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(E76-10300) THE IDENTIFICATION OF SELECTED VEGETATION TYPES IN ARIZONA THROUGH THE PHOTOINTERPRETATION OF INTERMEDIATE SCALE AERIAL PHOTOGRAPHY M.S. Thesis (Oregon State Univ.) 155 p HC $6.75 CSCL 08F G3/43 — N76-24655 Unclas 00300

AN ABSTRACT OF THE THESIS OF

George Franklin Ross for the Master of Science
(Name) (Degree)

in Range Ecology presented on December 19, 1973
(Major) (Date)

Title: THE IDENTIFICATION OF SELECTED VEGETATION TYPES IN ARIZONA THROUGH THE PHOTOINTERPRETATION OF INTERMEDIATE SCALE AERIAL PHOTOGRAPHY

Abstract approved:

In a time when increased demands are being made on our natural resources, in this case rangeland resources, methods which expedite the process of gathering information on these resources are essential. Interpretation of various types and scales of aerial photography is one of these methods which is being used to extract information concerning vast acreages of relatively unknown rangelands within a short time. As a result of this process it is necessary to know what information and how accurately it may be extracted from various types and film-filter, scale combinations of aerial photography. This study is a result of that need and attempts to evaluate the relative accuracy with which types of vegetation in southeastern Arizona may be determined through interpretation of two types of intermediate scale photography.

Two purposes of the study were to test how well the classes of an independently derived vegetation classification (at the association

level) could be interpreted on 1:34, 000 scale black-and-white aerial photography and on 1:32, 000 scale color infrared aerial photography. Another aspect of the study was to catalogue the various problems encountered with this testing. Investigators in the future could then attempt to correct or make allowances for these problems previous to testing of this nature. A comparative evaulation of different types of photography for vegetation interpretation or other interpretation purposes would then more truly reflect their respective usefulness.

Three photo interpretation tests were devised. Twelve interpreters took all three using black-and-white aerial photography. Subsequently 10 of those 12 took the three tests using color infrared aerial photography. Seven different interpreters also took the same three tests using color infrared aerial photography. The tests were designed to give increasing amounts of information as one progressed from one to three. All three tests used stereo pairs for the interpretations. They depicted the same study areas but with different orientation in color infrared than in black-and-white.

Test 1 requested the interpreters to arrange the test stereo pairs into any number of groups as long as the members of each group contained similar images of the delineated areas.

Test 2 also requested that similar test images be placed together but the interpreters were informed that there were seven classes of vegetation.

In Test 3 the interpreters were again told that there were seven vegetation classes and were supplied with identified stereo examples of each class. They were then requested to place the test photographs with the matching examples into seven classes.

Tests 1 and 2 for both types of photography were evaluated by compiling the results from the interpreters for each test into a table which was arranged according to a standard key. The resulting patterns of groups of photographs aligned with respect to the key indicated whether or not the interpreters were successful in interpreting the vegetation classes in question.

Tests 3 for both types of photography were evaluated by percentage tables for correct and incorrect interpretation responses. Totals were determined, and t-tests were made for significant differences in interpretation performance between types of photography and between interpreter groups.

Under the conditions of the test, intermediate scale photography and usually sparse southeastern Arizona vegetation, the interpretation performances with the black-and-white aerial photography were better than with color infrared aerial photography. The tables formed by the results of Tests 1 and 2 with the black-and-white photography showed more complete and more distinct patterns in relation to the established vegetation classes.

The Tests 3 results with black-and-white photography were significantly better at the 99% confidence level than with either interpreter group using color infrared aerial photography. The interpretation performance with color infrared aerial photography of Interpreter Group 1 was significantly better at the 99% confidence level than Interpreter Group 2.

The major factors influencing interpretation success appeared to be landform and vegetation pattern.

The major problems encountered with interpretation were with the color infrared aerial photography and its capabilities were probably reduced as a result. These problems were:

1. Some resolution reduction through reproduction.
2. Color was not tone balanced throughout the prints.
3. The advantage of color infrared photography was not expressed due to dormant season photography.
4. The print finish was silk and not glossy (under magnification the silk finish exhibits a grainy surface which interfers with image identification).
5. The example photographs were either unrepresentative or insufficient in number to show the increased variability in image pattern which was introduced by color.

The most consistently identified vegetation classes in all tests were:

Class	Vegetation Type
3	tobosa grassland
4	burroweed - lovegrass grassland
2	yucca - grama - three-awn grassland
7	mortonia mixed shrub-grassland

The least consistently identified vegetation classes in all tests were:

Class	Vegetation Type
5	ocotillo - acacia - aloysia - grama mixed shrub-grassland
1	acacia - creosotebush - tarbush shrubland
6	agave grassland

These tests evaluated interpretation performance at the association level of classification. Many of the errors that were made were only in level of classification. At a broader level of classification such as grassland, shrubland or mixed shrub-grassland, a greater percentage of the interpretations were correct.

The Identification of Selected Vegetation Types in Arizona Through the Photointerpretation of Intermediate Scale Aerial Photography

by

George Franklin Ross

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THE IDENTIFICATION OF SELECTED VEGETATION TYPES IN ARIZONA THROUGH THE PHOTOINTERPRETATION OF INTERMEDIATE SCALE AERIAL PHOTOGRAPHY

INTRODUCTION

Remote sensing has become an extremely useful tool in today's fast-moving world. It can provide timely, accurate information on certain conditions of the earth's atmosphere, surface and subsurface in small to very large scale treatments. Indications are that remote sensing will play an increasingly important role as applied technology is developed to reduce cost and extend its usefulness to more people outside the scientific and research community.

Aerial photographs are the oldest and one of the most useful of the remote sensing tools. Rangeland managers are particularly interested in the vegetation and the myriad of conditions which it can reflect. Since a wide variety of types and scales of aerial photography are being used for rangeland management and planning, it is important to know how accurately information can be determined from certain scales and types of aerial photographs.

Several problems are inherent in the photointerpretation of vegetational features in arid regions. One problem is scale. At smaller scales landforms and drainage patterns become the overriding features. At intermediate scales, due to the oftentimes sparseness of the vegetation, the soil plays an important role as an image feature and may cause confusion unless vegetation-soil relationships are clearly indicated. At large scales, cost becomes more important, and increased detail may or may not be helpful.

Another problem is type of photography -- whether to use color, black-and-white, or color infrared. Black-and-white aerial photography is the least expensive and enables the best quality control. Color aerial photography gives the most "natural" view, but expense is greater, quality control is more difficult, and the increased discrimination of detail provided by color may or may not be useful, depending on the objectives. Color infrared is generally considered to be the most useful for vegetation studies due to the film's sensitivity range and the reflectance characteristics of vegetation in the near infrared region. The expense is slightly more than color and the quality control is even more difficult to maintain.

An additional problem is season of photography. Vegetation in my study area, southeastern Arizona, is best studied during the growing season which is mid- to late-summer, although some types of vegetation are best discriminated in the dry season. It has been difficult to study the relative merits of different types of aerial photography because we were unable to obtain two different types of photography flown over the same area, at approximately the same time of year, at approximately the same scale, and with equally good quality control.

Interest in this study was brought about by the classification of the vegetation on a large tract of land in the vicinity of Tombstone, Arizona, by Garcia-Moya (1972). He classified the vegetation into a hierarchical system using a computer technique. During the study he carefully located his 389 ground study points on aerial photography. After the classification was completed, he prepared vegetation maps based on his classes and on image comparisons made at the ground data points. These maps provided an excellent ground truth record for the study area. In addition, several kinds and scales of aerial and space photography are now available for this tract of land. These two factors -- the availability of vegetation mapping as ground truth, and good aerial photographic coverage of the same area -- gave an excellent opportunity to do a study of the interpretability of the rangeland vegetation of the Tombstone vicinity on intermediate scale photography.

The major problem in making full use of remote sensing capability for rangeland inventories or monitoring is knowing the reliability with which vegetational features can be photoidentified. In the setting of this study, the problem has three facets: (1) How well does an independently derived phytosociological classification of the vegetation provide useful classes for photointerpretation? (2) At what levels do these vegetation classes correspond to image classes? (3) How consistently and at what accuracy levels can meaningful image classes be interpreted?

The purpose of this study is to determine whether vegetation associations as they have been independently classified produce characteristic images on aerial photography which will allow an interpreter to recognize and distinguish them from each other. The specific objectives of this study are:

1. To determine the reliability of vegetation image interpretation at the association level on 1:34,000 scale black-and-white aerial photography.
2. To determine the reliability of vegetation image interpretation at the association level on 1:32,000 scale color prints made from 1:114,000 color infrared positive transparencies.
3. To compare the problems encountered in photointerpretation tests with these two types of photography as guidelines for future work of this nature.

The photointerpretation testing was limited to the 164,000-acre area around Tombstone, Arizona, on which vegetation mapping was available for ground truth and for which photography was already available through the Environmental Remote Sensing Applications Laboratory and the Arizona ERTS-1 experimental project at Oregon State University. Intermediate scale photography was used as a cost compromise between the amount of area covered per frame and the detail resolved. The black-and-white photography was taken in September of 1971 at a scale of approximately 1:34,000.

The color infrared photography used requires a more detailed explanation. I had hoped to compare black-and-white photography with original color infrared photography at approximately the same scale. The only high quality, cloud-free color infrared photography available for the same area was flown at an approximate scale of 1:114,000 in December of 1972. It would have been very expensive to enlarge the full 9" x 9" frames to obtain stereoscopic coverage of the study area. Also, with full frame enlargements, stereo viewing would have been impossible with the equipment available. To avoid these problems, it was decided to copy and enlarge only the portions of the 1:114,000 frames necessary for testing purposes. Stereo models at approximately 1:32,000 scale were prepared for each test site. The technique for preparing this photography is described in Appendix A.

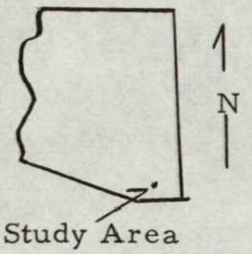
AREA OF STUDY

The study area is a 164, 000-acre tract of land surrounding Tombstone, Arizona, in Cochise County (Figure 1).

Just outside the boundaries of the study area are the Dragoon Mountains to the north and northeast, the Mule Mountains to the south and the San Pedro River to the west. Probably early in the Pliocene and under the influence of regional rather than local forces, the area was torn by great normal faults which blocked out the above major topographic features that have survived to the present day. The San Pedro Valley, an intermontane trough that includes the study area, was formed at this time and largely filled by fan gravels and associated playa deposits from the adjacent mountains. Later in the Pleiocene, erosion scoured out much of the San Pedro Valley fill and permitted the development of the Tombstone pediment which has been dissected to older levels along its drainages until the present-day, complex formations have been exposed. The Tombstone Hills, lying in the west-central portion of the study area, are practically the only elevated features within the study area. The exposed hills are composed of limestone called the Horquilla, Earp and Colina formations of Pennsylvanian and Permian ages (Gilluly, 1956).

The elevation varies in the area from approximately 4, 000 to 5, 500 feet above sea level. There are four major landforms: hilly

Figure 1. Study area in southeastern Arizona.
This half-tone reproduction of an Earth Resources Technology Satellite-1 image is delineated to show the major topographical features. The scale is approximately 1:300, 000.



lands; rolling, moderately dissected lands; flat, slightly dissected lands; and flat, smooth lands. The hills, which are composed of limestone, sandstone, and shale, have predominantly rocky, loam soils. Gravelly clay loams are developed upon the dissected landforms and sandy loams are developed upon the smooth land forms (Gelderman, 1970).

The climate is warm and semiarid with a mean annual temperature of 63.1°F and an average 239-day frost-free season. The annual precipitation occurs mostly during the summer months July and August and the first half of September (Green and Sellers, 1964).

Most of the study area is used as rangeland, the present condition of which depends on its past grazing and fire history and the potential of each particular site. The vegetation in the study area consists of three main physiognomic types: (1) shrub types, (2) grass types, and (3) mixed shrub-grass types. Shrubby vegetation types comprise the major portion of the study area. The main species in the shrub type are *Acacia vernicosa* (mescat acacia), *Larrea tridentata* (creosotebush), *Flourensia cernua* (tarbush) and *Mortonia scabrella* (mortonia). The major grasses of the grass type are *Bouteloua eriopoda*, *B. curtipendula*, *B. hirsuta* (grama grasses); *Aristida barbata*, *A. divaricata*, *A. lanlulosa*, *A. pansa*, *A. wrightii*, *A. glauca* (three-awn grasses); *Hilaria mutica* (tobosa); and *H. belangeri* (curly mesquite). The major species of the shrub-grass type are the shrubs *Acacia constricta* (whitethorn), Fouquieria splendens (ocotillo), and Aloysia wrightii (Wright lippia); and the grasses Bouteloua curtipendula (sideoats grama), B. eriopoda (black grama) and Eragrostis intermedia (plains lovegrass) (Garcia-Moya, 1972).

