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USE OF THE SRI ELECTRONIC SATELLITE IMAGE ANALYSIS CONSOLE FOR MAPPING SOUTHERN ARIZONA PLANT COMMUNITIES FROM ERTS-1 IMAGERY[1]

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ABSTRACT

Cloud-free imagery covering the Tucson, Ariz., region for the period from August 22 to November 2, 1972, was used to determine the utility of ERTS-1 data for discriminating boundaries between plant communities.

The following studies were made from imagery analyzed by use of Stanford Research Institute's Electronic Satellite Image Analysis Console:

(1) Console-generated color composites from MSS-5 and MSS-6 bands were recorded photographically from the console color monitor. The color photographs were then used to compare with short-term changes in vegetative cover observed on the ground.

(2) Using the console, microdensitometric traces were made along selected traverses to quantify changes in scene irradiance across the image field. MSS-6 minus MSS-5 densitometry values were employed as a relative measure of plant cover in the wide range of vegetative zones covered by the traverses.

(3) Quantitative plant coverage data, collected at ground-truth stations along the traverses, were compared with the densitometric values.

INTRODUCTION

The U.S. Geological Survey is engaged in a program aimed at mapping southern Arizona vegetation from ERTS-1 imagery. This report describes preliminary results in which both time-lapse, color-composited imagery and microdensitometry are used to delineate and identify plant communities. The imagery was analyzed on the Electronic Satellite Image Analysis Console at Stanford Research Institute, Menlo Park, Calif., and I wish to acknowledge the important contribution of SRI scientists, especially Wm. E. Evans and S. M. Serebreny.

1/ Publication authorized by the Director, U.S. Geological Survey.

Detailed mapping of arid region vegetation using satellite imagery depends upon detecting differences in the timing of plant growth activity among the communities comprising the region's vegetative mosiac. The short-term repetitive viewing capability of the ERTS series satellites provides an especially forceful means for performing this task. In arid subtropical regions with wide elevational differences, such as southern Arizona, the varied environment gives rise to diverse plant growing regimes. Among the kinds of plants present are those that are evergreen (such as pines and live oaks at higher elevations or creosote bush at lower elevations) and those that are green only seasonally. Among the latter are winter-active species (ephemeral grasses and forbs) and summer-active species (perennial and ephemeral grasses and ephemeral forbs). At lower elevations where the dominant perennial plants tend to be widely spaced, distinguishing one open community from another would be difficult if it were not for the temporarily dense growths of the small ephemeral species that appear during seasons of favorable rainfall. Where such plants with distinctive periods of foliation grow densely enough to be detected by the relatively low-resolution systems of satellites, it should be possible to employ seasonal growth differences to map the areas they occupy.

Of basic importance to our approach is the unique manner in which green plant tissues respond to the wavelengths sensed by the ERTS-1 multispectral scanner. Our efforts to date have relied heavily on the differences in plant reflectance between the MSS band 5 and the MSS band 6. In the MSS-5 spectral range (0.6 to 0.7 micrometers) plants reflect little energy; through the MSS-6 range (0.7 to 0.8 micrometers) they irradiate strongly. Although leaf irradiance in the two bands is influenced by separate systems, one having to do with leaf pigment chemistry and the other with leaf anatomy, both systems are closely related to the quantity of foliage, the variable that we are attempting to detect.

METHODS

ERTS-1 multispectral scanner bulk imagery in 70-mm format for the Tucson, Ariz., region was used in this study. During the preliminary period covered by this report, use of MSS bands 5 and 6 was emphasized. Diapositives of cloud-free scenes were employed throughout. Use was made principally of image numbers 1030-17271-5 and 1030-17271-6 for August 22, 1972, and numbers 1102-17280-5 and 1102-17280-6 for November 2, 1972.

As one approach, microdensitometry was performed by the console across two east-west traverses (Fig. 1). Each traverse was four console TV lines wide, representing, for the magnification used, about 800 meters on the ground. Scene irradiance values along the four parallel traverses were measured and averaged for the MSS-5 and MSS-6 images. The MSS-5 values were subtracted from the MSS-6 values, and the resulting differences as seen by the traces on the console oscilloscope were compared with an elevation profile and known vegetation patterns for the traverses. To assure image-to-image and date-to-date uniformity, densitometric readings were first made across the grey scale on each image; adjustments were then made on the console to produce comparable curves of voltage versus grey step number for all scenes. Following this adjustment, a given grey level represents the same amount of reflected energy on all scenes.

