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Effect of Vegetation on Rock and Soil Type Discrimination

Natural vegetation can significantly mask and alter the spectral response of the ground as measured by airborne multispectral scanners.

Abstract: *The effect of naturally occurring vegetation on the spectral reflectance of earth materials in the wavelength region of 0.45 to 2.4 μm has been determined by computer averaging of in situ acquired spectral data. Natural vegetation can significantly mask and alter the spectral response of the ground as measured by aircraft and satellite multispectral scanners. The significance of the vegetative cover depends on the amount and type of vegetation and the spectral reflectance of the ground. Low albedo materials are the most significantly affected and may be altered beyond recognition with only ten percent green vegetation cover. Dead or dry vegetation does not greatly alter the shape of the spectral reflectance curve and only changes the albedo with minimum wavelength dependency. With increasing amounts of vegetation the LANDSAT MSS band ratios 4/6, 4/7, 5/6, and 5/7 are significantly decreased whereas MSS ratios 4/5 and 6/7 remain relatively constant.*

Introduction

The effect of naturally occurring vegetation on the spectral reflectance of earth materials as measured by aircraft and satellite multispectral scanners is a subject that deserves attention. To date, most studies have considered either mapping natural vegetation (Anderson *et al.*, 1973; Baumgardner *et al.*, 1973; Driscoll *et al.*, 1974; Cibular, 1975), determining vegetation health (Murtha, 1973; Kumar and Silva, 1974), detecting and correlating stressed vegetation with base metal depositis (Canney, 1975; Lyon, 1975), or correlating vegetation with terrain features (Schrumpf *et al.*, 1974).

This paper assesses and describes the quantitative effects of varying amounts of vegetation on the spectral reflectance of common rock types. Emphasis is placed on the Landsat MSS bands because these data are readily available and are extensively used for mineral exploration and reconnaissance geologic mapping.

Natural vegetation is present in all but the most arid regions and its presence may severely hinder or limit computer automated and/or photo-interpretative studies of multispectral data for soil mapping and lithologic discrimination. In large-scale, high-resolution imagery the effect of vegetation may be greatly reduced because of the relatively small instantaneous field of view of the scanner. With high-resolution systems it is possible, in all but completely covered areas, to look between the vegetation clumps

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and obtain a reasonably accurate measure of the spectral response of the ground. However, in small-scale, low resolution images, such as LANDSAT, the spectral response of each picture element represents the area-weighted average of the reflectance characteristics of all components of the surface in the measured wavelength region. Consequently, the measured brightness represents a composite spectrum composed of soil, rock, vegetation, and other organic materials.

Even in terrains sparsely covered by vegetation, such as in the south-western United States, the total amount of vegetative cover may be significant, and the contribution of its reflectance may completely dominate the overall spectrum. The effect of the vegetation spectrum on the composite spectrum will depend not only on the amount of vegetation, but also on the type of vegetation and the spectral response of the ground itself.

Data Collection and Analysis

Representative spectral reflectance data in the wavelength region of 0.45 to 2.4 μm were obtained for nine common rock types and four forms of naturally occurring vegetation (see Table 1) by means of the JPL portable field reflectance spectrometer (PFRS) (Goetz, *et al.*, 1975). At the nominal operating height of 1.3 m, the PFRS has a field of view of 200 cm². A spectrum of the ground is first taken, followed immediately by the spectrum of a white Fiberfrax standard in the same orientation. The data are recorded on digital cassettes; a PDP-8 computer and plotter are later used for processing and data display. The reduced spectrum is produced by taking the ratio of the ground spectrum to the standard spectrum, point by point. This procedure allows comparison of spectra taken at varying data acquisition times, sun angle, sky conditions, etc.

