REMOTE SENSING APPLICATIONS IN FORESTRY

INVENTORY OF NATIVE VEGETATION AND RELATED RESOURCES FROM SPACE PHOTOGRAPHY

by

Charles E. Poulton
James R. Johnson
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Department of Range Management
Agricultural Experiment Station
Oregon State University

Annual Progress Report — 30 September, 1970

A report of research performed under the auspices of the

Forestry Remote Sensing Laboratory,
School of Forestry and Conservation
University of California
Berkeley, California

A Coordination Task Carried Out in Cooperation with
The Forest Service, U.S. Department of Agriculture

For

EARTH RESOURCES SURVEY PROGRAM
OFFICE OF SPACE SCIENCES AND APPLICATIONS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY OF ACCOMPLISHMENTS

Ecological resource inventory and analysis of naturally vegetated areas are continuing as the primary concern of the Oregon State University group in Range Management. During the fiscal year concepts, philosophies and procedures presented in earlier reports have been brought further toward an operational level. Procedures for gathering and recording ecological resource information and the operational details remain basically unchanged from earlier reports (Poulton et al., 1969).

Using these procedures, a vegetational resource map has been essentially completed for slightly over 90 percent of Maricopa County, Arizona. Three frames from the S065 experiment aboard Apollo 9 were used. The vegetational resources legend first developed for the Tucson-Willcox-Ft. Huachuca triangle (Poulton et al., 1969 and Colwell et al., 1969) was adapted to the Maricopa County area. The relative ease of adaptation substantiated the validity and regional applicability of the concepts that guided the initial legend development.

Additional attention has been given to vegetation-landform relationships as they relate to the interpretation of space and high flight photography. Macrorelief, the grossest characteristic of landform, is the surface feature most easily identified from small scale photography of arid lands. Because macrorelief features are ecologically related to specific kinds of vegetation, photo identification of macrorelief classes is often a prerequisite for maximum exploitation of small scale photography when vegetation resource analysis is the principal objective. A macrorelief ground truth map was completed for the Tucson-Willcox-Ft. Huachuca area, and an initial assessment of the interpretability of

[illegible]

[illegible]

[illegible]

[illegible]

macrorelief classes from Apollo 6 photography was conducted. These interpretation tests helped identify some common errors where special attention in training will be required and gave a reasonable indication of photo interpretation accuracy when working from written instructions alone.

Three segments of our research are not being reported in detail at this time. These are: (1) Intensive phytosociological investigation to establish maximum refinement of ground truth in a special test area. (2) Development of multiseasonal photography as an aid to photo identification of native vegetation. (3) Analysis of multispectral linescan imagery of range vegetation at our Squaw Butte Test site in Oregon.

The last of the required field data were gathered in this fiscal year for the intensive phytosociological classification of range vegetation near Tombstone, Arizona. This investigation is under the leadership of Edmundo Garcia Moya. The data will be classified to develop both a highly refined and a hierarchial set of classes to use in photo interpretation experiments and in quantitative studies of the consistency of the photo image characteristics associated with each vegetational class. Current indications are that the vegetation of this limited study area can be grouped into 14 classes that are widespread and of great aerial significance and 8 classes of limited extent and importance when 1:200,000 photography is used.

Our study of multiseasonal photography is under leadership of Barry J. Schrumpf and he is also responsible for obtaining ground truth data for rangeland subjects to support the high flight program. On critical flight dates additional personnel assist with high flight and multiseasonal

ground truth. This phase of the project has been indeterminantly delayed because of weather problems at scheduled flight dates and by the RB57A wing problem. In addition, our project leader on this work contracted a serious infection of Valley Fever and had to restrict field activity for a substantial part of the late summer. Ground truth records were, however, kept up and considerable laboratory and library work was done that should contribute to progress once the full spectrum of multiseasonal imagery becomes available. We did obtain one flight in September over the area for which we are primarily responsible. Although several dates of photography are available for the non-agricultural portions of the Phoenix test area, vegetation in this region does not display the magnitude of diversity desirable for multiseasonal testing.

In late September, Jerry Lent and Jim Nichols of the Forestry Remote Sensing Laboratory and C. E. Poulton went to Purdue and earnestly began to massage selected portions of our 1966 multispectral linescan imagery. The data are still as appropriate to use as the day they were taken because of stability of the rangeland subjects. The selected data included a representative native vegetation area and a range area improved by seeding and by brush spraying. Data analysis on both of these areas was carried through classification and display and a thermal overlay of the 12-channel data was successfully carried out. Results look promising and will be reported after a more thorough study of the analysis, displays, and tabular summaries of accuracy of classification.

