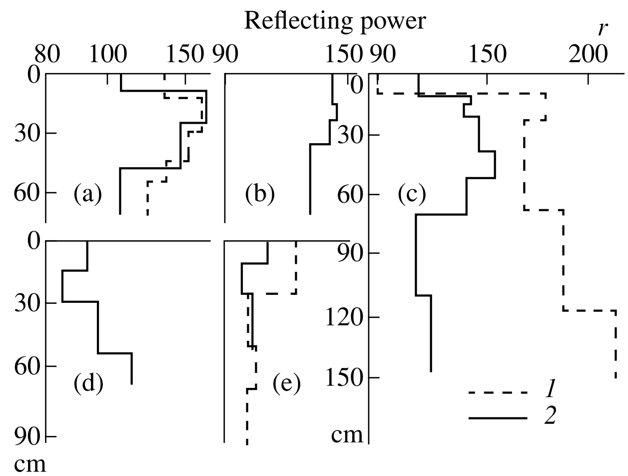

Fig. 2. The distribution of the semiquantitative index down the profile of (*1*) continental and (*2*) insular soils: (a) typical marsh, (b) typical maritime meadow-boggy, (c) typical maritime meadow, (d) marsh mucky–peaty, and (e) maritime meadow-boggy mucky–peaty soil.

The differences in reflective properties of the investigated soils were also estimated using the profile-averaged indices. The applicability of averaged characteristics for comparing the properties of specific multilayered soils with different profile depths was validated by the analysis of the integral reflecting power averaged for the entire soil profile with this property averaged for the upper horizon (0–50 cm). The data obtained (Table 1) show that these two indices do not differ much. The differences vary within the range of 2% with an average value

Table 1. Spectrophotometric analysis of the entire soil profile and its upper layers

Soils	Soil pit	Averaged integral reflection	
		entire profile	0–50 cm layer
Maritime			
Purely meadow	6–92	21.8	20.8
	4–92	25.1	24.1
	1–92	23.7	24.7
	7–92	30.3	29.8
	213a–93	31.0	28.9
	6–94	20.1	21.2
Meadow-boggy	3–92	24.9	23.8
Boggy mucky–peaty	233–93	23.4	25.2
Marsh			
Typical	1–93	21.8	21.1
	213–93	31.9	30.2
	9–93	22.6	23.4
Alluvial-marsh	2–94	22.9	18.5
	3–94	26.8	27.1
	4–94	22.6	21.4
Mucky–peaty	115–92	16.7	14.4
	2–93	19.2	18.3
	5–93	20.1	18.1

of 1% (except for the case of alluvial-marsh soils). The correlation between the averages for the entire profile and its upper part is reliable and reaches 0.93. Such a close similarity confirms the applicability of the indices averaged for the entire profile, as well as those averaged for the upper layers only.

The data on the profile-averaged parameters in the investigated soils are ambiguous. The average R_{pr} of continental thalassosols reaches 25%, the variation interval is 29%, and the most probable variation interval is 17–21%. These indices are lower for insular thalassosols: 20, 9, and 17–22%, respectively. The total sample of reflecting power records from continental thalassosols is heterogeneous and can be subdivided into several groups that correspond to morphological peculiarities of these soils. The average integral reflecting power is lower in organic soils compared to mineral ones. The most frequent values of R_{pr} in the first and second soil groups are within the limits of 17–22 and 22–27%, respectively (Table 2).

Similar but more distinct regularities were revealed using the semiquantitative index r_{pr}. The general range of its values obeys a normal distribution and is a positive, weakly asymmetric set with low-manifested positive excess. The standard deviation σ is equal to 34; variance coefficient V is equal to 25%. The average r_{pr} for the total sample of thalassosols is 136 with the variation from 71 to 229 and the characteristic interval of 110–150. All investigated organic soils are characterized by lower r_{pr} compared to organomineral soils (Fig. 3). Soil reflectance decreases from typical to mucky–peaty subtypes of marsh soils. In maritime-boggy soils, this index