In a second analysis, plant coverage was measured at roughly 18-day intervals at five sites along two additional traverses, the Sierrita Mountain and Mile Wide Road transects (Fig. 1). The measurements, made as close to the day of the satellite's imaging overflights as feasible, were gathered from representative open communities of the desert and of the grassland bordering the desert. Changes in measured plant coverage are shown in figure 2 for the period from October 1972 through January 1973, with extrapolations made through the remainder of the twelve months. These curves show actual changes and anticipated changes in the amount of green foliage covering the soil surface. The hypothetical projected changes are shown only to illustrate how repetitive imagery may be used for identifying plant communities. The actual changes in plant cover were compared with MSS-6 minus MSS-5 densitometric traces along only the Sierrita Mountain transect. This analysis was performed on an enlarged view of part of the same images as noted above. The traverse used for densitometric analysis was four scan lines wide representing, at the magnification selected, a width of about 250 meters on the ground.

In the third analysis, additive color displays, using two primary colors, were recorded photographically from the console's color monitor. As before MSS bands 5 and 6 were employed. Cyan was paired with MSS-5 and red was paired with MSS-6, providing a partial simulation of false-color IR photography. The 35-mm full-frame images and an enlarged view of an area supporting a heavy growth of phreatophytes were analyzed for qualitative scene changes that can be used to map vegetation and to estimate the amount of plant foliage.

RESULTS

Densitometric studies.--In figure 3 may be seen the changes in scene irradiance across the Old Baldy Transect from the vicinity of the Baboquivari Mountains on the west to the Mule Mountains on the east, a distance of 170 kilometers. The oscilloscope trace gives the values obtained when MSS-5 scene irradiance is subtracted from MSS-6 scene irradiance. The images used were for August 22, 1972 (numbers 1030-17271-5 and 1030-17271-6). The difference curves resulting from this manipulation vary directly, for the most part, with changes in plant coverage. Patches of dense vegetation in moist habitats, such as valley bottoms and high mountains, show the greatest difference values. The Santa Cruz River valley, Old Baldy (Mount Wrightson), Babocomari Creek, and the San Pedro River valley give the highest values where crossed by the transect on this image.

In figure 3, the difference trace for the Old Baldy Transect is shown for November 2, 1972 (numbers 1102-17280-5 and 1102-17280-6). Compared to the August 22 trace, there is a tendency toward a decrease in the magnitude of the difference values. The flattening of the difference curve indicated by the November trace occurs with the end of the summer rainy season and the coincident loss of foliage by the ephemeral and deciduous perennial plants as they enter the period of winter quiescence. Later, as winter annuals begin growth in response to winter rains, it is anticipated that the differences will again increase, but only for the lower elevations. At higher elevations, where evergreen oaks and pines dominate, the matrix of grasses and forbs will remain dormant during the winter resulting in values that are somewhat lower than those of summer.

In figure 4, difference traces for the Mine Transect for two dates (August 22 and November 2, 1972) are shown. A flattening of the November difference curve, as noted for the Old Baldy Transect, can also be seen here. Of particular interest is the change in the curves where the transect crosses the extensive grassland bordering upper Cienega Creek. The change is interpreted as representing a decline in green cover as the grasses enter the winter dormant condition. The low mountains along the Mine Transect have relatively low difference values in the winter because of the sparse growth of evergreen trees. Mesquites, other summer foliating shrubs, and grasses dominate the landscape at these intermediate elevations.

In figure 5, two difference traces for the Sierrita Mountain Transect for August 22 and November 2, 1972 are shown. Plant coverage is being measured at two sites (Sierrita Mountain 1 and 2, Fig. 2) along this transect for comparison with the difference traces. (Although ground-truth data are being collected at three nearby sites along the Mile Wide Road Transect, densitometry for this part of our work is incomplete and will not be reported upon at this time.) It is too early in our program to determine how closely the plant coverage values will follow fluctuations in the difference traces. As expected, the maximum difference values for November are lower than for August. At the point where the transect crosses a low area with dense phreatophyte vegetation near Brawley Wash, the values are low in November compared with August because the plants have become leafless by November. Cultivated fields, some of which are fallow and some cropped, produce characteristic sharp changes near the extreme right end of the difference curves.

Time-lapse studies of color-additive images.--Phreatophyte vegetation along a short reach of the San Pedro River near Benson, Ariz., and in an area at the confluence of Rillito and Sabino Creeks near Tucson are being examined in detail. Changes in the enlarged, color-composite, video images will be compared with observed changes in foliation among the dominant phreatophyte or riparian species occupying the sites. It should be possible to map the vegetation of these habitats where dense, pure stands of these species occur. Identification of the species should be possible by observing the difference in timing of foliation.

Time-lapse viewing of console-generated, color-additive, full-frame ERTS images will be used to construct vegetation maps covering the main study site, an area 100 nautical miles on a side with Tucson at the center. In compiling the vegetation map, which is the final product of this project, scene changes on the multispectral images will be examined in conjunction with other analyses performed on the Electronic Satellite Image Analysis Console, such as color slicing, scene-to-scene differencing, and densitometry.

