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Influence of surface soil clod structure on spectral response of soil cover

Influence des structures de sol motteux sur la réponse spectrale des sols

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SUMMARY

This paper qantitavely determines the influence of surface soil clod structure of bare soils on their spectral response in the sensitive range of photographic techniques. The study is based on a thesis that the discussed influence reflect itself through self-shadowing of soil surface in the sunshine.

Laboratory and field investigations, verified by desitometric analysis of panchromatic aerial photograph image of soil cover were used. It was found that of the self-shadowing of lessivés soils and black earths on the level of their spectral reflectance increases together with wavelength and is stronger for bright than for dark soils. This influence is extremely important, i.e. if cloddiness of the black earths were completely eliminated, the soils in question would be characterized by a very similar spectral reflectance as the lessivés soils in natural conditions.

RESUME

Ce papier détermine quantitativement l'influence des structures motteuses des sols nus sur la réponse spectrale dans la gamme de sensibilité des techniques de photographie. L'étude est basée sur une thèse qui discute de l'influence de la réflexion sur l'auto-ombrage d'une surface de sol au soleil.

Des investigations au laboratoire et au champ contrôlées par des analyses densitométriques d'images aériennes de couvertures de sol ont été utilisées. Il a été trouvé que l'auto-ombrage des sols léssivés et des terres noires avait un niveau de réflectance qui croissait avec la longueur d'onde et qu'il était plus élevé pour les sols brillants que pour les sols sombres. Cette influence est extrêmement importante et si la rugosité des terres noires était éliminée les sols seraient caractérisés par une réflectance spectrale très similaire à celle des sols lessivés dans des conditions naturelles.

INTRODUCTION

Surface soil clod structure is one the most important elements conditioning differentiation of bare soil density image on aerial photographs /1,2/. This term refers to soil surface roughness, connected with existence of different size and compactness of soil clods. These illuminated clods generate partial self-shadowing of soil surface. Changes of the soil clod structure or solar altitude cause visible modification of soil optical density on an aerial photograph because total reflection energy is modified by change of soil self-shadowing area participation.

The study results on quantitavely determination of influence of surface soil clod structure on soil spectral response in aerial photographs sensativity range are presented in this paper.

METHODS

This study was caried out on typical soils of Kościan diluvial plateau in Wielkopolska Lowland.

The discussed influence was investigated by laboratory measurement of soil reflectance. These values were determined on 1.6 cm diameter air-dry soil samples in comparison with the barium sulphate standard by the SPEKOL-Reflectometer R45/0 of Zeiss Jena firm in the range of 400-860 nm. The self-shadowing of the soil surface was simulated by placing artificial shaped spherical soil clods of 3-4 mm diameter on smooth soil samples.

An equation making possible calculating the self-shadowing coefficient of soil surface with natural cloddiness in specified solar altitude was determined by ground photographs image analysis of soil with the highest possible clod differentiation. These photographs were made from height of 2 m by 80 mm camera PENTACON Six TL in solar altitude range 18-56^{0}. This analysis was carried out by image analysing computer Cambridge Quantimet 720 of IMANCO firm.

The laboratory investigation was verified by optical density measurements of the soils with the use of panchromatic aerial film FOTOPAN 10 sensitived in the range of 380-710 nm. These aerial photographs in a scale of 1:10,000 were synchronycally made with taking photos on the ground at the solar altitude of 53.5° on 13th May, 1982. These densitometric measurements were made by microdensitometer GII Zeiss Jena through 0.5 x 0.5 mm slot.

The field investigations of the soils were supplemented by their laboratory analysis of:mechanical composition /aerometric method/, organic matter content /burning at temperature 460°C/ and soil moisture content /in relation to wight od dried soil at 105°C/.

RESULTS

According to Polish soil classification studied soil cover represents lessivés /grey-brown podsolic/ soils, eroded lessivés soils, initial denudative soils, degradated black earths and proper black earths. A general characterization of these soils was suppplemented by table II. Cloddiness of the soils was described in table I by their maximum diameter /$\emptyset_m$/, average diameter /$\bar{\emptyset}$/ and participation of total soil clod area in top view /ΣP/.

