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Color for Shrubs*

Large-scale, 70-mm, color and color-infrared aerial photos are used to test the ability to identify shrubs, such as species of sagebrush, rabbitbrush, etc., in different plant communities.

Abstract: *Identification of individual shrubs was significantly better on large-scale (1:800—1:1,500) 70-mm color-infrared aerial photographs than on normal color. Seven of 11 species were identified correctly more than 80 percent of the time on color infrared; two 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 larger) were required for low-growing species in dense stands.*

Introduction

Anyone responsible for the management and use of native vegetation must have an inventory of that vegetation. He must have data about the location and distribution of plant communities and information concerning the kinds and amounts of individual plant species within those communities. Ecologists, range and wildlife habitat analysts, foresters, and watershed managers need such data to make intelligent management decisions about land use.

Normal- to small-scale (1:12,000-1:30,000) panchromatic and, more recently, color aerial photographs are continuously being used to classify and map plant communities. Information about the structure of these communities, especially the shrubby and herbaceous components, is obtained by expensive ground sampling which usually includes only small portions of the total community area. Also, quantitative structure of these communities will likely change during the sampling period due to natural phenological phenomena. Therefore, data interpretation is complicated and the results may produce a false notion about community structure.

Recent research has shown that large-scale (1:2,000 or larger) 70-mm aerial photographs can be used in tree identification, timber inventories, and forest stand damage (Sayn-Wittgenstein 1960, 1962; Heller et al. 1964, 1967; Parry et al. 1969; Langley et al. 1969). Aldrich (1966) identified the advantages of the 70-mm system as a forest sampling tool. Reference has been made to potential uses of the system for vegetation other than trees (Carneggie and Reppert 1969; Reppert and Driscoll 1970), but without quantification.

The following describes results of research designed to define the season and photoscale threshold for most accurately identifying shrub species on large-scale 70-mm color and color-infrared film.

Field Procedures

Ground Data

Three test sites were selected for this research:

*Research conducted in cooperation with the National Aeronautics & Space Administration, Earth Resources Survey Program, Houston, Texas, and the Forest Remote Sensing Project, Pacific Southwest Forest & Range Experiment Station, USDA Forest Service, Berkeley, Calif.

- A mountain grassland at an altitude of approximately 3,000 meters above mean sea level. Two shrubs, shrubby cinquefoil (*Potentilla fruticosa* L.) and Parry rabbitbrush (*Chrysothamnus parryi* A. Gray), occurred throughout the area.
- A shrub type at approximately 2,500 meters above mean sea level. Six shrub species were included in the experiment: big sagebrush (*Artemisia tridentata* Nutt.), low sagebrush (*Artemisia tridentata arbuscula* (Nutt.) H. & C.), Vasey rabbitbrush (*Chrysothamnus vaseyi* (A. Gray) Greene), antelope bitterbrush (*Purshia tridentata* (Pursh) D.C.), broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. and Rusby) and mountain snowberry (*Symphoricarpos oreophilus* Gray).
- A pygmy forest community at an elevation of approximately 2,300 meters above mean sea level. Two shrubby species, true mountainmahogany (*Cercocarpus montanus* Raf.) and big sagebrush, were common. Two small trees, pinyon pine (*Pinus edulis* Engelm.) and Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), were also included.

Ground data consisted of ground-marking individual shrubs near the center of a flight line approximately 1 kilometer long at each test site (Francis 1970). At all test sites at least 10 shrubs of each species, except shrubby cinquefoil and Parry rabbitbrush, were ground-marked for positive aerial photo identification to identify image characteristics and develop photointerpretation keys. Identification of six examples of these two scarce species was ground verified on aerial photographs by a person not involved in subsequent photointerpretation testing.

Phenology of each species was defined at each photo mission according to the state of leafiness, flowering, fruiting, and growth cessation. Although Munsell color notations of the foliage and total plant of each species were attempted, the data were not used due to extreme color differences caused by variations of the external morphology of the leaves of most species and inclusion of dead wood in shrub crowns.

AERIAL PHOTOGRAPHY

Two Maurer KB-8A* 70-mm cameras, each with Schneider Xenotar lenses, $f=150$ mm (5.90 inches), were mounted in an Aero Commander 500-B to provide simultaneous stereo photographs. Details on the use of this camera system, its advantages and limitations have been defined by Aldrich (1966).

