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MEASUREMENTS OF SPECTRAL REFLECTIVITIES IN STUDIES OF OVERGRAZING

[...] go thy way forth in the footsteps of the flock...
Song of Songs, Chapter 1, Verse 8

INTRODUCTION

Some images of arid or semi-arid steppe regions taken by the Earth Resources Technology Satellite (now LANDSAT) show in a sharp contrast, demarcation lines between regions of protected or partially protected natural vegetation ecosystems and neighboring areas subject to anthropogenic pressures [2, 3]. The most important factors in changing the characteristics of the surface in the impacted ecosystems are:

a) overgrazing by goats, sheep, camels and cows,

b) agricultural cultivation,

c) collecting shrubs and trees as firewood and as construction material [5].

The impacted ecosystems, characterized largely by unstable bare soil, show up as brighter in all the spectral bands of LANDSAT multispectral scanner (operating in the wavelengths from 0,5 to 1,1 micrometers). The fact that the unimpacted ecosystems of natural vegetation are darker in the reflective infrared is surprising, since healthy vegetation typically reflects very strongly above 0,75 micrometers. The contrasts between such ecosystems have been observed in many parts of the world and quantitatively studied from the LANDSAT computer compatible tapes [6].

Among others, the contrast ratios as observed from space between the bright, overgrazed Sinai and the dark Negev, where grazing is limited (see Fig. 1, a LANDSAT image of the area) were measured and computed

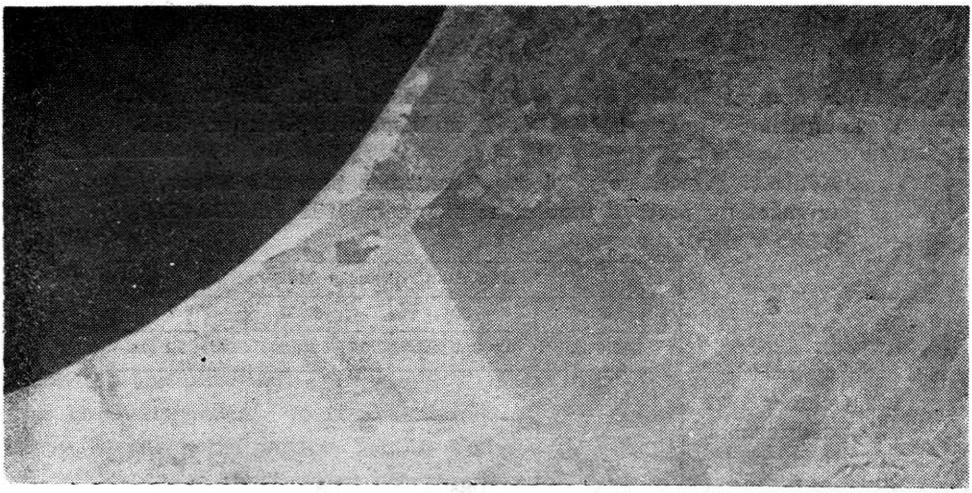

Fig. 1. Negev, Sinai and Gaza Strip, section of LANDSAT image E-1145—07484, band MSS-6, 15 December 1972, showing a sharp demarcation line between the overgrazed areas in the Sinai and Gaza Strip and the Negev, protected from overgrazing

Fot. 1. Pustynia Negev, Synaj i Strefa Gazy, wycinek z obrazu LANDSAT E-1145—07484, pasmo MSS-6, 15 grudnia 1972; widać wyraźnie linię oddzielającą wypasione obszary Synaju i Strefy Gazy od pustyni Negev nie dopuszczonej do wypasu

for three pairs of points, one just inside the Sinai and one just inside the Negev. The contrast ratios range from about 2,0 for the part closest to the Mediterranean where the average annual precipitation is 150 mm, to about 1,2 for an inland pair where there is less precipitation and the soil is more sandy. The space contrasts in the 4 spectral bands of the multispectral scanner are given in Table 1. The seasonal variations in contrasts are not very pronounced [6].

