REMOTE SENSING APPLICATIONS IN FORESTRY

A report of research performed under the auspices of the

FORESTRY REMOTE SENSING LABORATORY,
SCHOOL OF FORESTRY AND CONSERVATION
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

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

For

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

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REMOTE SENSING APPLICATIONS IN FORESTRY

THE IDENTIFICATION AND QUANTIFICATION OF HERBLAND AND SHRUBLAND VEGETATION RESOURCES FROM AERIAL AND SPACE PHOTOGRAPHY

by W12-996

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Annual Progress Report 30 September, 1969

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ABSTRACT

This is the second annual progress report of a study to assess the merits of large-scale color and infrared color aerial photography for detecting and identifying herbaceous and shrubby plant species and communities at four test locations in Colorado. Added emphasis was placed on multistaged sampling techniques to quantify earth resources photography from space using Apollo 9 color infrared photographs of an area around Roswell, New Mexico, for base data.

Space photographs of the earth's resource areas similar to those obtained by the Apollo 9 mission of the Roswell, New Mexico area, provide the instantaneous synoptic base for classifying and pre-stratifying groups of associated plant communities. These data provide knowledge on location and areal extent of generalized vegetation types and are useful for broad land use planning and management decisions. However, as more detailed quantitative information is required of the plant community types included in the generalized stratifications, multiscaled aerial photographs are required to provide sampling bases of these units.

A multiple sampling technique involving subsampling is described whereby color infrared aerial photos at scales of 1:80,000, 1:20,000, and 1:2,400 are used to estimate the areal extent of the specific plant communities and to estimate specific plant species density. The 1:80,000 scale photos, sampling the Apollo 9 photo base, are satisfactory for determining the area of ecosystems with image boundary characteristics markedly different from adjacent units. Photoscales of 1:20,000 are required for those units with subtle image differences between units. The 1:2,400

scale photos provide the data base needed to estimate plant density and dispersion in shrub environments where individual species are widely spaced.

A photo interpretation key for shrubs was developed to compare film type and photoscale for identification of individual shrubs. Image characteristics used were class categories of crown shape, crown margin, foliage texture, foliage pattern, plant size, shadow, and color. Large-scale (1:800) color infrared photos obtained in early summer have a slight advantage over color photos for this purpose. The degree of identification accuracy achieved by photo interpreters varied according to photo interpretation experience and knowledge of the area photographed. The least experienced interpreter identified 6 of 11 species with accuracies greater than 90 percent using color infrared photos. Reducing photoscale to 1:2,400 lessened the usefulness of the image characters except for shrub stands where individual plants were spaced greater than three feet apart.

The need for multiseasonal photography obtained both from earth orbiting satellites and from aircraft for herbland and shrubland inventory is discussed.

ACKNOWLEDGMENTS

This research is being performed under the Earth Resources Survey Program in Agriculture/Forestry under the sponsorship and financial assistance of the National Aeronautics and Space Administration, ~~Contract No. R-09-038-002.~~ This is the second annual progress report of a cooperative program with the Forest Service, U. S. Department of Agriculture. The study involves two Forest and Range Experiment Stations: the Rocky Mountain at Fort Collins, Colorado, and the Pacific Southwest at Berkeley, California. Salaries of all professional employees are being contributed by the Forest Service.

The landowners, especially ranchers, in the Roswell, New Mexico, area were very helpful in providing access to their lands for conducting the multistaged sampling part of this research.

Special appreciation in extended to Drs. P. O. Currie, O. C. Wallmo, and H. W. Springfield who contributed their talents and resources in the conduct of this research.

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THE IDENTIFICATION AND QUANTIFICATION OF HERBLAND AND SHRUBLAND VEGETATION RESOURCES FROM AERIAL AND SPACE PHOTOGRAPHY

by

Richard S. Driscoll

INTRODUCTION

This is a continuing study designed to define and describe herbland and shrubland resource inventory procedures utilizing aerial and space photography. Primary emphasis to date has been aimed at defining the use of color and color infrared photography to identify specific plant communities as well as plant species within these communities. This research also involves determining optimum altitudes for sensing with different film/filter combinations and developing multistaged sampling procedures to gain increasing amounts of information about the resource with various scales of photography. As these objectives are reached, other problems to be solved include the finding of photogrammetric techniques, both manual and automated, for quantifying plant community characteristics as imaged and identified on the photography.

This is the second annual progress report detailing work undertaken from October 1968 to the present. The earlier report (Driscoll and Reppert, 1968) summarized the importance of the problem to range resource management decisions. In addition to supplying needed forage for livestock grazing as previously defined, the range resource is the major source of food and cover for wildlife. It also provides the natural protective soil cover without which soil erosion would cause destructive events to domestic and commercial water supplies.

There are two primary areas where remote sensing technology and applications are of particular importance to land use and management. These are (1) for resource inventory and analysis -- determining where the resource is located and the makeup of the resource, and (2) resource monitoring -- determining cause and effect relationships of changes in the vegetation resource -- data needed for management decisions. Especially with herbland and shrubland vegetation, the solving of a major problem requires securing facts about the population with which we are dealing within a sufficiently narrow time span to avoid population changes caused by normal seasonal vegetational development. Space and aerial photography and other kinds of remotely procured imagery offer this possibility. Such imagery captures and preserves a scene at a moment in time by recording on film, tape or other medium facts about the population that can subsequently be analyzed without fear of confounding caused by seasonal changes in the vegetation. Space photography provides the superior synoptic base for broad level classifications and prestratification. Underflights are needed to provide more refined detail on specific characteristics of the area in question.

We have learned a great deal on the need of sequential photography to secure facts about a specific parameter, e.g. the identification of a specific plant species or the delineation of a plant community. Our findings are summarized under METHODS in relation to use of the Apollo 9 photographs as well as in RESULTS concerning identification of individual plant species. The implications for use of space photography for resource inventory are apparent and are discussed under RESULTS.

THE STUDY AREAS

COLORADO

Four study areas were selected in Colorado to represent a variety of sites, plant communities, and plant species of the generalized herbland and shrubland vegetation types (Fig. 1). These include: (1) Black Mesa on the Gunnison National Forest near Montrose. This is a high elevation (9,800 feet) mountain grassland interspersed with groves of engelman spruce (*Picea engelmanni* Parry) and aspen (*Populus tremuloides* Michx.). (2) Manitou on the Pike National Forest near Colorado Springs. The generalized vegetation type here is the Ponderosa pine-bunchgrass type typical of much of the lower montane zone along the eastern slope of the Rockies. It occurs at an elevation of approximately 7,700 feet. (3) Kremmling, near the town of Kremmling in north-central Colorado, at an elevation of 8,000 feet. The vegetation of this area is a mixed shrub type including big sagebrush (*Artemisia tridentata* Nutt.) alkali sage (*Artemisia longiloba* (Osterhout) Beetle), rabbitbrush (*Chrysothamnus* sp. Nutt.), snakeweed (*Gutierrezia sarothrae* (Pursh.) Britt. and Rusby), bitterbrush (*Purshia tridentata* (Pursh.) D. C.) and snowberry (*Symphoricarpos* spp. Duhamel.). (4) McCoy in the upper Colorado River drainage within a rolling to hilly topographic complex at an elevation of 7,400 feet. The general vegetation here is an open pinyon-juniper woodland with a shrubby understory.

More specific descriptions of these areas, including vegetation, climate, and soils, appeared in the earlier report. These areas were