Table I

Soils	$\emptyset_m$/cm/	$\bar{\emptyset}$/cm/	ΣP
Initial denudative soils	<4	<1	0.08–0.15
Lessivés soils	<5–7	1.3–1.8	0.3 –0.4
Degradated black earths	<9	1.0–1.7	0.25–0.45
Proper black earths	15	1.7–2.7	0.3 –0.75
Eroded lessivés soils	8–15	1.3–3.0	0.35–0.75

The lessivés and initial denudative soils lie on a field, which was draged, harrowed and sawed with corn 8 day before taking photographs. The black earths lie within the neighbouring field. It was again sowed with spring wheat after winter wheat had been freezed. Immediately before taking photographs the wheat 7–10 cm high were eliminated from the investigated points.

The present study is based on a thesis that the discussed influence reflect itself through self-shadowing of illuminated soil surface. The self-shadowing coefficient of soil surface /S/ refers to participation of shaded soil area in top view in comparison with total soil area being analyzed.

The artificial cloddiness formed on the soil samples enabled to precisely calculate of the shaded soil area in the samples and also enabled to determine their spectral reflectance curves by specified self-shadowing coefficients. The results obtained this way demonstrate the stronger influence of the self-shadowing coefficient on spectral response for soil with high level spectral reflectance /initial denudative and lessivés soils/ than for soil with the level being low /black earths/ /Fig. 1/.

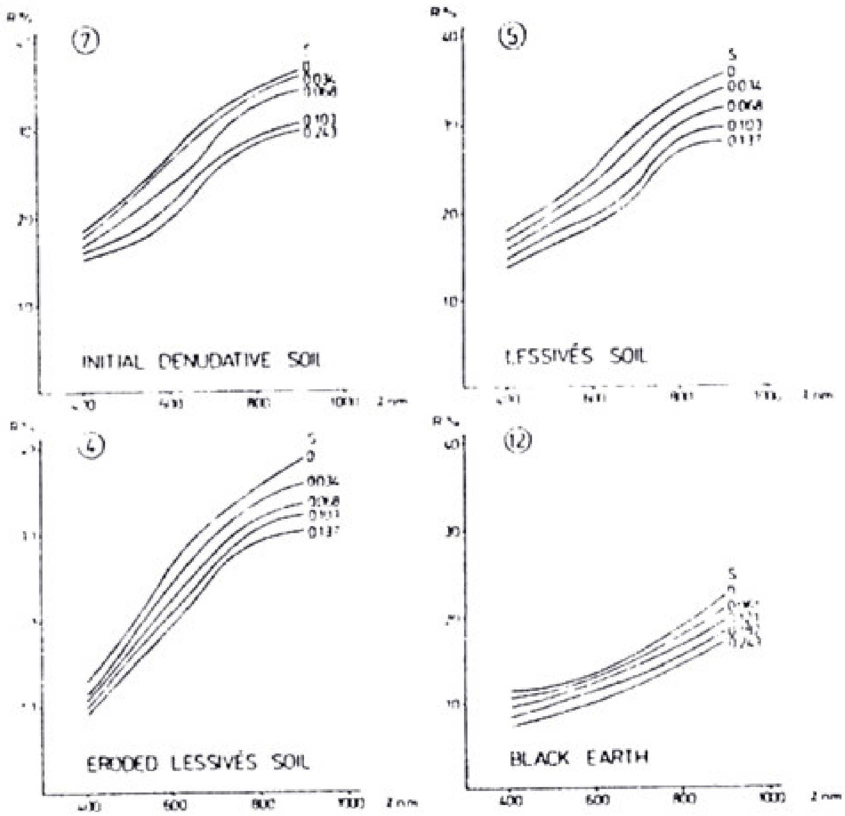

Fig. 1. Typical spectral reflectance curves of studied soils in different self-shadowing conditions /S/.

The diagram in Fig 2 shows an average reduction of spectral reflectance level /ΔR/ among the above mentioned soils, caused by their self-shadowing, expressed through self-shadowing coefficient of soil surface /S/ in specified wavelength /λ/. It also proves clearly, that the influence of soil self-shadowing on their spectral response increases with the wavelength.

During this research it was attempted to find the means for calculating the self-shadowing coefficient /S/ in specified solar altitude /α/ in conditions of natural soil cloddiness.

It was found that this coefficient can be calculated by means of a simple parameter for macroscopic evaluatin of soil surface structure, determinig participation of total soil clod area in top view /ΣP/. This parameter can be evaluated even by using the diagrams designated to a visual evaluation of a blot participation in soil profile. The exponential equation:

$$S = 0.3845\Sigma P + 0.0346 + 2.87 \times 10^{-5}/90 - \alpha/^{2.1831}$$

describes this relationship in the range from 15 to 60^{0} on a significence level lower than 0.05.

