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FOR PERIOD ENDING
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A Study to Explore the Use of Orbital Remote Sensing
to Determine Native Arid Plant Distribution
MMC #250 GSFC #UN613

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ACCOMPLISHMENTS

Avra Valley Study Area

The Avra Valley, an area just west of Tucson, was chosen as an area for an intensive study of the feasibility of using ground truth imagery as an aid to the interpretation of ERTS imagery. This area was chosen because there are a variety of vegetation types represented within easy traveling distance of each other. Also, ground truth data collection sites would all be included on the same ERTS image. High-altitude color and color infrared photography (ERAP Mission 101) was used in conjunction with the ground search to locate large ($1mi^2$), relatively uniform sites for data collection. The eight sites selected include a variety of vegetation types and soil conditions.

At each site, several scenes were photographed at vertical, low oblique, and high oblique angles from a 12 ft. ladder, using 35 mm color and color infrared film to obtain matching photographs. Since the primary purpose of the photographs was to record phenological changes and the accompanying changes in spectral signature, each scene at each site was rephotographed at several periods from November 1972 to June 1973. A total of 37 scenes were photographed during each of the following periods: late November 1972, early February 1973, mid-March 1973, early April 1973, and late June 1973. To supplement the photographs, observations on species composition and phenology were recorded for each site. We are now in the process of correlating the ERTS imagery and ground truth data for the period November 1972 - June 1973. Preliminary analysis indicates that large to moderate differences between sites in the amount of winter annual cover are readily detectable on ERTS imagery. Differences in annual cover between some (perennial) vegetation types are detectable and may be useful in delineating the perennial vegetation types. Full details and final conclusions will be reported when the analyses are completed. Preliminary analysis of the Avra Valley ground truth and ERTS imagery suggests that a quantitative radiometric method of analysis may yield more precise interpretations of ERTS data.

In order to obtain quantitative data on the spectral signatures of the vegetation and soil surface of each site, radiometric measurements were made in conjunction with the early April and late June photographs. An Exotech ERTS Radiometer was used to measure the reflected radiation in each MSS wavelength band in photographed scenes, as well as in additional non-photographed scenes at the same sites. Total incoming radiation (global irradiance) was measured so that reflectivity values could be calculated. A total of 137 spectral signatures were obtained. Different ways of expressing or characterizing spectral signatures of the various types of scenes have been used and compared.

Some other investigations have been carried out in the Avra Valley area using data other than that collected at the eight intensive study sites. A contrast between light and dark areas on the Sierrita Mountains bajada at the south end of the Avra Valley was noted on the ERTS imagery and on high-altitude color photography.

Our data from the two intensive study sites on this bajada did not provide a conclusive explanation of this phenomenon, so additional imagery was obtained from a light airplane and from the ground. It was found that the light areas have very little vegetative cover and a high percentage of completely bare sheet-eroded soil. The darker upper bajada and the darker areas of the lower bajada have more shrub and tree cover and are not severely eroded. Our preliminary conclusion is that a major cause of the darkness of these areas is the greater amount of litter and organic matter at the soil surface. Details have been presented in our Type II Progress Report for the period ending February 16, 1973.

Side-looking airborne radar (SLAR) imagery of the Avra Valley (courtesy of Goodyear Aerospace and the Strategic Air Command), was examined after ground truth data on vegetation distribution had been collected. Preliminary analyses indicate that plant communities with different physiognomy may be readily distinguished on SLAR imagery. Bare eroded soil, grassland without shrubs or trees, shrub-dominated communities, and tree-dominated communities could be distinguished, sometimes more easily than on high-altitude color infrared imagery. A sparse shrub cover is more apparent from a low angle (SLAR) than from the vertical view (e.g., high-altitude photography).

An ERTS image (1030-17271), which includes the Avra Valley, was pretyped according to red band brightness (using a video density analyzer) and terrain type (mountainous or non-mountainous). It was hoped that a widespread ground truth survey of the area would reveal a correspondence between the mapped units and some vegetation types. However, because of the greater potential success of other lines of investigation, this line of investigation was discontinued.

Correction of ERTS Radiometric Data for Atmospheric and Sun Angle Effects

The use of ERTS radiometric data to determine the distribution of plant species or communities would be facilitated if the ERTS radiometric data could be corrected for atmospheric and sun angle effects and converted to reflectivity values. The theory of a method for making these corrections and conversions has been developed and was presented in our Type II Progress Report for the period ending February 16, 1973. We are now in the process of conducting a trial run of this procedure for the June 25, 1973 ERTS overflight of the Avra Valley study area. Ground truth radiometric data for the two Avra Valley calibration sites were collected on the day of the overflight. This method requires an accurate determination of scene radiance from the density of the scene on the ERTS image. Access to a Macbeth TD504 densitometer was arranged through the courtesy of Joel Gray of the University of Arizona Optical Sciences Center. Preliminary analyses were made of 9.5 in. black and white ERTS images of two dates. Densitometric resolution of the lightest steps in the gray scales of these images was impossible. Therefore, linear density transparencies were ordered for the trial run of the atmospheric and sun angle effects correction method. These transparencies have been received and will soon be analyzed.

Yuma Study Area

To record the distribution and phenology of the vegetation of the Yuma County study area, trips were made to the area in late March and in early June. Color and color infrared 35 mm photographs and notes on species composition and phenology were taken at several locations. No observations were made in the mountainous parts of the area because of limited accessibility. Color infrared photography of ERAP Flight 73-016 was used in the field for precise location of observation points in relation to the small-scale pattern of land forms and vegetation types. The March observations recorded the winter rainy season aspect of the vegetation, and the June observations recorded the fore-summer drought aspect. During the June trip, soil samples were collected from many locations in the study area, and chemical and physical analyses of these samples were later conducted by the Arizona Agricultural Experiment Station at the University of Arizona. (See Appendix)

Using the ground truth data and the Flight 73-016 color infrared photographs, a vegetation type map of the study area was prepared from ERTS image 1069-17441-5. This map shows the major communities of the bajadas, plains, and dissected alluvial hills of the area. Use was made of the correlation between the presence of one vegetation type and the presence of desert pavement soils which are readily seen on ERTS imagery. We have advanced a tentative explanation, based on the soil data, of the mechanisms responsible for this correlation.

Communication with Other Investigators

1. An excerpt from our Type II Progress Report for the six-month period ending February 16, 1973 was sent to seven ERTS investigators and to one other scientist who has done research on the spectral signatures of desert plants. The excerpt describes the theory of our method for obtaining spectral reflectivity signatures from ERTS data. Criticisms and comments on the method were solicited.

2. Discussions were held with Carol Breed of the U.S. Geological Survey regarding the ERTS investigation with which she is involved (MMC #131, A Study of Morphology, Provenance, and Movement of Desert Sand of Sand Seas in Africa, Asia, and Australia: Principal Investigator: Edwin D. McKee, GSFC ID# IN402). Ground truth data for many of their study areas are scarce or non-existent, and for interpretation of ERTS imagery they must rely on comparisons with North American analogs for which ground truth data are available. Our correlations between ERTS and ground truth imagery of desert pavement areas in the Yuma study area aided them in their interpretation of similar dark areas which are seen on ERTS imagery of Saudi Arabia.

3. On May 4, some results of our investigations were presented to the Biology Section of the 1973 annual meeting of the Arizona Academy of Sciences at the University of Arizona. An abstract of the paper ("The Use of ERTS-1 Multispectral Imagery to Determine Native Desert Plant Distributions", by H. Brad Musick and Edward F. Haase) accompanied our Type I Progress Report for the period April 16, 1973 - June 16, 1973.

4. In August 1973, Raymond M. Turner (GSFC ID# IN411, Principal Investigator for MMC #342-08, Dynamics of Distribution and Density of Phreatophytes and Other Arid Land Plant Communities) consulted our ground truth radiometric data to check the validity of the radiometric criteria he is using to distinguish vegetation on ERTS imagery.