Garcia-Moya (1972) classified the vegetation into broad physiognomic types which resulted in 3 alliances including 9 associations and 23 subassociations and in 4 unallied associations with 8 subassociations (Appendix B). In other words, nine of the associations had a vegetation composition which related them to one or more of the other associations within an alliance, whereas four associations were distinct or unallied with any other similar vegetation within the study area. This enabled one to group the vegetation into 7 categories of 3 alliances and 4 unallied associations. Garcia-Moya mapped the area at the association and sometimes down to the subassociation level. These seven groups (Table 1) were used for testing purposes in this study.

Table 1. Seven test classes. The vegetation type and the % non-vegetated ground are shown for each association.

Test Class	Alliance	Association	Vegetation Type	Percent Non-Vegetated Ground
1	I	A	Shrub	46
		B	Shrub	47
2	II	C	Grass	25
		D	Grass	35
		E	Grass	40
		F	Grass	33
3		G	Grass	15
4		H	Grass	23
5	III	I	Mixed shrub-grass	25
		J	Mixed shrub-grass	32
		K	Mixed shrub-grass	31
6		L	Grass	44
7		M	Mixed shrub-grass	31

LITERATURE REVIEW

A review of the literature indicates that the type of film, the scale and the season of photography which should be used should be determined by the objectives of the study. No single scale, type or season of photography should be considered suitable for all purposes.

Jenson and Colwell (1949) stereoscopically compared panchromatic-minus blue, versus infrared minus-blue[1] aerial photography for forestry purposes in California at scales of 1:15, 000 and 1:20, 000. The objectives were to survey (1) the kind of vegetation cover and other conditions occupying the land; (2) the densities of timber stands and all woody vegetation; (3) the age classes of the tree stands; and (4) the segregation of timber croplands from other lands. The panchromatic minus-blue was found to be superior over all the study objectives, but the infrared minus blue was found best for the separation of hardwoods and conifers. They recommended the use of both for total information and cautioned that the most suitable film-filter-scale combination was a local problem dependent on the vegetation and the objectives to be achieved.

In 1960, Colwell studied the uses of panchromatic photography and infrared photography for the management of wildland areas in California. Using the 1:10, 000 and 1:20, 000 scales of photography

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[1] Any reference to infrared photography is black and white unless color infrared is specified.

used for range surveys, he found infrared more useful for differentiating between areas of rangeland having a dense growth of grass, with a high animal-carrying capacity, and areas having a sparse growth of grasses with a low animal-carrying capacity. He also said that panchromatic was better for some other purposes but that using both provided much more information than either used alone. In 1961 Colwell published an expanded study on foothill range in Contra Costa County, California. He studied panchromatic, infrared, color and color infrared for their usefulness in determining range conditions of herbage volume and species composition. He compared these types of aerial photography at four scales ranging from 1:2, 000 to 1:20, 000 and taken at four different seasons, spring, summer, fall and winter. The optimum time for a study of this nature was determined to be late spring when the sparse vegetation on shallow soils has turned brown, whereas dense vegetation on deep soils was still green. 1:5, 000 color film with a haze filter was found best with the same scale panchromatic with a light-red filter next best.

Spurr (1949) found infrared minus blue to be more useful in the eastern United States where he considered the separation of conifers and hardwoods to be more important. He recommended that test strips be taken to decide the film-filter-scale combinations best to use for local conditions and study objectives.

Using 1:7,200 scale, Schulte (1951) compared panchromatic, infrared and color aerial photography for the identification and distribution of eight major tree species in southeastern Canada. For the objectives of the study, he found infrared to be preferable over the other two, considering them about equal. However, in his summary he states that panchromatic is better in the tundra of the North and the grasslands of the plains, where the vegetation is all more or less shrubby, since it produces more tonal differences and detail. One of the most important aspects of vegetation interpretation according to Schulte is the knowledge of what type of vegetation to expect as determined by the soils, climate, drainage, and vegetation zones. In other words, familiarity with the study area and its vegetation is essential for vegetation interpretation.

Brunnschweiler (1957) studied crop identification with 1:13,000 scale black and white aerial photography. He found that different dates of photography offer the optimum for different interpretation purposes and that most crops and all land use types have specific pictorial characteristics which are a function of time (which corresponds to plant phenological development) rather than place. Again, familiarity with the study area and its vegetation helped a great deal in obtaining maximum results through photointerpretation.

Inventory and estimation of commercial forest area and timber volumes are the foremost aims of extensive forest surveys of interior

Alaska. Under interior Alaska conditions, Haack (1962) found that infrared film was better for distinguishing between vegetative types and stand sizes and for the measurement of tree heights than panchromatic or color. Each film type (1:5, 000 scale) was ascertained to have desirable features. The superiority of the infrared was shown by the interpreters' ability to differentiate between softwood and hardwood components of mixed stands. The cost of color was considered prohibitive since it did not produce superior results. The panchromatic was found to be best for ground detail.

In 1945 a new dimension, color, was added to aerial photography. Smith (1963) said that since 1959 it was no longer true that panchromatic was better than color for resolved details. He went on to say that with the new film types and new processing methods, color aerial photography worked best for Coast and Geodetic Survey purposes and that obtaining color did not add appreciably to the total survey cost over panchromatic coverage.

Through a photointerpretation test, Anson (1966) evaluated 1:30, 000 panchromatic, color and color infrared aerial photography for mapping drainage, vegetation, soils and cultural features. Using features identified on the ground as controls he established that color infrared photography was superior to color and panchromatic for mapping vegetation and drainage; and that color photography was superior to panchromatic and color infrared for mapping soils and cultural features.

For ecological surveys of savannah regions of Africa, Wickens (1966) found 1:20,000 to 1:40,000 scale panchromatic aerial photography satisfactory for broad scale mapping. Culver and Poulton (1968) found panchromatic aerial photography to be suitable for mapping eastern Oregon rangelands at the simple taxonomic unit level (single vegetation-soil system). Munn _et al._ (1966) mapped rural land use in Canada and found infrared to be more reliable than panchromatic for crop identification and acreage estimates. Carneggie and Lauer (1966) backed up conventional panchromatic photography (1:15,840 and 1:20,000) with imagery from the thermal infrared and radar bands of the electromagnetic spectrum. They found that using them together provided much more detailed information on vegetation boundaries, grazing units of varying vegetation density, annual and perennial vegetation, non-productive areas, soil moisture relationships, water supplies and eroded areas.

Carneggie (1968) applied remote sensing technology for improving range resource inventories. He evaluated four types of photography for their relative usefulness for determining vegetation, soil, and moisture characteristics on perennial bunchgrass-sagebrush range in northeastern California. The four film types at a scale of 1:8,500 were:

1. Panchromatic (Plus X, type 240) minus blue filter
2. Infrared Aerographic (type 5424) Wratten 89B filter
3. Ektachrome Infrared Aero (type 8443) Wratten 15 filter
4. Ektachrome Aero (type 8442) haze cutting filter

> It was concluded, however, the Ektachrome Infrared Aero photography, due to its distinctive color characteristic and sensitivity to energy wavelengths in both the visible and near infrared position of the spectrum (.5 to .9 micron) was the most useful for identifying the greatest number of range features and mapping vegetation-soil boundaries. In addition, Ektachrome Infrared Aero photos were most useful for (1) analyzing moisture regimes such as springs, ponded water and marshy vegetations; (b) determining the relative cover of forage in many of the vegetation types, and in this manner making qualitative estimates of the productivity of one range site relative to another; and (c) identifying important browse species.
>
> It should be realized that while the evaluation made for these four film types applies to the specific kind of range environment included in this study, it does not necessarily apply in all range environments. In fact, there is evidence that Ektachrome Infrared Aero photography would offer little additional advantage when compared to panchromatic photos for the mapping of vegetation -soil types in very arid environments where the cover of herbage is very low and where moist areas are few and far between. That the Ektachrome Infrared Aero was found to be so useful in northeastern California is attributed to the great variety of vegetation types, soil types and surface conditions, and to the presence of numerous types and surface conditions, and to the presence of numerous marshy and moist sites, all of which are readily discerned more readily (sic) on color infrared photography. (Carneggie, 1968, p. 375)

Pettinger (1969) used high altitude (1:150,000) photography for mapping vegetation cover at Bucks Lake Test Site in California. He typed and delineated ground cover into six broad categories with the minimum aerial extent being 160 acres. He found color infrared to be more suitable than infrared or panchromatic. He concluded that while cover type features were not as easily discriminated as on color infrared that typing could be done fairly consistently on panchromatic.

In comparing film types for crop identification in Maricopa County, Arizona, Drager et al. (1970) found Ektachrome MS aerographic (2448) film to be the best overall compared to four other film types. However, the tests were conducted with Ektachrome and Infrared Ektachrome at a scale of 1:120, 000 while the Panchromatic-25, Panchromatic-58, and the Infrared 89B film-filter types were as a scale of 1:500, 000. The authors stated, "It was realized at the outset that the scale differences between RC-8 and Hasselblad imagery would probably affect the success with which crop types could be distinguished." Since it was the only imagery available, the scale differences were accepted as another constraint within which the test had to be administered.

The literature shows that aerial photography for range information purposes is gradually taking a trend toward the more sophisticated types of photography.

> In spite of the problems associated with interpretation of vegetational resources from conventional panchromatic photography, this system of remote sensing is greatly underdeveloped in relation to its potential contribution. (Poulton, 1970, p. 28)

He goes on to explain that in the past black and white aerial photography was not well used due to problems with quality and reluctance to spend funds for photography especially suited to the needs of the range resource analyst. Presently black and white photography is being pushed aside due to interest in more sophisticated systems, but with its low cost and the flexibility with which it can be used, we should not be too quick to discard the present high quality black-and-white photography.

One of the primary objectives of this study is to determine the interpretability of rangeland vegetation at a specific level of classification on specific scales and types of photography. With Garcia-Moya's (1973) dissertation in mind, Poulton (1972) wrote:

> We immediately saw the need also to demonstrate a vegetational classification approach that was hierarchical and that would produce classes that were sound from the plant sociological point of view as well as useful in remote sensing image interpretation under a multistage concept where both broad and highly specific vegetational classes would be required. (Poulton, 1972, p. 15)

The reasoning in the preceding two paragraphs brought about the determination to conduct tests to learn the compatibility of specific image classes with specific vegetation classes using black and white and color infrared aerial photography.

Predominantly these workers have used three approaches to the evaluation of various types and scales of aerial photography. In one approach the investigator supplied his own ground truth information and also did the interpretation. He did this by selecting a key area, interpreting aerial photography of it according to the purposes of his study and then preparing a guide by ground checking this area. Using the material prepared for the key area as a guide, he then interpreted aerial photography of a larger area and subsequently checked his results on the ground. In this manner he compared the effectiveness of different types and scales of aerial photography in providing the desired information. Schulte's (1951) work is illustrative of this approach.

Another approach was for the investigator to interpret aerial photography and check the accuracy of his results with information supplied by ground survey crews. This approach is typified by the work of Anson (1966).

The third and most popular approach is where the investigator(s) worked alone or with ground survey crews in collecting specific ground truth information. He then prepared aerial photography training aids with which he trained a group of interpreters. The interpreters subsequently interpreted different types of aerial photography according to the purposes of the study. Then the investigator compared the results and decided on the best type and scale of aerial photography of those used for the purposes outlined in his study. Carneggie's (1968) work is an example of this approach.

METHODS

Data Acquisition and Analyses

The vegetation maps made for the study area by Garcia-Moya (1972) were on clear acetate overlays for individual frames of 9" x 9" 1:34, 000 black-and-white aerial photography. He mapped primarily at the association level. In order to get a clear picture of the vegetation on the study area as a whole, it was necessary to compile these into one map. The author did this by preparing an overlay for a 40" x 40" uncontrolled mosaic of the study area laid by Faulkner of the Environmental Remote Sensing Applications Laboratory. The individual frames were viewed in stereo through the overlays delineating the vegetation types. These delineations were transferred to a single, large overlay for the mosaic with the type lines matched between the stereo models. Ground study points, representing Garcia-Moya's ground data locations, were pinpointed on another overlay.

The black-and-white aerial photography used in this study was taken by commercial contract. A 6" focal length camera with a minus-blue filter was used from an altitude of 17, 000 feet above mean sea level. The color infrared photography was flown by a NASA U-2 with an RC-10 6" focal length camera from an altitude of 65, 000 feet above mean sea level.

Black-and-White Aerial Photography Interpretation Testing

Interpretation tests, based on the actual ground examination points of Garcia-Moya (1972), were performed on stereo pairs cut from high quality black-and-white prints. Volunteer interpreters representing a wide range of experience were used. The first step was to select a representative sample of the ground truth sites. Candidate test sites were chosen by random drawing and screened for acceptability on the basis of four criteria. The following are the screening considerations:

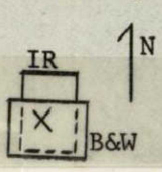
1. Each interpretation test site must be a reasonably typical example of one of Garcia-Moya's associations.
2. Each of the photo image types corresponding to an association must be represented in the sample set and there must not be too many, in order to maintain interest in the tests.
3. The ground truth site must be within a reasonably homogeneous delineation which is correspondingly identified and which comprises at least one-third of the area of the stereo pair.
4. Any two test sites for the same association must be far enough apart that a stereogram for each could be made without overlapping.