Table 1. Rock Types and Vegetation Analyzed

Rocks	Vegetation
Andesite	Green Grass
Basalt	Manzanita Bush
Rhyolitic Flows (red-orange)	Piñon Pine
Quartz Latite	Dry Sage
Limestone	
Shale (red)	
Limonitic Argillized Fragments and Soil	
Silicified Limestone	
Limonitic Dolomitic Marble	

The reduced plotted spectra for the different rock types and vegetation in this study were first hand-smoothed in order to minimize high frequency noise introduced mainly by incomplete cancellation of the effects of the 0.95 and 1.14 μm atmospheric water bands. The smoothed spectra were then redigitized for data analysis. The effect of varying amounts of vegetation on the different rock types was determined by appropriately weighting and combining rock and vegetation spectra in order to produce a composite spectrum. LANDSAT-1 MSS values for each rock type, each type of vegetation, and the composite spectra were computed by weighting the observed spectral reflectance values of the filter functions of the MSS scanner (Norwood *et al.*, 1972). The six MSS ratios were computed by standard means.

Results and Discussion

The spectral reflectance contribution of varying amounts of green grass, manzanita bush, and dry sage cover (see Figure 1) on andesite, limestone, and limonitic argillized fragments and soil is illustrated in Figures 2, 3, and 4 respectively. The figures show reflectance spectra (0.45 to 2.4 μm) of the rock and soil materials and their computer weighted vegetation composite spectra. Composite reflectance spectra of the other rock types and vegetation listed in Table 1 fall, in general, within the extremes illustrated in Figures 2, 3, and 4 and therefore are not presented.

As expected, the effect of vegetation on the reflectance spectrum is most pronounced for rocks with low albedos. With only 10 percent green grass cover, (see Figure 2) the spectral characteristics of andesite and limestone are masked and identification would be difficult. The spectrum showing the addition of 30 percent green vegetation

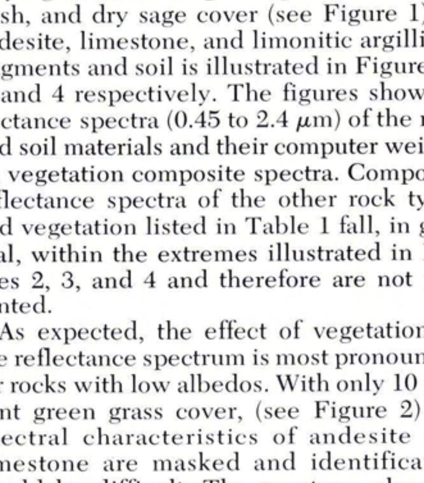

Fig. 1. Reflectance spectra of green grass, manzanita bush, and dry sage. The breaks in the data at 1.45 and 1.9 μm are the regions of the saturated atmospheric water absorption bands.

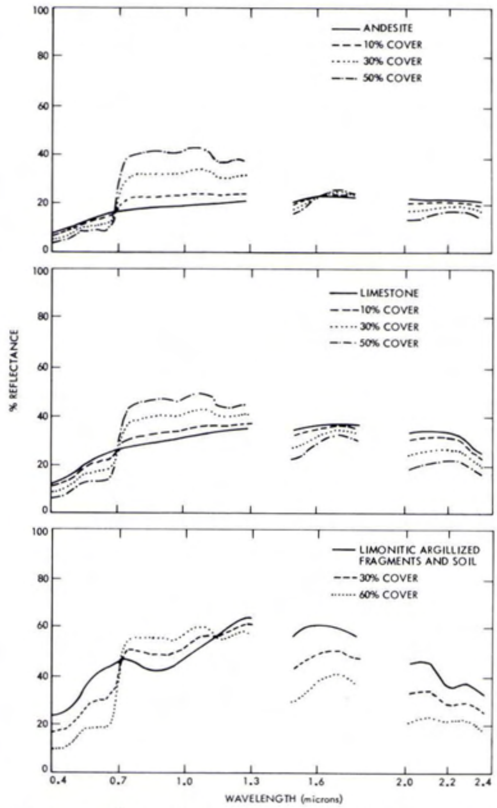

FIG. 2. Effect of varying amount of green grass, cover on the spectral reflectivity of andesite, limestone, and limonitic argillized fragments and soil.