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VEGETATIONAL RESOURCE INVENTORY IN MARICOPA COUNTY, ARIZONA

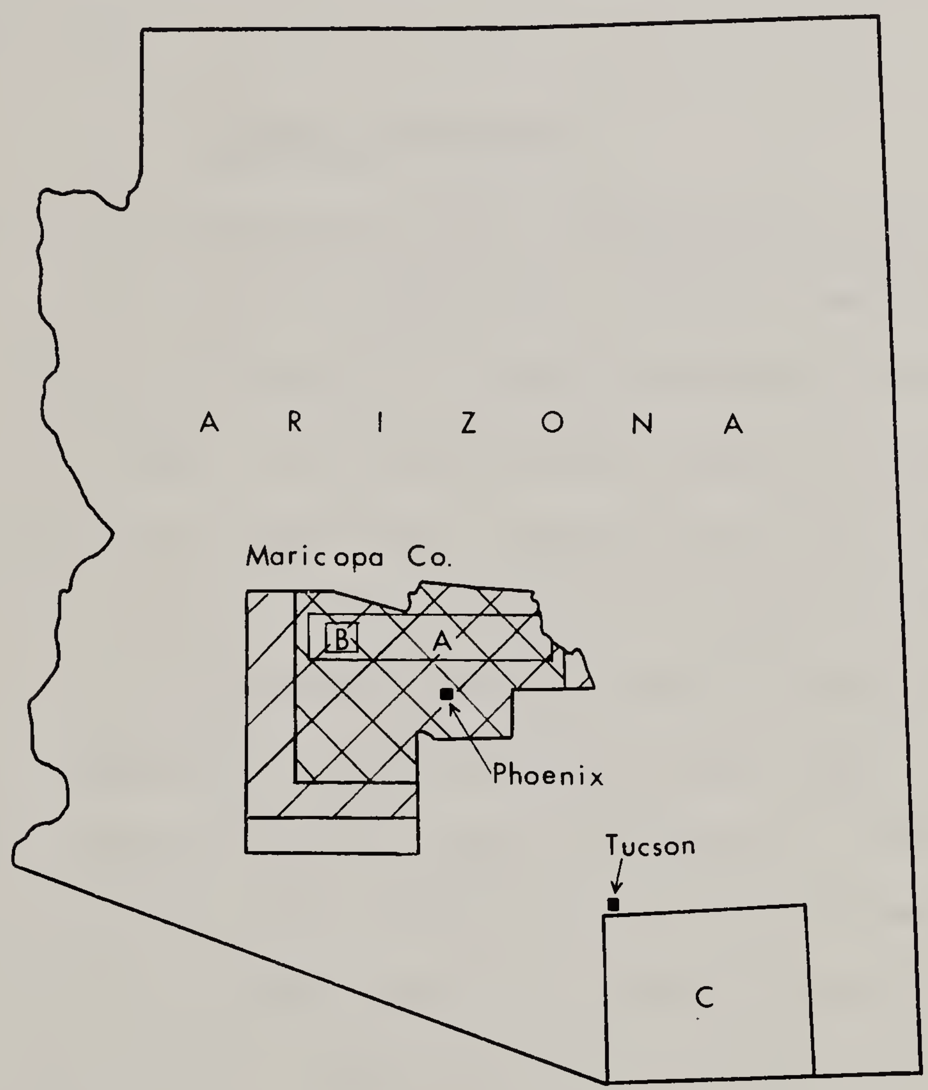
James R. Johnson

Introduction

As a part of a concentrated effort to more fully utilize space and high flight photography in a developing region, our staff accepted the primary responsibility of examining "natural" resource features for large portions of the selected study area, Maricopa County, Arizona (Figure 1). We are preparing ecologically based vegetation-landform and land use maps at two intensities (scales). The low intensity study is depicted in mapped form utilizing three frames from Apollo 9 as a base. The intermediate intensity study is being prepared on a photomosaic base created from high flight photography. A single frame sample is shown in this report. Completion of the intermediate level of inventory is anticipated for the December, 1970, NASA high flight report. This latter project is, in part, a joint contribution of Forestry Remote Sensing Laboratory personnel and ourselves. The F. R. S. L. staff is concentrating their efforts on cropland resources of the County.

Although current and/or suggested land use in the natural resources areas has not been a primary consideration in this project, land use has not been totally ignored. Our legend accommodates land uses that result in a conversion or strong modification of the natural vegetation. The vegetation-landform units we have identified have an ecological basis and are, therefore, meaningful from a land use point of view because they identify areas with unique potentials or limitations for use or development under various land uses. Examples of these relationships are given.

Figure 1. Locations of vegetation inventory (hashed portions of Maricopa County) and macrorelief study (near Tucson).



Highflight photo coverage in Maricopa County.

Apollo 9 space photo coverage in Maricopa County.

A Area of intensive ground checking.

B Area of mapped highflight example.

C Area of macrorelief study.

Additionally, totally realistic proposals regarding land use can only follow identification of users and consultation with same to assess their needs in relation to the ecology of the landscape as revealed by the ecological resource inventory. This phase of resource analysis is beyond the scope of this study.

Résumé of Procedures

Work began with delineation pretyping of photographic prints. The low intensity pretyping was done on S065 color infrared frames AS-9-26A-3800 through -3802 enlarged to a scale of about 1:760,000 with physical dimensions of 8 x 8 inches. Type boundaries were determined largely by changes in macrorelief and image color. Visible physical developments such as agricultural land and urban complexes were separately delineated. Intermediate intensity pretyping was similarly done on eleven NASA high flight 9 x 9 color ektachrome transparencies (film type 2448), frames 2775 through 2785, taken with a RC 8 camera on Mission 127. Scale of the photography was 1:124,000. Color infrared film was not selected because of exposure difficulties. When mosaiced the effective area shown in "A" of Figure 1 was 9" x 44". Type boundaries on the high flight photography were determined by utilizing the same criteria as for the space photography, except that stereoscopic coverage provided greater accuracy.

Units of image similarity within scales were identified and assigned common numerical designators for purposes of reference. This process amounted to a basic stratification technique which simplified subsequent ground checking by minimizing the number of units which had to be examined or visited. Had photographs of the scale and type used not been available,

a much greater expenditure of field time would surely have resulted. Without photographs, not only would initial recognition of areas of ecological similarity have been seriously hampered, but accurate delineation would likely have been impossible. Furthermore, much time was saved because recent photographs of appropriate resolution and scale, such as the 1:124,000 high flight imagery, provide the ground observer with better information about roads, trails, and general accessibility than many readily available road maps or unmanageable larger scale photographs.

Working from the pretyped photographs, ground information was gathered and recorded for each stop. Initially, the four man field crew (all of whom have moderate to high levels of capability in resource ecology) spent one day on location traveling and training together. Through independent observation, note comparison, and discussion, a remarkably high degree of uniformity was achieved in vegetation analysis, in macrorelief classification, and soil surface characteristic determinations. On five subsequent days of field examination, the crew split into two parties to facilitate examination of the area, mostly in area "A" of Figure 1. On a later date, one of the crew rented a small fixed-wing aircraft for a low elevation reconnaissance flight. The purpose of the flight was to record information about major plant species and macrorelief in delineations on the SO65 frames which had not been ground checked. The additional information thus gathered proved to be adequate for mapping from the space photographs (low intensity) but insufficient for some details of legend assignment from the high flight imagery (intermediate intensity).

Legend Modification and Expansion

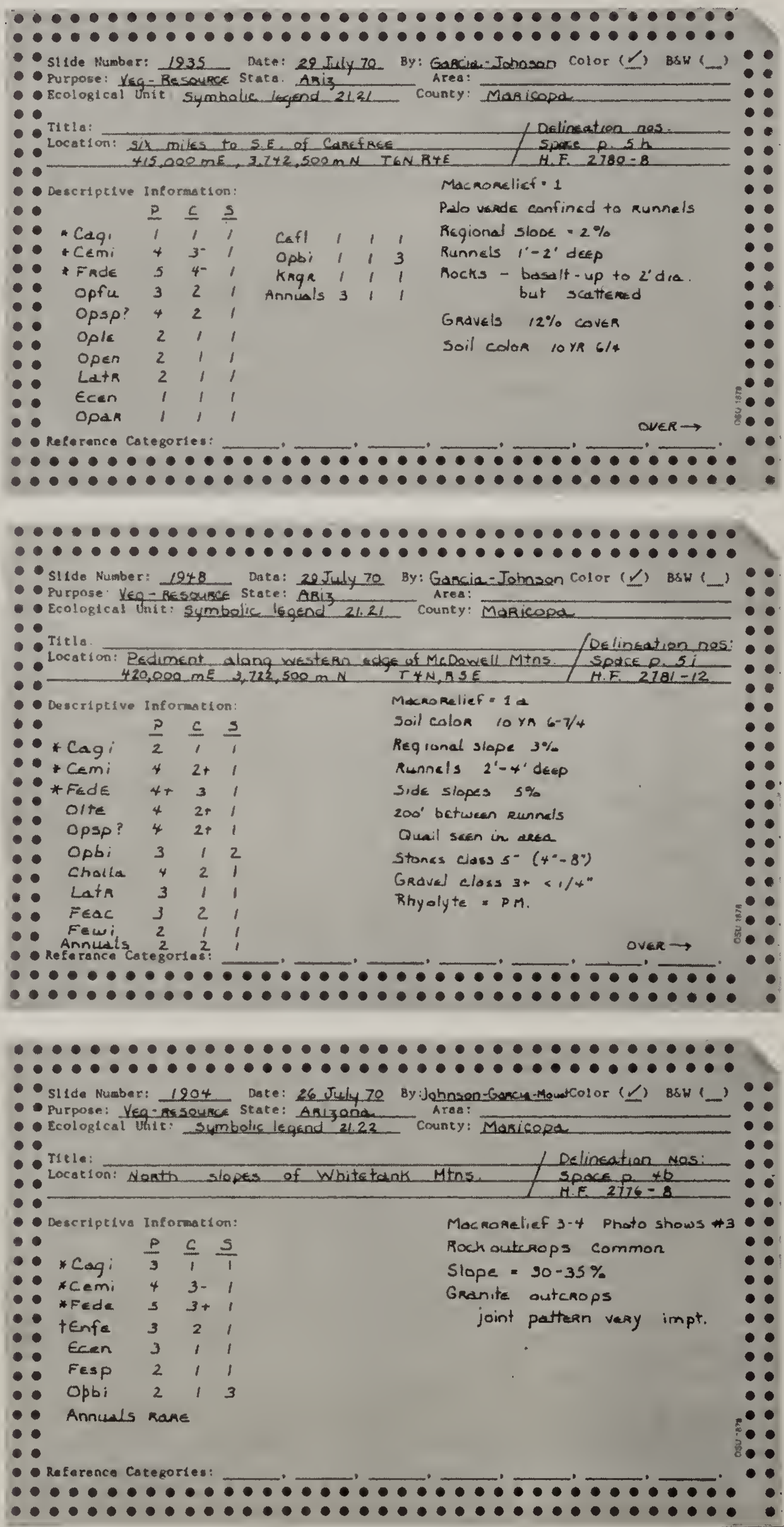
Most of the secondary vegetational legend presented by Poulton et al. (1969) was developed for vegetation-soil systems in the Tucson-Willcox-Ft. Huachuca area of Arizona. Some of these same systems, when classified at comparable levels, were found in Maricopa County. Some modifications of and additions to the legend were necessary to fit the expanded area.