Figure 1. Part of an ERTS-1 image (1156-17280-5) showing location of transects mentioned in the text (1 = Mile Wide Road Transect, 2 = Sierrita Mountain Transect, 3 = Mine Transect, 4 = Old Baldy Transect).

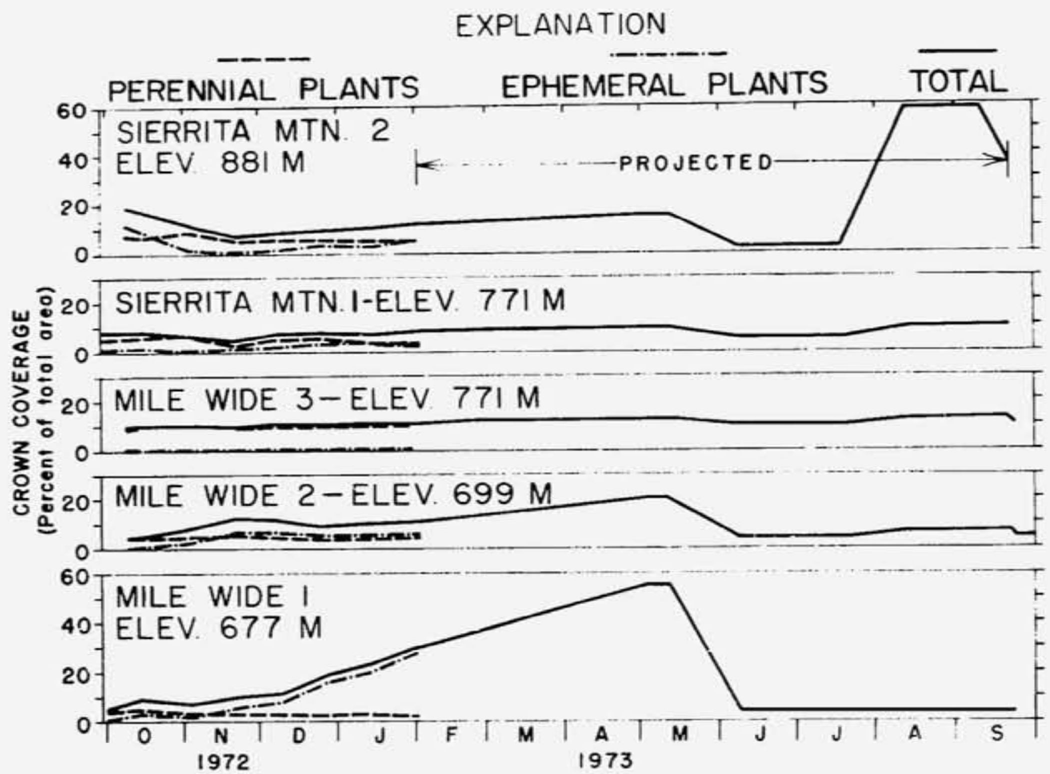

Figure 2. Actual and projected changes in plant crown coverage at five stations near Tucson Arizona. Differences in quantity and timing of foliation will be used to distinguish the plant communities as viewed on ERTS-1 imagery.

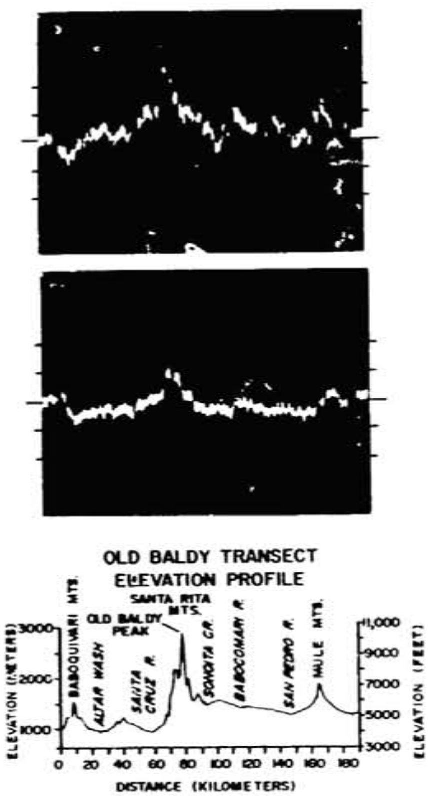

Figure 3. Elevation profile of Mount Baldy Transect and corresponding MSS-6 minus MSS-5 scene irradiance values for August 22, 1972 (upper oscilloscope trace) and November 2, 1972 (lower trace). Vertical scale = 100 millivolts/division.

