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12. Revised by

Evlyn M. L. M. Novo

13. Authorized by

Nelson de Jesus Parada
Director General

9. Authorship *José Carlos Neves Epiphanio*
Ícaro Vitorello

Responsible author

14. Abstract/Notes

This study describes an experimental test on two bare Oxisol plots, located in Central Brazil, with the objective of observing their spectral behaviour under varying surface moisture and roughness conditions, and the effects of view angles in relation to the sun. Reflectance factor determinations were made at azimuthal angles of 0° and 90°. Before irrigation, both plots presented similar surface roughness, but after irrigation the surface of the irrigated plot became smoother because the soil aggregates were dispersed into finer and more compacted particles. Consequently, the effect of shadow associated with the rougher conditions of the non-irrigated plot was more conspicuous for the 90° view angle determinations. In this case, the reflectance factor values of the non-irrigated plot were very similar to the irrigated plot, making it very difficult to spectrally distinguish the plots with substantially different moisture content. On the other hand, with a view angle of 0°, the shadow effect becomes minimun and the irrigated plot is better differentiated from the non-irrigated.

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INTER-RELATIONSHIPS BETWEEN VIEW ANGLES (AZIMUTH) AND SURFACE MOISTURE AND ROUGHNESS CONDITIONS IN FIELD-MEASURED RADIOMETER REFLECTANCES OF AN OXISOL

J.C.N. Epiphanio, I. Vitorello

Instituto de Pesquisas Espaciais - INPE
Departamento de Sensoriamento Remoto
Caixa Postal 515 - 12200 São José dos Campos - SP (Brasil)

SUMMARY

This study describes an experimental test on two bare Oxisol plots, located in Central Brazil, with the objective of observing their spectral behaviour under varying surface moisture and roughness conditions, and the effects of view angles in relation to the sun. Reflectance factor determinations were made at azimuthal angles of 0^{o} and 90^{o}.Before irrigation, both plots presented similar surface roughness, but after irrigation the surface of the irrigated plot became smoother because the soil aggregates were dispersed into finer and more compacted particles.

Consequently, the effect of shadow associated with the rougher conditions of the non-irrigated plot was more conspicuous for the 90^{o} view angle determinations. In this case, the reflectance factor values of the non-irrigated plot were very similar to the irrigated plot, making it very difficult to spectrally distinguish the plots with substantially different moisture content. On the other hand, with a view angle of 0^{o}, the shadow effect becomes minimum and the irrigated plot is better differentiated from the non-irrigated.

RÉSUMÉ

Cette étude est constituée d'un travail expérimental réalisé sur deux parcelles d'Oxisols sans couverture végétale, au Brésil Central. Le but était:

1. observer leur comportement spectral sous différentes conditions d'humidité et de rugosité,
2. étudier les réponses spectrales en fonction de différentes angles de visée vis-à-vis de l'angle d'inclinaison solaire.

Les déterminations de reflectance furent réalisées aux angles de 0 et 90 degrés. Avant de procéder à l'irrigation, les deux parcelles présentaient une rugosité superficielle similaire. Cependant la parcelle irriguée est devenue plus lisse parce que les agrégats du sol furent dispersés (particules fines et particules plus compactes).

Les résultats indiquaient que l'effet de l'ombre associé à des conditions de rugosité plus élevées des parcelles non-irriguées était plus remarquable pour les déterminations d'angle de visée à 90 degrés. Dans ce cas les valeurs de réflectance de la parcelle non-irriguée étaient presque similaires a ceux de la parcelle irriguée, ce qui rend très difficile de séparer spectralement les parcelles avec differents contenus d'humidité. Par contre en utilisant l'angle de 0^{o}, l'effet de l'ombre devient minimal et la parcelle irriguée est mieux séparable de celle non-irriguée.

1. INTRODUCTION

In recent years, several studies have been directed to the understanding of ground reflectance anisotropy, obtained from spectral measurements made at various sun-target-sensor geometries. Such an understanding is pursued since it provides the basis for the analysis of data collected at off-nadir angles (for instance oblique viewing capability proposed for the SPOT and the MRS - Multispectral Resource Sampler), the selection of sensor bands for enhancement of target characteristics, determination of illumination effects on target discriminations, and so on(2).