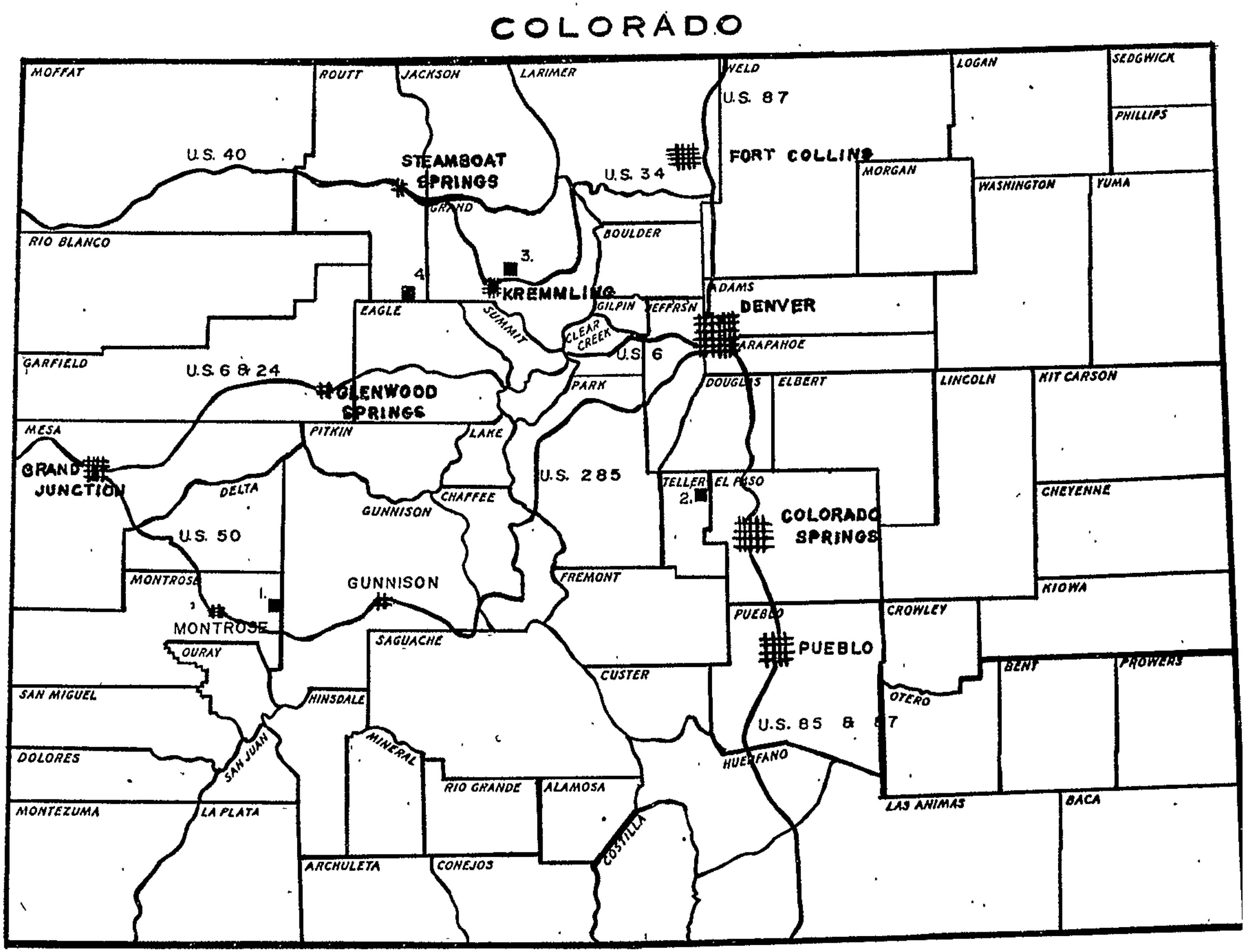

Figure 1. Location of the study areas: 1. Black Mesa: Mountain grassland; 2. Manitou: Ponderosa pine bunchgrass type; 3. Kremmling: mixed shrub type; 4. McCoy: Pinyon-juniper woodland with shrubby underst

used primarily in conjunction with multiscale sequential photography for identification of plant species and communities and investigations of automated photo interpretation using a GAF Model 4 automatic recording microdensitometer.

NEW MEXICO

An additional study area was established in southeastern New Mexico in which applications of space photography for herbland and shrubland resource inventory and analysis could be defined (Fig. 2). This area includes approximately 10,000 square miles in the vicinity of Roswell and extends from Fort Sumner on the north to Lake Arthur on the south and from the Capitan Mountains on the west to the Mescalero Ridge on the east.

Four general vegetation units occur in the area (Küchler 1964). These are: (1) Grama-galleta steppe in the northwestern portion. This is a low to medium tall grassland with few woody plants. Blue grama (*Bouteloua gracilis* (H. B. K.) Lag.) and Galleta (*Hilaria jamesii* (Torr.) Berth.) are usually the dominant components of the vegetation. (2) Creosote bush-tarbush in the south-central part of the area. The physiognomy appears as fairly dense to very open stands of shrubs, dwarf shrubs and grass. The dominant species of the type are creosote bush (*Larrea divaricata* Cav.) and tarbush (*Flourensia cernua* D. C.). Species of grama (*Bouteloua* Lag.), hilaria (*Hilaria* H. B. K.), and dropseed (*Sporobolus* R. Br.) are locally important. (3) Grama-tobosa shrubsteppe in the southern part of the area. This type is characterized by short grasses with a shrub synusia varying from very open to dense. Black grama (*Bouteloua eriopoda* Torr.), tobosa (*Hilaria mutica* (Buckl.) Berth.) and creosote bush are the more dominant

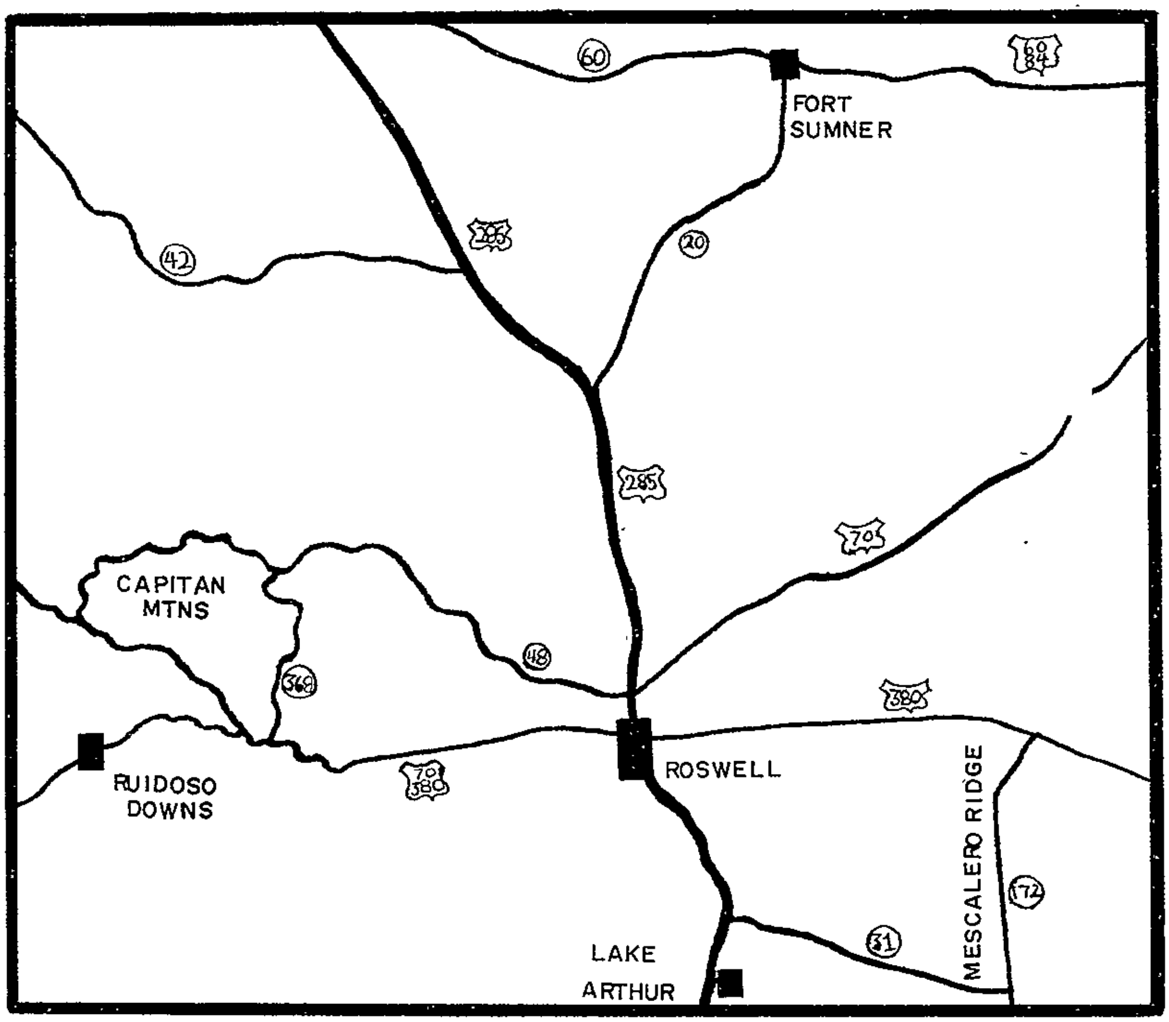

Figure 2. The New Mexico study area included in Apollo 9 frame AS9-26A-3806.

species in relatively undisturbed stands. (4) The eastern one-third of the area, east of the Pecos River, can generally be characterized as a mesquite-shinnery shrub unit. Honey mesquite (Prosopis juliflora var. glandulosa (Torr.) Cockerell) and shinnery oak (Quercus havardii Rydb.) occur in mixed or in nearly pure stands. Where in pure stands, the mesquite occurs on quite well drained clay loam soils and the oak groves on soils underlain by caliche, a calcareous hard pan. Since the presence or absence of this caliche is of economic importance in agricultural development or designed manipulations of native vegetation, it would be desirable to detect the extent of such areas (as indicated by vegetation) for management decisions.

