SECTION 32 Forestry

# IDENTIFICATION AND MEASUREMENT OF SHRUB TYPE VEGETATION ON LARGE-SCALE AERIAL PHOTOGRAPHS

by

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## ABSTRACT

Important range-shrub species were identified at acceptable levels of accuracy on large-scale (1:600 to 1:1,500) 70 mm color and color infrared aerial photographs (positive transparencies). Identification of individual shrubs was significantly higher, however, on color infrared. Eight of 11 species were identified correctly more than 80 percent of the time on color infrared and two species were correctly identified 100 percent of the time. Six species were identified more than 80 percent correctly on color photographs but none were identified 100 percent correctly. Photoscales smaller than 1:2,400 had limited value except for mature individuals of relatively tall species, and then only if crown margins did not overlap and sharp contrast was evident between the species and background. Larger scale photos (1:800 or less) were required for low-growing species in dense stands. The crown cover for individual species was estimated from the aerial photos either with a measuring magnifier or a projected-scale micrometer. Photo measurements were significantly correlated with ground measurements. These crown cover measurements provide techniques for earth-resource analyses when used in conjunction with space and high-altitude remotely procured photos.

## INTRODUCTION

The Nation's rangelands include approximately one billion acres of land not suitable for cultivated crop production. They produce forage for domestic and wild grazing animals, and provide recreational and intangible natural beauty benefits. They include the drainages of many river systems from which domestic and commercial water supplies are derived. These wildland areas, especially in the West, are relatively inaccessible due to topographic constraints or lack of access routes by land vehicles.

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The range resources of these lands need to be more frequently inventoried and evaluated as a basis for developing national policies and programs for integrated rangeland use. Such an inventory would provide periodic data on quantity and quality of the resource. Inventories, including the extent and composition of plant communities, have been conducted by ground sampling for decades, but only a small fraction of the range area has been covered in detail. Because ground sampling requires considerable time, the relative composition of the communities may change due to natural phenology changes. Consequently, data interpretation is complicated and the results may produce a false image of the resource.

Aerial and space photographs (the scale depending on information needs) will potentially provide the data base required for a dynamic range resource inventory and information system. It has been demonstrated how space and high-flight aerial photographs can be used to locate, map, and determine the areal extent of plant communities (Poulton, Driscoll and Schrumpf, 1969). The next level of information needed for this kind of a resource inventory is the identity of the plant community components as well as some measure of quantity.

The purpose of this paper is to review results and progress on use of color and color infrared aerial photographs to identify and measure species components of plant communities dominated by shrubs. It deals with large-scale (1:600-1:2,400) 70 mm aerial photographs. Increased ability to interpret data from such photos will help us to better interpret space or high-flight aircraft photographs.

## AERIAL PHOTOGRAPHY AND GROUND DATA

Three areas were selected for this research, all in Colorado: (1) A high-mountain grassland in which two shrub species, shrubby cinquefoil and Parry rabbitbrush, were widely distributed within heterogeneous herbaceous communities. (2) A pygmy forest with pinyon pine and juniper as the major species; true mountain-mahogany, big sagebrush, and some bitterbrush occurred in the understory. (3) An area with a heterogeneous stand of shrubs including big sagebrush, alkali sagebrush, bitterbrush, Douglas rabbitbrush, snowberry, and broom snakeweed.

Aerial photographs were taken from the Forest Service Aero Commander assigned to the Remote Sensing Research Project at the Pacific Southwest Forest and Range Experiment Station, Berkeley, California. The camera package consisted of two Maurer KB-8 70 mm cameras mounted in a single frame to provide simultaneous photographs with two film/filter combinations. Film used was color infrared (Ektachrome Infrared Aero Type 8443) filtered with a Wratten 12 filter, and normal color (Ansco D-200 Type 7230) filtered with a Wratten 1-A skylight filter.