Vegetation-Soil System Relationships

Classification of subjects is an essential component of resource inventory whenever the area becomes large and vegetation-soil units numerous. In classification systems, those that are most useful are based on logical, easily characterized divisions. Phytosociological vegetation classification systems provide an opportunity to establish these kinds of meaningful units of similarity. Here, vegetation characteristics and other relevant ecological features of the landscape can be synthesized into a hierarchial classification which, by its very nature, identifies those units of the landscape that can be expected to reflect similar values for and/or reactions to land use. Because it is a hierarchial classification, various kinds of information can be conveyed at each of several levels. The approach is completely compatible with and enhanced by incorporation into symbolic and descriptive legend formats. The mapped photographs shown amply serve to demonstrate this compatibility once the meaning of the symbolic legend units is understood.

The type of information which is gathered on the ground is displayed in Figure 2. Corresponding photographs for each of these locations are shown in Figure 3. The upper two score cards in Figure 2 were grouped

Figure 2. Ground record cards of three stands described in Maricopa County. For purposes of this study, consistent occurrence of groups of characteristic plant species, or of differentiating species, were the determining factors in identifying similar vegetational units. In addition to occurrence, the information given for species is (1) "P", relative prominence; (2) "C", cover; and (3) "S", sociability or gregariousness. The least prominent species are indicated by 1, ranging to the most prominent, 4 or 5. Cover classes range from 50-75% cover, class 4, to 0-5% cover, class 1. Species approaching random distribution are indicated by sociability class 1. This additional information detail would be necessary in identifying more specific vegetation-soil systems and is often helpful in identification and characterization of units at the broader level discussed herein.



Slide Number: 1935 Date: 29 July 70 By: Garcia-Johnson Color (✓) B&W ( )
Purpose: Veg-Resource State: Ariz Area:
Ecological Unit: Symbolic legend 21.21 County: Maricopa
Title:
Location: 5½ miles to S.E. of Carefree / Delineation nos. Space p. 5h
415,000 mE, 3,742,500 mN T6N R4E / H.F. 2780-8
Descriptive Information:

	P	C	S
*Cagi	1	1	1
*Cemi	4	3-	1
*Fede	5	4-	1
Opfu	3	2	1
Opsp?	4	2	1
Ople	2	1	1
Open	2	1	1
Latr	2	1	1
Ecen	1	1	1
Opar	1	1	1
Cafl	1	1	1
Opbi	1	1	3
Krgr	1	1	1
Annuals	3	1	1

Macrorelief = 1
Palo verde confined to runnels
Regional slope = 2%
Runnels 1'-2' deep
Rocks - basalt - up to 2' dia. but scattered
Gravels 12% cover
Soil color 10 YR 6/4
OVER →
Reference Categories: ____, ____, ____, ____, ____, ____, ____.

Slide Number: 1948 Date: 29 July 70 By: Garcia-Johnson Color (✓) B&W ( )
Purpose: Veg-Resource State: Ariz Area:
Ecological Unit: Symbolic legend 21.21 County: Maricopa
Title:
Location: Pediment along western edge of McDowell Mtns. / Delineation nos: Space p. 5i
420,000 mE 3,722,500 m N T4N, R5E / H.F. 2781-12
Descriptive Information:

	P	C	S
*Cagi	2	1	1
*Cemi	4	2+	1
*Fede	4+	3	1
Olte	4	2+	1
Opsp?	4	2+	1
Opbi	3	1	2
Cholla	4	2	1
Latr	3	1	1
Feac	3	2	1
Fewi	2	1	1
Annuals	2	2	1

Macrorelief = 1a
Soil color 10 YR 6-7/4
Regional slope 3%
Runnels 2'-4' deep
Side slopes 5%
200' between runnels
Quail seen in area
Stones class 5- (4"-8")
Gravel class 3+ < 1/4"
Rhyolyte = P.M.
OVER →
Reference Categories: ____, ____, ____, ____, ____, ____, ____.

Slide Number: 1904 Date: 26 July 70 By: Johnson-Garcia-Mouat Color (✓) B&W ( )
Purpose: Veg-Resource State: Arizona Area:
Ecological Unit: Symbolic legend 21.22 County: Maricopa
Title:
Location: North slopes of Whitetank Mtns. / Delineation nos: Space p. 4b
/ H.F. 2776-8
Descriptive Information:

	P	C	S
*Cagi	3	1	1
*Cemi	4	3-	1
*Fede	5	3+	1
†Enfe	3	2	1
Ecen	3	1	1
Fesp	2	1	1
Opbi	2	1	3
Annuals rare			

Macrorelief 3-4 Photo shows #3
Rock outcrops common
Slope = 30-35%
Granite outcrops
joint pattern very impt.
Reference Categories: ____, ____, ____, ____, ____, ____, ____.