The major thrust has been in the area of vegetated surfaces where the combination of sunlit and shaded leaves and soils produces a strong anisotropic reflection behaviour. In the case of crops, the soil background can have substantial contribution to the reflectance. Relatively large differences in canopy reflectance, observed during the growing cycle of plants, have been associated to variations in soil types, moisture content and surface roughness (3). The characterization of the effects of soil upon scene radiation needs to be better understood since soil cover percentage and soil properties in general are major components in crop canopies models (3) and yield predictions (9).

Nevertheless, reflectance characteristics of soils have had considerably fewer studies than vegetation, despite the fact that they possess several chemical and physical properties which affect the absorption and reflectance of the incident radiation. In general, reflectance behaviour of soils have been studied with the purpose of identifying different types of soils with distinct soil characteristics related to iron oxides, organic matter, moisture, cation exchange capacity, salinity, parent material, particle size and surface roughness (1, 5, 8, 13, 20, 21).

The authors believe that further analysis should be conducted over inter-relationships of these parameters with varying environmental conditions. Thus, the present study is intended to be a contribution to the understanding of the effects of soil surface moisture and roughness on spectral determinations obtained at a given view angle (azimuth) with other variables kept constant.

The influence of soil moisture on the soil spectral reflectance has been recognized by many authors (4, 6, 7, 12, 16). In summary, as soil moisture increases, the reflectance decreases in all wavelengths, mainly at the water absorption bands.

Surface roughness has also been well studied (6, 15, 17, 18, 19). A major conclusion reached is that as the diameter of the soil aggregates increases, the reflectance decreases due to greater scattering and the presence of shadows. On the other hand, when soil becomes wet it gets a more uniform superficial crust (14).

Therefore, since the soil surface is not a perfectly diffuse reflector (Lambertian surface), soil reflective response is related to the azimuthal view angle and the illumination angle, as previously noted by Egbert and Ulaby (10). Their conclusion was that for each target considered there should be made an analysis of the best angle geometry.

In the present case, we set out to observe two situations: 1) the effect of moisture and roughness on the reflective response of bare soil according to two viewing angles; and 2) the effect of decreasing water content over spectral discrimination of irrigated and non-irrigated plots.

2. DATA COLLECTION

The experimental test was conducted on two bare Oxisol plots, located at EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), Central Brazil.

Determinations were made according to Figure 1, by sequentially measuring the target of interest and a reference panel ($BaSO_4$) with a radiometer held at approximately 1,6 meters above the ground. Constant solar altitude and minimum irradiance variations were attained by making measurements at same local time (9:00 a.m.) and during cloudless skies. The incidence angle was maintained at 30^o, but the azimuth angles were 0^o and 90^o. The spectral reflectivity data were collected with a hand-held radiometer developed at the Institute for Color Technology - Chiba University, Japan.The radiometer operates at wavelengths centered at 450, 500, 550, 600, 650, 750, 850 and 1050 nm (11). A field of view of $5^o40'$ permitted to define a sample size of about 400 cm^2 on the ground.

The plot positions, in respect to viewing and illumination directions, are seen in Figure 2. Both plots were tilled into a uniform surface and one of them was irrigated on the 10^{th} of September of 1981, after which was left alone for natural drying out, until the 16^{th}. The sampling scheme was to measure both plots with viewing directions parallel (direction 1) and normal (direction 2) to the sunlight.

3. RESULTS AND DISCUSSION

Before irrigation both plots presented similar surface roughness: the particles were disorderly arranged and formed irregularly shaped aggregates of varying sizes. With irrigation, the aggregates broke up into finer particles which rearranged themselves in a more compact and orderly fashion resulting in a homogeneously smoother surface for the irrigated plot.

Consequently, when the irrigated and non-irrigated plots are observed at varying observation angles under a fixed illumination condition, their different degrees of surface roughness play an important role. To illustrate this point one can observe the effect of shadows in Figure 3 when the surface is observed from two positions. The shadow effect should be greater when the observation is made perpendicular to the illumination direction (azimuth=90°).