A fifth major type of limited extent occurs in the west-central portion of the area. This is a juniper-pinyon pigmy forest in which one-seed juniper (Juniperus monosperma (Engelm.) Sarg.) was the dominant tree overstory. Waveyleaf oak (Quercus undulata Torr.) is clumpy in the understory. Various species of three awn (Aristida L.), grama (Bouteloua Lag.) and dropseed (Sporobolus (R.) Br.) are common components of the herbaceous understory.

The topography of the area is classed as flat to undulating and rolling land with all drainage leading into the Pecos River. The elevation varies from approximately 3,400 feet at Lake Arthur to 5,000 feet at the eastern flank of the Capitan Mountains.

The climate is semi-arid. Precipitation at Roswell averages 13 inches per year. Eighty percent or over 10 inches occur from May through November when temperatures are high and evapotranspiration is high. Storms are of high intensity and short duration resulting in excessive overland water flow and limited infiltration into the soil.

Herbaceous vegetation has adapted to a summer growth pattern to take advantage of precipitation when it occurs during the warm season. The deciduous shrubs initiate growth in late March and early April at the onset of increasing spring temperatures, taking advantage of over-winter soil moisture storage. Due to these variable growth patterns among different life forms of vegetation, the merits of sequential photography for resource inventory are obvious. This will be discussed further under METHODS and RESULTS.

METHODS

Emphasis has been added to our program on use of space imagery for herbland and shrubland resource inventory and analysis. The fact that space photography is useful for this purpose, primarily for mapping, has been documented (Poulton, Schrumpf, Garcia-Moya 1968). Due to very small photographic scale and the complexity of the plant communities involved, it must be understood that a mapped unit represents a set or group of ecosystems,[1/] rarely an individual entity. As the need for more specific definition of the resource components is required, other than location and extent of broad vegetation classes, a multiple sampling procedure using progressively larger scale photographs is necessary. Therefore, work to date on this part of the project has been to develop a preliminary multistaged sampling technique using space photographs as a base.

[1/] The ecosystem as used here is a land unit repeated in space having analogous environment and identified and characterized by a specific plant community.

Work has continued on developing interpretation keys using large-scale photographs to identify individual plant species. For this reporting period, attention has been devoted to identification of shrub species using Ektachrome Infrared Aero (Type 8443) and Anscochrome D-200 (Type 7230).

MULTISTAGED SAMPLING WITH SPACE PHOTOGRAPHS

The original intent of this research was to relate the AS-6 photograph (AS6-2-1448, film SO-121) of the Las Cruces-Jornada, New Mexico, area with a color infrared (film SO-180) photograph of the same area from the AS-9 mission. This was not possible since usable AS-9 imagery of that area was not available due to extensive cloud cover at the time scheduled for the photographic orbit. Consequently the frame showing the Roswell, New Mexico, area was selected as soon as it was known with certainty what areas were included in usable imagery.

On 18 April, the multispectral Apollo 9 photos were acquired from the Forestry Remote Sensing Laboratory at Berkeley. After detailed examination, it was decided that the color infrared photo provided the best contrast between generalized vegetation types, agricultural cropland and other land uses, even though native vegetation was still in winter dormancy at the time of the photo mission (12 March 1969). In addition, a color photo (conventional aerial Ektachrome film) exposed from the spacecraft with a handheld camera and included the areas subsequently selected for detailed study was used for backup decisions made relative to vegetation mapping using the color infrared photo. This was done because over the majority of the area, 60-70 percent bare soil and rock surface was showing through the vegetational cover. Bare soil discriminated better on the color photo. All quantitative decisions were made on exposure 3806 (color infrared) and exposure 3449 (color).

Detailed ground examination of the area was delayed for two weeks, until 5 May, at which time deciduous shrubs were in full leaf. This provided for use of convergent and associated evidence, as interpreted from the imagery, to be used with ground observations to make decisions regarding location and extent of major vegetation types. Thus, distinctive features, such as landform and landmarks, interpreted from the AS-9 photos and related to ground observations provided for more precise delineation of the major vegetation types.

Five locations were selected for detailed study of multistaged sampling. Preliminary determinations on the extent of the areas were made on exposure 3806 (Fig. 3). Exposure 3449 was used congruently to ascertain these decisions (Fig. 4). These locations were selected as representative examples of the generalized vegetation units of the whole area.

Brief descriptions of these locations are:

1. A juniper-pinyon pygmy forest in which one-seed juniper comprised the overstory. Waveyleaf oak was the dominant understory shrub. Herbaceous species were minor.
2. A semi-desert grassland, part of the grama-galleta steppe, in which portions had been burned on 5 March.
3. A shrub type, part of the creosote bush-tarbush unit, in which creosote bush was the dominant species. Areas of pure grass stands were interspersed throughout.
4. A shrub type, part of the mesquite-shinnery unit. Mesquite was

the most abundant plant in the area, occurring on sandy hummocks one to two feet higher than the surrounding ground base.

5. A shrub type, part of the mesquite-shinnery unit, characterized by numerous sand blowouts. Shinnery oak was the most abundant species, frequently occurring on dunes three to four feet above the surrounding ground base.

On June 4 and 5, aerial photos using Ektachrome Infrared Aero and Anscochrome D-200 were obtained simultaneously with a Forest Service Aero Commander 500-B equipped with twin-mounted 70 mm Maurer KB-8 cameras. One four-mile strip was flown over each location to secure photo scales of 1:80,000, 1:20,000, and 1:2,400 along the same flight line. The time delay was important to provide a needed correlation as to stage of plant development with the Apollo 9 photos.

The sampling design was basically a subsampling procedure in which larger scale photographs were used successively to sample the next smallest scale photographs for certain attributes. The multistaged design included:

Stage	Altitude	Camera	Film	Scale
1. Apollo 9	120n.m.	Hasselblad 80 mm	SO-117	1:2,790,000
2. Aerial Photography	13,000'	Maurer KB-8 38 mm	EIR D-200	1:80,000
3. Aerial Photography	13,000'	Maurer KB-8 150 mm	EIR D-200	1:20,000
4. Aerial Photography	4,800'	Maurer KB-8 150 mm	EIR D-200	1:2,400
5. Ground	Using the sampling photos in conjunction with ground examination, determined species composition of imaged plant communities, proportions of bare soil surface and vegetation cover, soil colors and surface stoniness, and identification of individual plant species. Ground work completed by July 14.			

Figure 3. A 3-X enlargement of Apollo 9 exposure 3806 (color infrared) of the Roswell, New Mexico area. Generalized vegetation types or ecosystem sets include: (A) Bouteloua-Hilaria steppe, (B) Bouteloua-Hilaria shrub steppe, (C) Larrea-Flourensia shrub, (D) Prosopis-Quercus shrub. Agricultural lands (E) occur primarily in the south-central portion of the photo. The native vegetation, except for evergreen species, was in winter dormancy when the photo was taken on March 12, 1969. Therefore, the characteristic reddish image color of green growing vegetation was not available as an interpretative aid. Five units representing ecosystem sets were used to initiate multistaged sampling experiments. Unit 3 was used to develop preliminary sampling techniques described herein.

Figure 4. A 3-X enlargement of Apollo 9 exposure 3449 (conventional aerial Ektachrome). Soil surface colors, which relate general soil groupings, are discerned more consistently on color photos than on color infrared. This photo was used in making decisions on location and extent of ecosystem groupings identified on the color infrared photo (see Fig. 3).

Location 3 (see Fig. 2) was used to develop the preliminary sampling scheme reported herein. The color infrared photos were the primary sampling photos.

Ground examination with the sampling photography revealed four primary ecosystems in this ecosystem set (Fig. 5). These were: (1) Sink holes -- depressions in the landscape vegetated with near pure stands of tobosa grass. (2) Larrea-Tridens hills with creosote bush and fluffgrass about equally important in amount of ground cover. (3) Larrea hills with creosote bush comprising approximately 90 percent of the total vegetation. (4) Alkali sacaton (Sporobolus airoides Torr.) swales with pure stands of this grass.

The 1:2,400 scale photos were used to sample for specific detail the number of shrubs per unit area of the shrub systems (Fig. 6). The sample photos consisted of systematically spaced stereo triplets along the flight line. On this basis, there were 8 principal sampling units each representing a 4-acre area, available for use. Each sample unit was subdivided into 16, 1/4-acre subsample units. Four of these subsample units were randomly selected to make shrub counts by photo interpretation. The results were then expanded to provide an estimate of the number of shrubs per unit area interpreted from the 1:20,000 scale photos.