The contrast ratios Sinai/Negev of about 2,0 were considerably higher than that found in other locations. Detailed ground truth observations and measurements were taken in this area. The vegetation is moisture limited and grows in clumps, separated by large interstices. This holds true both for the Negev and the

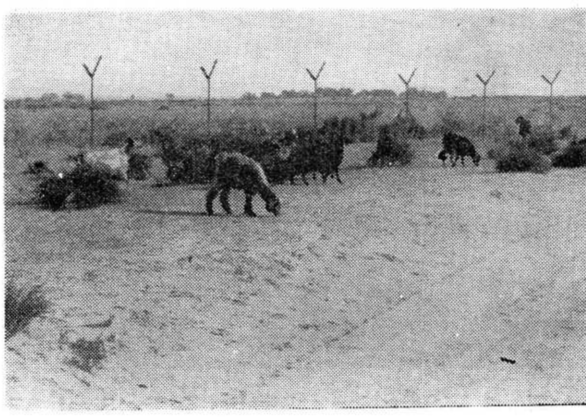

Fig. 2. Sheep grazing in the Sinai, with a fence between the Sinai and the Negev and the darker Negev in the background

Fot. 2. Wypas owiec na Synaju; widać wyraźne zróżnicowanie między Synajem a pustynią Negev; ciemniejsza pustynia Negev na dalszym planie

Table 1
Tabela 1

Space Contrast Ratios Sinai/Negev Computed from the Computer Compatible Tapes of LANDSAT Multispectral Scanner, MSS

Kontrast przestrzenny między Synajem a pustynią Negev, wyznaczony przez komputer ze skannera MSS LANDSAT

	MSS Band (kanały MSS)			
	4	5	6	7
	0,5—0,6 μm	0,6—0,7 μm	0,7—0,8 μm	0,8—1,1 μm
22 October 1972 (22 października 1972)				
Site (Stanowisko) 1	1,55	1,88	1,87	1,73
2	1,29	1,41	1,41	1,33
3	1,23	1,30	1,29	1,27
2 January 1972 (2 stycznia 1972)				
Site (Stanowisko) 1	1,49	2,03	1,85	1,69
2	1,26	1,53	1,43	1,36
3	1,19	1,24	1,22	1,22

Fig. 3. Watermelon cultivation in the Sinai. All the weeds are removed, so they would not compete for the soil moisture

Fot. 3. Uprawa arbuzów na Synaju. Usunięto wszelkie chwasty, aby nie pochłaniały wilgoci z gleby

Sinai. In the protected ecosystems of the Negev the soil is stabilized, slightly crusted in many locations and dark plant debris litter the interstices between the plants. In the impacted areas of Sinai there are less plants to produce the debris. Such debris that are produced tend to be trampled under by the grazing animals or covered by dust raised from the unstable, crumpled soil [5].

Overgrazing seems to be the main impact (see Fig. 2, a view of the fence separating the Negev from the Sinai, with sheep grazing in the Sinai and the protected Negev with more plant cover beyond the fence). However, cultivation in small plots, which depends on rain, dew and ground water also contributes locally to the areas of bare, crumpled soil, since the natural vegetation, i.e., weeds, are carefully removed so they would not compete for moisture with the cultivated plants (see Fig. 3, cultivation of watermelons in the Sinai).

METHOD OF MEASUREMENTS

In order to monitor by methods of remote sensing and photo interpretation the processes taking place in the impacted ecosystems, especially due to overgrazing, or the recovery of the ecosystems when steps are taken to offer protection to the plant life, quantitative characterization of reflectivities of the key components of such ecosystems is necessary. With this aim in mind, a program of spectral reflectance measurements was undertaken at the Negev/Sinai demarcation line and the first results are presented here.

The spectral reflectivities were measured using Exotech — 100 Radiometer, an instrument designed specifically for ground-truth observations in the studies of LANDSAT imagery. This radiometer operates in the 4 spectral bands of LANDSAT: MSS-4, 0,5—0,6 μm, green-yellow; MSS-5, 0,6—0,7 μm, orange-red; MSS-6, 0,7—0,8 μm, red-infrared; and MSS-7, 0,8—1,1 μm, infrared. By pointing the instrument upwards and using 2π lenses, the impinging hemispheric radiation is measured. By taking the ratios of the reflected radiation to the impinging radiation, the reflectivity is measured.