5. We have been cooperating with Dana M. Slaymaker (MMC #327, Desert Plant Species Identification by Spectral Signatures: C. H. Lowe, Principal Investigator) in several aspects. Some ground truth radiometric data for our calibration sites has been collected jointly. Discussions have been held in which we discussed and compared methods and results.

SIGNIFICANT RESULTS

Ground truth spectral signature data for various types of scenes, including ground with and without annuals, and various shrubs, were collected. When these signature data are plotted with infrared (MSS Band 6 or 7) reflectivity on one axis and red (MSS Band 5) reflectivity on the other axis, clusters of data from the various types of scenes are distinct. This method of expressing spectral signature data appears to be more useful for distinguishing types of scenes than a simple infrared to red reflectivity ratio.

Large areas of varnished desert pavement are visible and mappable on ERTS and high-altitude aircraft imagery. A large-scale and a small-scale vegetation pattern were found to be correlated with the presence of the desert pavement. The large-scale correlation was used in mapping the vegetation of the area. It was found that a distinctive soil type was associated with the presence of the varnished desert pavement. The high salinity and exchangeable sodium percentage of this soil type provide a basis for the explanation of both the large-scale and small-scale vegetation pattern.

Problems:	None
Published Articles, Etc.:	None
Recommendations:	None
Changes in Standing Order Forms:	None

APPENDIX

Yuma Study Area

Trips to the Yuma study area for ground truth data collection were made in late March and in early June. During the late March trip, the winter annuals and the perennials were near their peak of vegetative development. The early June trip was during the foresummer drought, and therefore there were few annuals present and most of the perennial species were in a state of reduced vegetative activity.

Observations on vegetation and physiography were made along roads crossing the area. High-altitude color infrared photography (Mission 73-016) and ERTS imagery (E-1069-17441-4 and 7, 9.5 in. black and white transparencies) were consulted in the field. Large, apparently homogeneous areas on ERTS imagery were sometimes found to be mosaics of dissimilar areas on high-altitude imagery. High-altitude imagery was useful in determining the precise location of the ground observation points in relation to the various elements of the mosaic.

At some observation points more detailed notes were taken, along with matched 35 mm color and color infra-red photos at vertical, low oblique and high oblique angles from a ladder. At some locations, photos were taken without the use of the ladder. During the early June trip, soil samples were taken at some of the observation points, and some of these were subsequently analyzed by the Arizona Agricultural Experiment Station.

Vegetation Map of Yuma Study Area

A vegetation map of the study area was prepared from ERTS image E-1069-17441 (Figure 1). In addition to ERTS imagery and ground truth data, imagery from Flight 73-016 was used in the preparation of the map. Urban and agricultural areas are delineated on the map but are not mapped in detail because the study of these areas is outside the scope of this investigation. Mountainous areas are delineated on the amp, but the vegetation types of the mountains are not described because limited accessibility would have greatly increased the time necessary for adequate ground truth data collection.

Descriptions of the Vegetation Types Mapped in Figure 1

Type A: Palo verde (Cercidium microphyllum) and ironwood (Olneya tesota), with desert pavement on interfluves.

Vegetation:

Except for an occasional creosotebush (Larrea tridentata) or bursage (Ambrosia dumosa), and a few annuals, all the vegetation occurs in drainageways, which vary in size from small rills to large washes. The aspect is dominated by palo verde (Cercidium microphyllum and sometimes Cercidium floridum), ironwood (Olneya tesota), and occasional individuals of saguaro (Carnegiea gigantea). In the small rills are found creosotebush (Larrea tridentata), bursage (Ambrosia dumosa), and brittlebush (Encelia farinosa), with infrequent small individuals of palo verde and ironwood. A few ocotillo (Fouquieria splendens) occur on the slopes of the more deeply incised rills. In the large washes, palo verde and ironwood are larger and more numerous than in the small rills. All of the shrubs mentioned above occur in the large washes, along with the following species: Hyptis emoryi, Dalea spinosa (at lower elevations only), Ambrosia ambrosioides, Acacia greggii, Simmondsia chinensis, and Bebbia juncea. The most abundant winter annual in this area in May 1973 was Plantago insularis.

Physiographic Relations:

This vegetation type occurs on gently sloping bajadas. Between washes and rills are smooth, level or gently sloping areas covered with dark brown desert pavement. The desert pavement is a close-set, continuous gravel layer on the soil surface. Between washes and rills the gravel stones are covered with a thin dark brown varnish, which is apparently a weathering phenomenon. These interfluves with varnished desert pavement have almost no plants on them, except in one situation which is discussed below.

Shallow rills or drainageways three to ten meters wide traverse the pavement areas. The soil surface in these rills is commonly covered with a discontinuous gravel layer, but few of the stones have the dark brown varnish coating. There is some soil visible between the small stones. The discontinuity of the gravel surface layer, and especially the lack of dark varnish coatings, result in the rills having a much lighter soil surface tone than the interfluves.

Larger washes, which are wider and deeper (two to four meters) than the small rills, also traverse the pavement areas. The soil surface in the wash area is sandy and rough in the small channels, but there are also islands of relatively level, partially gravel-covered surface. Nowhere in the wash area are varnish covered rocks prominent on the surface.

On the level varnished pavement areas there are circular areas, mostly two to six meters in diameter, of lighter soil surface color. On some of these the surface gravel layer is discontinuous and the center is slightly mounded and lumpy. On others little mounding is evident and there is nearly continuous gravel pavement surface. On all of these circular areas, the dark varnish is absent from most of the surface gravel. As with the rills, the discontinuity of the gravel surface and especially the lack of varnish on the surface gravel make these areas very light-toned in contrast to the surrounding dark pavement. These circular areas of fresh soil and rock are apparently due to the activity of burrowing rodents. On these circular areas, Larrea tridentata and Ambrosia dumosa may occasionally be found, and the winter annual Plantago insularis is common, but vegetative cover is low.

Type A': Palo verde (Cercidium microphyllum) and ironwood (Olneya tesota), with desert pavement weakly developed or absent.

Vegetation:

Species present are those listed for Type A, with Cercidium microphyllum and Olneya tesota usually dominating the aspect.

Physiographic Relations:

This type occurs on gently sloping bajadas and on moderately sloping alluvial fans at the bases of mountains. On the bajadas, microtopography is similar to Type A, but there is less strongly developed pavement with varnish, resulting in a lighter soil surface tone. On the sloping alluvial fans at the base of the mountains, the microtopography is rough, with many small rills and large boulders on the surface. There are no nearly level pavement-like surfaces. The soil surface tone in the alluvial fans is relatively light.

Type B: Creosote bush (Larrea tridentata) and bursage (Ambrosia dumosa)

Vegetation:

Together, creosotebush and bursage dominate this vegetation type in aspect and in coverage. The relative abundance and size of these two species varies somewhat according to local conditions. On sandy soils, they are joined by big galleta (Hilaria rigida) and on stony soils by ocotillo (Fouquieria splendens). In some areas, mesquite (Prosopis juliflora) is common in the washes, but in other areas palo verde (Cercidium microphyllum) and ironwood (Olneya tesota) are the wash trees. Few other shrubs are of major importance in this vegetation type. The winter annual cover of late March 1973 was variable in composition, possibly in response to differences in soil factors. Plantago insularis was common everywhere.