Photo missions were flown four times during the growing season to determine when during different plant growth stages the species previously mentioned could most accurately be identified in the resultant photographs. Various photoscales ranging from 1:600 to 1:4,800 were obtained each time to determine the resolution threshold for identifying the various plant species at an acceptable level of accuracy.

Ground data were obtained from a series of 6-meter-square plots aligned near the center of the flight lines at each location (Fig. 1). Within and around these plots, individual shrubs were marked and identified so they could be located and positively identified in the aerial photographs. In addition the position of four line transects were marked within the plots so they could also be identified in the aerial photographs. Foliage or crown cover of each shrub species was measured on the ground by a line intercept technique (Canfield 1947). These ground data were compared against cover estimates of individual shrub species measured on the line transects directly on the aerial photographs. The photo measurement devices used are defined in a subsequent section.

## RESULTS AND DISCUSSION

### SPECIES IDENTIFICATION

Detailed interpretation of the aerial photographs revealed that we could extract the greatest amount of information from photographs taken in early July. This does not mean that this photography provided the "best" information for the identification of all species. The selection was based on the inference that if an investigator, because of budgetary or other constraints, had to limit efforts to a single time for data gathering, early July would provide the most useful information.

Image characteristics used to develop a dichotomous photointerpretation key for the nine shrubs and two small trees included relative size, shadow, crown margin, crown shape, foliage pattern, texture, and color. At least 10 replicates were selected for nine of the species; more than six for the other two species, for a photointerpretation test. Four image analysts with varying degrees of experience and knowledge of the areas photographed completed the test. The results of the test, primarily with 1:600 to 1:1,500 scale photos, were as follows:

1. Identification of individual shrubs was significantly higher ($P = .01$) on color infrared positive transparencies, regardless of interpreter experience or shrub species.

2. There was a significant difference ($P = .01$) among interpreters for identifying the species which depended on photointerpretation experience and knowledge of the area imaged in the photos.

3. Identification of larger species was significantly better ($P = .01$) regardless of film type or interpreter.

In general, 82 percent of the total 456 test specimens were correctly identified on the color infrared photos; 76 percent were correctly identified on color (Table I). Eight of the 11 species were identified at acceptable levels of accuracy ( > 80 percent) on color infrared; two of them were identified 100 percent by all interpreters. Six species were identified correctly more than 80 percent of the time on color photos, and none were identified 100 percent correctly by all interpreters.

Greatest differences in species identification between film types were for bitterbrush, snowberry, and mountainmahogany. Bitterbrush and snowberry had very similar colors both on the ground and in the color aerial photos. Consequently, identifications of these species were frequently confused. Greater color contrasts between the images of these two species in the color infrared photos improved identification (Fig. 2).

Mountainmahogany was frequently confused with small pinyon pine in the color photographs, especially when the apparent morphological characters as viewed in the film were similar. In the color infrared photos, color differences between the two species were sufficiently contrasting that errors in identification of the species were very unlikely (Fig. 3).

Image character differences among snowberry and the two species of rabbitbrush were so subtle that the species were hard to distinguish, regardless of film type or photoscale used (Figs. 2, 4). The most experienced interpreter identified these species in the color infrared photos correctly 90, 92, and 92 percent, respectively.

Differences among interpreters were related to interpretation experience and knowledge of the area. The image analyst with the most experience and knowledge of the area scored highest on the photointerpretation test. The least experienced analyst with least knowledge of the area or the species scored lowest.

With the camera system used for this research, mature plants of relatively tall species such as mountainmahogany and big sagebrush were readily identified with photoscales at 1:1,500. Photoscales to 1:2,400 proved satisfactory provided plant crown margins did not overlap and there was relatively high contrast between the species and background. Ability to identify individual species in heterogeneous shrub communities where plant crowns intermingled deteriorated rapidly at photoscales smaller than 1:950.