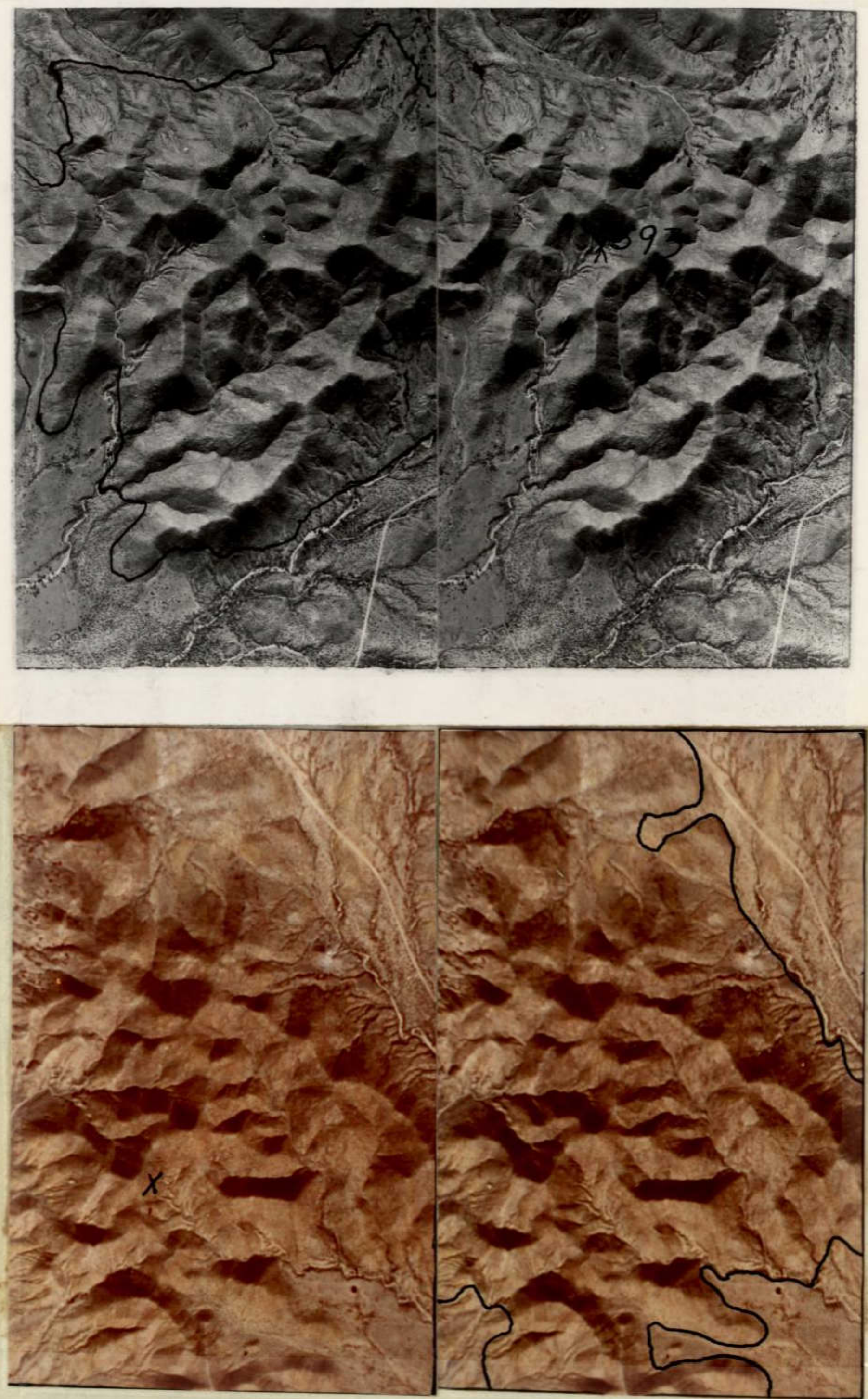
Random numbers were selected until three test sites were chosen for each of the allied associations and four test sites for each of the unallied associations, plus one test site for each association to be used as a training example. Thus a total of 56 test sites were selected.

Forty-three test sites were felt to be compatible with a maximum time limit for tests of about an hour's duration. Since the vegetation within the alliances was related, as were their images, it was felt that fewer test sites were necessary to represent these similar vegetation groups.

After the test sites were selected, photography to make the stereo pairs was ordered. Since much depends on tone contrast and consistency in panchromatic photography, sample prints were ordered first in a range of specifications for exposure, paper type and contrast and printing technique. The best examples were Log-Etronically printed on single weight, high contrast paper, with medium exposure for optimum and consistent tone balance. A full set was then ordered to these specifications with Log-Etronic printing to insure uniformity. The 56 test and example sites were located on these prints and a 2-1/4" by 3-1/2" clear plastic template was used to mark out stereograms around each ground sample point. The stereograms were made so that at least one-third of the area shown contained homogeneous vegetation surrounding each test site. On one print of each stereo pair the test site, or ground data point, was marked with an X, and on the other the surrounding vegetation type was delineated according to the work of Garcia-Moya (1972). Therefore, when viewed in stereo, each X appeared within definite boundaries which contained the image of interest (Figure 2). By use of a "blink" technique the interpreter could also examine the exact ground truth location without obstruction.

Figure 2. Example black-and-white and color infrared stereo pairs. Both sets of photographs represent the same ground study point but have a different orientation to prevent recognition.





Each stereo pair was cut out and glued to 5" x 8" cards to facilitate ease of handling and stereo viewing. These were placed on the card in proper orientation to the flight line and spaced for stereo viewing by "naked-eye" or with a pocket stereoscope. An identification number was placed on the front of each card and keyed to show the identification of the subject vegetation in the stereo pair. Only the author had access to this key.

Three black-and-white and three color-infrared aerial photography interpretation tests were given using the above stereograms. The tests were designed so that increasing amounts of information were supplied with the second and third tests with each type of photography.

The next step was to make an experience and background information sheet for the interpreters and a test sheet with instructions for each of the three black-and-white and three color-infrared interpretation tests. The information sheet was a questionnaire to determine each participant's background and experience (Appendix C1). The instruction sheets for performing the black-and-white tests are illustrated in Appendix C. My objective was to have at least ten people perform the three black-and-white tests and also the three color infrared tests. Twelve interpreters with a wide variety of photointerpretation experience took the three black-and-white tests. Ten of the 12 also volunteered to take the three color infrared tests after a waiting period of at least two weeks. It was felt that some bias might be introduced, through carryover, into the results of the color infrared tests. It was hoped that this delay would eliminate most of the bias.

There were two reasons for conducting the full battery of tests with the same interpreters. It is difficult to find 50 to 60 different people to take the individual tests. Also, it is difficult to comparatively evaluate results compiled by different interpreters due to differences in interpreter ability and experience.

Tests 1, 2, and 3 for the black-and-white interpretation are detailed below.

Test 1: Black-and-White

Test 1 was given to 12 people with experience ranging from 0 to 20 years. The 43 stereograms were given to the participants with instructions to view the designated areas stereoscopically and to sort them into any number of groups with similar image and subject characteristics. In this test there was no right or wrong. The main objectives were: (1) familiarization with the material, and (2) determination of the consistency with which individuals could group images into meaningful classes but without respect to the specific subjects represented. It was also intended to determine the range in number of initial groups and if there were any relationship between these groups and the seven classes used in Test 3. The other objective of

Test 1 was to determine which of the images were consistently grouped together and which images were particularly difficult, as evidenced by being consistently alone or erratically placed.

Test 2: Black-and-White

In Test 2 the same 12 participants were given the 43 stereograms and asked to place the designated images into seven groups which looked the most alike. The purpose of this was to see if specification of the number of subject classes enabled volunteers to make better decisions. This information was supposed to enable interpreters to have confidence in splitting groups if they had made too few in Test 1, or in consolidating the test samples if they had made too many in Test 1. Informing the participants that there were seven classes forced them to make a decision on image variability in relation to the subject or on variable image features that may have been separately grouped in Test 1.

Test 3: Black-and-White

Again in Test 3, the same 12 people took the test. In addition to the information that there were seven classes, they were given 13 example stereograms of the 13 associations which represented the range of image variation in the seven classes. Associations A and B formed Class 1: C, D, E, and F formed Class 2; G was Class 3;

H was Class 4; I, J, and K were Class 5; L was Class 6, and M was Class 7 (see Table 1). The test participants were asked to organize the 43 test stereograms into seven classes by placing each stereogram in a group which contained the example image with which it matched the best. The purpose here was to provide a specific subject guide and test example upon which the results could be statistically evaluated.

Color Infrared Aerial Photography Interpretation Testing

The three tests which were conducted on the color infrared were the same as those conducted with the black-and-white, except for two details. One difference was to change the orientation of the long axis for viewing of the stereo pairs. It was hoped that this would minimize carryover bias for those performing both tests. The flight lines for the black-and-white photography were north-south, and the long axis of the stereo pairs were east-west. The color infrared photography was flown east-west, and the long axis of these stereo pairs was north-south. As a result, even though the same ground truth locations were covered in both types of photography, the areas covered by the stereo pairs were slightly different. Secondly, seven new interpreters took the color infrared tests. The experience range of these interpreters was comparable to the ten interpreters who had taken both sets of tests. The purpose of this was to see if a significant amount of learning from the black-and-white tests allowed the first ten interpreters to do better than the seven interpreters who took only the color infrared tests.

Analytical Methods

The results of each test in black-and-white were analyzed the same as the results from the comparable test with color infrared. The purpose was to compare similarities of groupings between interpreters when all results were aligned against a key. The results of Test 1 for each interpreter were arranged in tables keyed to the known identity of each image (Tables 2 and 3). Each group established was placed in an individual column with the identity number of each test image aligned in the row corresponding to the same number in the key. A complete table of the groups established by each interpreter with each row corresponding to only one test image was made in this manner. Each column representing an interpreted group of similar test images was then cut into a strip. The columns were then rearranged to detect patterns or similarity in the results of the interpreters.

The groups resulting from Test 2 were also arranged into individual columns with each image identity number keyed to the row corresponding to the known identity. Here it was easier to detect patterns when the columns were rearranged because of the limited number of groups.

Table 2. Raw data results of one interpreter for Test 1: Black-and-White - Interpreter Group 1.

Interpreter: BS

Date: May 14, 1973

Image sets:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	485	656	388	446	589	650	696	431	548	569	593	602	652	420	558
	495	738	459	679	686		697	516	690	663	596	605	753	566	747
	683	745	407	782				534		746	728	635		768	755
			732					616							
								688							
								699							

The 3 digit numbers in the table are code numbers assigned to each of the stereo models.

Table 3. Raw data from Table 2 for one interpreter of Test 1: Black-and-White - Interpreter Group 1 organized with respect to the key.

KEY			Image Sets														
Associations		Test Sites	3	9	8	7	4	2	1	6	14	10	13	11	12	15	5
Alliance I	A	388	388														
		459	459														
		589															589
	B	407	407														
		548		548													
		732	732														
Alliance II	C	431			431												
		688			688												
		690		690													
	D	696				696											
		697				697											
		699			699												
	E	516			516												
		534			534												
		616			616												
	F	446					446										
		679					679										
		782					782										
	G	495							495								
		656						656									
		738						738									
		745						745									
	H	485							485								
		650								650							
		683							683								
		686															686
Alliance III	I	652											652				
		663										663					
		728												728			
	J	566									566						
		753											753				
		768									768						
	K	420									420						
		569										569					
		605													605		
	L	593												593			
		596												596			
		602													602		
		635													635		
	M	558														558	
		746										746					
		747														747	
		755														755	

Tests 3 were also arranged into keyed tables for a visual appraisal of the results. Also, Test 3 for each type of photography was analyzed by tables of omission and commission. Tables of omission and commission show what are called Type I and Type II errors in statistics. Omission errors, Type I, are the correct responses which are left out of a particular group. Commission errors, Type II, are the incorrect responses which are included in a particular group. The tables show the actual number of correct responses, the number of Type I and Type II errors, the percent Type I and Type II errors, and the total percent correct and incorrect.

Students' t-test was calculated to determine if there was a significant difference in performance between each of the number 3 tests. A correlation coefficient was determined to indicate the relationship between success and experience in Test 3 - Black-and-White - Group 1. Also a normal approximation to the binominal was used to determine the number of test images which must be correctly identified in the number 3 tests in order to show that the results were not random.

RESULTS

General

One of the problems encountered with photointerpretation testing is the varying levels of experience of the interpreters. In order to be able to conduct statistical comparison tests, one must be able to numerically rank his interpreters in relation to each other. Before these tests, each interpreter was asked to fill out an information sheet which, it was hoped, would supply the necessary information to rank interpreters based on previous experience with aerial photography (Appendix C1).

It was found that the information sheet was not satisfactory to place interpreters along a scale of integers beginning with 1 for no experience and increasing with experience. I was able to separate the interpreters only in a more general way, that is, to place them in one of three categories: low, intermediate, and high experience. All the interpreters in each of these groups were by no means equal but at least were more closely related to each other than to the other two groups (Table 4).