Table 2. The averaged reflecting power of the Far East Thalassosols

Integral reflection (R_{pr})				Index of the slope of the curve ($\Delta\rho_{pr}$)				Semiquantitative index (r_{pr})			
average	minimum	maximum	characteristic interval	average	minimum	maximum	characteristic interval	average	minimum	maximum	characteristic interval
Marsh											
26	14	41	22–37	14	4	29	12–18	143	81	229	110–170
Maritime-boggy											
22	13	37	22–27	13	4	27	12–18	124	71	186	90–150
Maritime-meadow											
26	14	38	22–27	15	2	28	6–18	140	73	207	110–150
Organic thalassosols											
20	13	37	17–22	11	4	22	6–18	109	76	165	90–110
Organomineral thalassosols											
26	13	41	22–27	15	2	29	12–18	144	71	229	130–150
Thalassosols (general range)											
25	13	41	17–27	14	2	29	12–18	136	71	229	110–150

Table 3. Estimation of the correlation between the soil reflecting power and the electric conductivity (E) of the water extract

Soils	0–50 cm layer				Superficial horizon	
	Number of samples	R–E	$\Delta\rho$–E	r–E	Number of samples	R–E
Marsh	45	–0.34	–0.26	–0.34	No data	No data
Maritime, boggy	19	–0.42	–0.56	–0.38	"	"
Maritime, meadow	27	–0.53	–0.26	–0.57	"	"
Thalassosols	91	–0.39	–0.33	–0.51	24	–0.39

decreases in the sequence from typical meadow-boggy to peat meadow-boggy soils. In maritime meadow soils, the reflectance decreases in the following sequence: typical, gley, and mucky–peaty soils. Differences in the reflecting power of thalassosols are pronounced not only at the type level, but also at the subtype level. It must be mentioned that coastal soils of Sakhalin Island have lower reflectance compared to similar continental soils (Fig. 4).

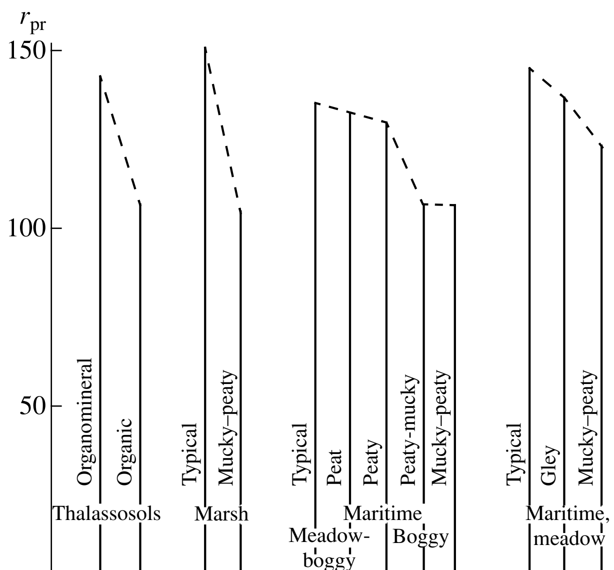

Fig. 3. Stability of r_{pr} in different soil groups.

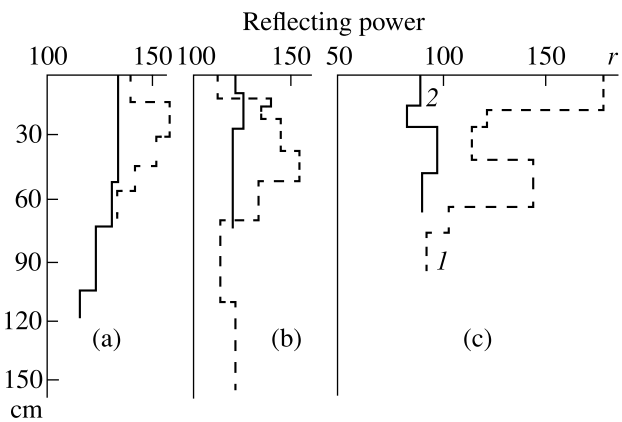

Fig. 4. The distribution of reflecting power (r) down the profiles of (*1*) continental and (*2*) insular soils: (a) typical maritime, (b) typical maritime-meadow, (c) maritime meadow gley.

The correlation between the reflecting power of thalassosols and their salinity was estimated using the electrical conductivity data obtained for the superficial humus horizon and for the entire layer of 0–50 cm. The obtained data vary within a wide range (Table 3), and the correlation coefficients are not statistically significant.

CONCLUSIONS

(1) Spectrophotometric data on the reflecting power of thalassosols in the coastal areas of the Russian Far East were obtained and analyzed.

(2) The reflecting power of coastal soils is different and corresponds to the taxonomic position of these soils (at the type and subtype taxonomic level).

(3) No reliable correlation between the integral soil reflection and the conductivity of the water extract was found.

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