The 1:20,000 scale photos (Fig. 7) were used to sample the area covered by the 1:80,000 photos for the areal extent of the four previously defined primary ecosystems. Complete stereo-coverage along the flight line was available for use. This provided four primary sampling units, each consisting of 256 acres. A template was placed over the center of

Figure 5. Ground examinations and photo interpretation revealed 4 primary ecosystems within the ecosystem set mapped as unit 3 on the space photograph. A--sink holes with pure stands of *Hilaria*. B--*Larrea*-*Tridens* hills. C--*Larrea* hills with little other vegetation. D--*Sporobolus* swales.

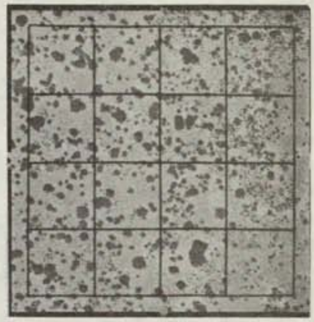

Figure 6. 1:2,400 scale photo used to determine number of shrubs per unit area when sampling 1:20,000 scale photos. In addition to quantifying amount of shrubby vegetation at a moment in time, this kind of photography will be useful for monitoring specific changes in vegetation over time by evaluating such parameters as plant dispersion and density changes caused by events such as grazing, fire, or insect and disease depredations.

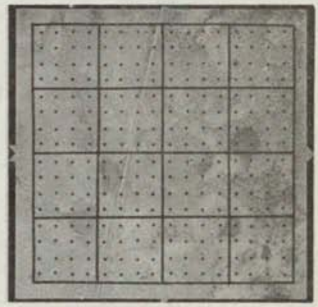

Figure 7. 1:20,000 scale photos were used to sample 1:80,000 scale photos to determine the areal extent of each of the four ecosystems represented in the delineated area on the space photograph. Each dot represents 1 acre.

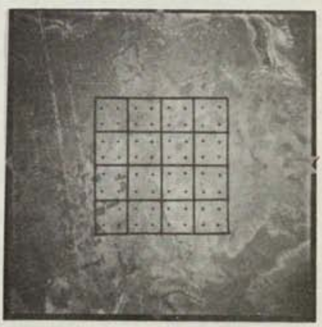

Figure 8. 1:80,000 photos were used to provide a final sample estimate of the extent of each of the four ecosystems represented in the mapped unit. Subtle image differences between the junction of Larrea-Tridens hills and Sporobolus swale ecosystems resulted in interpretation errors. This photoscale would likely be unusable for complete subsampling of space photographs except for those ecosystems with image boundaries markedly different from adjacent units. This is represented by the sharp demarcation between the Larrea hills and Sporobolus swales.

each stereo pair so the area within the template included the 256 acres. This area was then subdivided into sixteen equal subsample units, each unit representing 16 acres. Eight of these subunits were randomly selected for ecosystem sampling by using a dot-grid, each dot representing one acre. The amount of area of each ecosystem within each sampling unit was determined by interpreting the category covered by each dot.

The 1:80,000 photos were used to sample the extent of each ecosystem included in the total area covered by the ecosystem set delineated in the Apollo 9 frame (Fig. 8). Complete stereo-coverage was again used for the total flight line. This represented approximately 42% of the total area of the Apollo 9 photo.

Three primary sample units, each consisting of 1,024 acres, were available for use. A dot-grid/template arrangement was also used for this part of the problem. In this case, however, each dot represented 64 acres and the unit category under each dot was interpreted as to one of the four primary ecosystems. Eight subsamples were randomly selected from each primary sample.

SHRUB SPECIES IDENTIFICATION

Camera malfunctions, film irregularities, and poor weather conditions during some preplanned photo missions in 1968 provided atypical aerial photographs for our species identification work. Therefore, photography was obtained during the 1969 season to fill the data gaps existing from the previous year.

Ground and aerial photo procedures were the same as those reported in 1968 (Driscoll and Reppert 1968). On the Colorado test sites, surveyor stakes were used to mark specific plant species on the ground. This provided reference material for positive identification of the imaged objects in the aerial photographs. In addition, ground photography of the test species was secured at each photo mission to provide additional reference material. Film types used were 35 mm Kodachrome X, Kodacolor X, Ektachrome Infrared Aero, and 4 X 5 Polapan type 52 Polaroid.

Aerial photography using Ektachrome Infrared Aero and Anscochrome D-200, properly filtered, was obtained at various scales to fill in existing data gaps. The photo missions were flown with a Forest Service owned Aero Commander 500-B equipped with dual-mounted 70 mm Maurer KB-8 cameras. The available photography we now have for plant species and community identification is summarized in Table 1. From this photography we hope to be able to determine the threshold of interpretability for those landscape features which are seasonal, vegetational density, and photoscale dependent.

All aerial films were processed at the photo laboratory of the Pacific Southwest Forest and Range Experiment Station Remote Sensing Project at Berkeley. The finished product was a continuous roll of positive transparencies with approximately 60% overlap for stereo study.

A Bausch and Lomb Zoom 70 stereoscope mounted on a Richards light table color corrected to 3,500°K was used to discover and define interpretable image characteristics. In addition, an Abrams CB-1 stereoscope was used to refine and justify these data in an order of magnitude available to potential users.

Table 1. Location, Season, and Scale of Aerial Photography of the Colorado Test Locations.

Location	Spring (6/1-15)	Early Summer (7/1-15)	Late Summer (8/1-15)	Early Fall (10/1)
Black Mesa		1:600 1:2,400 1:4,800	1:600 1:2,400 1:4,800	1:600 1:2,400 1:4,800
Manitou	1:600 1:2,400 1:20,000 1:105,000 1:140,000	1:600 1:2,400	1:600 1:2,400 1:4,800 1:9,600 1:20,000 1:80,000 1:140,000	1:600 1:2,400 1:140,000
Kremmling	1:600 1:2,400 1:4,800 1:10,000	1:600 1:2,400 1:4,800	1:600 1:2,400 1:4,800 1:10,000	
McCoy	1:1,200 1:2,400	1:1,200 1:2,400	1:1,200 1:2,400	

RESULTS

Data collection and analysis have continued through September 1968. Especially with the multistaged sampling problem, analyses are not complete for all the unit locations selected for this part of the project. However, preliminary data syntheses of information from Unit 3 (see Fig. 3) provide clues on the probable nature of the results and define additional problems to be solved. Included in this section are interpreted features of the Apollo 9 photo in relation to ground conditions with inferences to the ERTS-A program.

A dichotomous key to identification of shrubby plants by use of large-scale color and color infrared aerial photographs is presented. Additional research is required to define the threshold photoscale at which the selected image characteristics fail to be useful. The problem is not only one of scale dependency but is also vegetational density dependent.

MULTISTAGED SAMPLING WITH SPACE PHOTOGRAPHS

Evaluation of Unit 3

As previously mentioned, the 1:2,400 scale photos were used to sample for numbers of individual shrubs per unit area; the 1:20,000 and 1:80,000 scale photos were used to subsample for the areal extent of the specific ecosystem type within the delineated data base of the Apollo 9 frame.

Using the 1:2,400 scale photos to sample for number of shrubs, the sampling and prediction data are as follows:

Photo Scale	No. Shrubs	Sampling Error
1:2,400 (Sample Data)	37	± 15 shrubs
1:20,000 (Prediction)	148	± 60 shrubs

No attempt was made to differentiate between individual shrub species since the problem was defined relative to the total shrub population.

The large standard error, ± 40%, was due to a very large number of shrubs, proportionately, in two of the sampling units. This indicates the need to either: (1) increase the subsample size, which would reduce the standard error to some acceptable level, or (2) scrutinize closely the original stratification to determine if ecosystem delineations represented in the primary and secondary sample units were meaningful and included only the shrub systems. The two sampling units with large shrub counts could conceivably represent different range condition classes[2/] within a single ecosystem in which the shrub population had increased due to events such as excessive grazing. When this happens, the competitive strength of some plant species is reduced allowing other species, in this case shrubs, to increase in number to fill a vacuum in the community. On the other hand, these two units may actually represent completely different ecosystems whereby a sampling technique would have to be designed specifically for those units. These hypotheses can be answered only by further detailed ground-aerial photo study.

[2/] A range condition class is defined as a departure of the plant community and physical habitat structure from some pre-defined norm judged desirable for the highest level of biological and economic use.

Table 2. Preliminary Multistage Sampling Results Using Apollo 9 Frame 3806 as the Data Base.