For statistical analysis, in Test 3 the interpreters in the low group were arbitrarily assigned a numerical value of one, in the intermediate group a numerical value of three, and in the high group a value of five. The three groups may not be equidistant from each

Table 4. Experience of Interpreters.

Black-and-White Tests 1, 2, 3
Group 1 (12 people)

Experience Rating	1 Low (0-1 year)	3 Intermediate (1-3 years)	5 High (3+ years)
	EP	JJ	DF
	JH	BS	CP
	CA	DM	
	NL	GM	
	KM	JC	

Color Infrared Tests 1, 2, 3
Group 1 (10 people - repeats)

Experience Rating	1 Low (0-1 year)	3 Intermediate (1-3 years)	5 High (3+ years)
	EP	JJ	DF
	CA	BS	CP
	KM	DM	
		GM	
		JC	

Color Infrared Tests 1, 2, 3
Group 2 (7 new people)

Experience Rating	1 Low (0-1 year)	3 Intermediate (1-3 years)	5 High (3+ years)
	DS	CW	JN
	CS	BP	TL
			RR

other in reality, but faced with the impossible task of assigning more meaningful values to the interpreters' experience levels, the categories are suitable for the analyses undertaken here.

In the low group were placed people with less than one year of experience, in the intermediate group one to three years of experience, and in the high group three-plus years of experience.

X is a random variable denoting the outcome of classifying a picture correctly,

$$X = \begin{cases} 1, & \text{if the picture is classified correctly} \\ 2, & \text{if the picture is classified incorrectly} \end{cases}$$

The formula $\sum_{i=1}^{43} x_i = SN$, is the total number of correctly classified and S_N has a binomial distribution.

In each Test 3 we wanted to test the null hypothesis that each interpreter was classifying the stereo pairs at random against the alternative that he was not doing it randomly, i. e.,

$H_O: P = 1/7$ (there are 7 categories, therefore, the probability that a stereo pair was put into the correct category if assigned randomly is 1/7)

$H_1: P > 1/7$

The author used the normal approximation to the binomial to find the critical region. That is, I wanted to find a number, K, $0 \leq K < 43$, such that if an interpreter classified more than K pictures correctly, then we could not accept that H_0 and must conclude that there are too many pictures classified correctly to say that the interpreter was classifying the pictures at random.

For a confidence level of 95%, $\alpha = 0.05$, we have

$$P\ (5_N \leq K) \doteq \emptyset \frac{K-Np}{\sqrt{N_p(1-p)}}$$

From a normal table, we have then that:

$$\frac{K-Np}{\sqrt{N_p(1-p)}} = 1.645$$

and

$$K = 1.645\sqrt{43 \cdot 1/7 \cdot 6/7} + 43 \cdot 1/7$$

$$K = 9.9175.$$

From the above, we can conclude with 95% confidence that any interpreter who identified more than ten stereo pairs correctly was not doing it at random and was actually able to see image similarities between the vegetation on the test and the example stereo pairs. From the 29 individual sets of interpretations which took place in all of the number 3 tests, the least number of images which were correctly identified was 15.

Students' t-test, Table 5, was calculated for significant difference in performance at the 99% levels of confidence between all Tests 3, Performance in Test 3 -- Black-and-White - Interpreter Group 1 --

Table 5. Student's t-test for Tests 3.

$$t = \frac{\bar{x} - \bar{x}}{s_{\bar{d}}}$$

Black-and-White
Interpreter Group 1
$\bar{x}$ = 25.9

Color Infrared
Interpreter Group ~~2~~ 1
$\bar{x}$ = 22.2

$$t = \frac{25.9 - 22.2}{\sim 1.60}$$
$$= 2.31^{**}$$

The table t value at the 99% confidence level with 20 degrees of freedom is 1.725.

Black-and-White
Interpreter Group 1
$\bar{x}$ = 25.9

Color Infrared
Interpreter Group 2
$\bar{x}$ = 18.7

$$t = \frac{25.9 - 18.7}{\sim 1.68}$$
$$= 4.29^{**}$$

The table t value at the 99% confidence level with 17 degrees of freedom is 3.965.

Color Infrared
Interpreter Group 1
$\bar{x}$ = 22.2

Color Infrared
Interpreter Group 2
$\bar{x}$ = 18.7

$$t = \frac{22.2 - 18.7}{\sim 1.65}$$
$$= 2.12\cancel{^{**}} \text{ n.s.}$$

The table t value at the 99% confidence level with 15 degrees of freedom is 4.037.

was significantly greater at the 99% level of confidence than either Tests 3 -- Color Infrared - Interpreter Group 1 -- or Color Infrared - Interpreter Group 2. Also the results of Test 3 -- Color Infrared - Interpreter Group 1 -- was significantly better at the 99% level of confidence than the results of Test 3 -- Color Infrared - Interpreter Group 2. It is apparent that there was some carryover of learning from Test 3 -- Black and White - Interpreter Group 1 -- to Test 3 -- Color Infrared - Interpreter Group 1.

For Test 3 -- Black-and-White - Interpreter Group 1 -- the correlation coefficient, $r = 0.508$, was calculated for the independent variable of experience. The coefficient of determination which was 0.258, indicates that the independent variable experience accounts for only 25.8% of the variation in interpreter performance in this test.

Test 1: Black-and-White - Interpreter Group 1

The 12 interpreters for this test made from 8 to 13 groups of images. There was no apparent correlation between the number of groups made in this initial test and success in Test 3 with black-and-white photography. The most successful interpreters in Test 3 made both large and small numbers of initial groups in Test 1, as did those who were less successful. In this test, in which the interpreters were instructed to group similar images into as many classes as they felt were distinct, the results came out in a pattern ranging from distinct, good agreement with ground subject to variable or poor agreement with ground subject in this order:

	Vegetation Type
(1) Class 7 - Association M	mixed shrub-grass
(2) Class 4 - Association H	grass
(3) Class 3 - Association G	grass
(4) Class 2 - Association F (subclass)	grass
(5) Class 2 - Associations C, D, E (subclass)	grass
(6) Class 5 - Associations I, J, K	mixed shrub-grass
(7) Class 1 - Associations A and B	shrub
(8) Class 6 - Association L	grass

Association M (Class 7), which occupied the Limestone Hills and adjacent alluvial fans, was characterized by the outstanding physiognomy of its more prominent species, Mortonia scabrella, which is not found in any other association. It had abundant annual grass cover, but the image was dominated by shrubs. It occupied exclusively shallow soils underlain by limestone which gave the image a characteristic layered appearance from exposed rock strata.

Association H (Class 4) occupied an area of flat relief interrupted by depressions. Grasses, particularly Eragrostis lehmanniana (lovegrass), are the most prominent, with some scattered shrubs, mainly _Prosopis juliflora_ (mesquite). This association occupied reddish to reddish-brown soils, which may help account for the distinctness of its images.

Association G (Class 3) was found in valley bottoms, alluvial terraces, runnels, swales, and on the lower slopes of the Andesite Hills. It was predominantly covered with grasses with scattered shrubs. The grass cover was mostly _Hilaria mutica_ (tobosa) or tobosa mixed with species of grama grasses. It was apparently associated with lower areas which are more mesic and where there was increased soil depth.

Association F of Class 2 was set apart from the rest of Class 2 to form a distinct image class of its own. It occupied an area where grasses are the prominent cover, mostly _Bouteloua_ sp. (grama grasses) and _Aristida_ sp. (three-awn grasses), with some scattered shrubs in the drainages. Perhaps what set it apart as an image class from the rest of its class was the type of terrain it occupied. Associations C, D, and E were found on highly dissected areas in the northern part of the study area, while F was located on gently rolling to undulating topography to the northeast.

The rest of Class 2, Associations C, D, and E, also occupied areas where the most prominent cover was grama and three-awn grasses. Except for Class 1, Associations A and B, the cover here was sparser than in any other part of the study area and the image characteristics were greatly influenced by the bare soil.

Associations I, J, and K (Class 5) were of mixed shrub-grass composition with shrubs predominating the landscape and the photographic image. The shrubs were predominantly *Fouqueria splendens* (ocotillo), *Acacia constricta* (whitethorn), and *Aloysia wrightii* (aloysia), and *Bouteloua* sp. were the most common grasses. This class was the most complex of all, both in terms of vegetational variability and variety of topography upon which it was found. As a result, the images produced were highly varied and difficult to group. The areas of vegetation comprising this group were also the most disjunct and were found in the south and southeastern part of the study area, in the northeast end of the Mule Mountains, in the hills northwest of Tombstone, on the south and southwest facing escarpments of the Limestone Hills, and on isolated hills of both basalt and andesitic bedrock running from the southeast to the northwest.

Associations A and B (Class 1), found mostly in the north and northwest portions of the study, were of the shrub type, but the vegetation here was sparser than anywhere else. The shrubs were mainly *Acacia vernicosa* (mescat acacia), *Larrea tridentata* (creosotebush) and *Flourensia cernua* (tarbush). The landscape was highly dissected but slightly flatter than the landscape occupied by Class 2, as apparently the image characteristics were very similar.

Association L (Class 6) was a grass type that occupied the hills south of the Dragoon Mountains. Its image signature apparently was similar to the mixed shrub-grass type of Class 5 and somewhat similar to the grass type of Class 2 (C, D, E). This image class was evidently difficult to place due to its lack of either outstanding vegetation or topographic features. For a complete data set of the results of this test, see Appendix D1. (See pocket, inside cover.)

Test 1: Color Infrared - Interpreter Group 1

The ten interpreters who took this test generally did not make as distinct groups as they did when using black-and-white aerial photographs, and the average number of groups formed by them was slightly higher (10.9 to 11.6). Evidently, the added dimension of color caused increased difficulty in grouping similar images due to the increased complexity of the image appearance rather than clarifying it. Not all of the vegetation classes were readily evident, and the ones which did emerge were not always complete. The results of this test are arranged from most distinct to variable, as follows:

	Vegetation Type
(1) Class 3 - Association G	grass
(2) Class 4 - Association H	grass
(3) Class 2 - Association D (subclass)	grass
(4) Class 2 - Association F (subclass)	grass
(5) Class 2 - Association E (subclass)	grass

The rest of the classes did not stand out alone. Class 1, a shrub type (Associations A and B), was scattered throughout Classes 2 - a grass type, 3 - a grass type, and 4 - a grass type. Class 5, a mixed shrub-grass type, (Associations I, J, K), was mixed partially with Class 6, a grass type (Association L) and partially with Class 7, a mixed shrub-grass type (Association M). Also, there were several more columns than in black-and-white containing a seemingly random combination of images that could not be aligned with anything similar, and therefore were unable to contribute to any of the image groups. For a complete data set of the results of this test see Appendix D2.

Test 1: Color Infrared - Interpreter Group 2

In this test there were some distinct interpretations coinciding with the vegetation classification but not all of them agreed. It was also more difficult to place the classes in order of distinctness. The classes which were clearly distinguishable were more equal to each other in distinctness than in either of the previous Tests 1, and are ordered as follows:

	Vegetation Type
(1) Class 4 - Association H	grass
(2) Class 3 - Association G	grass
(3) Class 2 - Associations C, D, E (subclass)	grass
(4) Class 2 - Association F (subclass)	grass
(5) Class 5 - Associations I, J, K	mixed shrub-grass

The other three classes were scattered. Class 7, mixed shrub-grass type, was predominantly mixed with Class 5, a mixed shrub-grass type, but had a few columns which emphasized it alone. Classes 1, a shrub type, and 6, a grass type, were widely scattered.

Two individual items are worth mentioning. In Association A of Class 1, a shrub type, four of the seven interpreters placed the same image alone as unique by itself. Also, five of the seven interpreters made an identical grouping of one image from Association J, a mixed shrub-grass type, of Class 5, with one image from Class 7, a mixed shrub-grass type. The image of Association J thus grouped was the same one which had been grouped with a much more complete Class 7 in Test 1 -- Black-and-White - Group 1. The interpreters made a total of 122 individual groups in this test, which is higher than either of the previous Tests 1 and which indicates greater difficulty in grouping similar color infrared images. For a complete data set of the results of this test see Appendix D3. (See pocket, inside cover.)

Test 2: Black-and-White - Interpreter Group 1

The results of this test, in which the interpreters were told there were seven classes, changed the order of distinctness of pattern somewhat, but not radically. The same kinds of groupings were made, but the consolidation of the images made some patterns more complete and others less distinct. The order of grouping of similar images ranged from complete image classes with few outsiders to very mixed groups and is as follows:

	Vegetation Type
(1) Class 3 - Association G	grass
(2) Class 7 - Association M	mixed shrub-grass
(3) Class 2 - Associations C, D, E (subclass)	grass
(4) Class 2 - Association F (subclass)	grass
(5) Class 4 - Association H	grass
(6) Class 1 - Associations A, B,	shrub
(7) Class 6 - Association L	grass
(8) Class 5 - Associations I, J, K,	mixed shrub-grass

Class 3, a grass type, was made distinct by the fact that 7 of the 12 interpreters grouped at least three or four images in this class together without any images included from other classes, and four more of the interpreters put at least three of the images together, while consistently mixing them with members from only one other class, a grass type (Association F of Class 2).