Films used were Anscochrome D/200 (Type 7230) and Kodak Ektachrome Infrared Aero (Type 8443). A Wratten 1-A sky-light filter was used with the color film; a Wratten 12 with the color-infrared.

Photo missions were flown four times during the growing season: (1) immediately after the beginning of growth for most plants —leaves ¼ to ½ developed (around June 1); (2) at full leaf development and beginning of flowering and fruiting on some plants (bitterbrush, snowberry, sagebrush, true mountainmahogany, and shrubby cinquefoil) around July 1; (3) after fruiting for the previously mentioned species but during flowering for late-developing species (rabbitbrush and broom snakeweed) around August 1; and (4) at the cessation of growth of all species around October 1. On each date four photographic scales were obtained: 1:800, 1:1,500, 1:2,400, and 1:4,800.

All missions were flown between 1000 and 1130 hours, standard time. Atmospheric attenuation was deemed not to affect photo images due to the relatively high elevations of the test sites with clear and dry air and the low flying altitudes. All photography and film processing was done by the U. S. Forest Service Remote Sensing Project in Berkeley, California.

LABORATORY PROCEDURES

Both film types were processed to positive transparencies. The July photographs were used to develop the primary photointerpretation keys for P. I. testing. This does not mean that these photographs provided the *best* information for identifying each *species*. This selection was based on the requirement that if an investigator had to select a *single* time for data collection, early July would provide the best collective information about all species.

The basic photoscales used were 1:800 for the grassland and shrub types and 1:1,500 for the pygmy forest type. The 1:800 scale was selected because detection and possible image description of individual shrubs deteriorated rapidly at the smaller photoscales due to high plant density and community heterogeneity. The 1:1,500 scale was selected because the shrubs spaced 3 to 15 feet apart were detectable.

Identification of each ground-marked plant was verified in the aerial photographs from both film types. Photo image characters and character states (Table 1) were defined for each species to represent modal descriptions.

*Trade names and company names are used for the cognition of the reader and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.

TABLE 1. CHARACTERS AND STATES OF IMAGES USED FOR AERIAL PHOTO IDENTIFICATION OF SHRUBS.

1. Plant Height
   1. > 5 ft.
   2. < 5 ft.
2. Shadow
   1. distinct
   2. indistinct
3. Crown Margin
   1. smooth
   2. wavy
   3. irregular
   4. broken
4. Crown Shape
   1. indistinct
   2. round
   3. oblong
5. Foliage Pattern
   1. continuous
   2. clumpy
   3. irregular
6. Texture
   1. fine
   2. medium
   3. coarse
   4. stippled
   5. mottled
   6. hazy
7. Color is designated numerically and adjectively according to NBS ISCC-NBS color system (American Society of Photogrammetry 1968)

These data were used to develop dichotomous P. I. keys for each film type.†

Four image analysts with varying degrees of photointerpretation experience and knowledge of the respective areas were used in the test. They included:

A. A skilled interpreter familiar with the areas photographed and the associated vegetation.
B. A skilled interpreter unfamiliar with the areas but knowledgeable about the vegetation.
C. An experienced interpreter unfamiliar with the area but generally knowledgeable about the vegetation.
D. An inexperienced interpreter unfamiliar with the area or the native vegetation.

All interpreters had access for reference stereograms on which the plant species had been positively identified, descriptions of the species image characters and states, and copies of the keys. For P. I. testing, at least 10 replicates of each species were selected, marked, and numbered sequentially on stereograms unfamiliar to the interpreters. Variable 2- to 4-X power stereoscopes were used to view the transparencies. One viewing stage was used for each film type and the light intensity at the surface was compatible for each type (5,500° K for the color and 3,500° K for the color infrared).

†A copy of the P. I. keys and more nearly complete definitions of the image characters and states can be obtained from the Rocky Mountain Forest & Range Experiment Station, 240 W. Prospect, Fort Collins, Colo. 80521.

RESULTS AND DISCUSSION

Percentage correct identification by film type, interpreter, and species were used in a factorial analysis, which showed the following:

★ Identification of the plant species was significantly higher ($P=0.01$) on color-infrared transparencies, regardless of interpreter experience or species.

★ Photointerpretation experience and knowledge of the areas imaged in the photos significantly affected ($P=0.01$) interpreters' ability to identify plant species.