This fact has been observed and quantified in the study. Figure 4 shows the reflectance factor as a function of wavelength as measured in the non-irrigated and irrigated plot, selecting one of the days (13 of September 1981) as an example of the roughness effect. In the non-irrigated plot the reflectance factor is observed to be substantially greater when the view direction is parallel to the illumination (direction 1), whereas in the irrigated plot the values of reflectance for both directions are very similar, even though the values obtained from direction 1 have consistently remained slightly higher than from direction 2. This is likely indicative of the greater effect of shadows in the non-irrigated plot than in the irrigated plot, due to the surface smoothness caused by the irrigation process.

The above observations are quantified in Table I. It indicates the wavelengths at which the differences in reflectance values of observations made parallel (direction 1) or normal (direction 2) to the illumination are statistically significant at the 0.05 confidence level. In the non-irrigated plot this difference is not significant at the 450 nm, relatively low at 500 and 550 nm, and higher at wavelengths greater than 600 nm. In the irrigated plot the differences between both direction are not significant, except at the 750 nm.

In this example, it is shown that the presence of shadows makes the soil a non-Labertian surface affecting the spectral determination in a way that depends upon illumination angle, azimuth view angle and wavelength.

Furthermore, it is interesting to analyze the temporal spectral behaviour of the curves under the combined effect of roughness and decaying surface moisture of the irrigated plot, in terms of discrimination of moisture condition in the same type of soil.

In Figure 5, the left side sequence shows the values of reflectance as a function of wavelengths, illustrated for both plots viewed in a direction parallel to the illumination (Direction 1), during three intercalated days. The curve for the irrigated plot appears very depressed in relation to the one for the non-irrigated plot at the day immediately following irrigation (11 of September 1981), however it tends to rebound at the following days, probably due to natural drying out of the thin outer crust. A faster rebound of the curve for the irrigated plot is seen on the right side sequence of Figure 5, which compares the curves for both plots when viewed in Direction 2, normal to the illumination, for only 3 consecutive days. After the second day, the difference between both curves has almost disappeared.

Table I summarizes well these observations by showing that for Direction 1 the difference between the curves for the plots are statistically significant at the 0.05 level, whereas the difference is not significant for Direction 2 at any wavelength.

Based on the results, it is concluded that the possibility of detecting a moist or dry soil surface on the basis of its spectral response will depend on the view angle, illumination angle, roughness conditions, and capacity of the outer crust to retain water.

In summary, we have observed the effects of some intrinsic parameters of the soil surface (roughness and moisture) observed under varying extrinsic conditions (illumination angle, azimuth view angle and wavelength). Such extrinsic factors will determine if the intrinsic characteristics of the soil surface can be discriminated. In this study, the irrigated/non-irrigated condition was differentiated for a longer time only under observations made in the same direction of the illumination (0^o). When the soil was viewed in a direction normal to the illumination, the discrimination between irrigated and non-irrigated surface disappeared in 2 days.

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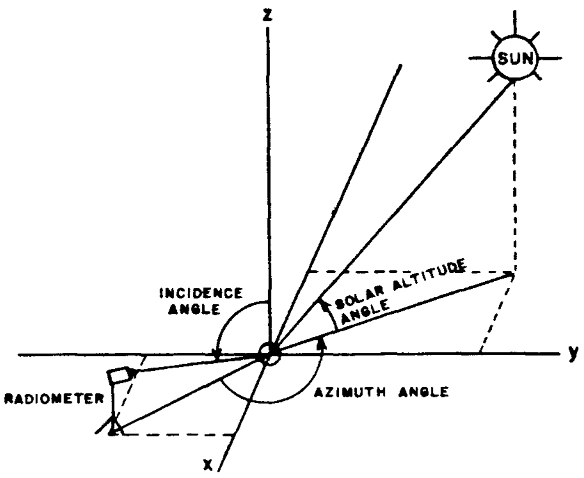

FIG. I - GEOMETRY OF THE ANGLES OF INTEREST. (AFTER EGBERT AND ULABY, 1972)

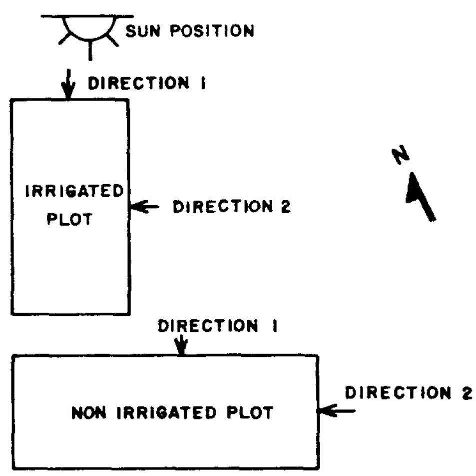

FIG. 2 - VIEWING POSITIONS IN RELATION TO THE PLOTS AND THE SUN.