Multiseasonal photography remains important, however, to gain the most information about individual species. When to secure data about individual species can be patterned after determining the seasonality of the species of interest. For example, some species such as rabbitbrush, gain full vegetational development late in the growing season. Others, such as bitterbrush, are fully developed relatively early in the growing season. Photoidentification of these species was improved by using either late season photography (rabbitbrush) or early season photography (bitterbrush). Some species, including sagebrush, shrubby cinquefoil, and mountainmahogany, contrast sufficiently with associated vegetation that they can be identified, using the proper photoscale, with acceptable accuracy at any time during the growing season.

We attempted to develop automated species identification using a GAF Model 650 scanning microdensitometer in cooperation with the Remote Sensing Research Project, Pacific Southwest Forest and Range Experiment Station. We used the aerial color infrared positive transparencies for this work because of the manual photointerpretation success with this film type. The instrument senses image optical density in the transparencies by means of a light beam passed through the film onto a photocell. A strip-chart recorder is activated to produce a continuous density trace of a predetermined scan line marked in a transparency.

Although the mean image densities of selected species appear to separate, the density ranges among individual species indicate this method is not yet feasible for automatic image interpretation if several species occur in the same plant community image (Table II). However, if photographs are of communities in which the two species of sagebrush are the only shrubs, the technique is potentially useful. The image density differences between bare soil and live vegetation cover indicate the system is capable of automatically separating these two categories. The technique has potential; additional research is needed to define machine aperture mode and light filtration for acceptable automated interpretation.

## MEASUREMENTS

Two kinds of measuring devices were used to relate photo measurements to ground measurements of foliage and crown cover of shrubs. One device was a simple 7-X measuring magnifier scaled for 0.1 mm (100 microns) measurements. The other was a projected-scale micrometer which, when attached to a Zoom 70 stereoscope, measures distance on aerial photographs directly to 0.00001 foot (3 microns).

The scale of each of these instruments was aligned along transect markers visible in the color infrared aerial transparencies. Crown cover of individual shrubs was estimated by determining the distance each shrub crown image covered along the scale line between the transect markers. These estimates were related to ground estimates by correlation and regression.

Our data for big sagebrush (Fig. 5) indicate that both measurement techniques provide acceptable information for relating photo to ground measurements of foliar cover of individual shrubs. Similar relationships existed for the other three species included in this work.

In all cases for all species, the correlation coefficients were highly significant (P = .01). In all cases, the correlation coefficients of data obtained using the measuring magnifier were greater than 0.86, whereas for the projected-scale micrometer they were slightly less. However, the projected-scale micrometer yields close to a one-to-one relationship (b = 1) between photo and ground measurements (Fig. 5). This instrument might therefore be selected for this photo measurement technique, except that its cost is 25 times that of the measuring magnifier, which provides equally acceptable information within the data range used for this work.

We discovered that the cost ratio of ground/photo measurements is in the magnitude of 10:1. This means that it costs 10 times as much to measure a transect on the ground as compared to the same transect imaged in the aerial photography. Therefore, we have defined an initial cost savings capability which, through multiple sampling techniques relating ground to photo measurements, will provide acceptable data about some parts of the range resource for large areas at less cost than ground sampling alone.

## CONCLUDING REMARKS

We have developed a way of measuring ground vegetation, at least shrubby species, using large-scale color infrared aerial photographs. The technique provides at least partially quantified information about the mapping units defined on space or high-flight aircraft photographs for use in range resource inventory. It has the advantage of complementing the multistaged sampling procedure and data handling system defined by Langley, Aldrich and Heller (1969). Additional research is needed, however, before such a data system is implemented to inventory range resources. These needs include:

1. We must develop the capability to extrapolate the research results we now have to other land areas of similar vegetation for species identification and measurement from aerial photographs.

2. We need to further define, develop, and refine multiple sampling techniques, including multistage sampling, to relate ground data to space or high-flight aircraft photography for range resource inventory and evaluation.

3. We need to develop automated interpreation techniques controlled by sample data of absolute information in order to transfer raw remote sensor data to the user of the information as rapidly as possible.