★ Identification of the taller species, such as true mountainmahogany, big sagebrush, pinyon pine, and Rocky Mountain juniper, was significantly better ($P=0.01$), regardless of film type or interpreter.

Of the total 456 test specimens, 83 percent were correctly identified from the color-infrared transparencies; 76 percent were correctly identified from color (Table 2). Seven of the 11 species were identified at acceptable levels of accuracy (> 80 percent) from the color infrared; two were identified 100 percent by all interpreters. Antelope bitterbrush was identified correctly 78 percent of the time using the color infrared; this lesser percentage was due to commission errors between antelope bitterbrush and mountain snowberry by the two least experienced interpreters. Six species were identified correctly more than 80 percent of the time from color transparencies, but none were identified 100 percent correctly by all interpreters.

Interpreter *A* scored highest on the test; interpreter *D* scored lowest. Interpreter *A*, an ecologist knowledgeable about the vegetation in all three areas, provided at least 90 percent correct identifications of all species using color infrared; six of the species were identified 100 percent correctly. This interpreter identified seven of the species more than 90 percent of the time on the color transparencies.

The other analysts had particular difficulty identifying the two species of rabbitbrush on both film types. These two species looked very similar at a distance on the ground; their growth forms were similar, and consequently the image characters also were similar. Therefore, photointerpretation alone, even by experienced interpreters using detailed keys, is not always satisfactory. Interpretation accuracy is significantly improved if the interpreter has an ecological knowledge about the area under investigation. This means knowing the plant species in the area, how they are distributed, and what associated evidences might be used in the interpretation process. For example, interpreter *A* (Table 2) knew that wherever shrubby cinquefoil was photo-identified, Vasey rabbitbrush would not be present because the ecological amplitudes of the two species do not overlap in the areas photographed.

Among all analysts, the greatest differences in species identification between film types were for antelope bitterbrush, mountain snowberry, and true mountainmahogany. Antelope bitterbrush and mountain snowberry had similar colors both on the ground and in the color aerial photos. Consequently, commission errors in the color photos between these two species were high. Greater color contrasts in the color infrared photographs of the species improved identification (Figure 1).

True mountainmahogany and small pinyon pine (Figure 2) were frequently confused by interpreter *D* using the color photographs when both species were approximately the same height. In the color infrared photos, color differences between the two species were sufficiently contrasting that commission errors would be unlikely.

Snowberry and the two species of rabbitbrush were the most difficult species to identify in both film types, regardless of photoscale used (Figures 1 and 3). Image characteristics among these species were so similar that only the most astute interpreter could provide satisfactory data (Table 2). However, interpreter *A* identified these three species in the color infrared photos correctly 90, 92, and 92 percent, respectively, which was significantly better than the correct identifications by the other three interpreters.

Photoscales smaller than 1:2,400 had limited value for shrub identification by visual interpretation. Mature plants of relatively tall species, such as mountainmahogany and big sagebrush, were readily identified with these photoscales if crown margins did not overlap and there was a relatively sharp contrast between the species and background. Larger scale photos (1:800 or larger) were required for identification of relatively low-growing shrubs, especially where associated vegetation was dense (crown margins close or touching). Species with conspicuous flowers such as shrubby cinquefoil, were identified equally well in late spring during blooming and in late summer when image characters differentiate the species from other associated vegetation.

In complex shrub stands where plant crowns intermingled, ability to identify individual shrub species deteriorated rapidly at photoscales smaller than 1:800. Some shrubs, such as species of sagebrush which maintained contrasting differences from associated vegetation throughout the growing season, especially actual color, were identified equally well at any time during the growing season.

Although interpreter *A* provided acceptable data for most species on both film types, other potential interpreters may not have similar capabilities. However, the other image analysts scored better with color-infrared in all but four of the 33 situations. In addition, the assessment of the best film type for identifying shrubs must consider the time involved in photointerpretation. The average time required for the interpreters to take the test using the color-infrared photos was 6 hours; it took 9 hours for the color photos.

Summary and Conclusions

§§ Identification of shrubs was significantly more accurate on large-scale (1:800-1:1,500) color-infrared aerial photographs than on normal color, regardless of interpreter experience or shrub species. Of 456 test specimens, 83 percent were correctly identified on color-infrared; 76 percent were correctly identified on normal color.