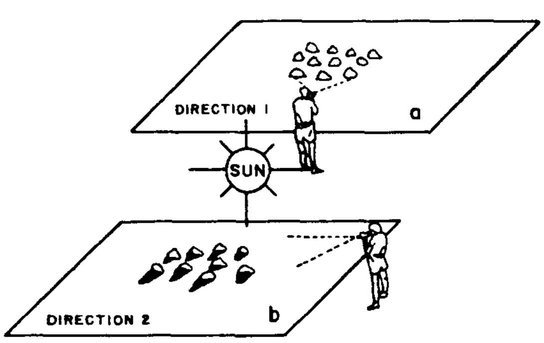

FIG. 3 - ILLUMINATION CONDITIONS: ROUGHNESS AND SHADOW EFFECTS.

TABLE I - VALUES OF THE TWO-TAILED PAIRED-SAMPLE *t* TEST FOR OBSERVATIONS FROM THE 11th TO THE 15th OF SEPTEMBER 1981

ANALYZED FACTORS	ESTABLISHED CONDITIONS	450	500	550	600	650	750	850	1050
Direction 1 vs. Direction 2	non-irrigated	2.370	3.000(*)	2.880(*)	3.819(*)	4.203(*)	4.381(*)	4.323(*)	3.560(*)
	irrigated	1.294	0.476	0.865	0.436	0.011	6.669(*)	0.978	1.099
non-Irrigated vs. Irrigated	Direction 1	7.280(*)	6.988(*)	7.654(*)	3.044(*)	10.721(*)	3.411(*)	3.729(*)	3.015(*)
	Direction 2	0.245	0.410	0.944	0.871	0.901	1.005	1.164	1.511

H_o : No differences in the analyzed factors

(*): Significant at the 0.05 level

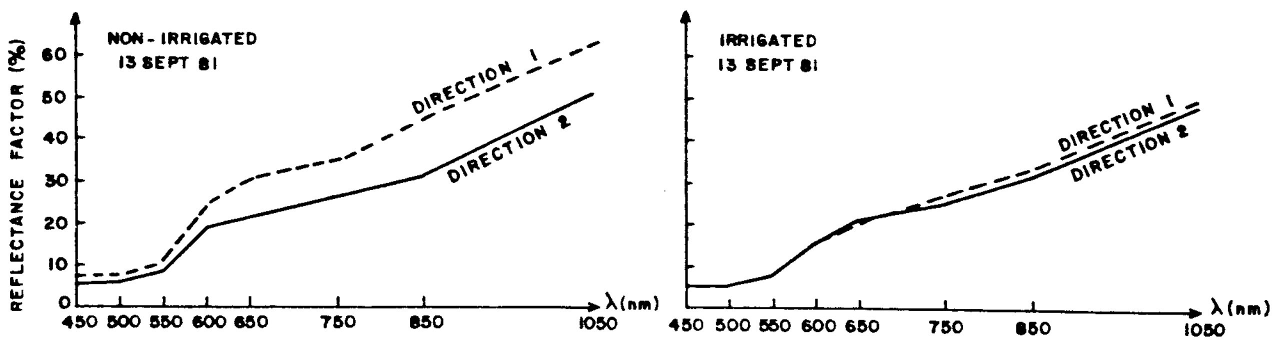

FIG. 4 - SPECTRAL BEHAVIOUR OF IRRIGATED AND NON-IRRIGATED PLOTS ACCORDING TO VIEWING DIRECTIONS 1 (0°) AND 2 (90°) IN 13 SEPT 81.