Ecosystem Type and Statistic	Photo Scale 1:20,000 (Sample Data)	1:80,000[1] (Prediction)	1:80,000[1] (Sample Data)	1:2,790,000[2] (Prediction)
Creosote Bush/ Fluffgrass				
% of Area		36		12
Acres ± $S\bar{y}$	5.7 ± 1.4	1392 ± 334	8.0 ± 5.3	1091 ± 720
Alkali Sacaton				
% of Area		23		45
Acres ± $S\bar{y}$	3.6 ± 0.8	889 ± 195	28.7 ± 5.9	4092 ± 818
Creosote Bush				
% of Area		40		42
Acres ± $S\bar{y}$	6.5 ± 0.9	1548 ± 201	26.7 ± 4.7	3818 ± 687
Sink Holes				
% of Area		1		1
Acres	0.16	38	0.7	90

[1] Total area sampled on 1:80,000 scale = 3,867 acres.

[2] Total area sampled on 1:2,790,000 scale = 9,091 acres.

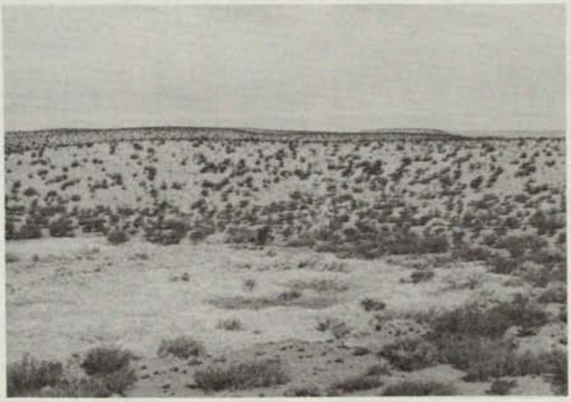

Figure 9. The sink hole type of unit 3 was estimated at one percent of the total area. These areas support a nearly pure stand of tobosa grass. The Larrea-Tridens hills system is shown in the background; the sparsely vegetated Larrea hills in the foreground. Even when this picture was taken, July 9, herbaceous vegetation was growing little. Sequential photography, both from space and aircraft, would provide better interpretation possibilities considering the seasonal aspects of different plant communities.

<u>Figure 10</u>. The <u>Larrea</u>-<u>Tridens</u> hills ecosystem. Broom snakeweed (<u>Gutierrezia</u> <u>sarothrae</u> (Pursh.) Britt. and Rusby) provides the general aspect of the area in this ground photo. Although vegetation appears dense in this low-oblique view, 60% to 70% of the soil surface shows through the foliage cover. The yellowish red (Munsell 5YR 5/6) color of the soil surface resulted in the distinctive reddish yellow (Munsell 5YR 6/8) color in the Apollo 9 photo.

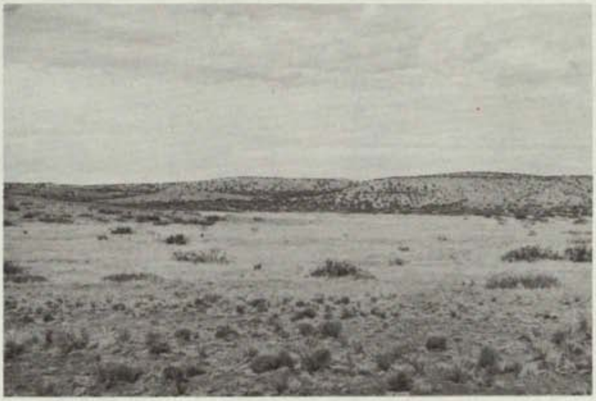

Figure 11. Vegetation in the *Sporobolus* swales had greened-up very little even by early July. The transition between this ecosystem and the *Larrea-Tridens* hills, seen in the background, was subtle in much of the area. Although the estimated total area of the two types was similar when using the 1:20,000 and 1:80,000 scale photos, the area of each system was significantly different as interpreted from the two photo scales. This was caused by broad transitional boundaries between the two systems resulting in commission errors in interpretation.

Approximately one percent (Table 2) of the total area sampled using the 1:20,000 scale photos as the sampling base was classified as sink holes (Fig. 9). The sampling error was not computed for this statistic. The ecosystem represented such a small portion of the total area and was so sparsely distributed that there were many zeros in the data. This represents two alternatives to provide reliable data: (1) With the sampling technique used for this problem, greatly increased sample size would be required to produce an acceptable estimate of the extent of the ecosystem. (2) A different sampling technique would have to be designed specifically for this item.

The type area estimated for the other three ecosystems using the 1:20,000 scale photos to sample the 1:80,000 photos were 5.7, 6.5, and 3.6 acres per 16-acre subsample unit, respectively, for the creosote bush/fluffgrass hills (Fig. 10), creosote bush hills, and alkali sacaton swales (Fig. 11). The sampling errors, respectively, were 24%, 13%, and 22%. Using expansion factors, these figures represent 37%, 40%, and 23%, respectively, of the total sample universe represented by the 1:80,000 photos.

The sampling errors computed for these data may or may not provide acceptable levels of precision. If only general knowledge of the areal extent of each ecosystem is required for a management decision, the magnitude of these sampling errors would probably be acceptable. However, if the management objectives are to determine the amount of area planned for a vegetation manipulation project or to define relative animal grazing capacity by ecosystem type, refined data would be needed due to the cost element. One way to do this would be to increase the number of subsample units. Another alternative involves altering the dot-grid system (essentially a point sampling technique) to increase the number of interpreted points.

Forty-two (42) percent of the area delineated as Unit 3 (see Fig. 3) on the Apollo 9 photo was covered by the 1:80,000 scale photos. Of this area, approximately one percent, 90 acres was estimated as the sink hole type based on the sampling technique used. The sampling error for this statistic was not computed because of a large number of zeros in the data. The same rationale for securing better data here applies as was mentioned when using the 1:20,000 scale photos as a sample.

The interpreted area of the creosote bush hills using the 1:80,000 scale photos was estimated at 42 percent (3818 acres) of the total area with an 18 percent sampling error. This corresponds very closely to the results obtained with the 1:20,000 scale photos (see Table 2). Using the larger scale, the type area was estimated at 40 percent with a 13 percent sampling error. Therefore, based on these data, the 1:80,000 scale photos would be an acceptable subsampling level to determine the area of this part of the ecosystem set interpreted from photos similar to those obtained by the Apollo 9 mission.

No such good relationships existed for the other two ecosystems of this set. The area of the two units was estimated at 57% of the total area delineated using the Apollo 9 base as compared to 59% estimated by the 1:20,000 scale photos sampling the 1:80,000 base. However, the area of each ecosystem was quite different: 12% creosote bush/fluffgrass hills versus 36%, and 45% alkali sacaton swales versus 23%. These discrepancies were primarily due to interpretation errors at the 1:80,000 scale level between the two ecosystems. The image differences between these two units were more subtle with the smaller photo scale, therefore providing greater chances of making incorrect interpretation decisions. Based on these data, the 1:80,000 scale photos may not be an acceptable sampling base to develop inferences about plant communities that do not have sharp image differences (see Fig. 11). The larger scale photos provide more detail on convergent evidence used to associate a sampled spot on the photo with a specific vegetation class.

Seasonal photography, including imagery available from the ERTS-A program, should provide data input to provide better discrimination among related ecosystem sets or even the individual plant communities. This is based on the fact that different plant species or species groups have different growth patterns and rates at different times of the year. Because of this fact, the image differences will vary to provide sharper contrast among ground defined units and allow more precise determination of ground truth facts by image interpretation. The series of sequential imagery will give an invaluable data bank for resource inventory, analysis, and surveillance.

We need to investigate further the full applicability of the sampling technique used for this problem. For example, the dot-system may be altered to include more dots per unit area to increase the probability of any particular point in a single photo frame being included in the sample. Alternative cluster sampling procedures to include optimum allocation of sample

Figure 12. Ground view of the one-seed juniper woodland. Excessive disturbance of vegetative cover on the sandy soils would result in severe wind erosion contributing to air and land pollution. Measurements of the total area from aerial photos, less costly than ground measurements, would provide needed data for changes in land use to avoid this kind of land destruction.

units among the predefined populations based on probability distributions need to be studied. This will be done as the multistage sampling problem is extended to the other selected units (see Fig. 3).

Characteristics of Other Sampling Units

Data reduction and analyses of the other selected units are continuing. A review of the composition of these mapped units will provide insight on the complexity of the problem.

The pigmy forest (Fig. 3 - Unit 1) represents essentially a simple or pure map unit. One-seed juniper provides the overstory, in some places as much as 70% cover (Fig. 12). Individual trees are seldom taller than 20 feet. Waveyleaf oak is the major species in the understory, occurring mainly on dune-like areas. The whole area is sparsely interspersed with small (1-2 acre) grassland parks. These parks are not discernible in the space photo. Sampling will be to estimate number of trees per acre (which is related to foliage cover), the foliage cover of waveyleaf oak, and to estimate the amount of the juniper-dominated portion of the area versus the grassland parks portion of the area. The whole area is important for livestock and deer food and cover, but equally important is the fact that soils are sandy and highly erosive by wind. Extended disturbance to destroy the vegetative cover would bare the soil to the frequent high intensity winds thereby causing excessive soil movement, an undesirable condition. Sequential photography, probably on a year to year basis, coupled with photogrammetric techniques would provide data needed to adjust land use to avoid the situation.