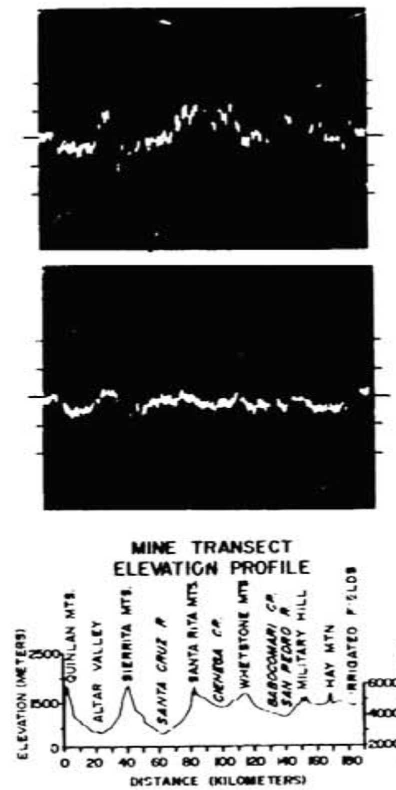

Figure 4. Elevation profile of Mine Transect and corresponding MSS-6 minus MSS-5 scene irradiance values for August 22, 1972 (upper oscilloscope trace) and November 2, 1972 (lower trace). Vertical scale = 100 millivolts/division.

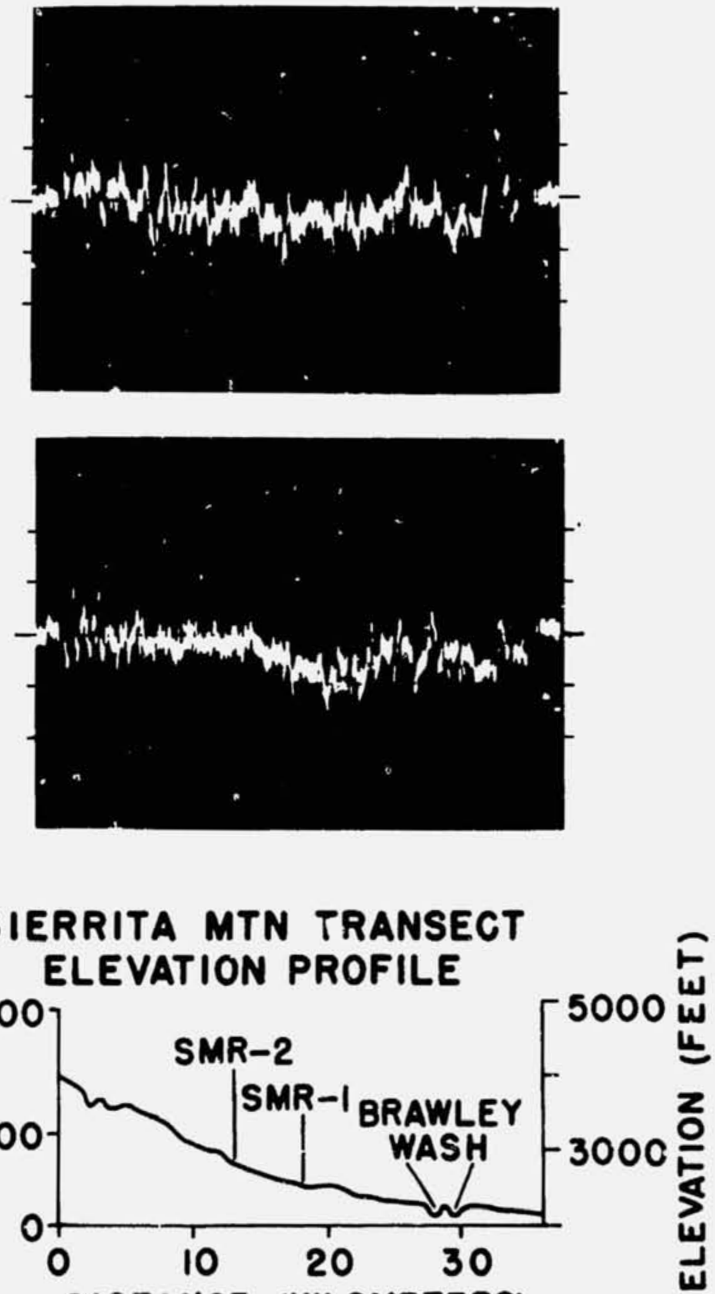

Figure 5. Elevation profile of Sierrita Mountain Transect and corresponding MSS-6 minus MSS-5 scene irradiance values for August 22, 1972 (upper oscilloscope trace) and November 2, 1972 (lower trace). Vertical scale = 100 millivolts/division.