Figure 3. Ground photographs of the three stands described in Figure 2. Good ground photographs are an essential aid in providing recall once field work is completed and in communicating recognition features to legend users. Differences in macrorelief are clearly evident. Shifts in species prominence are less readily apparent. In all three photographs, a small bronze-colored shrub, triangle bursage, is one of the most prominent species. In the bottom photograph, lower left foreground, a single plant of brittlebrush is seen. It is rounded, about 12 inches tall, and cream-bronze colored. Brittlebrush serves to distinguish this type of vegetation from the related type represented in the upper two photographs.

into the same broad vegetation-soil system, symbolic legend unit 21.21 (See Figure 4). This category can technically be described by the presence of three species (see asterisks on cards) common to both stands:

"Cegi"	Cereus giganteus	(saguaro)
"Cemi"	Cercidim microphyllum	(foothill palo verde)
"Frde"	Franseria deltoidea	(triangle bursage)

At this level of classification, presence of character species is the principal criterion of vegetation used to group stands of ecologically similar units. The third score card in Figure 2 shows the presence of the same three species; however, an additional species of particular importance is also present, namely, "Enfa", Encelia farinosa (brittlebrush). Thus, the third card characterizes a stand that represents a different, but closely related vegetation-soil system, symbolic legend unit 21.22.

If one had no more information than that provided on the cards in Figure 2, it would have been an impossibility to judge the top two cards as representative of the same unit while assigning another unit to the stand described on the bottom card. As one compares numerous similar stands and/or ground truth data cards, it becomes apparent that the occurrence of the species saguaro, foothill palo verde, and triangle bursage, is a common denominator characterizing closely related vegetation-soil systems. It is similarly discovered that these three species occur with or without brittlebrush, but it is not until consistent relationships to macrorelief were recognized that the diagnostic value of brittlebrush presence was fully appreciated. The upper two cards of Figure 2 list "macrorelief" classes of "1" and "1a" which are relatively flat lands as contrasted to the third card which shows a "macrorelief" class of "3-4",

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

hilly and mountainous land, for the area represented thereon. Our ground truth data showed, for example, that symbolic legend unit 21.22 consistently occurs on areas of hilly to mountainous macrorelief whereas unit 22.21 is found in flatter areas.

Figure 3 shows ground photographs which were taken at the same locations as the ground information cards of Figure 2. The value of good ground photographs cannot be overemphasized. They constitute a critical portion of the ground information becoming particularly useful following ground examination. Questions relating to certain types of score card information can frequently be resolved by reference to the corresponding ground photograph. In some cases, card notation concerning vegetation characteristics or macrorelief class are fortified or even corrected by reference to the photograph. Of equal importance is the aid given by adequate ground photographs as legend development or modification is formulated. In fact, it has been our experience that a person with a phytosociological understanding can be of considerable assistance in selecting stands of similar vegetation-soil type by reference to the records and photographs even though that person has never been in the study area.

As indicated, the top two photographs of Figure 3 represent variations of vegetation-macrorelief assigned to this particular unit. The similarity in macrorelief is immediately obvious from the photographs, as it is with reference to the appropriate ground cards of Figure 2. The bottom photograph of Figure 3 clearly illustrates macrorelief difference when compared to the upper two photographs. Vegetation differences are less apparent. In the bottom photograph, one small, gray-

colored shrub species, brittlebrush, serves to differentiate this legend unit (21.22) from the other unit (21.21) in the same Figure.

Once vegetational units are identified, symbolic, technical, and descriptive legends can be developed. A sample of the symbolic (mapping) legend and corresponding technical descriptions for vegetation classes identified in southern Arizona is shown in Figure 4. Since the system is hierarchial, the level consistent with a particular information need can be utilized. For example, if a person were interested in mapping at an extremely small scale, units such as 20., 30., or 50. might be adequate. Larger scale mapping intended for or suited to national, regional, or state interest might require a mapping scale which would accommodate units at the 21., 22., or 31. level. More localized needs could well require the most refined units shown. The local resource manager, practicing intensive management, may, on the other hand, find the lowest level units shown here to be too broad. In this case, specific vegetational units derived and characterized from a phytosociological analysis of all the species would have to be recognized in setting up the legend. These would define the fundamental or ultimately refined ecological classes, the basic vegetation-soil systems, or specific ecosystems that comprise the landscape. Although some of the high flight photography is of compatible scale/resolution for mapping specific vegetation-soil systems, this highest intensity of investigation was not within the scope of our objectives in the Phoenix area.

Figure 4. Sample of symbolic and technical legend developed for southern Arizona. A semiclosed, hierarchial legend format such as this can accommodate new units and be blended into a scheme which includes all vegetation types.

Symbolic Legend	Technical Legend
20.	Deserts. Bare ground is a conspicuous feature. Vegetation sparse.
21.	Microphyll-desert generally with cacti.
21.1	Larrea tridentata (creosotebush) with few cacti and other shrubs except in drainageways or depressions.
21.11	Larrea tridentata in nearly pure stands, sometimes supporting annuals during favorable years.
21.12	Larrea tridentata with Franseria dumosa (bursage).
	. . .
21.2	Franseria deltoidea (triangle bursage), Cercidium microphyllum (foothill palo verde), Cereus giganteus (saguaro), often with Encelia farinosa (brittle brush). Opuntia (cholla) common.
21.21	Encelia farinosa not present. Flora not rich. Larrea tridentata often present.
21.22	Encelia farinosa present. Flora not rich.
	. . .
22.	Microphyll-thorn scrub desert.
	. . .
30.	Steppes. Herbaceous layer, including perennial grasses usually prominent. Low to medium height shrubs (unlike chaparral) scattered or lacking except in some grazing disclimax situations--notably among Great Basin shrub-steppe types.

Figure 4. (continued)

Symbolic Legend	Technical Legend
31.	Desert grassland.
31.1	<u>Bouteloua</u> (grama grass) steppe.
31.2	<u>Nolina</u> and/or <u>Yucca</u> grassland.
	. . .
50.	Savannas. Dense stands of herbs or overlain by scattered individuals of tall shrubs or trees.
	. . .

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Photo Map Construction from an Ecological Base

Since, as will soon be seen, macrorelief classes are related to broad vegetation types and land use is strongly influenced by combinations of vegetation and macrorelief, it appears nearly intuitive to dwell upon vegetation-macrorelief relationships to provide highly useful, basic information about landscapes. Furthermore, appropriate space, high flight, and large scale photographic imagery provides a mapping base on which the information can best be portrayed.

The space-photo map in Figure 5 was quickly prepared from three frames of Apollo 9 once the necessary reservoir of ground truth information was compiled. It should be recognized that because of reconnaissance and interpretation techniques employed, mapping errors are possible, thus, the map should be considered tentative. The area of most intensive ground examination and, therefore, highest confidence in the identification of mapped delineations is shown in "A" of Figure 1, as is the geographical location of the entire mapped area. Limited ground checking was done elsewhere.

Development of statistics on vegetation-macrorelief classes is a natural outgrowth of such a project, and these statistics from the interpreted map are summarized in Tables 1 and 2. Although it was not an aim of this project to become deeply involved with land users or to make intensive inquiries about their various information needs*, the value of the space photo vegetation-macrorelief map is not to be discounted. This is basically an ecological resource inventory at about the broadest practical level. Even though the mapping units are large and/or complex, they can provide information for a high measure of confidence in the land use

* The authors already knew much about these needs from their many years of experience in working with the managers of arid lands.