RESULTS

The results of measurements taken in the Sinai, in the Negev and from samples brought to Tel Aviv are presented in Table 2.

The most significant points for interpretation of multi-spectral imagery are:

1. The crumpled sandy loess soils, such as from Sinai, can be very bright in the infrared, with reflectivity of about 0,55,

2. At least some of the arid region vegetation (artemisia monosperma, young growth) also has high reflectivity in the infrared, also about 0,55. The reflectivity in green-yellow is about 0,30 and in the orange-red (chlorophyllabsorption band) 0,20.

3. The dark plant debris that accumulate on the stabilized surface where there is no trampling by animals, are quite dark as compared to the bare soil. The reflectivities of debris are lower by a factor of 3,5 in the visible and by a factor of 2,5 in the infrared, than the bare, crumpled soil.

4. The crusted soil is somewhat darker than the crumpled soil, typically by 10 to 20%. The variability of reflectivity of the crust, even in the same area, can probably be ascribed to the variability of moisture conditions at the time the crust formed. A crust formed after a very strong rain, when the dark debris and organic materials floated to the surface, can be expected to be darker. When a crust forms in a gentle rain, there is less organic material visible on the surface and the crust is brighter.

5. Very recent sand in coastal dunes such as are found on the coasts of Israel and Sinai, are very bright — brighter than the sandy soils both in the visible and in the infrared. The reflectivity of such sands is about 0,40 in the visible and 0,60 in the infrared (not reported in Table 1).

Table 2

Tabela 2

Spectral Reflectivity Measurements by Exotech-100 LANDSAT Ground-Truth Radiometer

Pomiary odbicia spektralnego wykonane za pomocą radiometru Exotech-100 w zestawieniu z pomiarami LANDSAT

	MSS Band (kanały MSS)			
	4	5	6	7
	0,5—0,6 μm	0,6—0,7 μm	0,7—0,8 μm	0,8—1,1 μm
Sinai Soil No. 1 (Gleba synajska nr 1)	0,32	0,44	0,50	0,54
Plant Debris (Resztki roślinne)	0,09	0,13	0,17	0,26
Sinai Soil No. 1 Crust (Gleba synajska nr 1, zeskorupiałe resztki)	0,28	0,35	0,39	0,43
Artemisia Monosperma Young Growth (Pierwszy etap wzrostu)	0,30	0,20	0,47	0,56
Artemisia Monosperma Twigs (Rozwinięta)	0,29	0,21	0,31	0,43

The high space contrasts across sites 1 Sinai/Negev presented in Table 1 can be explained in view of spectral reflectivities reported in Table 2, by relative darkness of the plant debris. We can carry out a simplified calculation to quantitize the role of the debris. In band MSS-6, the reported space contrasts (1,87 in October 1972 and 1,85 in January 1973) practically did not change with seasons. Neglecting the contrast attenuating effects of the atmosphere for this band we equate the space contrast to the ground contrast, and take 1,86 as the average. If we further assume that in the Sinai the terrain is all crumpled soil and in the Negev the soil is crusted and a fraction of the ground x covered by debris, then we have the equation for the contrast:

$$\frac{\text{Reflectivity of Sinai}}{\text{Reflectivity of Negev}} = \frac{0{,}50}{(1-x)\,0.39 + x \cdot 0.17} = 1{,}86$$

Solving for x, one obtains $x = 0{,}55$, and one thus can conclude that about half of the terrain is covered by the debris. It should be stressed that in such a calculation great oversimplification of the problem is made, However, this calculation points out of the role of the debris in the dark appearance of the protected steppe.

If the calculation is repeated for the other bands, with the value of x equal 0.55 as derived above, one obtains for the band MSS-5:

$$\frac{0.44}{(1-0{,}55)\cdot 0{,}39 + 0{,}55 \cdot 0{,}13} = 1{,}92$$

which agrees well with the measured space contrasts, Table 1, of 1,88 and 2,03; and for the band MSS-4;

$$\frac{0{,}32}{(1-0{,}55)\cdot 0{,}28 + 0{,}55 \cdot 0{,}09} = 1{,}82$$

which compares with space contrasts of 1,49 and 1,55. This should still be regarded as a reasonably good fit, in view of the higher contrast attenuation of the atmosphere in this band.