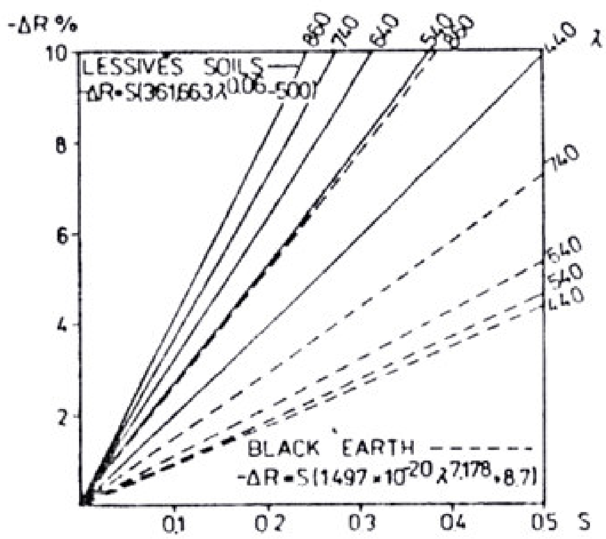

Fig.2. Reduction of soil reflectance /ΔR/ in self-shadowing /S/ and wavelength /λ/ functions.

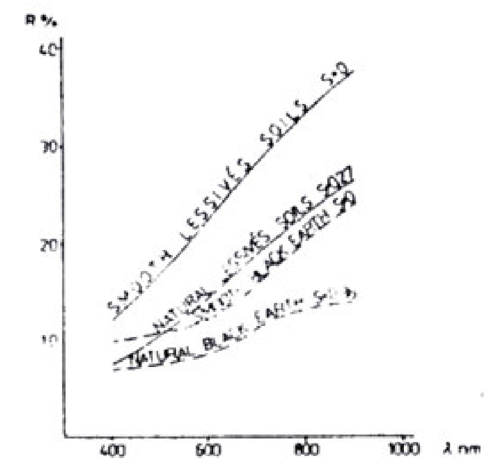

Fig.3. Average spectral reflectance curves for lessivés soils and black earths in smooth and natural conditions

The equation mentioned above and the equations showed on the diagram in Fig 2 were used to drawing average spectral curves of the lessivés soils and black earths corresponding to their natural cloddiness in angle of incidence 45^{0} applied in laboratory spectrophotometric investigation /Fig.3/. These curves demonstrated that the discussed influence is extremely important, i.e. if cloddiness of the black earths were completely eliminated, the soils in question would be characterized by a similar spectral reflectance as the lessivés soils in natural conditions.

Correctness of these laboratory investigation results, in the sensitive range of photographic techniques, was also verified by densitometric analysis of aerial panchromatic film. This analysis was made on the basis of discovered relationship connected with the laboratory designated soil reflectance data

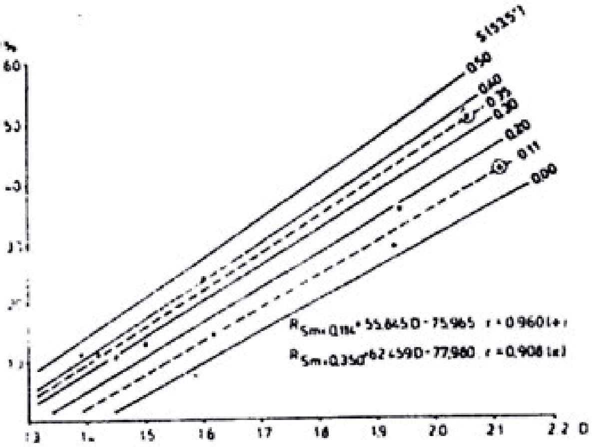

Fig.4. Relation between average soil reflectance $\bar{R}$, self-shadowing coefficient of soil surface /S/ and optical density of image in the aerial film /D/.