Class 7, a mixed shrub-grass type, ran a close second to Class 3, primarily because it was particularly confused with Association J (mixed shrub-grass type) of Class 5. Eleven of the 12 interpreters put at least three of the four test images together, but also included one or two images from Association J and sometimes one to two other random images from Class 5 or Class 1.

Associations C, D, and E of Class 2, all grass types, moved up from fifth place in Test 1, with the black-and-white photography, to third place when the images were restricted to seven classes. Of the nine candidate images in this portion of Class 2, one interpreter put four images together, one put five together, two put six together, three put seven together, one put eight together, and three put all nine of the images together. The most consistent images mixed with these were members of Class 6, a grass type (Association L), and a few members of Association B of Class 1, a shrub type.

Association F of Class 2, a grass type, was again an image class which was distinct from the other members of its class. The completeness of its image grouping (seven interpreters put all three images in this group together) was marred by the fact that four of the interpreters mixed an equally consistent image set from Class 4, also a grass type, with them. This in turn marred the results of an equally distinct image set for Class 4. The knowledge that there were seven total classes evidently forced several of the interpreters to believe that these two sets of images were related since they are both grass types. Very few other images from other classes were placed here, and they appeared to be random placement errors.

With Class 1, a sparse shrub type, the individuality of the image sets began to decrease. Only five interpreters out of ten managed to place images of Class 1 together with any consistency. They were mixed with only a few random images from other classes. The rest of the interpreters placed images of Class 1 erratically through all but one of the rest of the image groups. The exception was Class 3, a grass type.

Class 6, a grass type, and Class 5, a mixed shrub-grass type, were again the least distinct image sets. They were confused for the most part with each other, but also included with them were difficult images from several other classes. When not confused with each other, members of Class 6 were placed largely with Class 2 (Associations C, D, E) also a grass type, and members of Class 5 were most often placed with Class 7, also a shrub-grass type. In fact, one particular image from Association J of Class 5 was so consistently placed with Class 7 as to cause consideration of the possibility that it had been incorrectly typed, but investigation of the ground truth records of Garcia-Moya (1972) proved this to be untrue. For a complete data set of the results of this test see Appendix D.4.

Test 2: Color Infrared - Interpreter Group 1

The pattern of image classes formed by the ten interpreters in this test were clear, but only two of them corresponded to complete vegetation classes which were formed from the ground truth classification. The other two are separated members of the same class. They were, in descending order of completeness:

	Vegetation Type
(1) Class 3 - Association G	grass
(2) Class 2 - Associations C, D, E (subclass)	grass
(3) Class 4 - Association H	grass
(4) Class 2 - Association F (subclass)	grass

Class 3, a grass type, was formed by all ten of the interpreters, with at least three of the four images in the class represented in this set. The images from other classes placed with these were few and not consistent, except for one image from Association J of Class 5, a mixed shrub-grass type, which four of the interpreters included.

Part of Class 2, all grass types, (Associations C, D, E), again made a strong pattern, but was mixed somewhat consistently with the same image from Association B, Class 1, along with some random images from other classes.

Nine of the interpreters formed Class 4, a grass type, with at least three of the four images represented. The distinctness of this class was marred by the fact that four of the interpreters placed an equally consistent portion of images from Association F of Class 2, a grass type, here also. In addition, quite a few of the rest of the members of Class 1, a shrub type (Associations A and B), were placed here.

Three other interpreters formed almost complete sets of Association F, a grass type, of Class 2, but it was not enough to set it clearly alone.

Class 5, a mixed shrub-grass type, was about equally mixed with Classes 6, a grass type, and 7, a mixed shrub-grass type, to form two more consistent grouping patterns, but they do not correspond to the vegetation classification. Class 7, a mixed shrub-grass type, would again have been a very complete group, but was so completely mixed with Class 5, a mixed shrub-grass type, that it could not stand out alone. Class 6, a grass type, was again scattered through several image pattern sets, but the majority were mixed with images from Class 5, a mixed shrub-grass type, without which it would have been a weak pattern.

Overall, the results of Test 2 for the black-and-white were better than the results of Test 2 using the color infrared and Test 1 using the black-and-white photography and much better than the Test 1 color infrared results. All the image classes which were formed were more complete sets and were more distinct due to less mixing with images from other groups. For a complete data set of the results of this test see Appendix D5. (See pocket, inside cover.)

Test 2: Color Infrared - Interpreter Group 2

Rather than increasing the clarity of the classes made in Test 1 Color Infrared - Group 2, the knowledge that there were seven classes caused a decrease in the clarity of these groups. The classes which had stood out in Test 1 by these interpreters were also best in Test 2, but the total results were not as clear. Though there were other distinct patterns, clarity for individual classes according to the vegetation classification were as follows:

	Vegetation Type
(1) Class 4 - Association H	grass
(2) Class 3 - Association G	grass
(3) Class 2 - Associations C, D, E (subclass)	grass

Whereas Association F, a grass type of Class 2 had previously stood out individually in Test 1, it was consistently mixed with Class 3, a grass type, in this test. Class 5, a mixed shrub-grass type, was also well-established in terms of number correctly grouped together, but it was too well-mixed with Classes 6, a grass type, and 7, a shrub-grass type with some of the Class 2, a grass type. Class 1, a grass type, was widely scattered through all the patterns and was least identifiable as a unit.

In Test 1 with color infrared, these interpreters were able to place the more difficult images into individual groups of 1, 2, or 3 images which did not detract from the clarity of the established vegetation classification groupings when keyed out. In this test, the knowledge that there were only seven classes forced the interpreters to place these more difficult images with others and they placed them incorrectly for the most part. For a complete data set of the results of this test see Appendix D6, pocket, inside cover.

Test 3: Black-and-White - Interpreter Group 1

For this test 13 example stereo pairs were provided, each one representing one of the associations composing the seven vegetation classes. The interpreters grouped each test image with the example image to which it appeared the most similar. The results are summarized in Table 6, and the individual results are presented in Appendix E.

From a total of 516 images, 310 (or 61%) of them were correctly identified in this test. Class 3, a grass type (Association G), had the most distinctive image. It was correctly identified 92% of the time. Of the total number of images erroneously classified, 39%, 7% were placed in this group. Class 7, a mixed shrub-grass type (Association M) of vegetation, had the second most distinguishable example and test images, with 77% correctly identified. Out of the possible errors, 4% were placed here. With the aid of the examples, Class 1, a shrub-type, (Associations A and B), became much more distinguishable and only 4% of the total error was included. Class 5, a mixed shrub-grass type (Associations I, J, K), was next with 65% of the images forming this class matched to the correct examples. Six percent of the total error was included in this group. Class 2, a grass type (Associations C, D, E, F), with 62% of its images correctly identified, was the fifth most successfully identified group. It had 8% of the error, which was the largest. Class 6, a grass type (Association L),

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Table 6. Summary of test results from Test 3: Black-and-White - interpreter Group 1. Twelve interpreters.

		Associations							
Assoc.	Images	A, B	C, D, E, F	G	H	I, J, K	L	M	Total
A	#	27 *	1	3		4		1	36
	%	75.00	2.78	8.33		11.11		2.78	100.00
B	#	25	1	1	2	5	1	1	36
	%	69.44	2.78	2.78	5.56	13.89	2.78	2.78	100.00
Total	#	52	2	4	2	9	1	2	72
	%	72.21	2.78	5.56	2.78	12.50	1.39	2.78	100.00
C	#	4	23C *		7	1	1		36
	%	11.11	63.89		19.44	2.78	2.78		100.00
D	#	2	26D		3	5			36
	%	5.56	72.22		8.33	13.89			100.00
E	#		24E		4	1	7		36
	%		66.68		11.1	2.78	19.44		100.00
F	#		16F	10	6		4		36
	%		44.44	27.78	16.67		11.11		100.00
Total	#	6	89	10	20	7	12		144
	%	4.17	61.81	6.94	13.89	4.86	8.33		100.00
G	#		1	44 *	1	1	1		48
	%		2.08	91.68	2.08	2.08	2.08		100.00
H	#	1	13	22	6 *		6		48
	%	2.08	27.08	45.84	12.50		12.50		100.00
I	#	1	4		1	26 *	2	2	36
	%	2.78	11.11		2.78	72.21	5.56	5.56	100.00
J	#	4				20		12	36
	%	11.11				55.56		33.33	100.00
K	#	2	7		1	24		2	36
	%	5.56	19.44		2.78	66.66		5.56	100.00
Total	#	7	11		2	70	2	16	108
	%	6.48	10.19		1.85	64.82	1.85	14.81	100.00
L	#	1	15		9	11	12 *		48
	%	2.08	31.25		18.75	22.92	25.00		100.00
M	#	4	1			6		37 *	48
	%	8.33	2.08			12.51		77.08	100.00

* Indicates correct responses.

was sixth with 25% correctly identified and with 4% error. Class 4, a grass type (Association H), should have placed much higher. It was correctly identified only 13% of the time, whereas 46% of its test images were placed with Class 3, a grass type. This indicated that the example image for Group 4 was atypical. It also had the second highest error percentage of 7%.

The results of this test generally followed the patterns established in Tests 1 and 2, with the black-and-white aerial photography, which strongly supports the idea that all of these associations of vegetation have correspondingly distinct images which may be identified from black-and-white aerial photographs (Appendix D).

Test 3: Color Infrared - Interpreter Group 1

The total performance for correct identifications fell off 9% when compared to Test 3 -- Black-and-White - Interpreter Group 1 -- with 222 out of 430 (52%) of the test images being correctly identified. The results are summarized in Table 7, and the individual results are presented in Appendix E2.

Class 3, a grass type, was again the best identified set with 75% correct. Out of 48% total possible errors, only 4% was assigned to this image class. Class 5, a mixed shrub-grass type, moved up to second place with 73% of its images correctly matched to the example, but the second largest amount of error was also included here at 10%.

Table 7. Summary of test results from Test 3: Color Infrared - Interpreter Group 1. Ten interpreters.

		Associations							
Assoc.	Images	A, B	C, D, E, F	G	H	I, J, K	L	M	Total
A	#	15 *	8		5		1	1	30
	%	50.00	26.67		16.67		3.33	3.33	100.00
B	#	2	18	4	3	2		1	30
	%	6.67	60.00	13.33	10.00	6.67		3.33	100.00
Total	#	17	26	4	8	2	1	2	60
	%	28.33	43.34	6.67	13.33	3.33	1.67	3.33	100.00
C	#	3	21 *			4	2		30
	%	10.00	70.00			13.33	6.67		100.00
D	#		27			2	1		30
	%		90.00			6.67	3.33		100.00
E	#		10		1	4	15		30
	%		33.33		3.33	13.33	50.01		100.00
F	#	14	8	4F	2	1	1		30
	%	46.67	26.67	13.33	6.67	3.33	3.33		100.00
Total	#	17	66	4	3	11	19		120
	%	14.17	55.00	3.33	2.50	9.17	15.83		100.00
G	#	4	3	30 *	2		1		40
	%	10.00	7.50	75.00	5.00		2.50		100.00
H	#	3	12	9	14 *		2		40
	%	7.50	30.00	22.50	35.00		5.00		100.00
I	#		5		2	20 *	2	1	30
	%		16.67		6.67	66.66	6.67	3.33	100.00
J	#	1	1			18	1	9	30
	%	3.33	3.33			60.01	3.33	30.00	100.00
K	#		1			28		1	30
	%		3.33			93.34		3.33	100.00
Total	#	1	7		2	66	3	11	90
	%	1.11	7.78		2.22	73.34	3.33	12.22	100.00
L	#	1	9		3	22	3 *	2	40
	%	2.50	22.50		7.50	55.00	7.50	5.00	100.00
M	#	4	1			9		26 *	40
	%	10.00	2.50			22.50		65.00	100.00

* The box in which the asterisk appears indicates correct responses.

Class 7, a mixed shrub-grass type, fell to third place with 65% correctly identified, but with only 3% of the error, the smallest amount. Class 2, a grass type, had the largest amount of error at 14%, but placed fourth with 55% correct identification. Class 4, a grass type, had a low amount of error at 4%, but could only place fifth with 35% correct identifications. In this test, its images were largely included with Class 2, a grass type (30%) and again with Class 6, another grass type (22%). Class 1, a shrub type, was largely mistaken (43%) for Class 2, a grass type, with which it is closely related in the vegetation classification, and managed to place sixth with 28% correct. An intermediate amount of error (7% of the total) was incorrectly included with Class 1, a shrub type, mostly from Class 2, a grass type. Class 6, a grass type, again placed seventh and had 6% of the error. The 7% correctly identified fell so low as to make this vegetation category useless from a practical standpoint of image identification.

Test 3: Color Infrared - Interpreter Group 2

Interpreter Group 2 did not perform as well as interpreter Group 1 with either black-and-white or color infrared for Test 3. They were able to match 132 out of 301 test images, or 44%, with the correct example. This is a 17% drop in performance from the results in Test 3 -- Black-and-White - Interpreter Group 1 -- and an

8% drop in performance from the results in Test 3 -- Color Infrared -- Interpreter Group 1. The individual results for this test are presented in Appendix E3, and a summary, Table 8.