Figure 5. Legend and accompanying ecologically based space photo map developed using frames 26A-3800 through -3802 from Apollo 9. Approximate scale is 1:780,000.

LEGEND

Symbolic Legend	Description
Numerator	
21.1	Creosote bush with few cacti or other shrubs except in drainage.
21.11	Creosote bush in nearly pure stands sometimes supporting annuals during favorable years.
21.2	Triangle bursage, foothill palo verde, saguaro often with brittlebrush. Chollas common.
21.21	Triangle bursage, foothill palo verde, saguaro, without brittlebrush. Flora not rich. Creosote bush often prominent.
21.22	Triangle bursage, foothill palo verde, saguaro, brittle-brush. Flora not rich.
21.3	Saltbush a prominent vegetational feature.
21.41	Teddybear cholla clearly the prominent vegetational feature.
21.5	White thorn, prickly pear, Ocotillo.
21.9	Flood plains and drainageways of the microphyll desert.
31.4	Desert grassland with cactus.
61.	Pygmy forests and woodlands (may have cypress, juniper, pinyon, oak).
100.	Agricultural land.
210.	Cities and towns.
Denominator 1/	
1, 1a, 1b	Flat lands, undissected and dissected.
2, 2b	Undulating and rolling land, undissected and dissected.
3	Hilly land.
4	Mountainous land.

1/ See next section for detailed descriptions.

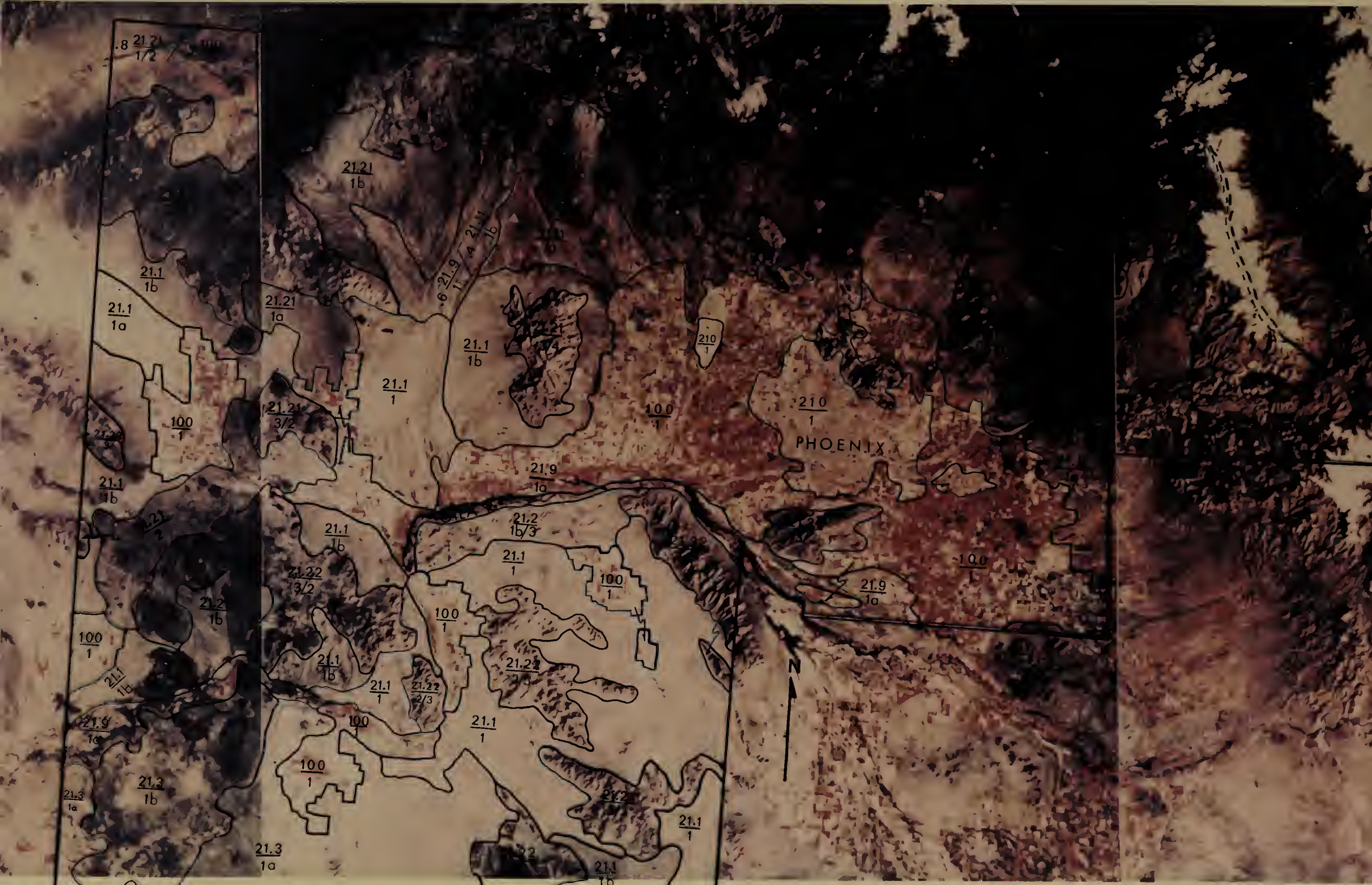

PHOENIX
N
210/1
100/1
21.9/1a
21.2/1b/3
21.1/1
21.1/1b
21.21/1b
21.21/1a
21.21/3/2
21.22/3/2
21.22/2/3
21.1/1a
21.3/1b
21.3/1a
21.9/1a
21.2/1b
21.21/1/2

Table 1. Vegetation, land use, and associated macrorelief statistics from space photo mapping in Maricopa County.

Symbolic (Mapping) Legend	Associated Macrorelief Classes 1/	Square Miles of Type	% of Area Typed
21.1	1	1,390	15.7
21.11	1	233	2.7
21.2	1 3	96	1.1
21.21	1 2	1,642	20.0
21.22	2 3 4	1,854	21.9
21.3	1	804	9.5
21.41	3	23	0.3
21.5	1 3	77	0.9
21.9	1	222	2.6
31.4	3	149	1.8
61.	3 4	99	1.2
100.	1	1,407	16.6
210.	1	214	2.5
Obscured		273	3.2
TOTAL 2/		8,483	100.0

1/ See following section for definition of classes. Classes underscored are the principal associates with vegetation (symbolic legend).

2/ Apparent discrepancies with other tables due to rounding error.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]
[illegible]	[illegible]		[illegible]

[illegible]

[illegible]

Table 2. Summary of macrorelief statistics developed from space photo mapping in Maricopa County.

Macrorelief Class 1/	Square Miles of Type	% of Area Typed
1	2,563	30.1
1a	1,008	11.9
1b	1,238	15.3
1/2 2/	356	4.2
1b/3	270	3.2
2	65	.8
2b	280	3.3
2/3	942	11.1
3/2	779	8.5
3	532	6.3
3/4	178	2.1
Obscured	273	3.2
Total 3/	8,484	100.0

1/ See following section for definition of classes

2/ Combinations of classes delineated as complex mapping units. The first class listed is the predominant one.