Physiographic Relations:

The various types of the creosotebush - bursage community occur on gently sloping lower bajadas and on nearly level plains or "mesas" below the lower bajadas. Variations in the relative abundance of the two dominant species, and the occurrence and abundance of subdominant species appear to be correlated with variations in soil factors, especially soil texture. Hilaria rigida occurs on sandy soils, and Fouquieria splendens occurs on gravelly soils. Our observations do not allow us to generalize about the relationship between relative abundance or coverage of the two dominants and soil texture. Phenology of the perennials might be expected to vary with soil type, but since our observations were limited to the peaks of the winter wet and fore-summer dry seasons, differences in the timing of leaf drop and leaf color changes at the end of the wet season were not included in our observations.

Generally, this vegetation type occurred on nearly level areas, sometimes with hummocks under the shrubs. In the vicinity of the Yuma Proving Ground headquarters, this community occurs on rolling hills. Large washes with "riparian" trees (Prosopis juliflora or Cercidium spp. and Olneya tesota) are very widely spaced in this vegetation type.

There is usually much bare soil exposed at the surface, with only scattered gravel which lacks a dark varnish. In some areas, there are a few small areas of desert pavement with varnish like that described for Type A. Generally, then, the soil surface in this vegetation type is light-toned, especially in the sandy areas.

Type B'

Vegetation:

In this variant of Type B, Ambrosia dumosa may be absent and the Larrea may be less dense. There are discontinuous clumps of Prosopis velutina, about about two or three meters tall, with dense Hilaria rigida under and between the mesquite clumps.

Physiographic Relations:

This type occurs along the largest washes of some of the valleys. The soil is fine and lacks gravel, and there is evidence of water flow into these areas from the surrounding bajadas. There may not be a well-defined wash channel, but rather a broad flat area which shows evidence of sheet flooding over the surface. Outside of the mesquite-galleta clumps, much of the highly reflective soil surface is exposed, but in the clumps themselves most of the soil surface is covered by vegetation.

Type C: Creosotebush (Larrea tridentata) and ocotillo (Fouquieria splendens) on dissected alluvial hills.

Vegetation:

Creosotebush and ocotillo are the most dominating of this type, but the total coverage of these and other shrubs is very low compared to the other vegetation types. The creosotebush are relatively small. On some slopes, cholla cacti (Opuntia spp.) are subdominant. In the washes between the hills are palo verde (Cercidium microphyllum) and ironwood (Olneya tesota) and probably many of the shrubs listed for large washes in Type A. Plantago insularis was the most common winter annual in March 1973.

Physiographic Relations:

This vegetation type is found on dissected old alluvium. Moderately steep slopes are prevalent. The soil surface is covered with stones and gravel which lack the dark varnish of pavement gravel. The natural color of some of the stones is dark, however. The soil surface is generally light-toned, but not extremely so.

Type A + C: This is a mosaic of Types A and C, with each type retaining its own characteristics.

Imagery Characteristics of the Vegetation Types

Type A can be distinguished from the other types by its dark tone on all wave-length bands of ERTS imagery, and by its occurrence on the bajadas proper rather than in drainageways in the center of the valleys. The dark tone is obviously due to the considerable area of desert pavement, the individual stones of which are coated with a dark brown varnish or weathering surface. The light-toned circular areas, possibly a result of current or previous rodent activity, are visible on high-altitude color IR imagery but no on ERTS imagery.

Type A' does not have as dark a tone as Type A, because in the former type the dark desert pavement areas are absent or less well developed. In some parts of Type A', the landforms and the distribution of vegetation in relation to the landforms are similar to Type A. In these areas, the flat interfluves are not as dark on the ERTS or high-altitude imagery as the flat interfluves of Type A. Further study would be neded to determine why these interfluves are not as dark on the imagery as the analagous interfluves of Type A. Possible factors might be the amount of true soil surface visible between the surface stones, the number of surface stones on which the dark varnish has formed, or a lighter color of the varnish itself. Also, there might be a smaller area of flat interfluve on which the dark pavement typically occurs. Geologic of mineralogical factors appear to be involved in the intensity of dark pavement development, since the dark pavement is less well-developed on outwash from rhyolitic and andesitic outcrops.

The gray tone of Type A' is intermediate between Types A and B on all ERTS bands. It was difficult to determine the location of the transition zone between Types A and B on the bajada below the west side of the Kofa Mountains. On the high-altitude color IR photographs, it was evident that a change from high drainage density to lower drainage density occurred at approximately the transition zone between Types A and B. Also, individual trees of Cercidium spp. or Olneya tesota can be detected on this imagery. Therefore, we used the high-altitude color IR to determine the location of this transition.

Type B characteristically exhibits a very light tone on all ERTS wavelength bands. This is undoubtedly due to the large amount of exposed, light-colored desert soil. There are some slightly darker streaks or spots evident in the Type B areas. Some of these are apparently due to small areas of dark desert pavement, but such areas are very infrequent in Type B. Other slightly darker areas in Type B are apparently due to locally higher densities of vegetation or litter.

Most of the Type B' area is lighter in tone than the adjacent Type B. The clumps of mesquite (Prosopis) and Hilaria rigida appear as distinct dark spots. Infrared reflectance of the clumps increases in late spring when the mesquite and the Hilaria put out new leaves. This type is recognized by the presence in valley bottoms of very light areas with distinct dark clumps strung out along the drainageway.

Soil Factors in Relation to Vegetation and ERTS Imagery in the Yuma Area

Soil samples collected at many of the ground truth photo sites were analyzed by the University of Arizona Agricultural Experiment Station (Tables 1 and 2). Samples 1-5 are from a variety of sites on the bajadas, plains, and dissected alluvial hills of the study area. There was no desert pavement at these sites. Samples 7-10 are from sites with varnished desert pavement on the surface. Sample 6 was taken from a non-pavement gravelly terrace in a large wash area traversing the pavement area. Locations are described in Table 3.

The pavement soils have unique physical and chemical characteristics. The A horizon is a light pinkish gray vesicular layer composed of prismatic peds approximately 3 in. in diameter. This layer is almost free of gravel and has less sand than the B horizon. The B horizon is friable reddish brown gravelly and cobbly loam. The physical structure of these pavement soils is very similar to that described for other soils beneath varnished desert pavement in other areas (Nevada: Springer, 1958). Both horizons are saline-alkali, with perhaps slightly lower salinity in the A horizon. Chemical analysis of some soils under desert pavement in Nevada also showed high exchangeable sodium and salinity (data for Bitterspring gravelly loam in S.C.S. and Nev. Ag. Expt. Sta., 1970).

These soil data allow us to suggest a hypothesis about the vegetation differences between the pavement-covered areas and the adjacent rills and washes, and between bajadas with and without extensive areas of desert pavement.

Soils with high ESP (exchangeable sodium percentage) and low soluble salts are generally very impermeable due to the deflocculation of the clay colloids. High salt concentration in the infiltrating water will prevent deflocculation of the clay particles and allow adequate infiltration. Even though the pavement soils are saline as well as sodic, we would expect infiltrating rainwater to quickly leach most of the soluble salts from a thin layer of soil near the surface. Then the clay colloids of this leached layer would be expected to disperse and a very impermeable surface layer would be present. Most of the subsequent rainfall would run off into adjacent washes, where ESP is not high (Sample 6, Table 2) and infiltration rates are probably high. As the pavement soil dries after the rain, the soluble salts leached from the thin surface layer would be drawn back into this layer by capillarity. Thus, this think sodic non-saline surface layer would not be present when the soil was dry. The saline-alkali soils under the desert pavement in Nevada are reported to have much run-off due to slow infiltration (S.C.S. and Nev. Ag. Expt. Sta., 1970).

The lack of plant cover on the desert pavement areas (the interfluves) is not surprising in light of these data. The chemical and osmotic effects of the high sodium and high salinity, combined with a probable lack of moisture below the upper layers of soil, present a very harsh environment, indeed. The apparent absence of desert halophytes is somewhat puzzling, however, since these plants are able to tolerate saline conditions elsewhere in the desert.