Class 5, a mixed shrub-grass type, test images were correctly identified 56% of the time but also contained a large amount of the total error at 12%. Class 2, a grass type, was second with 54% correct identifications but had the largest amount of commission error at 15%. Class 3, a grass type, fell to third place with 50% correct and contained 7% commission error. Classes 4, a grass type, and 7, a mixed shrub-grass type, were tied for fourth place with each having 39% correct identifications. Class 4 was considered to be slightly more distinct than Class 7 because it contained less error, 5% compared to 6%, respectively. Class 1, a shrub type, had 29% correctly placed and 8% of the error. Again, Class 6, a grass type, placed last, falling so low (14% correct and 3% of the total error) as to make it an impractical class for photo interpretation purposes.

Table 8. Summary of test results from Test 3: Color Infrared - Interpreter Group 2. Seven interpreters.

					Associations				
Assoc.	Images	A, B	C, D, E, F	C	H	I, J, K	L	M	Total
	#	10 *	5	3			3		21
A	%	47.63	23.81	14.28			14.28		100.00
B	#	2	12	2	1	1		3	21
	%	9.52	57.15	9.52	4.76	4.76		14.29	100.00
Total	#	12	17	5	1	1	3	3	42
	%	28.57	40.49	11.90	2.38	2.38	7.14	7.14	100.00
C	#		16C *			3	1	1	21
	%		76.19			14.29	4.76	4.76	100.00
D	#		14D			7			21
	%		66.67			33.33			100.00
E	#	4	8E	1		6	2		21
	%	19.05	38.10	4.76		28.57	9.52		100.00
F	#	6	7F	2	5	1			21
	%	38.58	33.33	9.52	23.81	4.76			100.00
Total	#	10	45	3	5	17	3	1	84
	%	11.90	53.58	3.57	5.95	20.24	3.57	1.19	100.00
G	#	8	4	14 *	1			1	28
	%	28.57	14.29	50.00	3.57			3.57	100.00
H	#	2	6	9	11 *				28
	%	7.14	21.43	32.14	39.29				100.00
I	#	1	4		3	5 *	1	7	21
	%	4.76	19.05		14.29	23.81	4.76	33.33	100.00
J	#		3		1	13		4	21
	%		14.29		4.76	61.90		19.05	100.00
K	#		2		1	17		1	21
	%		9.52		4.76	80.96		4.76	100.00
Total	#	1	9		5	35	1	12	63
	%	1.59	14.28		7.94	55.55	1.59	19.05	100.00
L	#	3	7	1	2	11	4 *		28
	%	10.71	25.00	3.57	7.14	39.29	14.29		100.00
M	#	1	4	2	2	7	1	11 *	28
	%	3.57	14.29	7.14	7.14	25.00	3.57	39.29	100.00

* The box in which the asterisk appears indicates correct responses.

DISCUSSION

In looking over the results of these tests, I searched for consistent factors which would give an indication of how the interpreters arrived at their conclusions. I investigated tone, color consistency, pattern, landform, amount of non-vegetated ground and quality of the examples. For the following discussion, please refer to Table 9.

Class 1, Associations A and B, was a sparse shrub type with 46% non-vegetated ground. It was poorly identified in eight of the nine tests. It had no distinctive vegetation pattern but was found on a distinctive low, highly dissected landform. This landform was almost identical with that associated with the vegetation subclass 2, a grass type, of Associations C, D and E. In the only test, Test 3 -- Black-and-White - Interpreter Group 1 -- in which Class 1 placed higher than Subclass 2, it was at the expense of a poor performance of Subclass 2. In the other eight tests, Subclass 2 (Associations C, D, and E) were placed about in the middle of the range of results. In the color infrared tests Subclass 2 (Associations C, D, and E) was interpreted better than in black and white due, I think, to a better color balance in both the test and example photographs than those found in Class 1.

Subclass 2, a grass type (Association F), was clearly separated from the rest of its class in all the tests in which the interpreters did not have examples. It was located on the most flat nondescript

Table 9. Consolidated table of all test results.

Photography:	Black-and-White			Color Infrared			Color Infrared		
Interpreter Group	1			1			2		
Test	1	2	3	1	2	3	1	2	3
Order of Agreement	Association	Association	Association	Association	Association	Association	Association	Association	Association
1	M	G	G	G	G	G	H	H	I, J, K
2	H	M	M	H	C, D, E	I, J, K	G	G	C, D, E, F
3	G	C, D, E	A, B	D	H	M	C, D, E	C, D, E	G
4	F	F	I, J, K	F	F	C, D, E, F	F	F	H
5	C, D, E	H	C, D, E, F	E	I, J, K	H	I, J, K	I, J, K	M
6	I, J, K	A, B	L	C	L	A, B	M	L	A, B
7	A, B	L	H	A, B	M	L	L	M	L
8	L	I, J, K		I, J, K	A, B		A, B	A, B	
9				L					
10				M					

% non-vegetated ground in each Association:

A = 46, B = 47, C = 25, D = 35, E = 40, F = 33, G = 15, H = 23, I = 25, J = 32, K = 31, L = 44, M = 31.

The Associations placed in columns below the darkened lines were not individually well separated.

terrain of all classes but had a reasonably distinct vegetation pattern with only 33% non-vegetated ground which allowed it to be identified in the midrange of the results. In the tests with examples it increased the identification success with the whole class.

Classes 3 and 4 (Associations G and H), both grass types, placed near the top in seven of the nine tests. Classes 3 and 4 had 15% and 22% non-vegetated ground, respectively, which were the lowest. They complemented each other on the photographs by being adjacent vegetation which produced a very distinct contrasting pattern. Class 3 vegetation was very dark both in black-and-white and color and was always found at the bottom of drainages. Class 4 vegetation was lighter and found on the gently sloping hillsides next to the drainages. Because of these two facts, a distinctive terrain and a distinctive vegetaion pattern, these two classes were usually easily identified.

Class 5, a mixed shrub-grass type (Associations I, J, and K), is the most difficult to assess. It had an estimated 39% non-vegetated ground which was third highest out of seven. Therefore the pattern of the vegetation was indistinct but it was located on a relatively distinct high, rolling, upland. In the black-and-white tests without examples it placed low in identification success. With examples it placed fourth out of seven. In the four color infrared tests without examples it was indeterminate in three and barely distinguishable as a separate class in the other. With examples in the color infrared tests it placed second by Interpreter Group 1 and first by Interpreter Group 2. The key appears to be the examples which allowed this diverse group to be pulled together, particularly in the color infrared tests. The color balance and the resolution in the color infrared tests were the best overall for this class.

Class 6, a grass type (Association L), was interpreted last or next to last in five of the nine tests and was indeterminant in the rest. It had no distinctive vegetation pattern with 44% non-vegetated ground, the second highest. It also was located on a nondescript type of low hills. This combination of indistinct pattern and the nondescript landform upon which it was located apparently made it very difficult to separate as a class.

Class 7, a mixed shrub-grass type (Association M), had an estimated 31% non-vegetated ground and a distinctive uniform dark pattern located on steep, distinctive hills. It was very successfully identified, first or second, in all the black-and-white tests but surprisingly was indeterminant in the color infrared tests with no examples and placed third and fifth in the tests with examples. The answer apparently lay in the photography. In the black-and-white photographs where the tone was consistent and the resolution excellent, there was a definite layered or striated appearance associated with the Class 7 image which was a singular characteristic caused by the limestone bedrock on which this type of vegetation was found. In the color infrared photographs the color balance was too dark and obscured this striated appearance, causing the examples to be most often confused with the most similar landform which was occupied by Class 5.

For the black-and-white photography, the decisive features for interpretation appeared to be the landform on which the vegetation was located and the pattern of the vegetation which was strongly influenced by the amount of non-vegetated ground.

In the tests with no examples, if the vegetation was sparse producing an indistinct pattern, the interpreters placed the stereo pairs together with similar landforms while often ignoring the differences in vegetation occupying different aspects of the same types of landscapes. If the vegetation was dense, producing a distinctive pattern, this became the decisive interpretation feature unless the landforms were distinctively different for the same vegetation class. This caused indecision and confusion.

The tests with the examples backed up these observations. If the vegetation pattern was indistinct, sparse cover, and the example and the test photographs showed the same landforms, they were placed together correctly. If the example photograph(s) showed landforms dissimilar to all of the test photographs, the test photographs were placed with an example having a more similar landform. If the test photographs with sparse vegetation of the same type occupied dissimilar landforms, then those with landforms similar to the example were placed with it and the rest with other examples having similar landforms. If the vegetation pattern was distinct thick cover, the interpreters had easy decisions as long as the landforms which the same vegetation occupied were not too dissimilar.

For the color infrared photography, landform again appeared to be the major influencing factor of interpretation, particularly where vegetation was sparse. Pattern was again the major influencing factor of interpretation where vegetation cover was dense. The influence of pattern was diminished somewhat due to inconsistency of color balance which caused patterns of the same vegetation to appear different. Soil shows much more strongly in color infrared than in black-and-white photography. It negatively influenced the interpretability of the two vegetation classes with very sparse cover. These two classes were (1) a shrub type, and (6) a grass type, which averaged 46% and 44% non-vegetated ground, respectively. It appears that over 40% non-vegetated ground greatly reduces the interpretability of vegetation in color infrared at intermediate scales. In both Tests 3 in color infrared, these two classes were interpreted less than 30% correct.

SUMMARY AND CONCLUSION

Nine photography interpretation tests were performed with a total of 19 different interpreters. Three tests were conducted with black-and-white intermediate scale photography and six tests with color infrared intermediate scale photography. The results of the tests with black-and-white aerial photography show that the interpretation of vegetation mapped at the association level of classification is reliable for all the classes used at a level of 61%.

The results of the tests with the color infrared photography indicate that the association level of mapping is unsatisfactory for vegetation interpretation of Classes 1 and 6. These tests indicate that with non-vegetated ground exceeding 40%, interpretation of the same vegetation becomes very difficult with color infrared photography. For the other five classes the reliability of the color infrared photography for vegetation interpretation over the combined results of both interpreter groups is 57%.

Students' t-test indicated that intermediate scale black-and-white photography is significantly better (P=.01) than this particular color infrared photography for the interpretation of southeastern Arizona vegetation mapped at the association level.

A coefficient of determination, $100r^2 = 25.8\%$, calculated for Test 1--Black-and-White - Interpreter Group 1 - showed that experience was not a significant factor in determining successful vegetation interpetation.

Several problems were encountered with the color infrared photography during the preparation of the tests. The results of these tests were not in line with results of better performance with color infrared indicated in the literature review. These problems are listed for purposes of reference so that future tests may more clearly indicate the usefulness of one type of photography versus another under certain conditions. These possible reasons for increased failure of vegetation image identification with color infrared are:

(1) Some resolution reduction through reproduction.
(2) Color was not tone balanced throughout the prints.
(3) The advantage of color infrared photography was not expressed due to the dormant season of photography.
(4) Print finish was silk and not glossy (under magnification the silk finish exhibits a grainy surface which interfers with image identification).
(5) Unrepresentative or insufficient examples due to the fact that soils show up more, and color introduces greater image variation.

Considering all the tests, the most consistenly identified vegetation classes were:

Class	Vegetation Type
3	tobosa grassland
4	burroweed - lovegrass grassland
2	yucca - grama - three-awn grassland
7	mortonia mixed shrub-grassland

The least consistenly identified vegetation classes were:

Class	Vegetation Type
5	ocotillo - acacia - aloysia - grama mixed shrub-grassland
1	acacia - creosotebush - tarbush shrubland
6	agave grassland

The tests in this study were designed to evaluate the interpreters' performance for vegetation interpretation at the association level of classification. In many cases where vegetation test classes were not individually well separated from each other, the classes which were mixed were of the same physiognomic type. Therefore, the errors that were made most often were errors only in level of classification. At a higher physiognomic level of classification the interpretations were correct. In Test 3: Black-and-White - Interpreter Group 1, Class 2, a grass type, was most often mistaken for Class 4, also a grass type (Table 6). Class 4, a grass type was most often misidentified as Class 3, a grass type. Class 6, a mixed shrub-grass type, was most often misidentified as Class 7, a mixed shrub-grass type. Class 7, in turn, was most often misidentified as Class 6. The results from all the other tests, Appendix D for Tests 1 and 2, and Tables 7 and 8 for Tests 3, also indicate that many of the errors made were only in level of classification.

In each of these tests the interpretive performance with the black-and-white photography was clearly superior. That is not to say that black-and-white photography is superior to color infrared in all cases. Under the conditions of these tests, the association level of vegetation mapping, the intermediate scale of photography, and the generally sparse Arizona vegetation, the interpreters were better able to detect similar patterns of vegetation arrangement with the panchromatic photography than with the color infrared test prints used.

BIBLIOGRAPHY

Anson, Abraham. 1966. Color photo comparison. Photogrammetric Engineering. 32:286-297.

Brunnschweiler, Dieter H. 1957. Seasonal changes of the agriculture patterns: A study in comparative airphoto interpretation. Photogrammetric Engineering. 23:131-139.