## LITERATURE CITED

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TABLE I.- CORRECT SHRUB AND SMALL TREE IDENTIFICATION PERCENTS BY INTERPRETER AND FILM TYPE

| Species | Interpreter[1] A | | B | | C | | D | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Film Type | | | | | | | | | |
| | EIR[2] | D-200[3] | EIR | D-200 | EIR | D-200 | EIR | D-200 | EIR | D-200 |
| Alkali sage | 100 | 100 | 100 | 100 | 100 | 90 | 100 | 100 | 100 | 98 |
| Big sagebrush | 100 | 80 | 90 | 90 | 70 | 100 | 100 | 100 | 90 | 93 |
| Mountainmahogany | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 67 | 100 | 92 |
| Parry rabbitbrush | 92 | 100 | 50 | 50 | 42 | 42 | 58 | 33 | 60 | 56 |
| Green rabbitbrush | 92 | 67 | 50 | 42 | 54 | 33 | 25 | 58 | 56 | 50 |
| Snakeweed | 90 | 90 | 100 | 100 | 100 | 80 | 80 | 80 | 93 | 88 |
| Juniper | 100 | 92 | 100 | 100 | 83 | 83 | 100 | 100 | 96 | 94 |
| Pinyon pine | 100 | 92 | 100 | 92 | 77 | 92 | 92 | 85 | 92 | 90 |
| Bitterbrush | 90 | 40 | 80 | 80 | 70 | 60 | 70 | 20 | 78 | 50 |
| Cinquefoil | 100 | 100 | 83 | 83 | 83 | 67 | 67 | 67 | 83 | 79 |
| Snowberry | 90 | 70 | 60 | 70 | 40 | 30 | 50 | 40 | 60 | 55 |
| Mean | 95 | 85 | 84 | 81 | 72 | 68 | 71 | 70 | 83 | 76 |

1/ A = Skilled interpreter familiar with the area

B = Skilled interpreter unfamiliar with the area

C = Medium experienced interpreter unfamiliar with the area

D = Inexperienced interpreter unfamiliar with the area

2/ Ektachrome Aero Infrared (Type 8443)

3/ Anscochrome D-200 (Type 7220)

TABLE II.- MEANS AND RANGES OF IMAGE DENSITY VALUES FROM 70 MM COLOR INFRARED POSITIVE TRANSPARENCIES EXPOSED IN JULY OF FOUR SHRUBS, TWO SMALL TREES, AND BARE SOIL, SCALE 1:1,100

| Species or Object | Image Density Values | |
| --- | --- | --- |
| | Mean | Range |
| *Cercocarpus montanus* | 3.676 | 3.15-4.42 |
| *Pinus edulis* | 3.655 | 3.26-4.12 |
| *Juniperus scopulorum* | 3.266 | 3.04-3.56 |
| *Purshia tridentata* | 3.169 | 2.97-3.53 |
| *Artemisia tridentata* | 2.805 | 2.56-3.00 |
| *Artemisia longiloba* | 2.768 | 2.62-2.72 |
| Bare Soil | 2.497 | 2.44-2.58 |