We have noted above that bajadas with extensive areas of desert pavement support palo verde and ironwood and a variety of other shrubs (in the rills and washes) all the way down to the center of the valley. Bajadas without desert pavement support this community only on the uppermost parts, with Larrea and Ambrosia (Type B) on the lower part. We believe this is so because, on a bajada with pavement, a given amount of rainfall will be concentrated in the drainages by the run-off from the pavement areas, whereas on the non-pavement bajadas this same amount of rainfall will be distributed more evenly over the whole area. The redistribution of rainfall on the pavement bajadas creates a mosaic of habitats, some more xeric (the pavement areas), and others less xeric (the rills and washes) than the more uniform habitat of the bajadas without desert pavement. Therefore, the rills and washes crossing the pavement support a less xerophytic plant community than the bajadas without desert pavement.

Summary

On ERTS imagery of Yuma County, there is a contrast between the dark tones of some bajadas and the lighter tones of other bajadas. Ground truth observations revealed that the bajadas which are dark on the ERTS imagery are dark because of their large areas of varnished desert pavement. Ground truth observations also revealed there are vegetation differences between the bajadas with large areas of desert pavement and those bajadas lacking desert pavement. Soils analysis revealed that the varnished desert pavement overlies a soil with distinctive physical structure and chemical characteristics. We could infer from the physical and chemical characteristics of the pavement soil that the moisture relations of the rills and washes on the pavement bajadas are more favorable than the bajadas lacking desert pavement. We conclude that this probable difference in moisture relations is a major cause of observed difference in vegetation between the bajadas with desert pavement and those without it.

Location	Depth[1] (in.)	% > 2mm	% of <2mm fraction			Texture Class
			% Sand	% Silt	% Clay	
Non-pavement soils:						
1	0-3	0.5	63.6	33.2	3.2	sandy loam
2	0-3	3.4	79.7	16.4	3.9	loamy sand
3	0-3	0.4	20.4	74.9	4.7	silt loam
4	0-3	35.2	60.5	35.0	4.5	g. sandy loam
5	0-3	29.4	64.3	32.3	3.4	g. sandy loam
6	0-3	13.2	58.0	37.4	4.6	sandy loam
Pavement soils:						
7	0-4	1.6	23.6	62.7	13.7	silt loam
7	5-8	62.2	47.3	41.3	11.4	v.g. loam
8	0-2	4.8	27.8	56.3	15.9	silt loam
8	5-8	32.8	43.4	40.2	16.4	g. loam

Table 1. Texture of selected pavement and non-pavement soils of Yuma County, Arizona

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[1] Superficial gravel and stones were not included in surface soil samples

Location	Depth[1] (in.)	pH		CEC meq./100g	Exch. Ca meq./100g	Exch. Mg meq./100g	Exch. Na % (ESP)	soluble salts (sat. extract)		
		paste	1:5					$EC_e \times 10^3$	(calculated) ppm	$\%CaCO_3$ equivalent
Non-pavement soils:										
1	0-3	8.15	8.9	5.0	4.7	0.3	0.8	0.33	231	
2	0-3	8.2	8.9	5.3	4.9	0.3	0.7	0.31	217	1.79
3	0-3	8.0	8.5	13.6	12.6	0.9	0.5	0.35	245	10.0
4	0-3	8.05	8.6	12.5	11.7	0.6	1.7	0.37	259	
5	0-3	8.05	8.6	10.9	9.9	0.8	1.2	0.42	294	
6	0-3	8.1	8.6	7.5	6.9	0.5	0.6	0.33	231	
Pavement soils:										
7	0-4	8.0	8.85	17.9	12.9	0.9	23.0	6.40	4,480	14.1
7	5-8	7.55	8.0	17.1	11.5	1.7	22.5	29.00	20,300	8.8
8	0-2	7.6	8.3	17.1	11.9	0.6	27.0	25.00	17,500	
8	5-8	7.45	8.0	11.6	8.6	0.5	21.9	33.00	23,100	

Table 2. Chemical data for selected pavement and non-pavement soils of Yuma County, Arizona

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[1] Superficial gravel and stones were not included in surface soil samples

Table 3. Location of soil sampling sites of Tables 1 and 2

Location No.	
1	N 1/4 of E 1/4 of Sec. 27, T6N, R19W* 11.8 mi. N of U.S. 60-70 on U.S. 95 elev. 875'
2	SE corner of Sec. 32, T8S, R17W* 0.4 mi. S of 18 on Ave 36E elev. 345'
3	SW 1/4 of Sec. 17, T2S, R19W* 1/4 mi. W of approx. 1 mi. SSW of Stone Cabin on U.S. 95 elev. 1530'
4	not surveyed 11.6 mi. N of Castle Dome Mine Road on U.S. 95 (near 1197' point) elev. 1190'
5	SW corner of N 1/4 of Sec. 34, T1N, R19W* U.S. 95 at Palm Canyon Road elev. 1340'
6 & 7	not surveyed 5.4 mi. NE of U.S. 95 on Castle Dome Mine Road (at Kofa Game Range Boundary) elev. 1020'
8	NE 1/4 of SE 1/4 of Sec. 34, T5N, R19W* 4.5 mi. N of U.S. 60-70 on U.S. 95 elev. 830'

*Gila and Salt River Base Line and Meridian

Ground Truth Imagery in Avra Valley (Methods)

The Avra Valley is a few miles west of Tucson, at latitude 32° to 32°20'W. This valley was selected as a ground truth data collection area. The alluvial slopes and floodplains of the valley support a variety of vegetation types and species characteristic of the Sonoran Desert and the desert-grassland transition area. Permanent ground truth sites could be located to minimize travel time to and between the sites, and to ensure that all sites would be included on a single ERTS image. High-altitude color and color infrared photography (ERAP Mission 101) was used in conjunction with a search on the ground to locate large uniform sites for data collection. Eight sites were selected:

1, 2, 3 Larrea tridentata (creosotebush) and annuals: the sites are on different soil types and support different amounts or kinds of annuals and different densities of creosotebush;

4 Bouteloua rothrockii (Rothrock's grama grass) and Haplopappus tenuisectis (burrowed) and annuals;

5 Prosopis juliflora (mesquite), Haplopappus tenuisectis and Gutierrezia bicida (snakeweed);

6 Desert grassland; Baccharis brachyphylla, Aristida spp. and other perennial grasses, Prosopis juliflora, Cercidium floridum (blue paloverde);

7, 8 Cercidium microphyllum (foothill paloverde), Carnegiea gigantea (saguaro), Ambrosia deltoidea (triangle leaf bursage), many other perennial species.

Ground Truth Data

Ground truth data for these sites consists primarily of 35 mm color and color infrared photographs. The same vertical low oblique and high oblique views at each site were photographed repeatedly during the year. Complete sets of photographs were taken during the following periods: 20-21 Nov. '72, 31 Jan. - 5 Feb. '73, 11-18 Mar. '73, 9-12 Apr. '73, and 19-21 Jun. '73. The primary objective of this data collection method was to record the phenological changes and the associated spectral signature changes simultaneously, in a photographic form which could be easily compared with ERTS or simulated ERTS imagery of the area.

Spectral Reflectivity Signatures of Vegetation and Soil

Measurements of incident and reflected radiation were made at the Avra Valley ground truth sites in conjunction with the ground truth photography of 9-12 Apr. '73 and 19-21 Jun. '73. Radiation in each MSS wavelength band was measured with an

Exotech ERTS Radiometer. Reflectivity of each scene was determined by dividing the reflected radiation measurement by the total incoming radiation measurement. A total of approximately one hundred spectral signatures of vertical and low oblique views were obtained.