§§ Identification of some shrubs was significantly easier regardless of film type, due primarily to shrub size and species diversity in the image area. Mature plants of tall species growing quite monospecifically are readily identified at photoscales of 1:1,500 and in some instances at photoscales up to 1:2,400. Larger photoscales (1:800 or larger) were required for identifying relatively low-growing shrubs in mixed stands.

§§ Some shrubs were identified equally well throughout the growing season. Species such as sagebrush, mountainmahogany, and shrubby cinquefoil maintain sufficient differences, primarily color, throughout the growing season that they can be accurately

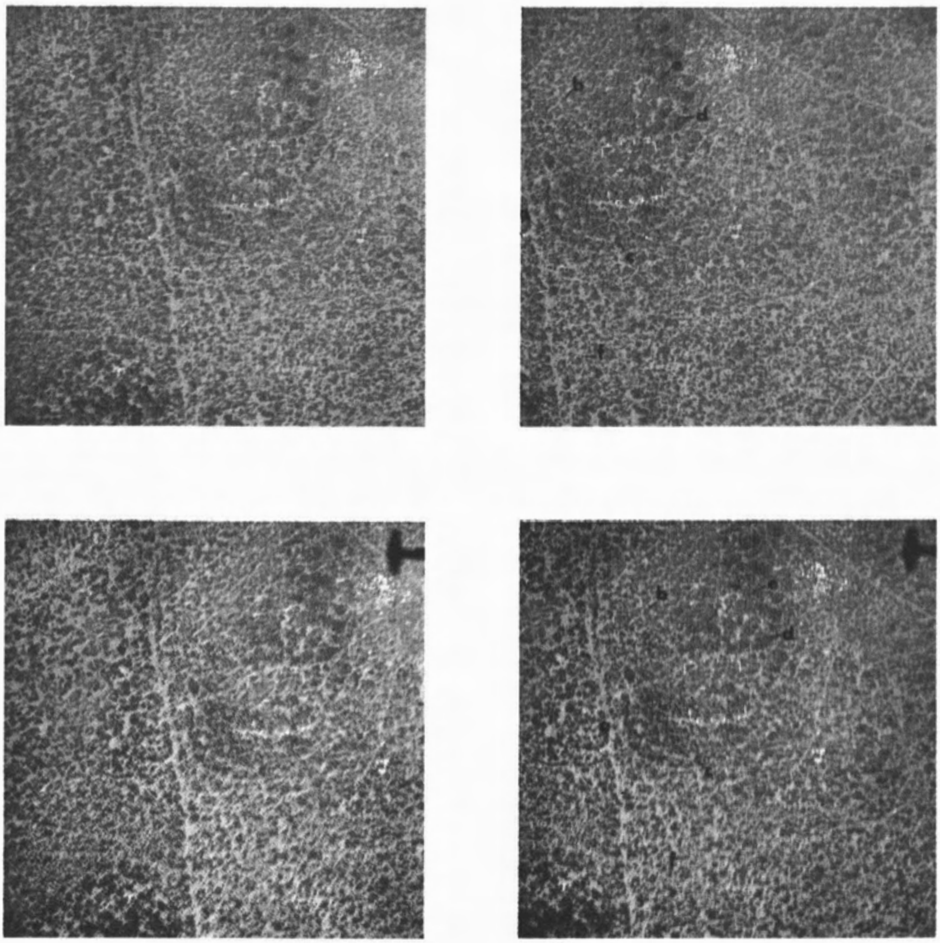

Plate 1. Top — Anscochrome D/200; Bottom — Ektachrome Infrared; both stereograms at a scale of 1:800. Commission errors in identification of mountain snowberry (d) and bitterbrush (e) were high in the color photos. Identification was improved from color infrared. Other species indicated are: (a) big sagebrush, (b) low sagebrush, (c) Vasey rabbitbrush, and (f) broom snakeweed.