Repeating this calculation for band MSS-7, one obtains a contrast of 1,60 appreciably lower than the values of 1,73 and 1,69 reported from space.

Considering the simplified character of the calculation, i.e. neglecting any differences in the plant cover and disregarding the observation that not all soil in the Negev is crusted, the over-all fit is satisfactory and the figure of 0,55, the derived plant debris ground cover fraction, can serve as quantitative indication of the degree of plant protection and soil stability in the Negev as compared to the overgrazing in the Sinai. This approach to quantitative characterization should be regarded as only a preliminary study, but from an examination of the reflectivities of Table 2 one can conclude that the debris have a predominant role in creating the contrast.

CONCLUSIONS

The high reflectivity of the impacted ecosystems, which can be very well observed and mapped from space, is largely due to crumpled soils. The dark appearance of the protected ecosystems is primarily due to accumulation on the surface of dark plant debris. The debris are darker than the bright sandy soil by a factor of 3,5 in the visible and 2,5 in the infrared.

The above observations are valid only in arid and semi-arid regions, where the moisture limited vegetation grows in isolated clumps, with large interstices. The accumulation of organic material in the natural steppe has been stressed by J. Curtis [1]. However, he reported compaction of the soil as a result of overgrazing, whereas we observed destabilizing and crumpling of the soil in the interstices as the main effect.

Since overgrazing is a crucial environmental problem with global implications, and since it is possible now to monitor overgrazing from the LANDSAT satellites [4] further studies to be conducted in depth, in various geographical locations, are certainly warranted.

ACKNOWLEDGEMENT

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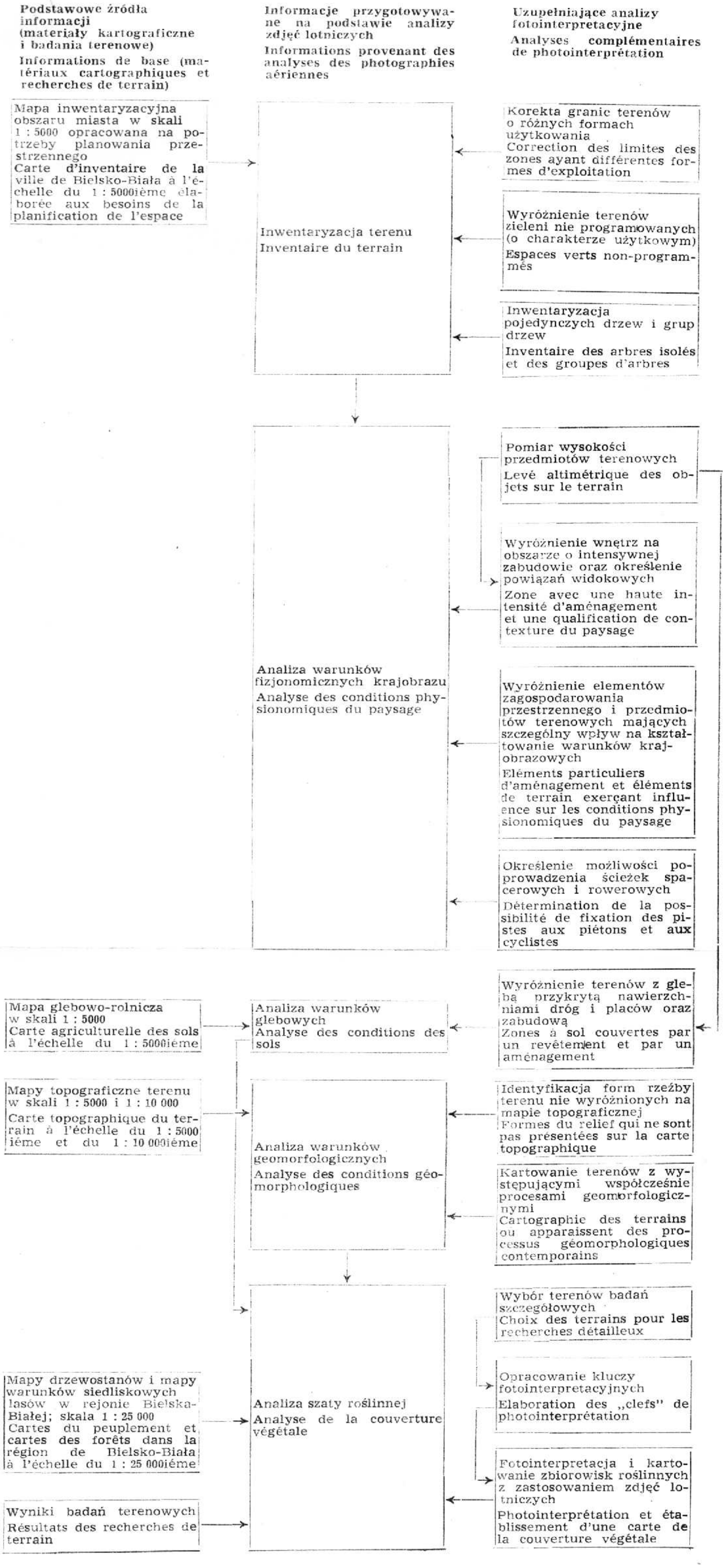
Schemat 1
Schémat 1