Unit 2 (see Fig. 3) included a portion of the grama/galleta steppe. The image appears as a dark colored area which could be confused for areas of ponded water except for the image pattern. This is a complex map unit consisting mainly of three ecosystems; tobosa grassland, giant sacaton grassland, and grama/three awn grassland. The multistage sampling will be to determine the areal extent of these ecosystems.

Part of the grasslands were burned nine days prior to the time the Apollo 9 photo was taken. No detectable image differences could be discerned between these and unburned areas in the space photos. However, by mid-July, these differences were very apparent (Fig. 13).

In the mesquite-shinnery unit, two areas were selected for multi-staged sampling. One area (see Fig. 3 - Unit 4) had a shrub component primarily of honey mesquite; the other (see Fig. 3 - Unit 5) was primarily shinnery oak. In the honey mesquite area, there are two wide-spread ecosystems that will be included in the multistaged sampling. These are a dune mesquite/grama-dropseed system (Fig. 14) and a dune mesquite/three awn-grama system. A main difference, other than plant species composition, between these two systems is the spatial distribution and hummocky occurrence of the honey mesquite. In the former case, the mesquite clumps occur on "dunes" 1 to 1 1/2-feet above the surrounding ground base. Also the foliage cover to bare ground ratio was approximately 50:50. In the latter case, "dune" areas with mesquite are approximately 2 to 2 1/2-feet above the ground base (Fig. 15). The foliage to bare ground ratio for this system was about 40:60. These specific items could not be detected on the space photo, but the integrated image differences were discernible and unique.

Figure 13. Burned grassland (right center) and unburned grassland (light yellow area left center) were not discernible in the Apollo 9 photo. A fenceline in the vicinity of the trees in the left background is barely visible in 1:80,000 scale photos, and then only because an unimproved road parallels the fence. Three primary ecosystems occur in this part of the major grama-galleta steppe: tobosa grassland in the background bottomlands, giant sacaton of the burned and unburned areas previously mentioned, and grama-three awn grassland in the left center.

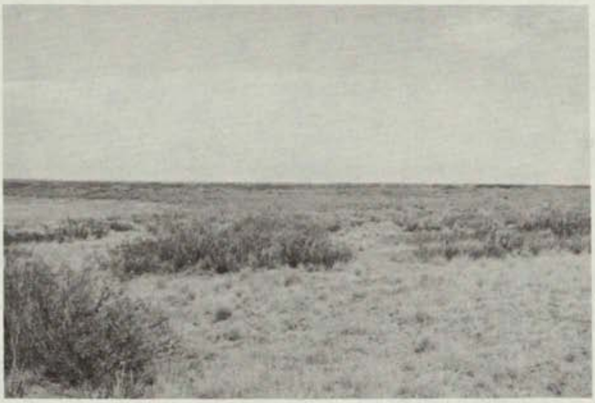

Figure 14. Wide-spaced honey mesquite on low dunes are unique to this honey mesquite/grama-dropseed ecosystem. Foliage cover of herbaceous vegetation between clumps of mesquite was approximately 50 percent. This provided a finely stippled image character in the space photo that was different from other plant community types but for mapping purposes, it was included as part of a map complex. Multistaged sampling with larger scale photography is needed to adequately describe the units of the complex.

Figure 15. Closer spaced honey mesquite on higher dune areas with less dense grass between dunes characterized this ecosystem as compared to the one illustrated in Figure 14. This represented a darker, less stippled image character in the space photo, thus providing a description that was useful in differentiating between the community types.

The last unit selected for the sampling problem was the shinnery member of the mesquite-shinnery vegetation unit. This area occurs in what is locally referred to as the Mescalaro Sands. Sand blowouts are numerous in the area with the shinnery oak covered dunes 5- to 8-feet above the surrounding ground base (Fig. 16). Foliage cover amounted to about 60% of the soil surface. Multistaged sampling will be used to determine the relative amounts of vegetated versus nonvegetated soil surface.

Variation occurs within the type where the herbaceous component becomes more apparent and bare soil or sand less abundant (Fig. 17). These areas are apparent in the 1:80,000 scale aerial photos and are important for resource inventory and management planning. Therefore, sampling to differentiate this sampling unit will be attempted.

SHRUB SPECIES IDENTIFICATION

Full inventory of shrubland and herbland resources requires data input on kinds and amounts of individual species in the plant community. Those of us concerned about these resources need to know what is happening to them over time. Data are gathered in many ways, mainly by expensive ground sampling techniques which generally include very small portions of the total area. Savings can be expected if ground sampling is supplemented with photogrammetry without sacrificing accuracy. The first requisite is to develop photo interpretation keys whereby the individual species can be identified by use of air photos. This provides base data from which photogrammetric techniques can be developed.

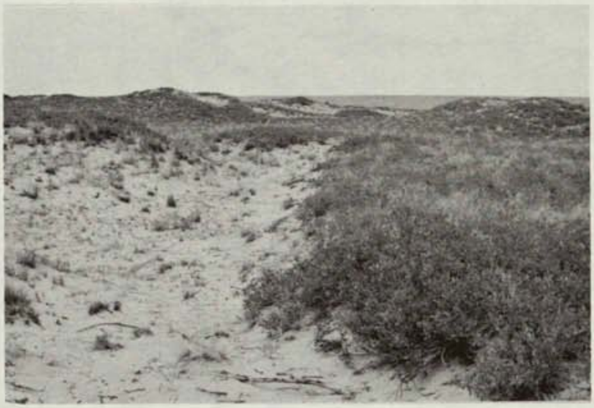

Figure 16. Five- to 8-foot high dunes provide the general aspect of the shinnery oak ecosystem. The plant was not foliated at the time the Apollo 9 picture was taken. This, in addition to a heavy litter cover on the ground, provided a photo image similar to some steppe areas creating extremely difficult interpretation. Space or aircraft photographs obtained when the shrub was in full foliage but before the steppes green-up would provide good differences for use in discriminating between the two community types.

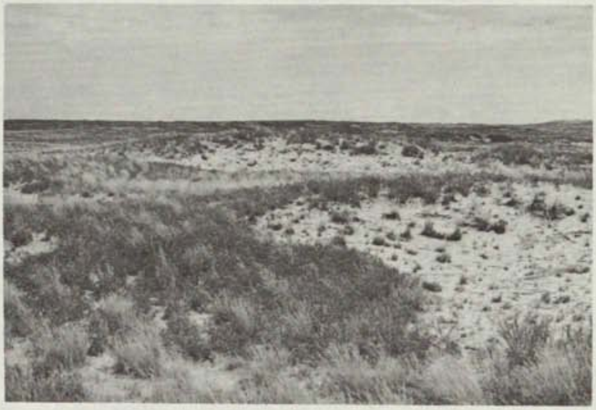

Figure 17. Some areas in the shinnery oak ecosystem have more herbaceous cover, smaller dunes, and less exposed soil than other areas. These are important management differences since they represent different degrees of excessive and active soil erosion. The differentiation of these areas on space or aerial photos is important to surveillance of vegetation over time. Also these areas appeared as similar images in the Apollo 9 photo to the honey mesquite areas. Sequential photography, both from space and aircraft, is needed to identify the units and quantify their characteristics.

Identification involves classification. Some basic principles of classification were discussed in the earlier report (Driscoll and Reppert 1968) but will be reiterated:

1. A differentiating characteristic must classify all individuals in a single population.

2. Greatly different groups of individuals require different differentiating characteristics at the same level of abstraction.

3. All groups of objects of the same category of a single population should be based on the same characteristic.

4. A differentiating characteristic in one category must not separate like things in a lower category.

A dichotomous photo interpretation key was developed for comparing two film types, Ektachrome Infrared Aero and Anscochrome D-200, for shrub species identification of the Colorado test locations. Early July aerial photos of the Kremmling and Black Mesa locations, scale 1:800, and McCoy, scale 1:1,500, were used. This date of photography was selected because close examination of all photos at all photographic dates (see Table 1) revealed that the plant species to be under test were discriminated best at this time. The 1:800 scale was selected because plant density on the ground was high causing a rapid decrease in detectability of individual plants and of differentiating characteristics. The 1:1,500 photo scale was selected because plants on the ground were spaced sufficiently far apart (3- to 15-feet) to avoid loss of detectability and ability to discriminate features at this scale.