/in the range of the used film/ with corresponding values of the soil optical density on the film and the self-shadowing coefficients of the soil surface during aerial photograph taking. Moisture of the soil cover to 1-2 cm depth during this aerial photograph taking was so low that it would not reduce their spectral reflectance level in comparison with completely dried soil /1/. The diagram in Fig.4, showing this relationship, was worked out on a base of two linear equations referring to data of similar values of the self-shadowing coefficient /points 6,7,9 and 8,11,12,13 in table II/. This relationship, was determined on a significient level of about 0.05. It confirms the correctness of the laboratory investigations results compared with the stronger influence of the self-shadowing coefficient among bright soils than dark one. It manifests itself the fact that modification of the self-shadowing coefficient of 0.1 among the black earths /of the average percent of reflectance between 11-15/ generates a change of the optical density on the aerial negative of about 0.06 D, whereas among the lessivés soils /of the average percent 19-35/ - of about 0.08 D. The above mentioned data also confirms the laboratory observation, that if cloddiness of the black earths were completely eliminated, these soils would be characterized by a similar spectral reflectance like the lessivés soils with natural clods, because the average optical density of the first soils in natural condition D = 1.43 would increase without clods to D = 1.66, whose value corresponded to the lessivés soils in natural conditions.

Table II. Some properties of studied soil surfaces and the results of the influence of their self-shadowing on the aerial film.

Point No	SC	s	si	c	OM	θ	C 10YR	ΣP	$\bar{R}$	S/53.5°/	S/45°/	D	D/R,S/
1	LS	76	17	7	2.0	1.5	5/3	0.321	19.3	0.166	0.275	1.64	1.67
2	LE	75	13	12	2.1	1.8	6/4	0.432	21.0	0.227	0.317	1.62	1.66
3	LE	75	13	14	1.9	1.6	6/6	0.536	22.9	0.302	0.357	1.61	1.64
4^x	LE	77	11	12	1.7	1.9	6/6	0.705	24.0	0.339	0.422	1.60	1.64
5	LS	90	8	2	1.2	1.4	5/3	0.340	25.3	0.245	0.284	1.75	1.72
6^x	ID	97	2	1	0.5	1.2	8/2	0.128	35.3	0.112	0.200	1.94	1.99
7^x	ID	98	1	1	0.4	1.3	8/2	0.057	28.8	0.088	0.173	1.93	1.89
8^x	BP	70	19	11	3.1	3.9	4/2	0.480	12.7	0.331	0.336	1.50	1.46
9^x	BD	90	8	2	1.6	1.6	5/2	0.203	14.6	0.141	0.229	1.62	1.60
10	BD	95	5	0	1.9	1.9	5/2	0.386	15.0	0.289	0.300	1.49	1.52
11^x	BP	73	19	8	5.0	3.9	3/2	0.456	11.0	0.344	0.327	1.42	1.43
12^x	BP	66	22	12	5.9	3.1	3/2	0.543	11.3	0.357	0.360	1.39	1.42
13^x	BP	78	12	10	3.4	4.9	4/2	0.500	10.8	0.380	0.367	1.45	1.41
14	BP	69	19	12	4.7	6.6	4/2	0.673	10.8	0.436	0.410	1.43	1.38

SC – soil classification: LS–lessivés soil, LE–eroded lessivés soil, ID–initial denudative soil, BD–degradated black earth, BP–proper black earth

Mechanical fraction /%/: s–sand, si–silt, c–clay
OM – organic matter content /%/
θ – moisture during aerial photograph taking /%/
C – soil colour during aerial photograph taking
ΣP – participation of total soil clod area in top view
$\bar{R}$ – average % of soil sample reflectance /380–710 nm/
S/53.5°/ – self-shadowing coefficient during aerial photograph taking
S/45°/ – self-shadowing coefficient during laboratory investigation

D – optical density in the aerial film
D/R,S/ – optical density determined by means of the diagram in Fig.4.
x – points used for drawing the diagram in Fig. 4.

CONCLUSIONS

1. An influence of surface soil clod structure on spectral response of bare soil cover manifests itself through a self-shadowing of illuminated soil surface.
2. The influence of soil surface self-shadowing /in the range of 400–900 nm/ on the spectral reflectance values rises with a wavelength.
3. Bright soils like the lessivés demonstrate a larger decrease of spectral reflectance because of the increase of their self-shadowing than dark soils like the black earths.
4. The influence of self-shadowing of the soil surface is so extremely important, that if cloddiness of the black earths were completely eliminated the soils in question would be characterized by a similar spectral reflectance level as the lessivés in natural conditions.
5. The self-shadowing coefficient of the soil surface in natural conditions in specified solar altitude can be calculated by a simple parameter for macroscopic evaluation of the soil surface structure, determinig participation of total soil clod area in top view.

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