Radiometric data from these two periods provide a contrast between spectral signatures during a period near the peak of vegetative activity following the winter rains (April) and during a period of reduced vegetative activity during the fore-summer drought (June). In April, the winter annuals had reached their peak of development and some plants were beginning to wilt and die. The creosotebush and bursage, both perennials, had abundant bright green leaves (bright grey-green on bursage). In June, the winter annuals were dead and no summer annuals had germinated. Creosote and bursage had lost many leaves, and those remaining were dead or very brownish and wilted or semi-dormant.

Samples of the ground truth spectral signature curves are shown in Figures 2, 3, 4, and 5. A comparison of the spectral signatures of ground surfaces partially covered by living annuals in April with those of the same scenes in June when the annuals were dead indicated that the presence of the living annuals did not increase infrared reflectivity, but lowered red reflectivity. A comparison of April creosotebush (vegetatively active) with June creosotebush indicated that red reflectivity was low for both, but infrared reflectivity was lower in June than in April.

Comparison and classification of spectral signatures as displayed in the graphical form of Figures 2,3,4, and 5 is difficult. Most methods of concise characterization of spectral signatures involve some comparison of red and infrared reflectivity when vegetation amounts or activity are of interest. The ratio of infrared to red reflectivity has been commonly used as an index of vegetative activity, but this ratio may not be the best way of concisely expressing the spectral signature of a scene. We have compared this method of expressing spectral signatures with a two-dimensional method which preserves the information contained in the absolute values of the red and infrared reflectivities.

The spectral signatures plotted in Figures 6, 7, 8, and 9 were first categorized according to the nature of the scene, as indicated in the legend. The "annuals and ground" category includes all scenes which included living annuals, even though many of these scenes had only a sparse cover of annuals. The "ground with litter" category includes scenes with old grayish litter partly covering the soil surface, and those with fresh yellowish litter of the dead annuals. A few scenes of soil which, due to erosion, completely lacked any cover of litter or plants on the bare mineral soil comprise the "bare ground" category. This category is noted by its own symbol, but is plotted along with the "ground with litter" category to make a cluster of all scenes which lack living plant material. A few scenes in the "annuals and ground" and "ground with litter" categories are denoted by special symbols. These scenes were on an area covered with red rock and may deviate somewhat from the general pattern because of the unusual signature of the red rock fragments on the soil surface.

In Figure 6, the signatures are plotted as points along a single axis representing the ratio of infrared (MSS Band 7) reflectivity to red (MSS Band 5) reflectivity. The infrared Band 6/red Band 5 ratio is plotted in Figure 7. The signatures of ground with annuals are mostly separated from the signatures of ground with living annuals, the signatures of creosotebush (Larrea) and bursage (Ambrosia) are not distinguishable from the other categories.

The signatures are plotted according to both infrared (Band 7) reflectivity and red (Band 5) reflectivity in Figure 8, and according to infrared (Band 6) reflectivity and red (Band 5) reflectivity in Figure 9. Lines are drawn to indicate the boundaries of the cluster of points of each category, except that the red rock points were not included with the "annuals and ground" category. The similarity of these signatures to those of scenes which lack living plants is not surprising considering the low infrared reflectivity of the soil surface and the very sparse cover of annuals at this site.

It is evident that signatures of the various categories are more distinctly characterized in Figures 8 and 9 than in Figures 6 and 7. Some relationships between the signatures of the various types of scenes are apparent in Figures 8 and 9. The signature clusters of dormant or semi-dormant creosotebush (Larrea) and especially bursage (Ambrosia) approximate a "darker" extension than the "ground with litter" cluster. This is probably partly due to the large amount of ground surface visible through the shrub foliage, the similarity in signature of the plant tissue and the ground, and the presence of shadows cast by the shrub stems and leaves.

This method of defining spectral signatures as a two-dimensional cluster where the two dimensions are reflectivity values in different wavelength bands could easily be extended to four dimensions (wavelength bands) with the aid of a computer. This method could also be used characterizing spectral signatures derived from ERTS data.

Interpretation of ERTS spectral signature data would seem to require ground truth spectral signatures for whole plant communities. Community reflectivity values could be measured directly or calculated from reflectivity data for the individual components of a scene (ground, each type of shrub or tree cover) if the relative area of each component is known. For desert plant communities, direct measurement (as from a light plane) seems preferable, since shadows extending beyond the crowns of shrubs or trees are a part of the community signature which would be difficult to sample accurately on the ground.

It should also be pointed out that since shadows are part of a community signature, part of the seasonal change in spectral signature (as taken at ERTS overflight time) will be due to changes in the amount and distribution of shadows, which are in turn a result of changes in sun angle. Without adequate ground truth data, this could cause difficulties in inferring phenological change from seasonal changes in ERTS spectral signatures.

Legend

Type A: Paloverde and Ironwood with highly developed desert pavement.

Type A*: Paloverde and Ironwood with little or no desert pavement.

Type B: Creosote bush and bursage.

Type B*: Creosote bush, mesquite and big galleta.

Type C: Creosote bush and ocotillo.

Type A+C: A mosaic of types A and C.

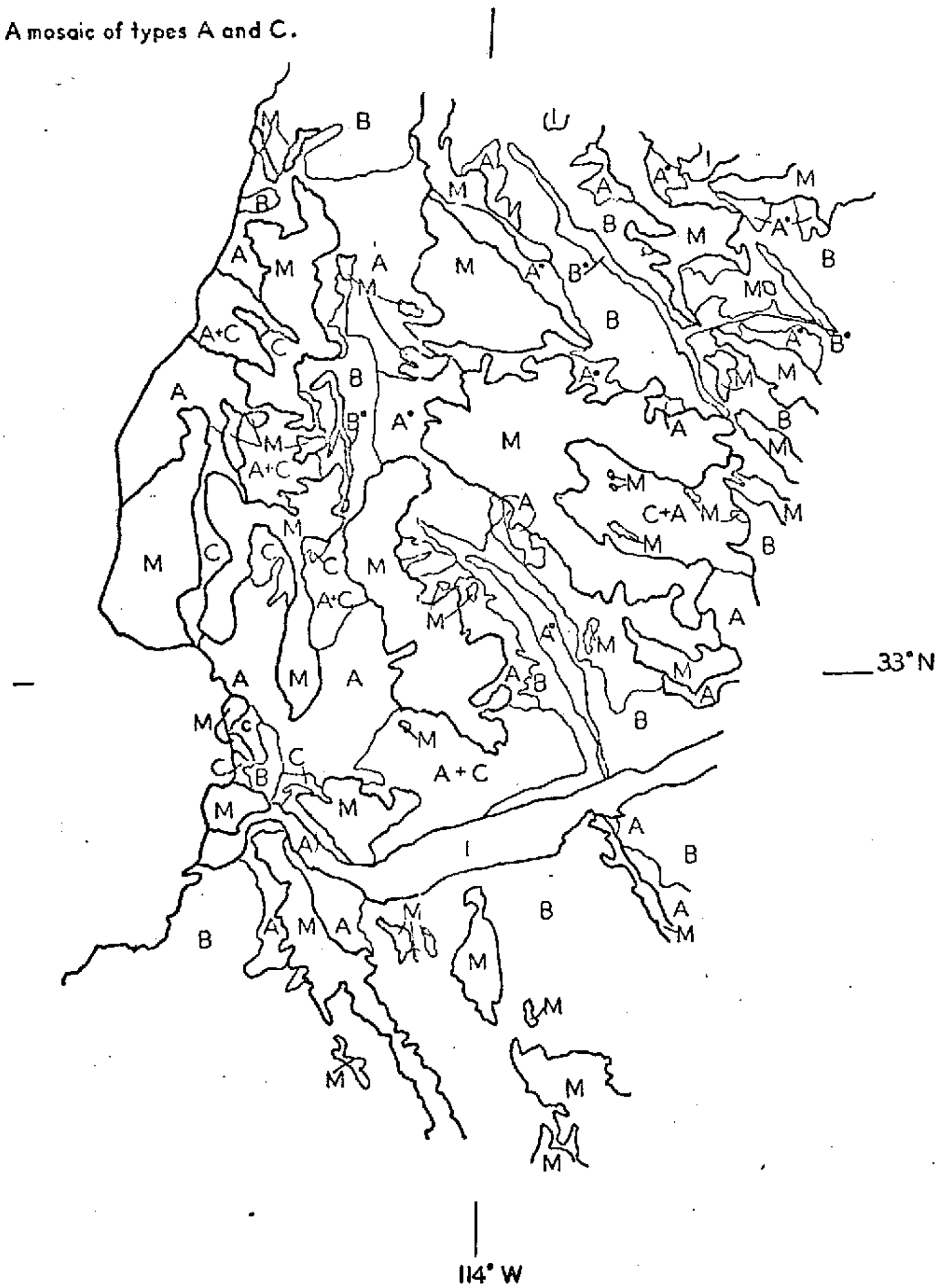


Figure 1. Vegetation map of Yuma study area prepared from ERTS image E-1069-17441. Key in text (Appendix)