Carneggie, D. M. 1968. Applying remote sensing technology for improving range resource inventories. Proceedings of the fifth symposium on remote sensing of environment. Ann Arbor, University of Michigan. p. 373-385.

Carneggie, David M., and Donald T. Lauer. 1966. Uses of multiband remote sensing in forest and range inventory. Photogrammetria. 21:115-141.

Colwell, R. N. 1960. Some uses of infrared aerial photography in the management of wildland areas. Photogrammetric Engineering. 26:775-785.

_______________ 1961. Aerial photographs show range conditions. California Agriculture. 15:12-13.

Culver, Roger N., and C. E. Poulton. 1968. Applications of ecology and remote sensing in the analysis of range watersheds. Corvallis, Oregon State University, Range Management Program. 91 numb. leaves.

Draeger, W. C., Lawrence R. Pettinger, and Andrew S. Benson. 1970. Analysis of remote sensing data for evaluating vegetation resources. Appendix I. Berkeley, University of California, School of Forestry and Conservation. p. 146-147.

Garcia-Moya, Edmundo. 1972. A preliminary vegetation classification of the Tombstone, Arizona, vicinity. Doctoral dissertation. Corvallis, Oregon State University. 195 numb. leaves.

Gelderman, F. W. 1970. Soil survey of Walnut Gulch Experimental Watershed, Arizona. Portland. A special report. 55 p. (U.S. Department of Agriculture. Soil Conservation Service and Agricultural Research Service in cooperation with the Arizona Agricultural Experiment Station.)

Gillully, J. 1956. General geology of central Cochise County, Arizona. U.S. Geological Survey professional paper 281. 169 p. and map.

Green, Christine R., and William D. Sellers, eds. 1964. Arizona climate. Tucson, University of Arizona press. 503 p.

Haack, Paul M. 1962. Evaluating color, infrared, and panchromatic aerial photos for the Forest Survey of interior Alaska. Photogrammetric Engineering. 28:592-598.

Jenson, H. A., and R. N. Colwell. 1949. Panchromatic versus infrared minus-blue aerial photography for forestry purposes in California. Photogrammetric Engineering. 15:201-223.

Munn, L. C., J. B. McClellan, and L. E. Philpotts. 1966. Airphoto interpretation and rural land-use mapping in Canada. Photogrammetria. 21:65-76.

Pettinger, Lawrence A. 1969. Analysis of earth resources on sequential high altitude multiband photography. Berkeley, University of California, School of Forestry and Conservation. Chapter 5.

Poulton, C. E. 1970. Applications and potential of remote sensing in ecological resource analysis for multi-use management of vegetation resources. In: Remote Sensing of the Environment, Engineering 807.4, a ten-day short course, August 3-14, 1970; Continuing Education in Engineering and Science, University Extension, U.C.L.A. and TRW Systems Group, Redondo Beach, California. Mimeo, illustrations.

__________ 1972. Inventory and analysis of natural vegetation and related resources from space and high altitude photography. Corvallis, Oregon State University, Range Management Program. 55 numb. leaves.

Schulte, O. W. 1951. The use of panchromatic, infrared, and color aerial photography in the study of plant distribution. Photogrammetric Engineering. 17:689-714.

Smith, John T., Jr. 1963. Color - a new dimension in photogrammetry. Photogrammetric Engineering. 29:999-1013.

Spurr, Stephen H. 1949. Films and filters for forest aerial photography. Photogrammetric Engineering. 15:473-481.

Wickens, G. E. 1966. The practical application of aerial photography for ecological surveys in the savannah regions of Africa. Photogrammetria. 21:33-41.

APPENDICES

APPENDIX A

Technique for Taking 1:1 Color Prints from 1:20, 000 Color Infrared Positive Transparencies for 3X Enlargement and Stereo Viewing

Equipment

Equipment used included a copy stand mounted, 35 mm Nikon camera equipped with a M-ring and a 55-mm 3. 5 f auto micro Nikkor lens which was situated over a Richard's light table.

Procedure

Six frames were cut from the roll of aerial film to provide stereo coverage of the whole test area. 1:1 copy required full extension of the camera lens so the camera was focused by moving the whole system up and down on the copy stand. Care was taken to insure that the transparency and the film in the camera were in parallel planes. I used a small level to do this. The aerial transparency was held flat by rubber-coated magnetic strips to insure that the whole picture taken was in focus.

Most of the pictures were taken at f8. The proper calculated f stop was f 7. 2. The shutter speeds varied from 1/2 to 1/30 of a second, according to the density of the portion of the transparency being copied. Copies were made with Kodacolor ASA80 film. The

ASA setting was adjusted to compensate for the focal length required for 1:1 copy.

Stereo pairs of the same area were photographed from consecutive frames of the color infrared transparencies. This was done by placing the split image center spot of the view-finder over identical ground points on each member of the stereo pair, and by identical orientation in the field of view.

The color infrared photography was flown along east-west flight lines. The copies were made so that their long axis was perpendicular to the flight line. These 35 mm copies were enlarged approximately 3.5X and printed in a 3-1/2" x 5" format. This increased the scale to approximately 1:32,000.

APPENDIX B

Associations and Character Species

Association	Character Species
Association A	Panicum hirticaule/Tidestromia lanuginosa-Boerhaavia coulteri
Association B	Rhus microphylla-Dalea formosa
Association C	Gutierrezia sarothrae/Eriogonum abertianum
Association D	Menodora scabra/Tridens grandiflorus
Association E	Hilaria belangeri
Association F	Gilia rigidula-Rhynchosia texana
Association G	Hilaria mutica/Eriochloa gracilis/Crotalaria pumila
Association H	Haplopappus tenuisectus/Eragrostis lehmanniana
Association I	Ayenia pusilla/Eragrostis intermedia
Association J	Cnidoscolus angustidens
Association K	Fouquieria splendens-Acacia constricta-Aloysia wrightii
Association L	Agave palmeri-Agave parryi/Haplopappus lacricifolius
Association M	Mortonia scabrella

APPENDIX C1

Example Information Sheet Filled out by Each Test Participant

Name____________________________ Date________________

Major____________________________

Indication of photointerpretation experience:

_____Have casually viewed stereo photography (imagery)
_____Have worked with stereo photography some (example: had a class in which it was used)
_____Have taken a class in aerial photography interpretation
_____Have worked with aerial photography a lot (up to a year, self-taught is okay)
_____Have had a great deal of aerial photography interpretation experience (1-3 years)
_____Have reached a professional level of aerial photography interpretation (3-plus years)

Range of experience in interpretation:

Scale:	1	2	3	4	5
	Low		Med		High

Urban: residential_____, industrial_____
Agriculture: cropland_____, rangeland _____
Forestry_____
Soils_____
Landforms_____

Other:__________________________

APPENDIX C2

Example Sheet for All Tests 1

Test 1 - Image Test

Name________________Date__________Began_________Finished______

Instructions

There are 43 different cards. On each card is a stereo pair of photographs. The cards may be viewed in stereo when the number on one card may be read, or when the card is turned so that the number is upside down. You are requested to do this test using stereoscopic viewing to make your evaluations.

The purpose of the test is to pile the cards into as many classes as necessary so that the vegetation images on the cards in each pile are similar. The stereo pairs are marked so that the x's fall within certain boundaries when viewed in stereo. These areas are the portion of each stereo pair to consider.

Please fill out below the number of groups and the numbers on the cards placed in each group.

Classes	1	2	3	4	5	6	7	8	9	10
Numbers										
1										
2										
3										
4										
5										
6										
	11	12	13	14	15	16	17	18	19	20
1										
2										
3										
4										
5										
6										

APPENDIX C3

Example Sheet for All Tests 2

Test 2 - Image Test

Instructions

There are 43 different cards. On each card is a stereo pair of photographs. The cards may be viewed in stereo when the number on one card may be read, or when the card is turned so that the number is upside down. You are requested to do this test using stereoscopic viewing to make your evaluations.

The purpose of the test is to pile the cards into seven classes so that the vegetation images on the cards in each pile are similar. The stereo pairs are marked so that the x's fall within certain boundaries when viewed in stereo. These areas are the portion of each stereo pair to consider.

Please fill out below the numbers on the cards placed in each group.

Classes	1	2	3	4	5	6	7
Numbers							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

APPENDIX C4

Example Sheet for All Tests 3

Test 3 - Image Test

Instructions

There are 43 different cards. On each card is a stereo pair of photographs. The cards may be viewed in stereo when the number on one card may be read, or when the card is turned so that the number is upside down. You are requested to do this test using stereoscopic viewing to make your evaluations.

The purpose of the test is to pile the cards into seven classes so that the vegetation images on the cards in each pile are most similar. An example stereo pair is provided to show the range of vegetation images in each group. The stereo pairs are marked so that the x's fall within certain boundaries when viewed in stereo. These areas are the portion of each stereo pair to consider.

Please fill out below the numbers on the cards placed in each group.

Classes	1	2	3	4	5	6	7
Numbers							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

APPENDIX D1-D6

(See pocket, back cover)

APPENDIX E-1

<u>Test 3: Individual Results for Black-and-White - Interpreter Group 1</u>

INTERPRETER BS
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	6	1						7	1	14.3
2		11		2		1		14	3	21.4
3			4	2				6	2	33.3
4				0	1	1		2	2	100.0
5					6	1	1	8	2	25.0
6					1	1		2	1	50.0
7					1		3	4	1	25.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	12	
# TYPE I ERRORS	0	1	0	4	3	3	1	12	31	27.9
% TYPE I ERRORS	0	83.3	0	100.	33.3	75.0	25.0		27.9	72.1

INTERPRETER DM
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	5							5	0	0
2		4						4	0	0
3		3	4	3				10	6	60.0
4	1	3		1				5	4	80.0
5					8	3	1	12	4	33.3
6		2				1		3	2	66.6
7					1		3	4	1	25.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	17	
# TYPE I ERRORS	1	8	0	3	1	3	1	17	26	39.5
% TYPE I ERRORS	16.7	66.6	0	75.0	11.1	75.0	25.0		39.5	60.5

INTERPRETER NL
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	4				1			5	1	20.0
	2		6		3		1		10	4	40.0
	3	1		4	1				6	2	33.3
	4		3		0		2		5	5	100.
	5					7		1	8	1	12.5
	6	1	3				1		5	4	80.0
	7					1		3	4	1	25.0
TOTAL # TYPES		6	12	4	4	9	4	4	43	18	
# TYPE I ERRORS		2	6	0	4	1	3	1	18	25	41.9
% TYPE I ERRORS		33.3	50.0	0	100.	11.1	75.0	25.0		41.9	58.1

INTERPRETER KM
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	4			1				5	1	20.0
	2		8			2	2		12	4	33.3
	3			4					4	0	0
	4	2	1		1				4	3	75.0
	5					6	2	1	9	3	33.3
	6		3		2		0		5	5	100.
	7					1		3	4	1	25.0
TOTAL # TYPES		6	12	4	4	9	4	4	43	17	
# TYPE I ERRORS		2	4	0	3	3	4	1	17	26	39.5
% TYPE I ERRORS		33.3	33.3	0	75.0	33.3	100.	25.0		39.5	60.5

INTERPRETER JH
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	4	1			3			8	4	50.0
2		5			2	1		8	3	37.5
3			2	3				5	3	60.0
4		4		0		1		5	5	100.
5	1	1	1		1			4	3	75.0
6		1	1	1	1	2		6	4	66.6
7	1				2		4	7	3	42.8
TOTAL # TYPES	6	12	4	4	9	4	4	43	25	
# TYPE I ERRORS	2	7	2	4	8	2	0	25	18	58.1
% TYPE I ERRORS	33.3	58.3	50.0	100.	88.9	50.0	0.0		58.1	41.9

INTERPRETER CA
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	4	2			1	1	4	12	8	66.6
2		8	1	1	2	1		13	5	30.8
3			2	1				3	1	33.3
4		1	1	0	1	1		4	4	100.
5	1	1			4			6	2	33.3
6				2		1		3	2	66.6
7	1				1		0	2	2	100.
TOTAL # TYPES	6	12	4	4	9	4	4	43	24	
# TYPE I ERRORS	2	4	2	4	5	3	4	24	19	55.8
% TYPE I ERRORS	33.3	33.3	50.0	100.	55.6	75.0	100.		55.8	44.1

INTERPRETER EP
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	5				1	D		6	1	16.7
	2		8			1	1		10	2	20.0
	3			4	3				7	3	42.8
	4		3		1		1		5	4	80.0
	5	1	1			6	2		10	4	40.0
	6						0		0	0	0.0
	7					1		4	5	1	20.0
TOTAL # TYPES		6	12	4	4	9	4	4	43	15	
# TYPE I ERRORS		1	4	0	3	3	4	0	15	28	34.9
% TYPE I ERRORS		16.7	33.3	0.0	75.0	33.3	100.	0.0		34.9	65.1