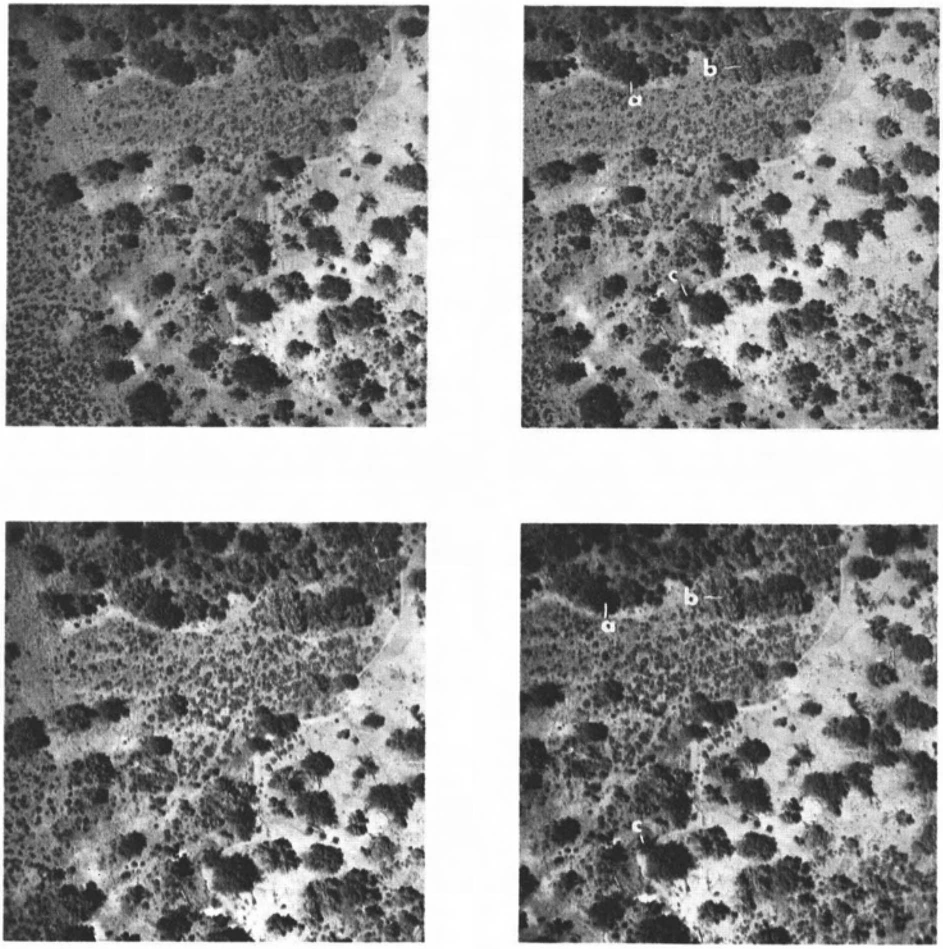

Plate 2. Stereograms in color (top) and color infared (bottom) of true mountainmahogany (c) at a scale of 1:1,500. Color differences between this species and all others were sufficiently contrasting in color infrared to provide 100 percent correct identification by all interpreters. One interpreter confused this species with small pinyon pine in the color photos causing a large number of commission errors.