Zakres, kolejność i powiązania analiz fotointerpretacyjnych przeprowadzonych w celu przygotowania informacji do studium zieleni Bielska-Białej

Programme des analyses de photointerprétation nécessaires à la préparation des informations concernant l'état de la verdure à Bielsko-Biała



JOSEPH OTTERMAN, A. IMBER, G. MARACCI

POMIARY ODBICIA SPEKTRALNEGO W BADANIACH NAD PASTWISKAMI

Streszczenie

Autorzy z ramienia fundacji USA — Izrael prowadzili pomiary radiometrem Exotech-100 po obu stronach granicy Negev—Synaj w tych samych przedziałach widma elektromagnetycznego co satelita LANDSAT. Były to kanały: MSS-4 = 0,5—0,6 μm (zielono-żółty), MSS-5 = 0,6—0,7 μm (pomarańczowo-czerwony), MSS-6 = 0,7—0,8 μm (czerwony-podczerwień) i MSS-7 = 0,8—1,1 μm (podczerwień). Celem badań było stwierdzenie przyczyn różnic spektralnych wspomnianych obszarów, widocznych na obrazach LANDSAT. Jasny obraz w podczerwieni pochodził od pyłowych gleb lessowych, ciemny natomiast od resztek roślinnych na pastwiskach. Jest to właściwe dla obszarów półpustynnych, gdzie gleba jest zeskorupiała. Również wydmy nadbrzeżne zarówno w Izraelu, jak i na półwyspie Synaj dały bardzo jasne odbicie spektralne.

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MESURES DE LA RÉFLECTANCE SPECTRALE DANS LES RECHERCHES SUR LES PÂTURAGES

Résumé

Les auteurs agissant au nom de la fondation des Etats-Unis et d'Israël ont effectué les mesures de la réflexion spectrale à l'aide du radiomètre „Exotech" de deux côtés de la frontière Neguev—Sinaï, dans les mêmes intervalles que ceux du satellite LANDSAT. C'était les canaux suivants: MSS-4 = 0,5—0,6 μm (vert-jaune), MSS-5 = 0,6—0,7 μm (orange-rouge), MSS-6 = 0,7—0,8 μm (rouge-infra-rouge), MSS-7 = 0,8—1,1 μm (infra-rouge). Ces recherches avaient pour but de constater les différences spectrales dans les régions citées ci-dessus, perceptibles sur les images LANDSAT. L'image claire dans l'infra-rouge provenait des sols loessiques et l'image foncée provenait de végétation. Ce phénomène est général pour les régions demi-désertiques où le sol est encrouté. Ansi, la même réflectance spectrale a été obtenue sur les dunes du littoral à Israël et à la péninsule Sinaï.