INTERPRETER DF
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	5	1						6	1	16.7
	2		7		2	1	2		12	5	41.7
	3			4	1				5	1	20.0
	4		2		1				3	2	66.6
	5	1				7		1	9	2	22.2
	6		2				2		4	2	50.0
	7					1		3	4	1	25.0
TOTAL # TYPES		6	12	4	4	9	4	4	43	14	
# TYPE I ERRORS		1	5	0	3	2	2	1	14	29	32.6
% TYPE I ERRORS		16.7	41.7	0.0	75.0	22.2	50.0	25.0	32.6		67.4

INTERPRETER GM
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	3				1			4	1	25.0
2		10		1	2		1	14	4	28.6
3	2	1	4	2				9	5	55.6
4				1		1		2	1	50.0
5	1				5	1		7	2	28.6
6		1				2		3	1	33.3
7					1		3	4	1	25.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	15	
# TYPE I ERRORS	3	2	0	3	4	2	1	15	28	34.9
% TYPE I ERRORS	50.0	16.6	0.0	75.0	44.4	50.0	25.0		34.9	65.6

INTERPRETER JJ
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	5	1						6	1	16.7
2		7		1		1		9	2	22.2
3		3	4	3				10	6	60.0
4				0		2		2	2	100.
5					8	1	1	11	3	27.3
6		1				0		1	1	100.
7					1		3	4	1	25.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	16	
# TYPE I ERRORS	1	5	0	4	1	4	1	16	27	37.2
% TYPE I ERRORS	16.6	41.7	0.0	100.	33.3	100.	25.0		37.2	62.8

INTERPRETER JC
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	4							4	0	0.0
	2	1	5				3		9	4	44.4
	3		3	4	3				10	6	60.0
	4		2		0				2	2	100.
	5	1	1			7			9	2	22.2
	6		1		1		1		3	2	66.6
	7					2		4	6	2	33.3
TOTAL # TYPES		6	12	4	4	9	4	4	43	18	
# TYPE I ERRORS		2	7	0	4	2	3	0	78	25	41.9
% TYPE I ERRORS		33.3	58.3	0.0	100.	22.2	75.0	0.0		41.9	58.1

INTERPRETER CP
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. B & W
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	3							3	0	0.0
	2	1	10		3	1	2		17	7	41.2
	3			4					4	0	0.0
	4		1		1				2	1	50.0
	5	2				5			7	2	28.6
	6		1				2		3	1	33.3
	7					3		4	7	3	42.8
TOTAL # TYPES		6	12	4	4	9	4	4	43	14	
# TYPE I ERRORS		3	2	0	3	4	2	0	14	29	32.6
% TYPE I ERRORS		50.0	16.7	0.0	75.0	44.4	50.0	0.0		32.6	67.4

APPENDIX E-2

Test 3: Color Infrared - Interpreter Group 1

C, 2

INTERPRETER CA
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	2	2	3		1		2	10	8	80.0
2	2	5		1	1			9	4	44.4
3	1		0					1	1	100.
4			1	3	1			5	2	50.0
5		2			5	3		10	5	50.0
6		3			1	0		4	4	100.
7	1					1	2	4	2	50.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	26	
# TYPE I ERRORS	4	7	4	1	4	4	2	26	17	60.5
% TYPE I ERRORS	66.6	58.3	100.	25.0	44.4	100.	50.0		60.5	39.5

INTERPRETER KM
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	1	1					1	3	2	66.6
2	2	8				1		11	3	27.3
3			4	1				5	1	20.0
4	3			3				6	3	50.0
5					8	3		11	3	27.3
6		3				0		3	3	100.
7					1		3	4	1	25.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	16	
# TYPE I ERRORS	5	4	0	1	1	4	1	16	27	37.2
% TYPE I ERRORS	83.3	33.3	0.0	25.0	11.1	100.	25.0		37.2	62.8

INTERPRETER EP
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	1	1				1		3	2	66.6
2	1	2	2	3				8	6	75.0
3			2					2	0	0.0
4	1			0		1		2	2	100.
5	2	4			6	1		13	7	46.2
6		5		1	1	0		7	7	100.
7	1				2	1	4	8	4	50.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	28	
# TYPE I ERRORS	5	10	2	4	3	4	0	28	15	65.1
% TYPE I ERRORS	83.3	83.3	50.0	100.	33.3	100.	0.0		65.1	34.9

INTERPRETER CP
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	0	2						2	2	100.
2	4	7			1	2		14	7	50.0
3			4					4	0	0.0
4	2	1		3				6	3	50.0
5					6	1	1	8	2	25.0
6		2		1		1		4	3	75.0
7					2		3	5	2	40.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	19	
# TYPE I ERRORS	6	5	0	1	3	3	1	19	24	44.2
% TYPE I ERRORS	100.	41.7	0.0	25.0	33.3	75.0	25.0		44.2	55.8

INTERPRETER BS
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

Interpreter's Identification	Vegetation Type Identification 1	2	3	4	5	6	7	Total # Groups	# Type II Errors	% Type II Errors
1	3	3						6	3	50.0
2	2	9		1			1	13	4	30.8
3	1		4	3				8	4	50.0
4				0	1	1		2	2	100.
5					6	3	1	10	4	40.0
6					1	0		1	1	100.
7					1		2	3	1	33.3
TOTAL # TYPES	6	12	4	4	9	4	4	43	19	
# TYPE I ERRORS	3	3	0	4	3	4	2	19	24	44.2
% TYPE I ERRORS	50.0	25.0	0.0	100.	33.3	100.	50.0		44.2	55.8

INTERPRETER JJ
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

Interpreter's Identification	Vegetation Type Identification 1	2	3	4	5	6	7	Total # Groups	# Type II Errors	% Type II Errors
1	3	1						4	1	25.0
2	2	8	1					11	3	27.3
3	1	2	2	3				8	6	75.0
4				1				1	0	0.0
5		1			8	4	2	15	7	46.7
6			1			0		1	1	100.
7					1		2	3	1	33.3
TOTAL # TYPES	6	12	4	4	9	4	4	43	19	
# TYPE I ERRORS	3	4	2	3	1	4	2	19	24	44.2
% TYPE I ERRORS	50.0	33.3	50.0	75.0	11.1	100.	50.0		44.2	55.8

INTERPRETER GM
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO Color IR
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	1	2						3	2	66.6
	2	5	7		4	1	1		18	11	61.6
	3			4					4	0	0.0
	4				0				0	0	0.0
	5		1			7	2	2	12	5	41.7
	6		2				1		3	2	66.6
	7					1		2	3	1	33.3
TOTAL # TYPES		6	12	4	4	9	4	4	43	21	
# TYPE I ERRORS		5	5	0	4	2	3	2	21	22	48.8
% TYPE I ERRORS		83.3	41.7	0.0	100.	22.2	75.0	50.0		48.8	51.2

INTERPRETER DM
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

		VEGETATION TYPE IDENTIFICATION							TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
		1	2	3	4	5	6	7			
INTERPRETER'S IDENTIFICATION	1	2	3					1	6	4	66.6
	2	2	6				1		12	6	50.0
	3			4	1				5	1	20.0
	4	2	1		0		1		4	4	100.
	5					8	2		10	2	20.0
	6		2				0		2	2	100.
	7					1		3	4	1	25.0
TOTAL # TYPES		6	12	4	4	9	4	4	43	20	
# TYPE I ERRORS		4	6	0	4	1	4	1	20	23	46.5
% TYPE I ERRORS		66.6	50.0	0.0	100.	11.1	100.	25.0		46.5	53.5

INTERPRETER JC
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	2		1	3				6	4	66.6
2	4	7			1	2		14	7	50.0
3		3	2					4	2	50.0
4			1	1				2	1	50.0
5		1			7	1	1	10	3	30.0
6		2				1		3	2	66.6
7					1		3	4	1	25.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	20	
# TYPE I ERRORS	4	5	2	3	2	3	1	20	23	46.5
% TYPE I ERRORS	66.6	41.7	50.0	75.0	22.2	75.0	25.0		46.5	53.5

INTERPRETER DF
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 1

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	2	2						4	2	50.0
2	2	7			3	2		14	7	50.0
3	1		4	1				6	2	33.3
4		1		3				4	1	25.0
5		2			5	2	2	11	6	54.5
6	1					0		1	1	100.
7					1		2	3	1	33.3
TOTAL # TYPES	6	12	4	4	9	4	4	43	20	
# TYPE I ERRORS	4	5	0	1	4	4	2	20	23	
% TYPE I ERRORS	66.6	41.7	0.0	25.0	44.4	100.	50.0		46.5	53.5

APPENDIX E-3

Test 3: Color Infrared - Interpreter Group 2

INTERPRETER RR
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

	VEGETATION TYPE IDENTIFICATION									
INTERPRETER'S IDENTIFICATION	1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	0	3		1	1			5	5	100.
2	2	4	1		3	2	1	13	9	69.2
3	1		3					4	1	25.0
4				3				3	0	0.0
5	1	5			4	1		11	7	63.6
6	1					1	1	3	2	66.6
7	1				1		2	4	2	50.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	26	
# TYPE I ERRORS	6	8	1	1	5	3	2	26	17	
% TYPE I ERRORS	100.	66.6	25.0	25.0	55.5	75.0	50.0		60.5	39.5

INTERPRETER TL
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

	VEGETATION TYPE IDENTIFICATION									
INTERPRETER'S IDENTIFICATION	1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	1	2						3	2	66.6
2	1	3						4	1	33.3
3	3	2	4	4				13	9	61.5
4				0	2	1	2	5	5	100.
5	1	5			4	1		11	7	63.6
6						2		2	0	0.0
7					3		2	5	3	60.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	27	
# TYPE I ERRORS	5	9	.0	4	5	2	2	27	16	62.8
% TYPE I ERRORS	83.3	75.0	0.0	100.	55.5	50.0	50.0		62.8	37.2

INTERPRETER BP
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	2	1	1					4	2	50.0
2	1	7	1		1	1		11	4	36.7
3	1		2	3				6	4	66.6
4				1	1	1		3	2	66.6
5		4			4	2	3	13	9	69.2
6	1				1	0		2	2	100.
7	1				2		1	4	3	75.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	26	
# TYPE I ERRORS	4	5	2	3	5	4	3	26	17	60.5
% TYPE I ERRORS	66.6	41.7	50.0	75.0	55.6	100.	75.0		60.5	39.5

INTERPRETER DS
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS	
1	1	2	2			1		6	5	83.3	
2	4	6			2			12	6	50.0	
3			0	1		1	2	4	4	100.	
4		1	1	3				5	2	40.0	
5	1	1			4	2	1	9	5	55.5	
6	[illegible]	2				0		2	2	100.	
7			1		3		1	5	4	80.0	[illegible]
TOTAL # TYPES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
# TYPE I ERRORS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
% TYPE I ERRORS	[illegible]	50.0	100.	25.0	33.3	100.	75.0		[illegible]	44.9	

INTERPRETER CW
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

Interpreter's Identification	Vegetation Type Identification 1	2	3	4	5	6	7	Total # Groups	# Type II Errors	% Type II Errors
1	3		1	1	1		1	7	4	57.1
2	2	11	2		2	2	1	20	9	45.0
3			1					1	0	0.0
4		1		3	1			5	2	40.0
5					5	2		7	2	28.6
6	1					0		1	1	100.
7							2	2	0	0.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	18	
# TYPE I ERRORS	3	1	3	1	4	4	2	18	25	41.9
% TYPE I ERRORS	50.0	83.3	75.0	25.0	44.4	100.	50.0		41.9	58.1

INTERPRETER CS
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

Interpreter's Identification	Vegetation Type Identification 1	2	3	4	5	6	7	Total # Groups	# Type II Errors	% Type II Errors
1	2	2	2			2		8	6	75.0
2	4	7		3			2	16	9	56.2
3		1	2					3	1	33.3
4				1	1			2	1	50.0
5		1			5	2		8	3	37.5
6		1				0		1	1	100.
7					3		2	5	3	60.0
TOTAL # TYPES	6	12	4	4	9	4	4	43	24	
# TYPE I ERRORS	4	5	2	3	4	4	2	24	19	55.8
% TYPE I ERRORS	66.6	41.7	50.0	75.0	44.4	100.	50.0		55.8	44.2

INTERPRETER JN.
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO. Color IR
GROUP 2

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1	2		2					4	2	50.0
2	3	7		3		2		15	8	53.3
3			2	1				3	1	33.3
4		3		0				3	3	100.
5		1			9	1	3	14	5	35.7
6						1		1	0	0.0
7	1	1					1	3	2	66.6
TOTAL # TYPES	6	12	4	4	9	4	4	43	21	
# TYPE I ERRORS	4	5	2	4	0	3	3	21	22	48.8
% TYPE I ERRORS	66.6	41.7	50.0	100.	0.0	75.0	75.0		48.8	51.2

INTERPRETER
EXPERIENCE LEVEL 1 3 5
TYPE OF PHOTO.
GROUP

TEST #3

INTERPRETER'S IDENTIFICATION	VEGETATION TYPE IDENTIFICATION 1	2	3	4	5	6	7	TOTAL # GROUPS	# TYPE II ERRORS	% TYPE II ERRORS
1										
2										
3										
4										
5										
6										
7										
TOTAL # TYPES										
# TYPE I ERRORS										
% TYPE I ERRORS										