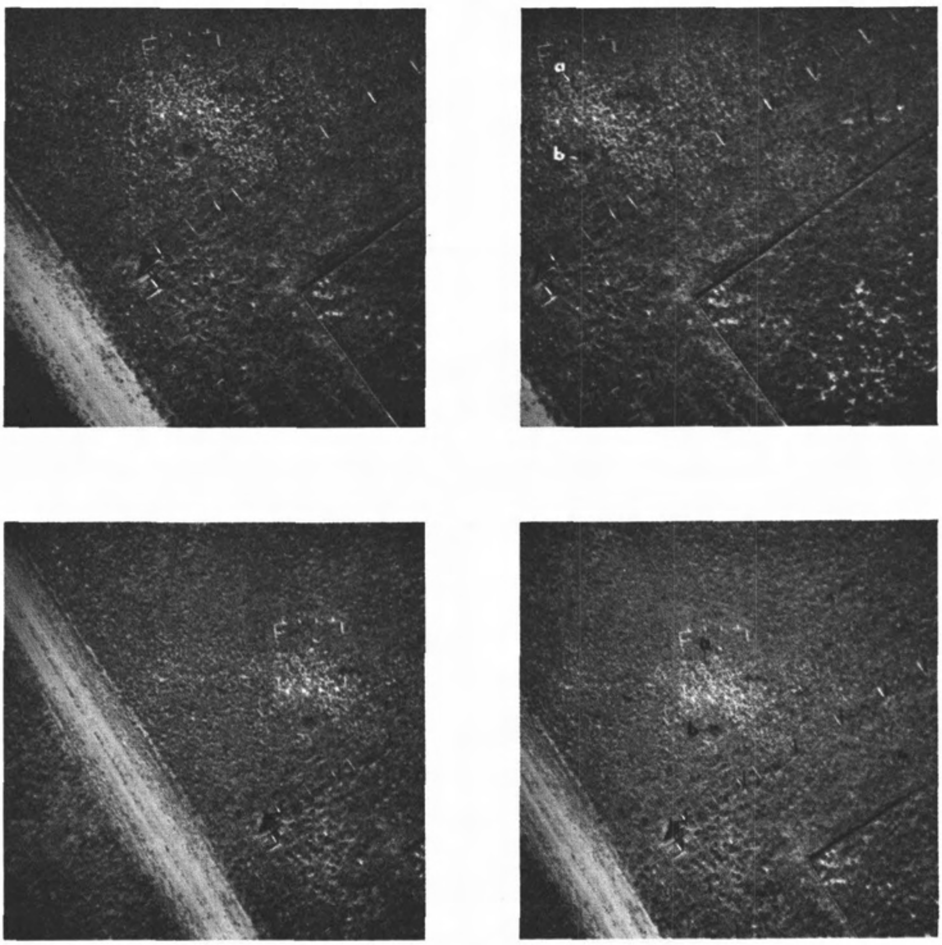

Plate 3. Parry rabbitbrush (a) was difficult to identify in either color (top) or color infrared (bottom) stereograms even at photoscales of 1:600. Unless the interpreter knew by ecological evidence that this was the only rabbitbrush species in the area imaged, commission errors were high among species of rabbitbrush and mountain snowberry (see Plate 1). Shrubby cinquefoil (b) is the other species indicated.

Table 2. Correct shrub and small tree identification percents by film type and interpreter — early July photographs.

Ektachrome Infrared

Species	Interpreter[1] A	B	C	D	Mean
Low sagebrush[2]	100	100	100	100	100
Big sagebrush[2]	100	90	70	100	90
True mountainmahogany[3]	100	100	100	100	100
Parry rabbitbrush[2]	92	50	42	58	60
Vasey rabbitbrush[2]	92	50	54	25	56
Broom snakeweed[2]	90	100	100	80	93
Rocky Mountain juniper[3]	100	100	83	100	96
Pinyon pine[3]	100	100	77	92	92
Antelope bitterbrush[2]	90	80	70	70	78
Shrubby cinquefoil[2]	100	83	83	67	83
Mountain snowberry[2]	90	60	40	50	60
Mean	95	84	72	71	83

Anscochrome D-200

Species	Interpreter[1] A	B	C	D	Mean
Low sagebrush[2]	100	100	90	100	98
Big sagebrush[2]	80	90	100	100	93
True mountainmahogany[3]	100	100	100	67	92
Parry rabbitbrush[2]	100	50	42	33	56
Vasey rabbitbrush[2]	67	42	33	58	50
Broom snakeweed[2]	90	100	80	80	88
Rocky Mountain juniper[3]	92	100	83	100	94
Pinyon pine[3]	92	92	92	85	90
Antelope bitterbrush[2]	40	80	60	20	50
Shrubby cinquefoil[2]	100	83	67	67	79
Mountain snowberry[2]	70	70	30	40	53
Mean	85	81	68	70	76

[1]*See text for description of interpreters*
[2]*Scale — 1:800*
[3]*Scale — 1:1,500*

identified regardless of season of photography.

§§ Some species such as snowberry and rabbitbrush were difficult to identify regardless of film type, season of photography, or photoscale. Image characters and character states were so subtle that identification was marginal.

§§ For the area and species studied, early July photographs provided the best information for shrub identification. Detailed phenological observations are advised before a time is selected to secure aerial photographs for photo identification of shrubs.

Potential Applications

These results can be used to develop various kinds of sampling techniques to quantify small-scale aircraft or satellite photographs. The first step is the development of classification techniques to stratify plant communities of interest from the small-scale photographs (Driscoll and Francis 1970). The second step involves multiple sampling using large-scale photographs and ground data to identify the plant species of interest and obtain other relevant quantitative information, including foliar cover or production. These two steps can then be combined to arrive at estimates with error of the characteristics of the vegetation. This is a new area of research in which new concepts must be developed and tested for applying photogrammetry and sample theory to native vegetation other than trees.

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