Four interpreters with varying degrees of experience and knowledge of the area completed the test. These were:

Interpreter	Experience
A.	An experienced interpreter familiar with the areas and associated vegetation.
B.	An experienced interpreter unfamiliar with the areas but knowledgeable about the native vegetation.
C.	A minimum experienced interpreter unfamiliar with the areas, but generally knowledgeable about the native vegetation.
D.	An inexperienced interpreter unfamiliar with the area and with native vegetation.

Eleven important shrub species were selected from the three locations. At least 10 replicates were selected of nine of the species; more than six replicates of the other two species. This fact was not revealed to the interpreters prior to testing. All test specimens were selected so physiographic features would not help the interpreter in identification. The species selected for test were:

1. Alkali sage (_Artemisia longiloba_ (Osterhout) Beetle)
2. Big sage (_Artemisia tridentata_ Nutt.)
3. Mountain mahogany (_Cercocarpus montanus_ Raf.)
4. Parry rabbitbrush (_Chrysothamnus parryi_ A. Gray)
5. Green rabbitbrush (_Chrysothamnus viscidiflorus_ (Hook.) Nutt.)
6. Broom snakeweed (_Gutierrezia sarothrae_ (Pursh.) Britt. & Rusby)
7. Juniper (_Juniperus scopulorum_ Sarg.)
8. Pinyon pine (_Pinus edulis_ Engelm.)
9. Bitterbrush (_Purshia tridentata_ (Pursh.) D. C.)

10. Shrubby cinquefoil (*Potentilla fruticosa* L.)

11. Snowberry (*Symphoricarpos* spp. Duhamel.)

The two tree species were included because they are important for wild-life cover and, in times of stress, provide emergency food. Included in the test were 10 replicates of non-test specimens which had photo images similar to but not identical with those of the test specimens.

In developing the photo interpretation key, seven major identification characters were defined with various character states for each. These were: plant size, image shadow, crown margin, crown shape, foliage pattern, image texture, and color.

1. Size: relative as to large for the trees or tall shrubs, or not large which included all other items.
2. Shadow: distinct or not distinct.
3. Crown margin: described as:
    a. smooth -- no distinct irregularity in the margin.
    b. wavy -- minor indentations in the margin.
    c. irregular -- deep pockets in the crown margin.
    d. broken -- a discontinuous margin but all parts obviously members of the same plant.
4. Crown shape: refers to the relative definition of the crown or the ability to detect in the imagery a definite crown. Character states were:
    a. indistinct -- no definite crown detectable.
    b. round -- detectable with a generally circular shape.
    c. oblong -- detectable but not generally circular in shape.

5. Foliage pattern: refers to the appearance of foliage within the crown area of the plant.

   a. continuous -- no openings in the crown; appears as a solid mass.

   b. clumpy -- openings within the crown give the appearance of small but related masses within the perimeter of the crown

   c. irregular -- appears as single, somewhat detached clumps of foliage; may appear similar to the broken margin character state described under crown margin.

6. Texture: the apparent "graininess" or continuity of pattern of of the crown image caused by leaf size, shape, arrangement, and density within the plant. Stated as:

   a. fine

   b. medium

   c. coarse

   d. stippled

   e. mottled

   f. hazy

7. Color: designated numerically and as a descriptive adjective according to National Bureau of Standards ISCC-NBS system of color designations.

The character states used to identify a particular species varied from specimen to specimen. This was caused by differential growth forms of a species and is also related to past disturbances to the plant such as animal grazing or insect attacks creating malformed plants. However, character descriptors used to discriminate a species described most commonly the species as viewed in the photographs.

The following keys, one for each film type, were developed by an experienced interpreter using positive ground identifications, and describing image characteristics from the aerial photos.

Photo Interpretation Key -- Color Infrared

1. Plants large (small trees or large shrubs)

    2. Foliage slightly purplish pink (247) to dark purplish pink (251); shadow distinct; crown margin usually irregular to broken; crown shape round or oblong; foliage pattern very clumpy; medium texture. . . . . *Juniperus scopulorum*

    2. Foliage red or shade of red

        3. Foliage medium reddish brown (43); shadow distinct; crown margin smooth to wavy; crown shape round; foliage pattern very clumpy; coarse to mottled texture. . . . . *Pinus edulis*

        3. Foliage very red (11) or deep red (13); crown margin wavy to broken; crown shape round or indistinct; fine texture; foliage pattern irregular (numerous single branches). . . . . *Cercocarpus montanus*

1. Plants not as large (small or medium shrubs)

    4. Foliage reddish purple or purplish pink

        5. Reddish purple

            6. Low-growing; light reddish purple (240) may almost be reddish brown in some plants; usually spreading (large diameter for height); shadow not distinct; crown margin

smooth to wavy; crown shape usually round; fine texture. . . . .*Artemisia longiloba*

6. Not low-growing; pale reddish purple (244) to light reddish purple (240); shadow distinct; crown margin broken; crown shape variable; foliage pattern clumpy medium texture. . . . . *Artemisia tridentata*

5. Slightly purplish pink (247) to dark purplish pink (251) shadow distinct; crown margin usually smooth to wavy; crown shape round or oblong; foliage pattern either in clumps or continuous; texture medium. . . . .*Juniperus scopulorum*

4. Foliage not reddish purple or purplish pink

7. Foliage pattern in clumps

8. Shadow distinct

9. Foliage medium reddish brown (43); crown margin smooth to wavy; crown shape round; texture coarse. . .*Pinus edulis*

9. Foliage not reddish brown

10. Texture coarse; light gray purplish red (261) or dark red (16); crown margin usually irregular (may be smooth in young plants); crown shape round or indistinct. . . . .*Potentilla fruticosa*

10. Texture fine; slightly pink (2) to deep pink (3) or dark red (16); crown margin usually smooth but variable; crown shape usually round or oblong but not conical. . . . . *Chrysothamnus parryi*

8. Shadow not distinct

11. Texture coarse or hazy; usually medium red (15) or slightly red (12) occasionally dark red (16) or deep red (13); crown margin smooth to wavy; crown shape variable. . . . .<u>Purshia</u> <u>tridentata</u>

11. Texture not coarse or hazy

12. Dark red (16) or deep red (13) (sometimes has slight pinkish or magenta cast to plant); crown margin smooth to wavy; crown shape usually more irregular than <u>Purshia</u> <u>tridentata</u>. . . . .<u>Symphoricarpos</u> spp.

12. Very dark red (17) or very deep red (14) (a maroon); usually smaller than <u>Symphoricarpos</u> spp. and larger than <u>Gutierrezia</u> <u>carothrae</u>; may be a spreading and very low-growing plant; crown margin irregular; crown shape usually oblong or indistinct; texture fine; color may be very similar to <u>Gutierrezia</u> <u>sarothrae</u>. . . . .<u>Chrysothamnus</u> <u>viscidiflorus</u>

7. Foliage pattern continuous

13. Dark reddish brown (44) or deep reddish brown (41); shadow not distinct; usually very low-growing plant with small diameter and not spreading; crown margin smooth; crown shape round or oblong; texture fine. . . . .<u>Gutierrezia</u> <u>sarothrae</u>

13. Not reddish brown

14. Slightly pink (2) to deep pink (3) or dark red (16) shadow distinct; crown margin smooth; crown shape round or

oblong; texture fine to medium . . Chrysothamnus parryi

14. Not pink

15. Shadow very distinct; very bright red (11) or sometimes dark red (16); crown margin wavy to broken; crown shape round or indistinct (numerous single branches); texture fine . . . . Cercocarpus montanus

15. Shadow not distinct

16. Foliage red

17. Medium red (15) or slightly red (12); crown margin wavy; crown shape round; texture fine . . . . Purshis tridentata

17. Very dark red (17) or very deep red (14); crown margin smooth to wavy; crown shape round or oblong; texture fine . . . . .Chrysothamnus viscidiflorus

16. Foliage slightly purplish (255) red to medium purplish red (258); crown margin smooth; crown shape round or oblong; texture fine . . . . Symphoricarpos spp.