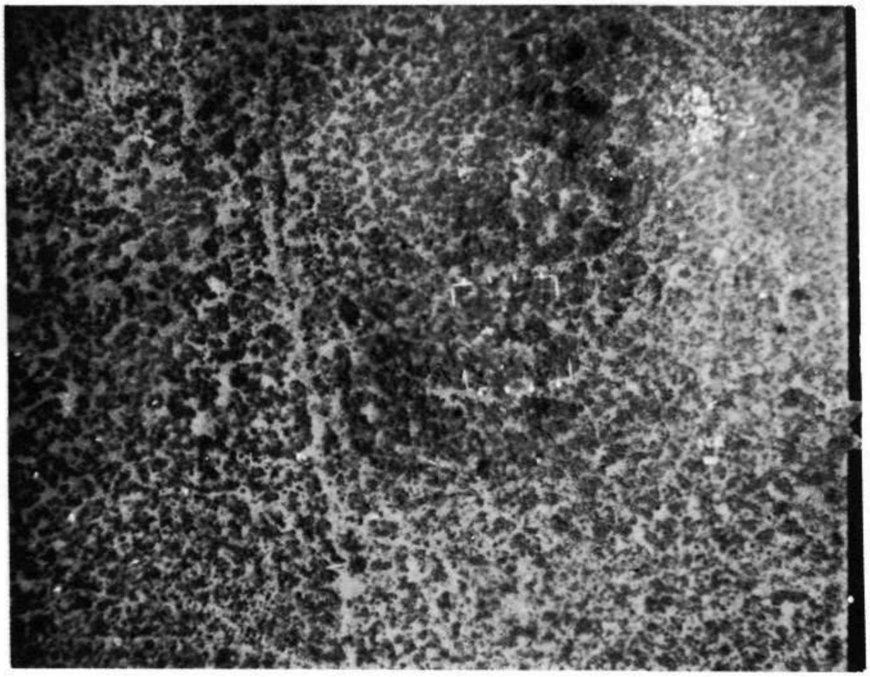

Figure 1.- A reproduction of an aerial photograph showing the plot marking system for identification and measurement of shrub species. The 6-meter-square plot is in the right center. Transect markers for measuring shrub crown cover are visible on the upper and lower boundaries of the plot. Markers identifying the location of individual shrub species are visible within the plot boundaries and in the lower left center.