3/ Apparent discrepancies with other tables due to rounding error.

decision processes at the regional or county levels. Units with the same vegetation-macrorelief descriptors could be expected to respond similarly to a land-use option. For example, units labeled $\frac{21.1}{1}$ or $\frac{21.11}{1a}$ include the same types of areas as have been developed for intensive agriculture. If the need arose for additional acreages of irrigated land, these types would be the best suited. On the other hand, types $\frac{21.21}{1a/2}$ have limited value for intensive agriculture due primarily to macrorelief and/or stony soil restrictions. Aesthetically, the 21.21 types might well be judged high, thus they provide potentially suitable areas for residential development. On a national or county level, the total amount and location of lands suited to various intensive or integrated uses could be readily derived from appropriate analyses of this kind of resource inventory (Figure 5 and Tables 1 and 2).

Mapping at larger scales provides the opportunity to display similar ecologically relevant surface features of the landscape as shown in Figure 6. Geographical location of this mapped frame is shown at "B" in Figure 1. A complete high flight, photo mosaic map is being prepared from this same imagery. Although the type of information conveyed in this sample of high flight mapping is not extremely different from that shown in the space photo mapping, the scale and detail of information would be sufficient for some use at the resource management level. Again, because the vegetation-macrorelief units are ecologically based, type suitability for various land uses could be derived readily. In some cases, it would be appropriate to use the information from this type of high flight inventory for broad scale resource management or land treatment applications.

Figure 6. Sample of ecological mapping using high flight photography. Frame shown is full scale copy of color ektachrome (SO-397/2E) taken with an RC8 camera during Mission 139. Scale is 1:120,000. Entire mapped mosaic of this mission is now in preparation.

LEGEND

Symbolic Legend	Description
Numerator	
21.11	Creosote bush in nearly pure stands sometimes supporting annuals in favorable years.
21.21	Triangle bursage, foothill palo verde, saguaro, without brittlebrush. Flora not rich. Creosote bush often prominent.
21.22	Triangle bursage, foothill palo verde, saguaro, brittle-brush. Flora not rich.
21.94	Flood plains and drainageways with blue palo verde and/or mesquite with assorted shrubs that may be predominant.
92.2	Canals and ditches.
100.	Agricultural land.
215.	Developing subdivisions and small-acreage suburbia.
220.	Townsand villages.
293.	Hard surfaced highway, 2 or 3 lanes each way.
294.	Unsurfaced roads, graded.
297.	Airport facilities.
Denominator	
1a, 1b, 2, 2b, 3, 4	Macrorelief classes, in general from level to mountainous (see next section).
B	Bottomland, undesignated or unclassified as to type.
C	Alluvial plains, fans, and terraces.
Ca	Bajadas and fans.
D	Level to rolling upland, benches, mesas, and plateaus.
F	Slopes--ecologically significant by virtue of a change in vegetation and/or soil with change in slopes.


215
21.21
1b Ca
294
21.21
2b Ca
21.21
3/2 D
220
294
215
21.21
1a Ca
21.21
1b Ca
293
US 89
21.22
3 F
21.11
1a C
294
100
1a
297
297
922
21.94
1a B
21.21
1b Ca
100
1a
Whitetank Mtns.
21.22
3/4 F
Mx 139 F6193

Expenditures in Relation to Area Inventoried

Work on the vegetational resources inventory of Maricopa County commenced in late June, 1970. By September 30, space photo mapping was complete with legend modification and adaptation well under way. The major amount of field work was completed by this date with an additional eight man-days of field examination anticipated before completion of the high flight photo mosaic map in December, 1970. Up to four team members at a time have actively participated in the project. Inasmuch as work on the space photo and high flight photo maps has evolved from the same inputs, no reasonable division of expenditures could be made between the two activities (Table 3). Man-hour and dollar costs represent our best estimate for expenditures at completion of the high flight photo map construction. Expenditures do not include costs incurred in obtaining imagery or report writing. Part of the Forestry Remote Sensing Laboratory staff at Berkeley will be involved in mapping the high flight map, but because they gathered their ground information for purposes other than this map, only that portion of their expenses attributed to laboratory map construction is included in the figures.

Considering surface areas involved versus dollar or man-hour expenses, costs per unit area appear to be extremely reasonable. Comparisons with more conventional resource inventories that contain similar information would provide a realistic assessment of space and high flight photography as they are applied in resource analysis. To date, such an appraisal has not been made. The reasons are threefold: (1) Resource inventories are generally conducted for purposes of determining specific information relating to a resource, such as timber volume, grazeable acreages, or

[illegible]

Table 3. Estimated expenditures and areas inventoried for Maricopa County vegetation-macrorelief space and high flight photo map construction.

EXPENDITURES

(Subsequent to Receiving Imagery)

Item	Man-hours	Dollars *
Field	300	2,700
Laboratory	1,000	5,300
TOTAL	1,400	8,000

* Includes travel and per diem costs

AREA INVOLVED

	Square Miles	Portion of County
Maricopa County	9,238	100.0%
Space Photo Map	8,479	91.8%
High Flight Photo Map	5,787	62.6%

wildlife value. (2) Few resource inventories that employ an ecological base are conducted at a comparable degree of intensity. (3) Resource analysis cost figures are often difficult to obtain.

Summary

Space and high flight photography which covers large areas supplies one of the best mapping modes for presenting ecologically sound vegetation and related surface feature information. Such maps can provide from gross to moderately detailed information consistent with the needs of various levels of resource policy and planning.

The ecological base is phytosociological, operating on the principle that vegetation mirrors environmental equivalence and potential. As such, within the constraints of mapping scale, ecologically equivalent units can be expected to index land use potential and limitations. Once the ecology of the units is understood, considerations of resource management thus derived enable realistic land use decisions. Benefits of specific land use can be weighed against impact (desirable or undesirable) on the resource. This approach to resource inventory and analysis can provide an ideal basis for land use planning or zoning.

Although considerable expenditures of time and money are necessary for determining and portraying specific vegetation-soil system units, less detail understandably requires lower costs. Low intensity mapping is by itself useful and of low cost. In addition, it offers an opportunity for short cutting expenses incurred in intermediate and high intensity mapping. This is made possible because low intensity inventories of the type described are a necessary superstructural stratification from which detailed ecological resource analysis of selected areas can evolve.

Although costs incurred per unit area appear to be highly reasonable, additional reductions are feasible. As more understanding is achieved about vegetational signatures, we anticipate greater ease in legend modification and adaptation, reduced field time, and increased photo interpretation accuracy. Similar benefits are expected as we gain greater facility in relating photographically interpretable features of the landscape, such as macrorelief, to the techniques employed in resource inventory and analysis.