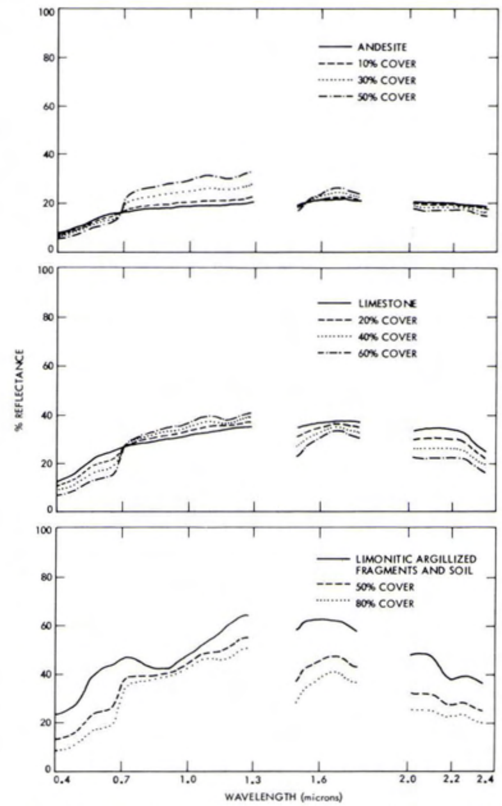

FIG. 3. Effect of varying amounts of manzanita bush cover on the spectral reflectivity of andesite, limestone, and limonitic argillized fragments and soil.

is totally dominated by the effect of the vegetation, although in the case of limestone the characteristic reflectance fall-off beginning at about 2.3 μm is still evident. For limonitic argillized fragments and soil, the effect of green grass cover is not so pronounced. With 30 percent vegetation cover, the strong and broad absorption band at 0.85 μm due to ferric iron (Hunt *et al.*, 1971) is still recognizable although greatly subdued. The absorption band at 2.2 μm due to the OH^- stretching overtone is still distinct. With 60 percent cover, the green grass spectrum completely dominates the composite spectrum, except at 2.2 μm where the OH^- band is weakly expressed. In all three cases, the slopes of the spectral curves are more strongly affected at shorter wavelengths because of the steep rise of reflectance in the vegetation beyond 0.68 μm.

A significant band in vegetation is centered at approximately 2.1 μm. (see Figure 1). Addition of vegetation to a scene containing hydrothermally altered rocks will produce a shift in the apparent position of the strong 2.2 μm OH^- stretching overtone band. This shift is important if the position of the 2.2 μm band is to be used for diagnostic purposes in separating clay types. The diagnostic information lies in the exact position of the OH^- band which can vary from 2.15-2.25 μm (Hunt *et al.*, 1971 and G. Hunt, private communication).

The effect of manzanita cover on andesite, limestone, and limonitic argillized fragments and soil is illustrated in Figure 3. In general, the effects are similar but less intense than those for green grass cover. The spectra of andesite, limestone, and limonitic argillized fragments and soil are completely dominated by manzanita cover of 30 percent, 40 percent, and 50 percent, respectively.

Dead or dry vegetation does not have so great an effect on the under-lying materials as green vegetation because of the increased proportion of stem material and the pronounced differences in pigments, internal leaf structure, and water concentration (Myers, 1975). Figure 4 illustrates the effect of varying amounts of dry sage on andesite,

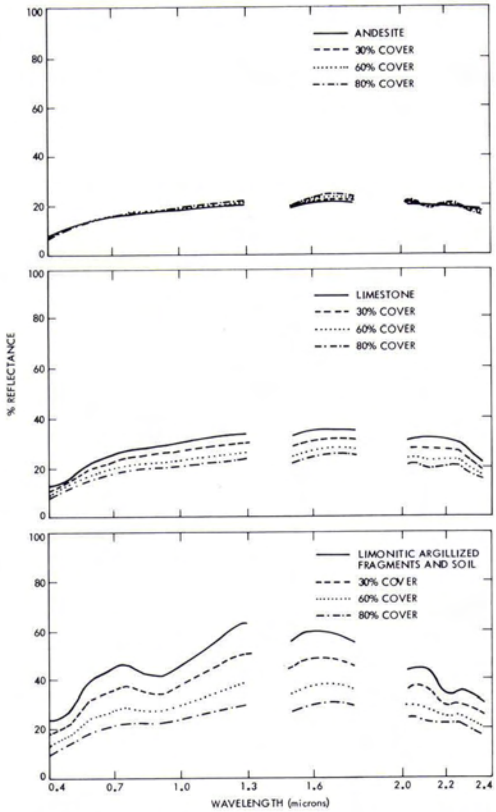

FIG. 4. Effect of varying amounts of dry sage cover on the spectral reflectivity of andesite, limestone, and limonitic argillized fragments and soil.

limestone, and limonitic argillized fragments and soil. With even 60 percent vegetation, the shape of the composite spectrum for each of the different rock types still resembles that of the lithic materials, although the average albedo has been changed.