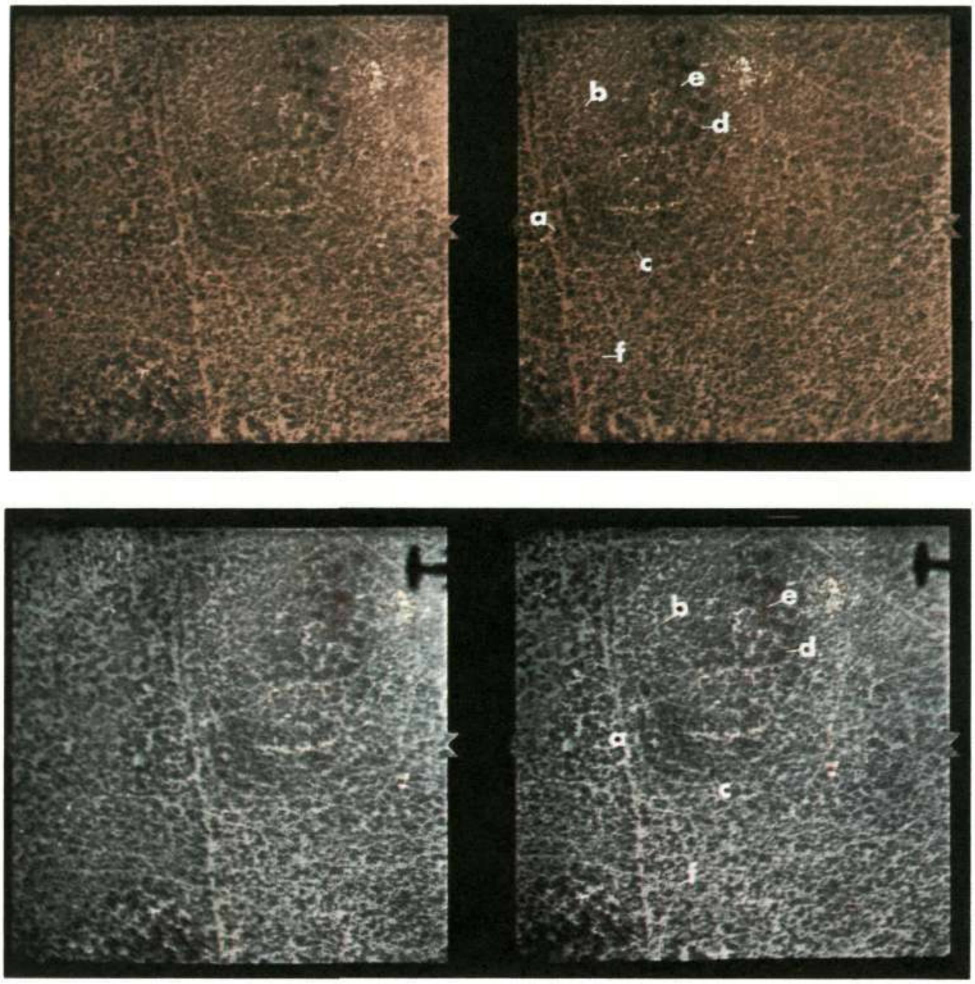


Figure 2.- Top--Anscochrome D-200; Bottom--Ektachrome Infrared stereograms at a scale of 1:800. Errors in identification of snowberry (d) and bitterbrush (e) were high in the color photos. Identification of the two species was improved in the color infrared. Other species indicated are: (a) big sagebrush, (b) alkali sagebrush, (c) green rabbitbrush, and (f) broom snakeweed.