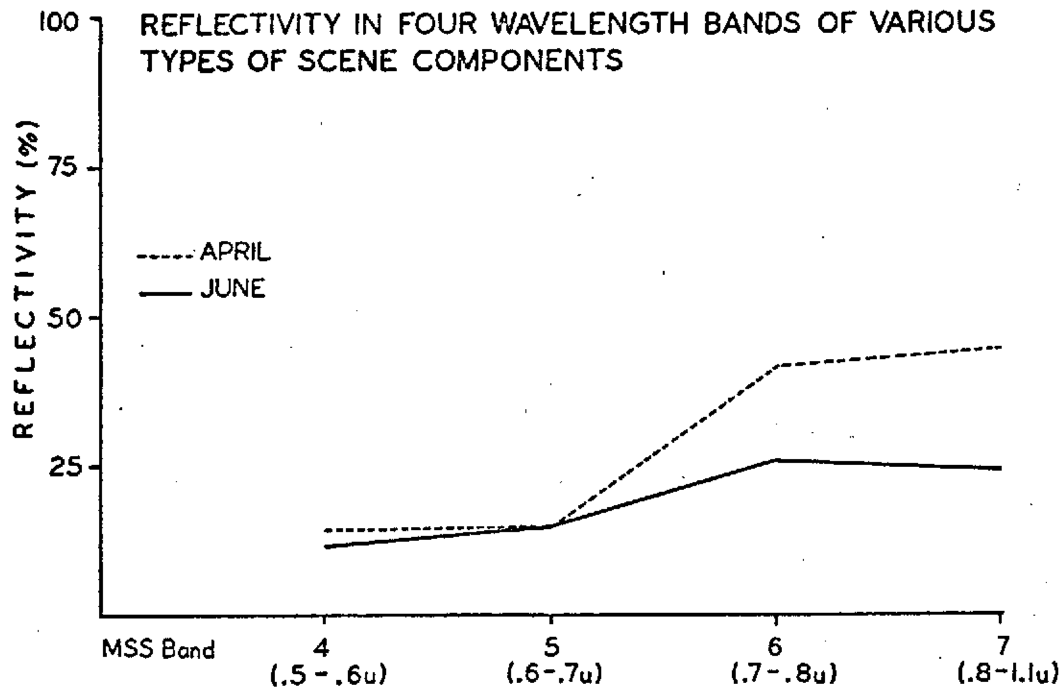


Figure 2. Larrea Type

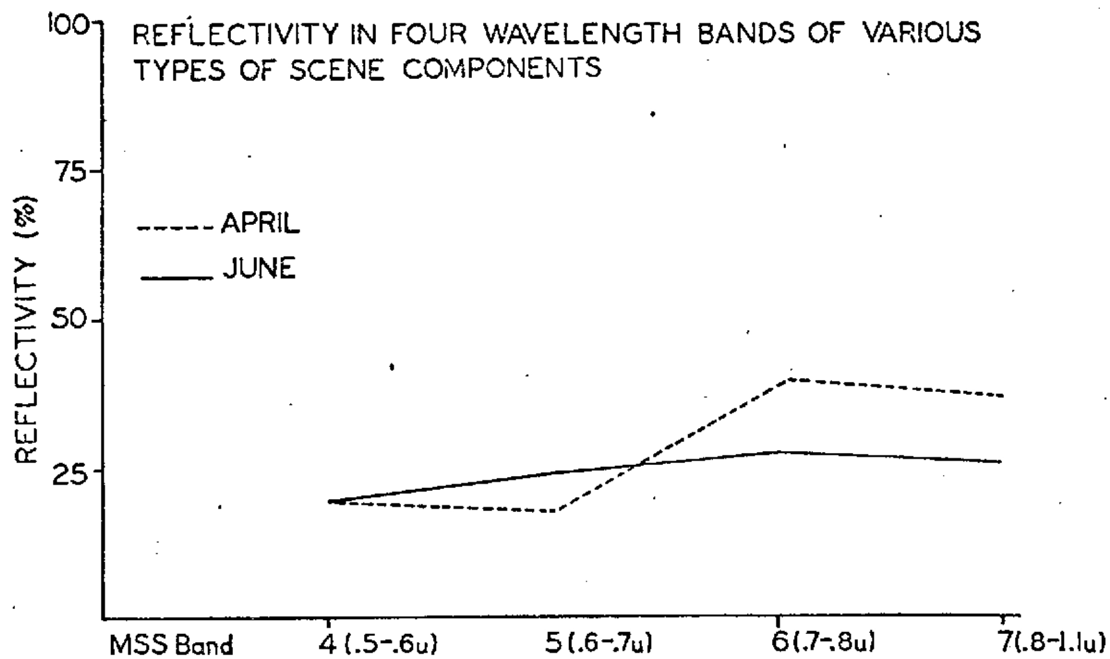


Figure 3. <u>Ambrosia</u> Type

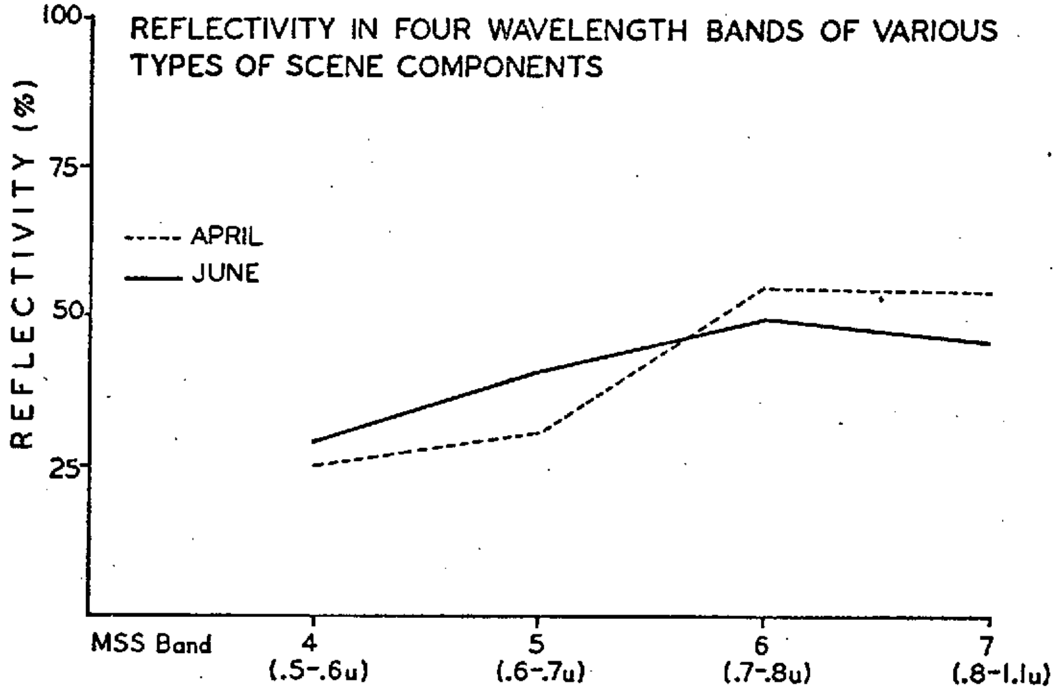


Figure 4. Soil with Annual Plants (April) and Soil with Litter of Annual Plants (June)