INTERPRETATION OF MACRORELIEF LANDFORMS ON APOLLO 6 PHOTOGRAPHY IN SOUTHERN ARIZONA

David A. Mouat

This report represents the initial phases of a comprehensive study of landform-vegetational relationships. Results of research reported in this section are concerned with the interpretation of macrorelief landforms on Apollo 6 photography. Six people photo interpreted macrorelief on an approximately 4,000 square mile parcel of land in southern Arizona. The study area is bounded by Tucson, Willcox Playa, Bisbee, and Nogales. Figure 1 illustrates the location of the study area.

The basis for this report is the analysis of small scale landforms on space photography. There has been a long tradition of small scale landform studies in the field of geomorphology. The reader is directed to Zakrzewska (1967), where an adequate summary of those studies is presented. There has been considerably less written, however, on small scale landform studies using space or high flight photography as a mapping base. As an example, in a chapter included in Colwell, et al. (1969), Pettinger and Benson discuss aspect and slope identification on high flight photography in northern California.

Rationale

It is one purpose of our program to accurately identify vegetation-soil systems on small scale photography. At scales of less than 1:100,000, individuals and small assemblages of plants cannot be discerned unless background contrasts are extreme. For that reason, it becomes necessary to use convergent and associative evidence for identification of

vegetation-soil systems. On small scale photography in sparsely vegetated areas, the principal image characteristics represent soil color (spectral reflectivity) and relief. This report is concerned with the relief. For accurate identification of vegetation-soil systems by using relief on space photography, two fundamental variables must be dealt with. The first of these is the theoretical interrelationship of landform-vegetation-soil systems. If there is a close correlation between landforms and vegetation-soil systems, the work of the resource analyst will be greatly facilitated (Colwell, et.al., 1969). In the forepart of this report, landform-vegetation relationships are discussed for Maricopa County, Arizona. This section represents the initial phase of a comprehensive landform-vegetation-soil system investigation in extreme southeastern Arizona. The second variable in accurate vegetation-soil system identification on space photography using landform interpretation as a key is the ability for interpreters to delineate landform classes. This latter variable is the specific subject of investigation in this section.

Procedure

The landform classes used in this report are based upon the small-scale geomorphic units developed by our project for use in resource analysis investigations. Poulton, et.al. (1969) presented a comprehensive legend system of which macrorelief was a part. For quantitative and geomorphic reasons, this investigator adapted the macrorelief portion of that legend system so that it would be most meaningful in terms of southern Arizona geomorphology. The adapted legend used for this investigation is shown in Figure 7. The six macrorelief classes are illustrated in Figure 8.

Figure 7. Mapping legend for macrorelief adapted to fit the geomorphology of southern Arizona.

Classes	Description
1	A generally flat landscape with prominent slopes less than 10 percent.
a	The landscape is essentially smooth. Dissection is minimal. The regional slope in this class is nearly always between 0 and 3 percent.
b	The landscape is relatively flat; however, dissection has progressed to a noticeable point. Dissection is either sharp and widely spaced (in which case side slopes may be over 10 percent), or gently rolling and more closely spaced. Where side slopes exceed 10 percent, microrelief is generally less than 10 feet.
2	A rolling or moderately dissected landscape with prominent slopes 10 to 25 percent (side slopes may exceed 2.5 percent in the case of dissected planar surfaces).
a	The landscape is rolling or hilly; a regional slope is not readily apparent - or - a regional slope of 10 to 25 percent is present.
b	The landscape consists of a moderately to strongly dissected planar surface (i.e. pediment, bajada, valley fill, etc.). The regional slope is generally between 2 and 6 percent; side slopes must be steeper than 10 percent. If side slopes are steeper than 25 percent, relief must be less than 100 feet. The drainage network is finer than that of 1b.
3	The landscape is hilly to submountainous; slopes are moderate to steep, predominantly exceeding 25 percent. Relief is generally over 100 feet but less than 1000 feet. Where relief approaches 1000 feet, the landform system appears to be relatively simple - with smooth slopes.
4	The landscape is mountainous, having high relief, usually over 1000 feet. Slopes are moderate to steep, frequently exceeding 50 percent. The landform and drainage systems are usually complex, with drainage networks having base levels quite independent of one another.

Figure 8. Examples of macrorelief classes taken from southern Arizona.