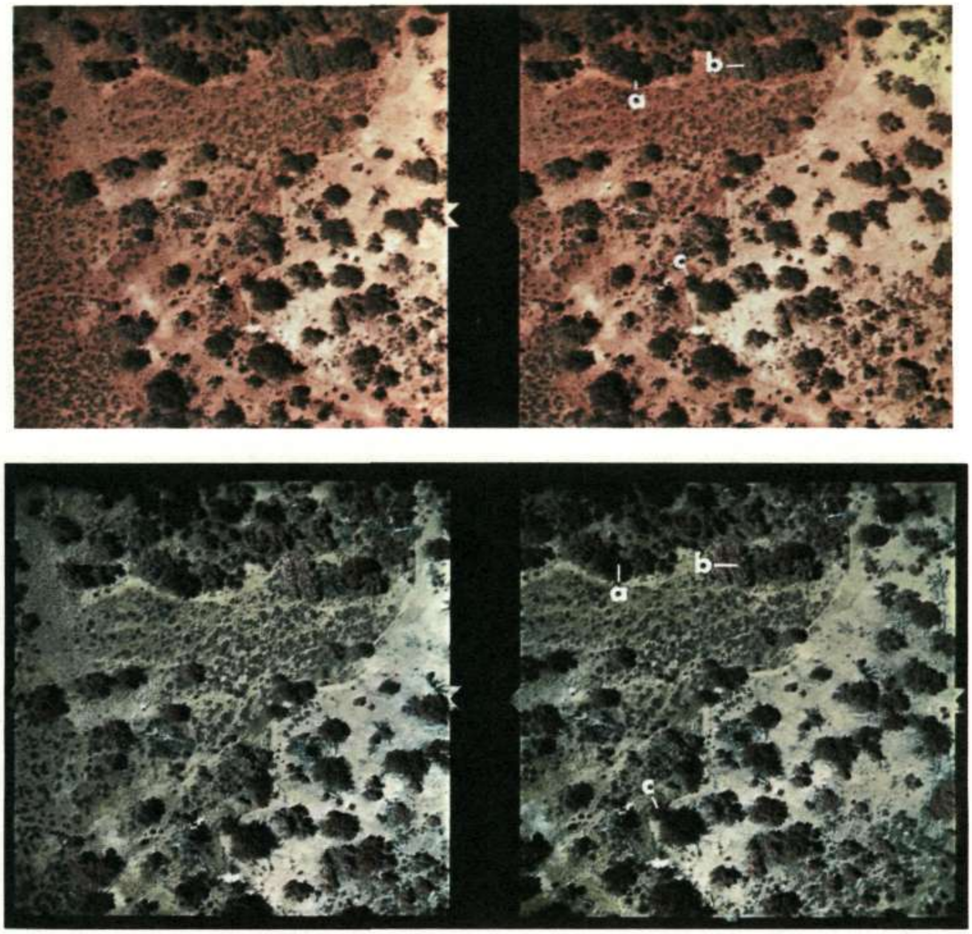


Figure 3.- Stereo pairs in color (top) and color infrared (bottom) of mountainmahogany (c) at a scale of 1:1,500. Color contrasts between this species and all others were sufficient in the color infrared to provide 100 percent correct identification. Some commission errors occurred between this species and small pinyon pine in the color photos, although not of sufficient magnitude to warrant complete rejection of color photos for identifying the species. Other plant species indicated are (a) pinyon pine and (b) juniper.

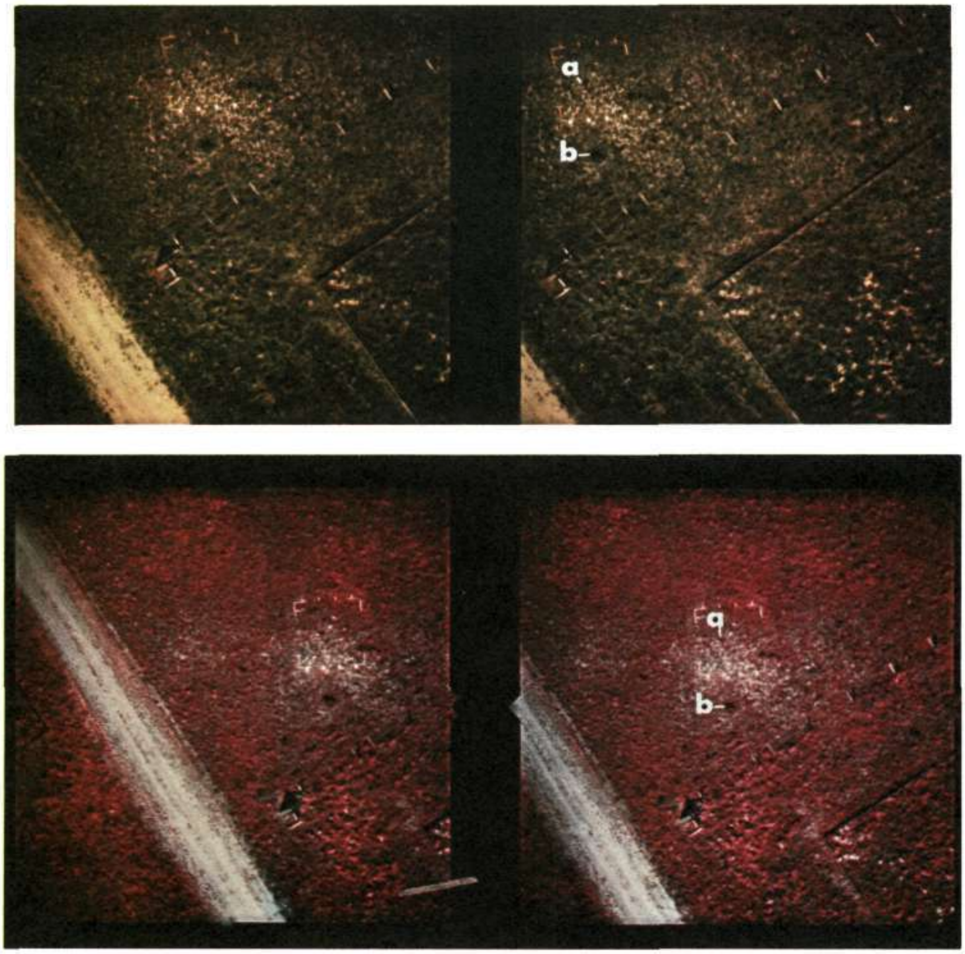


Figure 4.- Rabbitbrush (a) is difficult to identify in either color (top) or color infrared (bottom) stereograms even at photoscales of 1:600. Unless an interpreter knew that rabbitbrush was the only shrub species in the area imaged, commission errors were high, especially among the two species of rabbitbrush and snowberry. The other species indicated is cinquefoil (b). See Figure 2 (d) snowberry and (c) rabbitbrush for comparisons among the species.