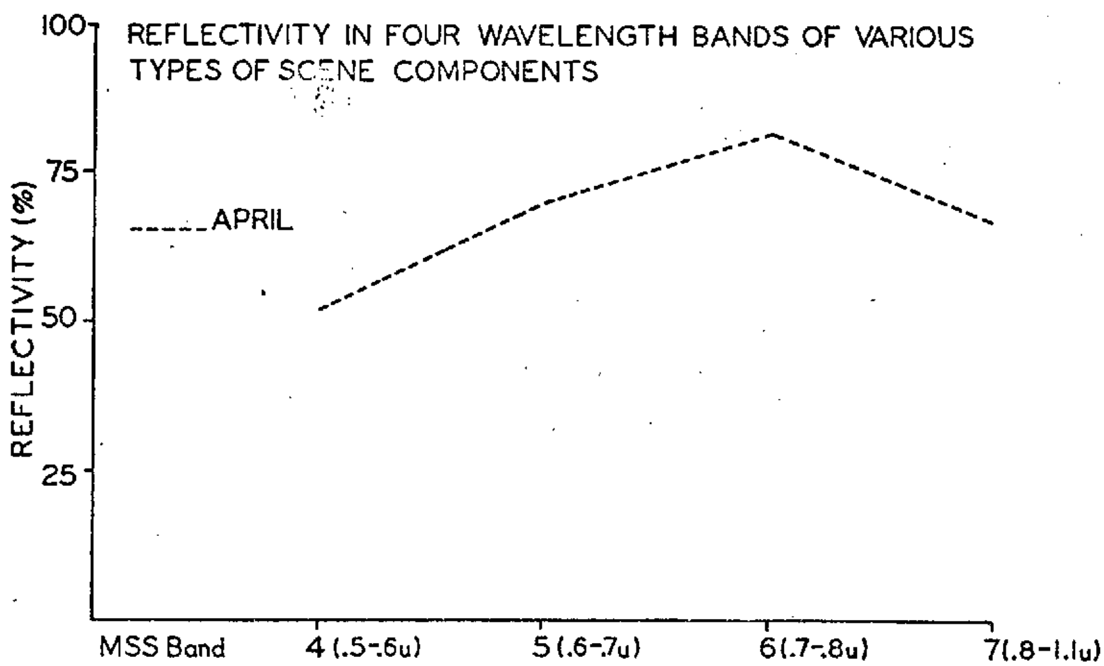
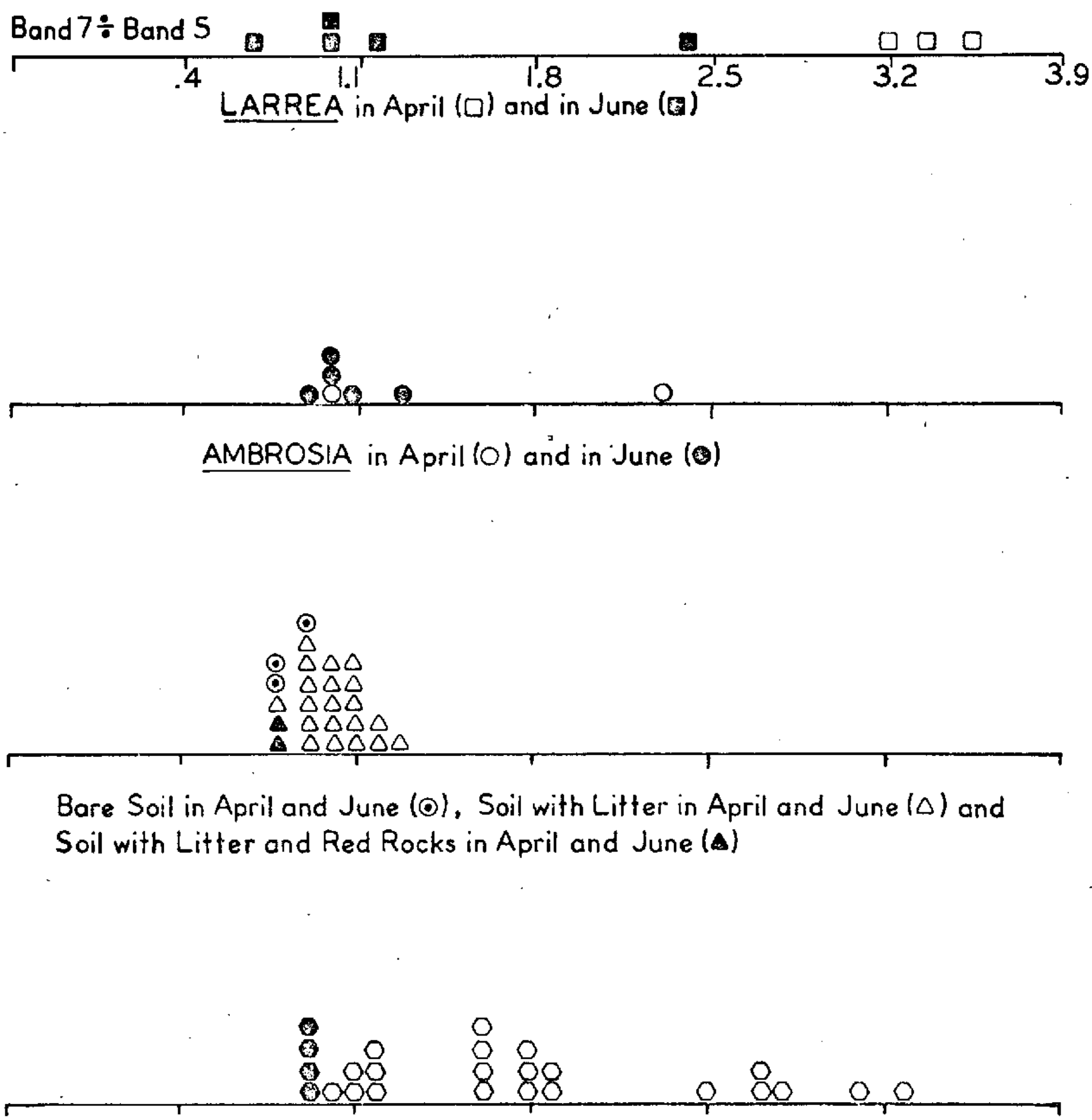


Figure 5. Bare Soil

Figure 6. Ratio of MSS Band 7 (0.8-1.1u) Reflectivity to MSS Band 5 (0.6-0.7u) Reflectivity for Various Types of Scene Components



LARREA in April (□) and in June (▣)

AMBROSIA in April (○) and in June (◉)

Bare Soil in April and June (⊙), Soil with Litter in April and June (△) and Soil with Litter and Red Rocks in April and June (▲)

Soil with Annual Plants in April (○) and Soil with Annual Plants and Red Rocks in April (◉)

Figure 7. Ratio of MSS Band 6 (0.7-0.8u) Reflectivity to MSS Band 5 (0.6-0.7u) Reflectivity for Various Types of Scene Components