1a flat, smooth topography

1b flat, slightly dissected

2a gently rolling, undissected

2b gently rolling, moderately dissected

3 hilly, 100'-1000' relief

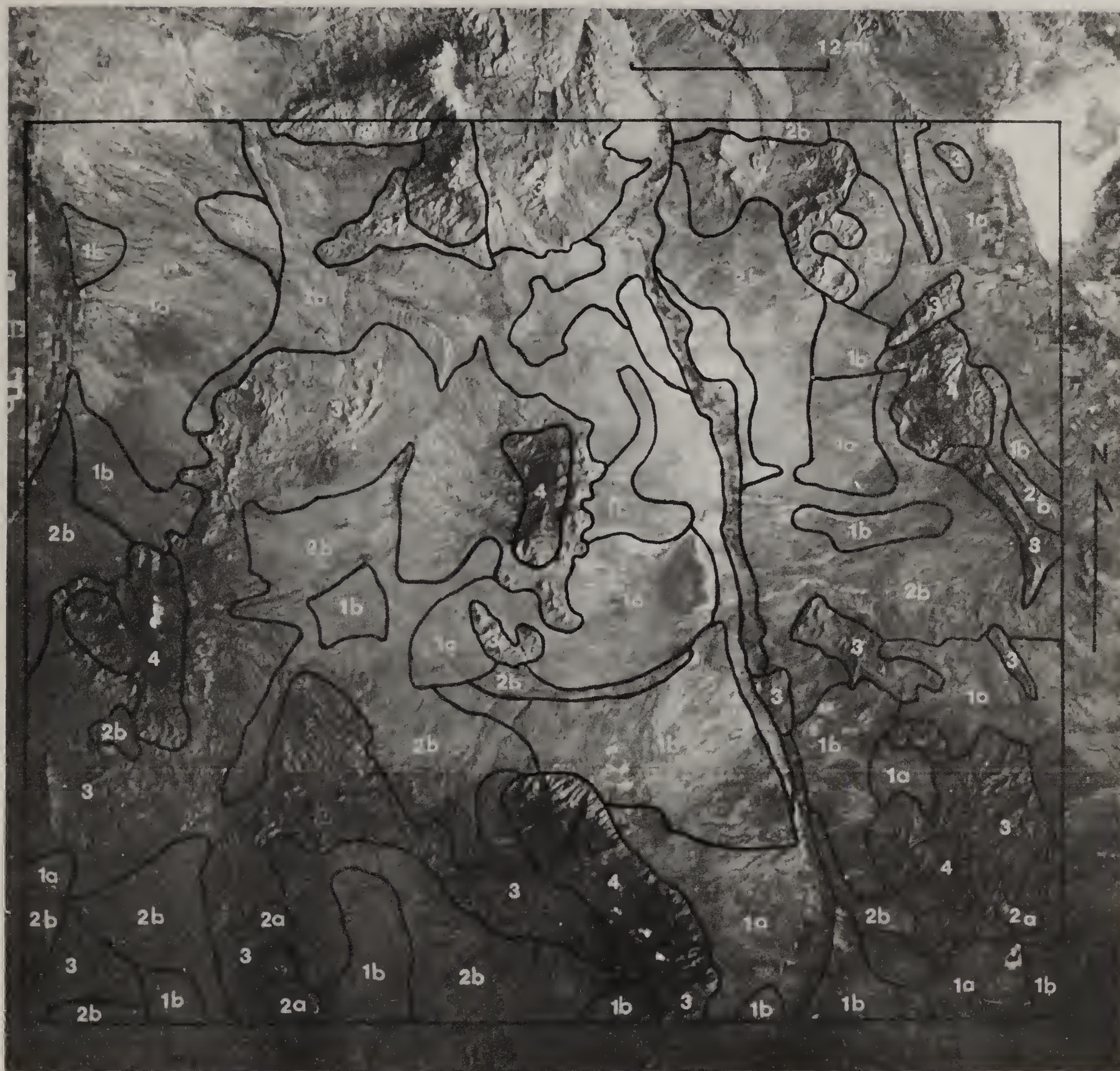
4 mountainous, >1000' relief

During the summer of 1970, field work was conducted by the investigator in the study area. Among the results of that field work was the compilation of a ground-truth map delineating the study area according to these macrorelief classes. This map was constructed at a scale of 1:250,000 using U. S. Geological Survey topographic sheets as a base. This ground truth map was next generalized and plotted on the Apollo 6 frame AS-6-1442. The map is illustrated in Figure 9.

The macrorelief legend was further adapted for use as an interpretation key so the classes might be accurately delineated on the Apollo 6 frame. This adaptation was intended to enable experimental interpreters to understand the legend system and hopefully to reach the right interpretive decision. Six people, all having had experience with photo interpretation but having varying degrees of acquaintance with the study area, with space photography, and with the macrorelief legend system, were selected to delineate the classes. The interpreters were given the same written instructions for making the delineations. In addition, an area identified by the investigator as being representative of each of the classes was circled outside the study area on frame AS-6-1443 and given to the interpreters.

The interpreters used frames AS-6-1441, AS-6-1442, and AS-6-1443 to insure full stereo coverage. They all used magnifying binocular stereoscopes. Care was taken to insure that there was no discussion among interpreters and that no extra information was given to any particular interpreter. In this way, it was hoped that results would be independent. The length of time required for each interpreter to complete his task was recorded to give us an idea of the time required for such tasks. One

Figure 9. Macrorelief of study area (on Apollo 6-1441 frame).



of the purposes was to evaluate interpretation accuracy when working without group training and to discover the kinds of interpretation problems that would need emphasis in subsequent training sessions.

Results

Data on the completed maps were compiled by determining the areas of each delineation with an electric area calculator. The delineations were summed and the percent area of each class charted. The results of the six interpretation maps are illustrated and compared with the ground truth data on Table 4. Also included in that table are the raw summed results of the relatively flat land categories (1a, 1b, 2a, and 2b) and the hilly and mountainous categories (3 and 4). In addition, an obviated error has been compensated for by adding or subtracting, as the case may be, 7 percent from the results.

Summarizing the true macrorelief of the study area, it can be seen that about 25 percent is essentially smooth (Willcox Playa falls into that category) 41 percent of the area belongs to the remainder of the relatively flat land categories (1b, 2a, and 2b). Most of that land represents dissected planar surfaces. It is interesting to note that less than 1 percent of the area is rolling topography not developed from a planar surface. Just over 25 percent of the study area is strongly hilly while the remainder, approximately 7 percent of the study area, can be considered mountainous land.

The interpreters varied quite widely amongst themselves in delineating the macrorelief and, at first glance, the results seem quite unsatisfactory. Principal errors occurred where very shallow drainage systems have a strongly contrasting vegetation associated with them than as

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[illegible]

[illegible]

Table 4. Interpretation results

Percent total area in following classes

		Relatively Flat Topography				Hilly-Mountainous	
		1a	1b	2a	2b	3	4
Interpreters	1	35	3	20	17	14	11
	2	30	17	10	16	22	5
	3	9	24	0	41	10	16
	4	20	42	2	17	15	4
	5	5	38	0	31	15	11
	6	9	29	7	29	12	14
Ground Truth		25	13	<1	28	26	7

				Alteration on Account of Principal Obviated Error (see text)	
		Relatively Flat Topography	Hilly or Mountainous	Relatively Flat Topography	Hilly or Mountainous
Interpreters	1	75	25	68	32
	2	73	27	66	34
	3	74	26	67	33
	4	81	19	74	26
	5	74	26	67	33
	6	74	26	67	33
Ground Truth		67	33	67	33

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[illegible]

[illegible]

[illegible]

found on the interfluves. This pattern suggests much rougher topography. Many interpreters had difficulty differentiating classes within the two principal categories. If the data of the individual classes are compiled in the two categories, the deviation among interpreters is not great (see Table 4). In one large area just west of the Whetstone Mountains, in the center of the study area, a bajada is dissected to such a degree that it falls into the "3" class. That area plus one other similar situation comprises 7 percent of the study area. Those dissected bajadas appeared on the imagery to belong the "2b" class. If that obviated error is accounted for, the results among interpreters compared to the ground truth data are remarkably similar.

Conclusion

From the results, it can clearly be seen that the interpretations of the macrorelief of the study area differed quite widely in terms of areal percentage of the classes. However, the results are quite similar when only the two major categories of relatively flat lands and hilly/mountainous terrain are compared. When the individual classes are compared, it must be remembered that errors of commission and omission appear to be twice as great. Macrorelief interpretation on space photography is a relatively subjective process. It is therefore essential, in lieu of the research reported in this section, to make the instructions given to the photo interpreters more clear.

In the future we plan to train the interpreters orally, assist them individually, and rewrite the instructions so that interpretation error

is minimized. It is felt that the macrorelief classes in themselves are still valid adaptations of the legend system but that the interpretation process must be more precise.

In summary, we accomplished four things in this research:

1. We adapted the resource analysis symbolic mapping legend to geomorphic considerations inherent in southern Arizona.
2. We constructed an accurate macrorelief map for the study area on AS-6-1442.
3. We discovered that photo interpreters exhibited a moderate variance in mapping the macrorelief from a written set of instructions.
4. We identified training problems in the interpretation process.

LIST OF COMMON AND SCIENTIFIC NAMES USED IN THIS REPORT

Common Name	Scientific Name
blue palo verde	Cercidium floridum
brittlebrush	Encelia farinosa
bursage	Franseria dumosa
cactus	Cactaceae
cholla	Opuntia spp.
creosote bush	Larrea tridentata
cypress	Cupressus spp.
foothill palo verde	Cercidium microphyllum
grama	Bouteloua spp.
juniper	Juniperus spp.
mesquite	Prosopis juliflora
nolina	Nolina spp.
oak	Quercus spp.
ocotillo	Fouquieria splendens
pinyon	Pinus edulis
prickly pear	Opuntia spp.
saguaro	Cereus giganteus
saltbush	Atriplex spp.
teddybear cholla	Opuntia bigelovia
triangle bursage	Franseria deltoidea
white thorn	Acacia constricta
yucca	Yucca spp.

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