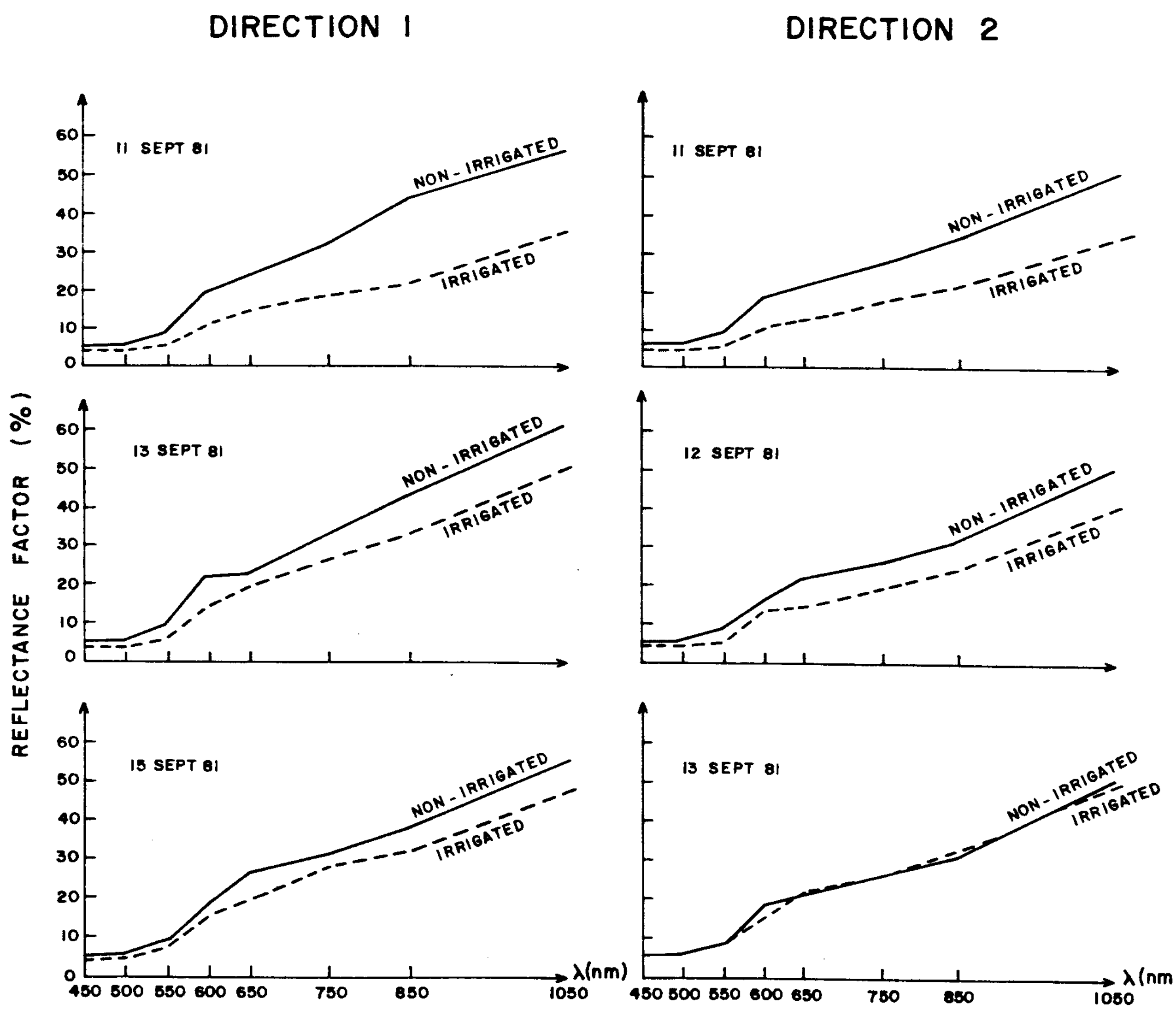

FIG. 5 - DISCRIMINATION OF IRRIGATED AND NON-IRRIGATED PLOTS BY TEMPORAL SPECTRAL BEHAVIOUR IN VIEWING DIRECTIONS 1 (LEFT SIDE SEQUENCE) AND 2 (RIGHT SIDE SEQUENCE).