Photo Interpretation Key -- Color

1. Plants large (small trees or large shrubs)

2. Foliage light gray olive (109); crown margin wavy to broken; crown shape irregular; foliage pattern clumpy; texture fine; shadow distinct . . . . Juniperus scopulorum

2. Foliage dark green

3. Foliage pattern irregular (numerous single branches); crown margin wavy to broken; crown shape round or indistinct; texture fine; dark gray green (151) or dark green (146). . . . . _Cercocarpus montanus_

3. Foliage pattern clumpy (no single branches); shadow distinct; crown margin smooth to wavy; crown shape usually round; texture coarse; dark gray green (151). . . . . _Pinus edulis_

1. Plants not as large

4. Low-growing

5. Foliage pattern usually clumpy; shadow not distinct; crown margin wavy to irregular; crown shape variable; texture medium; very dark green (147) gray olive green (127) or dark olive green (126). . . . . _Chrysothamnus viscidiflorus_

5. Foliage pattern more continuous

6. Spreading (usually large diameter for height); crown margin smooth to wavy; crown shape usually round; texture fine or grainy; gray olive (110). . . ._Artemisia longiloba_

6. Not a spreading plant; usually small round plant; shadow not distinct; crown margin smooth or wavy; crown shape round or oblong; texture fine; foliage blackish green (152). . . . . _Gutierrezia sarothrae_

4. Not as low-growing

7. Shadow distinct

8. Foliage light olive gray (112) or light gray olive (109)

9. Foliage light olive gray (112); crown margin broken; crown shape variable; foliage pattern clumpy; texture medium. . . . . _Artemisia tridentata_

9. Foliage light gray olive (109); crown margin wavy to broken; crown shape irregular; foliage pattern clumpy; texture fine. . . . . _Juniperus scopulorum_

8. Foliage dark gray green (151), dark green (146), or very dark green (147)

10. Foliage pattern irregular (numerous single branches); crown margin wavy to broken; crown shape round or indistinct; foliage fine textured; dark gray green (151) or dark green (146). . . _Cercocarpus montanus_

10. Foliage pattern continuous or clumpy

11. Texture coarse; crown margin smooth to wavy; crown shape usually round; foliage pattern clumpy; foliage dark gray green (151). . . . . _Pinus edulis_

11. Texture not coarse

12. Texture fine; crown margin variable; crown shape variable; foliage pattern continuous to clumpy; crown margin usually round or oblong but not conical; usually lighter green than _Potentilla fruticosa_; foliage dark green (146) . . . . _Chrysothamnus parryi_

12. Texture medium; usually larger than _Chrysothamnus parryi_; crown margin variable; crown

shape variable; foliage pattern continuous to clumpy; foliage very dark green (147). *Potentilla fruticosa*

7. Shadow not distinct

13. Texture hazy or coarse; crown margin smooth to wavy; crown shape variable but usually round or irregular; foliage pattern continuous to slightly clumpy; foliage medium olive green (125) or dark olive green (126). . . . .*Purshia tridentata*

13. Texture not hazy

14. Foliage very dark green (147), gray olive green (127) or dark olive green; plant small; crown margin wavy to irregular; crown shape variable; foliage pattern slightly clumpy to very clumpy; texture medium coarse. . . . . *Chrysothamnus viscidiflorus*

14. Foliage gray green (150) or dark green (146); crown margin variable; crown shape variable; foliage pattern slightly clumpy; texture fine. . . . .*Symphoricarpos* spp.

Statistical analysis, by arc sine transformation and analysis of variance, are not yet completed. However, good inferences can be drawn from the test results which are presented in Table 3.

In general, there was little difference in correct interpretations for all interpreters over all species between the two film types, 81 percent for color infrared and 76 percent for color. However, 8 species were correctly identified at acceptable levels of accuracy ($>$80%) on the color infrared photos; two of these were identified 100 percent correct by all interpreters. On the color photographs, only 5 species were identified correctly greater than 80 percent of the time and none of these were interpreted 100 percent correctly.

The most experienced interpreter, who was also very familiar with the vegetation of the areas photographed, identified six species 100 percent correctly on the color infrared photos and the other 5 species at least 90 percent correct. On the color film, this interpreter scored less than 80 percent correct identifications for three of the species, not an acceptable level. In general, the least experienced interpreter who had to be trained in photo interpretation and who had no knowledge of the vegetation, scored better using color infrared photos as compared to the color photos.

In assessing the "best" film type for identifying individual plants, the time element must be considered. On the average, time required for interpreters to take the test, including training, using color infrared photos was 6 hours; for the color photos, this time lapse was 9 hours. On this basis, in addition to the slightly favorable test scores using color infrared, this film type is superior to color film for plant species identification under conditions similar to those used in this test.

Decreased photoscales adversely affect the interpretative characteristics used in this test. This effect is closely related to ground plant density and plant size, however. For example, image characters, except shadows of big sagebrush, were little affected by decreasing photoscale to 1:2,400 at the McCoy location. Contrariwise, this same scale of the Kremmling location resulted in some loss in character detail of crown

Table 3. Correct Shrub Identification Percents by Interpreter and Film Type

	Interpreter								Mean	
	A		B		C		D			
	Film Type									
Plant Species	EIR[1/]	D-200[2/]	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
Mtn. Mahogany	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	80	50
Cinquefoil	100	100	83	83	83	67	67	67	83	79
Snowberry	90	70	60	70	40	30	50	40	65	55
Non-test Plants	91	91	100	71	55	46	46	91	73	65
Mean	95	85	84	81	72	68	71	70	81	76

[1/] Ektachrome Aero Infrared (Type 8443)

[2/] Anscochrome D-200 (Type 7220)

margin, foliage pattern, and crown shape. Texture characters were difficult to detect and the shadows were minimally distinct. For the Black Mesa location, all characters and character states were relatively useless with this scale except for individual plants isolated from all others. Differentiating colors on the infrared film were still good descriptors at this scale but were generally "lost" for the color film except where there was sharp background contrast.

Except for image color, all other characteristics were of little value for identifying the species tested with photoscales of 1:4,600 in the color infrared film. With the color film the color characters were of minimum value at this scale. Relative size of plant was about the only characteristic that was useful to differentiate among plants. This would classify plants only into relative size classes without regard to species.

DISCUSSION AND SUMMARY

Photographs from space, similar to those obtained from the Apollo 9 mission, are valuable for herbland and shrubland resource inventories. Such photographs provide the superior synoptic base upon which broad-level vegetation classifications and pre-stratification generally can be made. Such classifications are considered the basis for any inventory procedure. However, due to the combined effects of original photoscale and ground resolution, these classifications will nearly always consist of groupings of individual ecosystem types difficult to quantify from space photos alone. Consequently, multiscaled photos from aircraft are required from which detailed data on the extent and composition of the ecosystem types can be determined by sampling.

Photos at scales of 1:80,000 appear satisfactory for determining the areal extent of ecosystem types with image characteristics sharply contrasting from adjacent units. However, as the differences between ecosystems become more subtle on the ground, they will be reflected in the image characteristics which, in turn, become more subtle as photoscale becomes smaller. Therefore, scales of 1:20,000 or larger may be required to provide acceptable quantitative data for these kinds of units.

Large-scale photography will provide additional needed information about the resources. Such things as herbaceous or shrubby plant identity, density, and dispersion can be measured by using photographic scales of 1:2,400 of vegetation similar to the shrubby types of New Mexico. However, as plant density increases, photoscale must also be increased to gain the base from which to make quantitative statements.

In dense shrub types in Colorado, types in which plant crowns are touching or nearly so, 1:2,400 scale photographs are at the smallest scale for identifying individual shrub species. In fact, a photoscale approximating 1:800 is the best scale of these used to provide acceptable species identification results. "Acceptable" is defined as "correctly identifying a species at least 80 percent of the time." Color infrared photography is best suited for this work when interpretation time is considered.

Sequential seasonal photography from space and aircraft will provide more detail regarding the resources than photography taken at one point in time. Others have documented this fact, especially with aircraft photographs for species identification (Sayn-Wittgenstein 1966, Seely 1964). Plant species and even the communities show changing morphological characteristics during the growing season which makes them more easily identifiable in imagery at one point in time than at other periods. For example, wild geranium (Geranium fremontii Torr.) at the Black Mesa location can be identified on 1:800 scale aerial photography only in August after the species has matured. Other species are more identifiable at other times of the growing season. The integrated effects of these changes alter the reflectance characteristics of the communities as a whole; thus accurate identification of these communities using aerial photographs is time dependent.

Simply discovering how to determine kinds and amounts of vegetation in terms of density and dispersion in an area from various scaled aerial photography is frequently not sufficient to answer questions related to "how much." We initiated a study this year at the Manitou location to investigate use of color and infrared color aerial photography to quantify volume of herbage per unit area. We hope to obtain multispectral imagery on tape of the area next season to take advantage of narrow band data to determine herbage volume of different community types.

Sun angle and atmospheric conditions naturally have effects on image interpretability. Most of our photography has been flown between 10:00 a.m. and 2:00 p.m. local standard time. This corresponded to a high sun angle at the time of year herbland and shrubland species are actively growing; the time for best possible discrimination between species. The long axis of the foliage of many of these plants at this time is nearly parallel to the optical axis of the camera. This, combined with the high sun angle, minimizes energy reflectance of the target object available to the imaging system. Plans are to obtain diurnal aerial photography next season at one- to two-hour intervals to isolate the effects of these phenomena.

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APPENDIX

The following is a list of Forest Service, U. S. Department of Agriculture, personnel who contributed to this study and represent a major salary contribution to it:

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