The effect of increasing vegetative cover on the spectral response of the three lithic materials for the LANDSAT MSS band ratios 4/5, 4/6, 4/7, 5/6, 5/7, and 6/7 is illustrated in Figure 5. Ratio images are routinely used in LANDSAT data analysis (Rowan *et al.*, 1974; Vincent, 1973, 1975) to remove, to the first order, the variations in scene brightness due to topography and to bring together materials of like spectral shapes (Rowan *et al.*, 1974). The effect of vegetation on the MSS band ratios is dependent upon the wavelength, the spectral reflectance characteristics of the vegetation, and the parent material. In general, the ratios 4/6, 4/7, 5/6, and 5/7 are the most significantly affected. MSS ratio 4/5 is the least influenced, because the wavelength region of 0.5 to 0.7 μm does not include the pronounced green vegetation reflectance zone.

For various contributions of green grass and andesite, the MSS ratios 4/6, 4/7, 5/6, and 5/7 can vary from approximately 0.10 to 0.90. A similar range is observed for grass-covered limestone and for limonitic argillized fragments and soil.

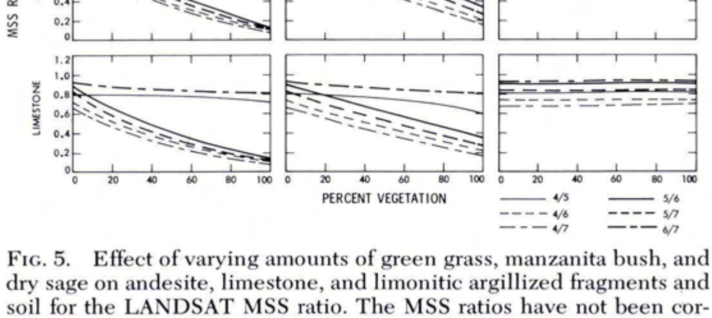

FIG. 5. Effect of varying amounts of green grass, manzanita bush, and dry sage on andesite, limestone, and limonitic argillized fragments and soil for the LANDSAT MSS ratio. The MSS ratios have not been corrected for atmospheric, solar illumination conditions, etc., and are therefore not representative of the absolute reflectances. However, relative comparisons are valid.

The effect of manzanita cover on the three parent materials is similar although not so intense because of the addition of non-green stem material to the vegetation spectrum. With both types of vegetation a 10 percent contribution reduces the MSS ratio values 4/6, 4/7, 5/6, and 5/7 a minimum of 15 percent.

Dead or dry vegetation has little effect on LANDSAT MSS band ratios, since the shapes of their spectral curves are similar to those of rocks. For altered material, 90 percent dry bush cover reduces the MSS ratios approximately 20 percent.

Summary and Conclusions

Naturally occurring vegetation significantly masks and alters the spectral response of earth materials. The significance of the vegetative cover depends primarily on the amount and type of vegetation and the spectral reflectance of the ground. Low albedo materials are the most significantly affected; a 10 percent green grass cover can mask beyond recognition the spectral characteristics of andesite and limestone. Wavelength regions from 0.68 to 1.3 μm are the most severely affected because of the steep rise of reflectance in the vegetation. The contribution of dead or dry vegetation does not greatly alter the spectrum but only changes albedo, with minimum wavelength dependency.

LANDSAT MSSS band ratios 4/6, 4/7, 5/6, and 5/7 are significantly decreased with increasing amounts of vegetation. MSS ratios 4/5 and 6/7 are the least influenced and thus will be more diagnostic of the spectral response of the ground.

The low reflectance of green vegetation beyond 1.4 μm indicates that this region will contain more spectral information on rock and soil type for a given percentage cover than will the shorter wavelengths. In addition, much diagnostic spectral information on rock and soil types is contained in this region, particularly between 2 and 2.5 μm. For these reasons greater emphasis in the future should be placed on imaging at wavelengths beyond 1.4 μm.

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