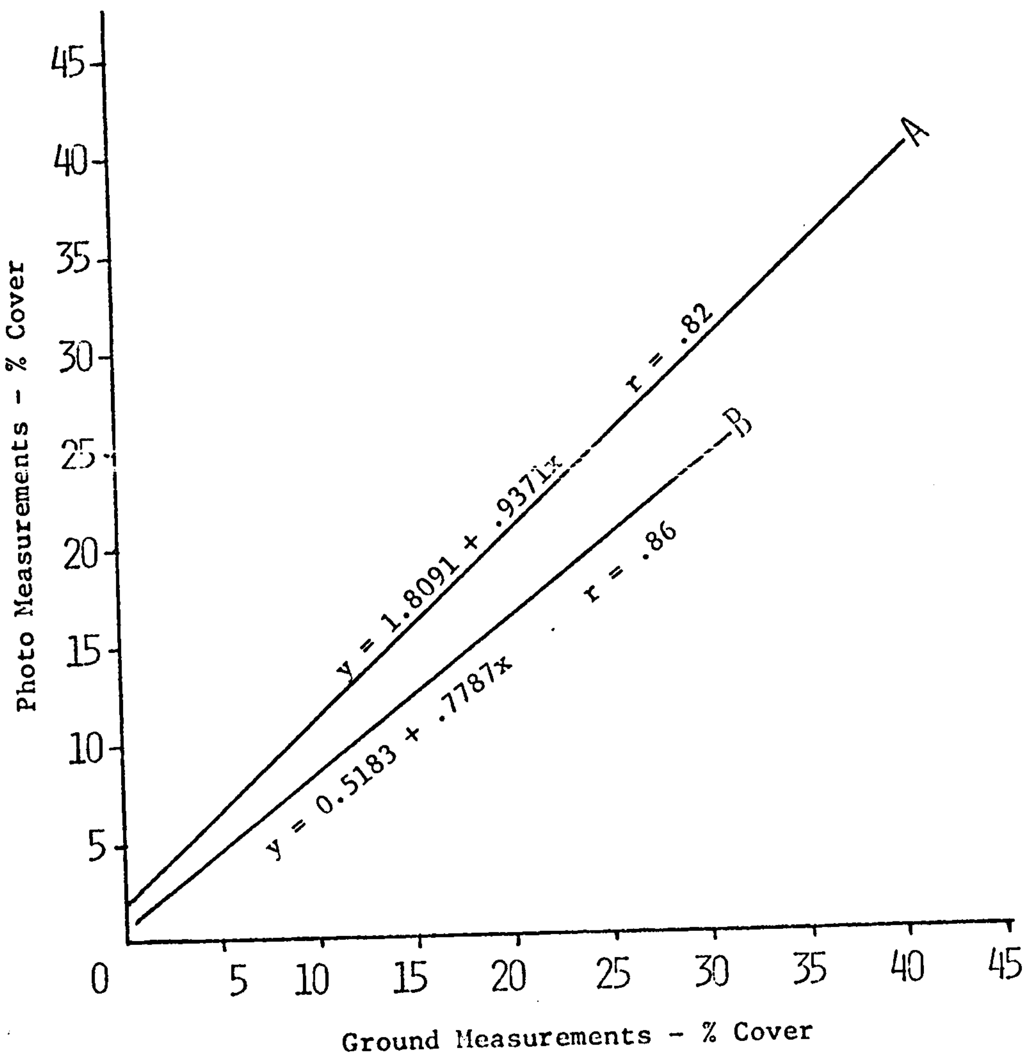


Figure 5.- Comparison of ground to photo measurements of percent cover of big sagebrush. (A): projected-scale micrometer; (B): measuring magnifier.