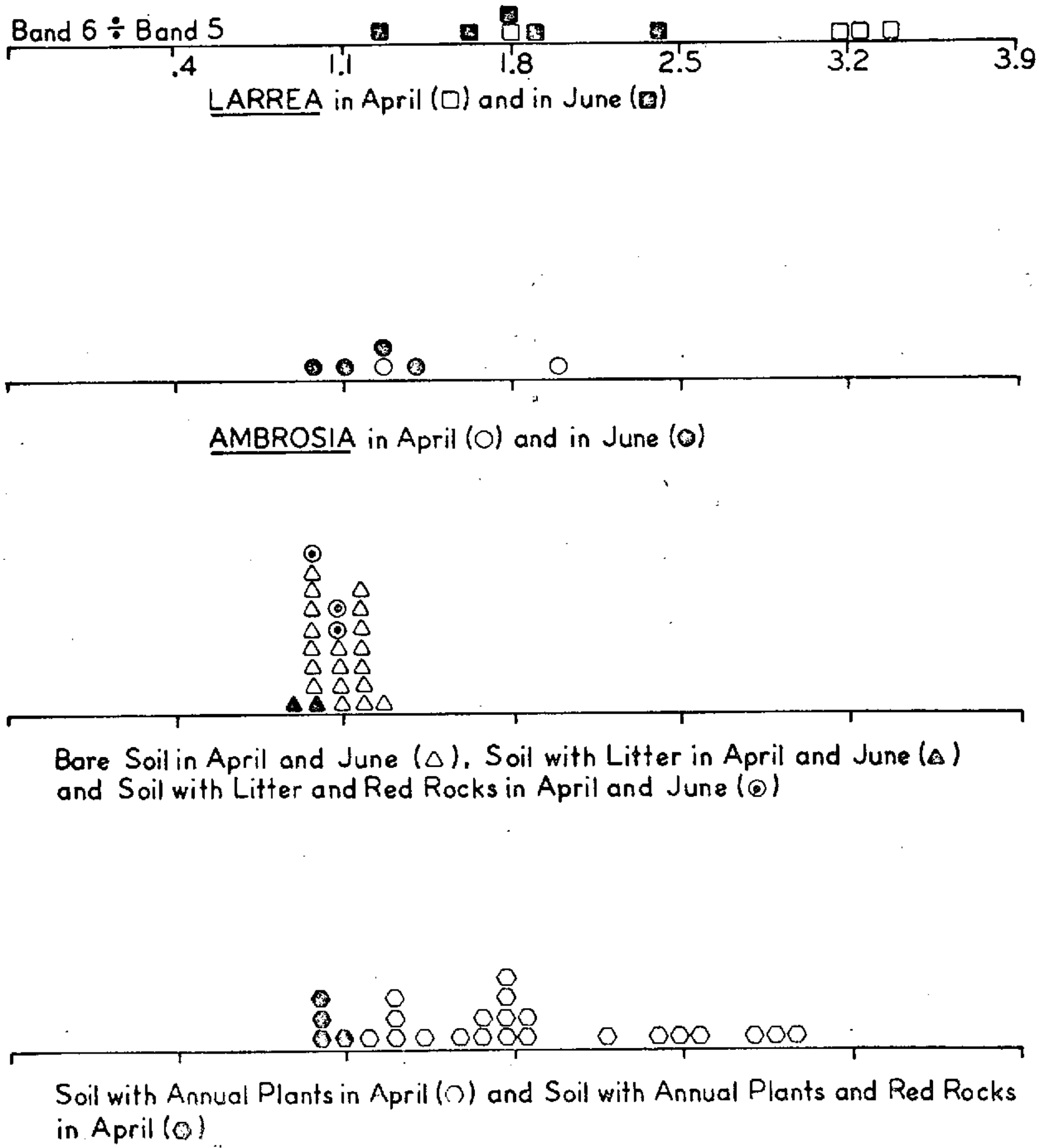


Figure 8. Reflectivity in MSS Band 7 (0.8-1.1u) vs. Reflectivity in MSS Band 5 (0.6-0.7u) for Various Scene Components

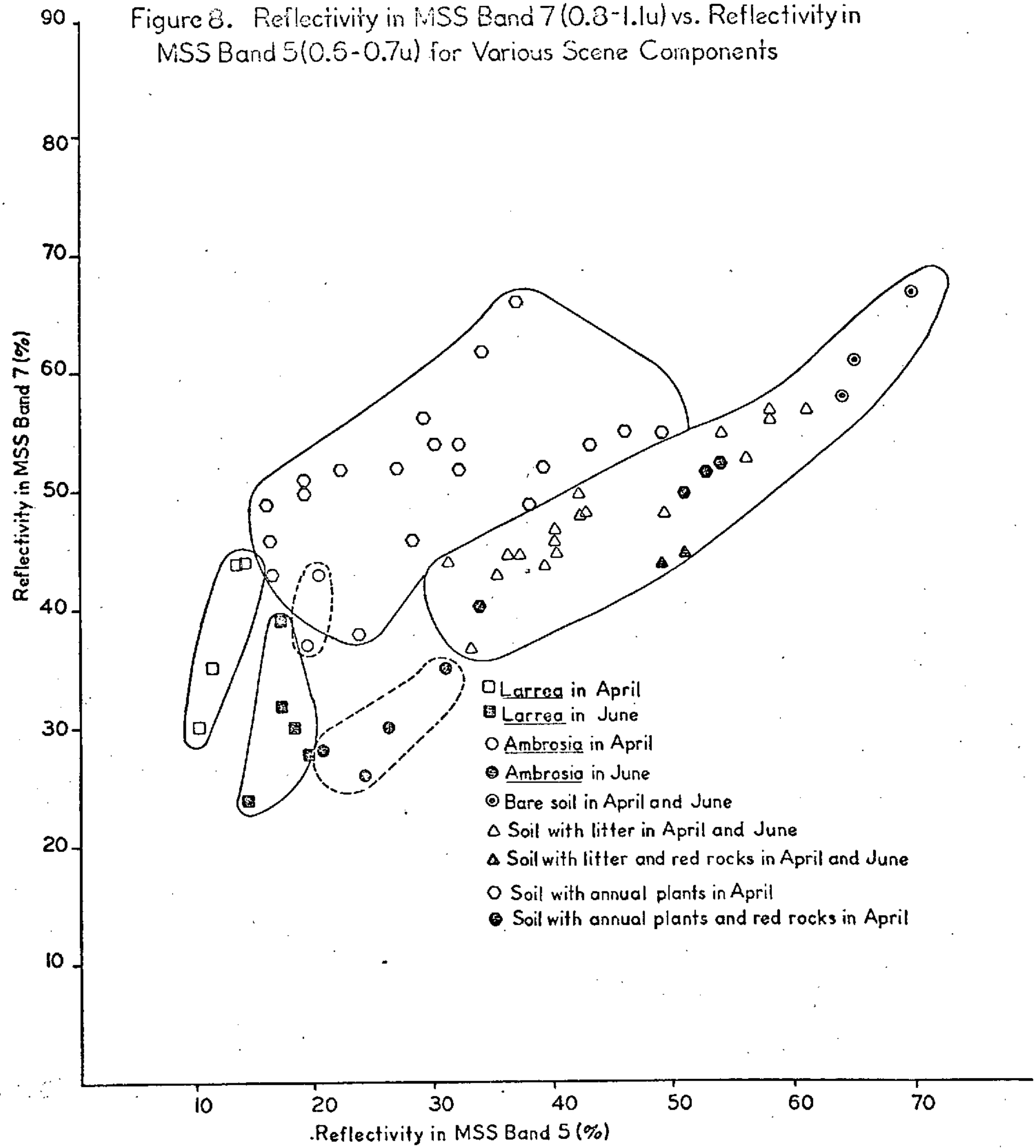


Figure 9. Reflectivity in MSS Band 6 (.7-.8u) vs. Reflectivity in MSS Band 5 (.6-.7u) for Various Scene Components