AERIAL COLOR AND COLOR INFRARED PHOTOGRAPHY-- SOME APPLICATIONS AND PROBLEMS FOR GRAZING RESOURCE INVENTORIES

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INTRODUCTION

Rangelands in the contiguous United States include over 1 billion acres that are not suitable for cultivated crop production. These lands, however, produce native forage for domestic and wild grazing animals. They also provide recreational and intangible natural beauty benefits and circumscribe 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 rough topography. This creates difficult management problems, and before any management can be achieved, resource inventories are needed to determine where, what, and how much grazing is available. These inventories are essential for integrating grazing with other resource uses including recreation, water and timber.

While inventories have been conducted by ground sampling for decades, only a small fraction of the range has been covered, and this very sketchily due to its extent and remoteness. On the other hand, aerial photographs, coupled with ground techniques, provide the opportunity to circumvent some of the sampling problem. The photographs contain much detailed information about the vegetation, can be obtained rather quickly, and may provide for some detailed study than would be possible by ground search alone. Color aerial photographs offer greater possibilities to enhance grazing resource inventory techniques than do conventional black and white photographs. The three color dimensions--hue, value, and chroma--provide more photo interpretive characteristics than do mere shades of gray.

HISTORIC USE OF AERIAL PHOTOGRAPHS FOR GRAZING RESOURCE INVENTORIES

Black and white panchromatic aerial photographs have been accepted assets to grazing resource inventories since 1937 (Interagency Range Survey Committee, 1937). Reid and Pickford (1942) recommended use of this kind of photography to provide more accurate vegetation type maps and to secure more dependable forage estimates. An application of a sampling procedure for range inventories based on this kind of photography has been described by Harris (1951). Primarily, this type of photography has been used for mapping broad vegetation types--grassland versus shrubland versus timberland-- and to locate cultural features including roads, fences, seeded areas, or special situations such as rodent infestations.

Through intensive interpretation, significant relationships between soil-vegetation physiographic units and photo patterns could be determined (Lord and McLean 1969). Generally, however, the photography was of average quality and usually of medium scale (1:15,840-1:30,000). In addition, the photographs frequently were obtained at a time during previous years that did not correspond to the time period the photographs would be used. Consequently, image characteristics observed in the prints did not represent current ground conditions except in a gross fashion, such as the apparent boundary between grassland and timberland.

THE STUDY

Foresters have used color aerial photography for tree identification and other forestry purposes to good advantage (Sayn-Wittgenstein 1960, 1961; Heller, et al. 1964, 1967; Aldrich 1966). Some potential values of large-scale color aerial photography for range resource inventories have been reported (Carneggie and Reppert 1969). The following reports some initial results with large-scale (1:600-1:4600) 70 mm color aerial photography for identifying native plant species, communities, and other habitat features in the range environment. Some potential values of small-scale photographs (1:135,000) are also defined.

AERIAL PHOTOGRAPHY. Flight lines varying from 250 feet to 4,500 feet long were established at four test locations in Colorado. Specific plant species, communities, and other items were marked on the ground so they could be detected and positively identified in the aerial photographs.

Dual mounted 70 mm Maurer KB-8A cameras equipped with 150 mm Schneider Xenotar lenses were used for the aerial photography[a/]. The two cameras, mounted in an Aero Commander 500 B aircraft, were impulsed simultaneously by an Abrams CP-3 intervalometer to provide identical photo coverage on the two film types used. The shutter speeds were set at 1/2000th second, with the airplane flying at 100 miles per hour, to reduce image motion and obtain 60 percent overlap for stereoscopic coverage.

The film types used were Anscochrome D-200, exposed with a Wratten 1-A skylight filter, and Kodak Ecktachrome Infrared Aero, exposed with a Wratten 12 filter. The film was processed to positive transparencies to avoid loss of resolution and color balance.

Four photo missions were flown over the test sites to coincide with: (1) the beginning of the growing season, (2) the peak of the growing season, (3) the initiation of dormancy of the most abundant species, and (4) after most plants were dormant but prior to snowfall.

These photo mission dates were selected on the basis that no single time period could be expected to provide optimal data for the photometric identification of vegetation.

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a/ Trade names and commercial products are mentioned for information only. No endorsement by the U. S. Department of Agriculture is implied.

TEST LOCATIONS. The four test locations represented contrasting native vegetation types important for grazing resources. They include:

1. A spruce-fir/grassland cattle range at an elevation of approximately 9,800 feet in west-central Colorado. Thurber fescue (Festuca thurberi), Idaho fescue (Festuca idahoensis), aspen fleabane (Erigeron macranthus), and wild geranium (Geranium fremontii) were the most common herbaceous species in the grassland areas.

2. A ponderosa pine/bunchgrass cattle range along the eastern slope of the Colorado Rocky Mountains, in a park-like opening at about 7,700 feet elevation. Arizona fescue (Festuca arizonica), blue grama (Bouteloua gracilis), pussytoes (Antennaria sp.), and fringed sagebrush (Artemisia frigida) were the most abundant species. Part of this area had been treated with fertilizers and herbicides to induce rapid change in vegetation.

3. A mixed shrub type used by range cattle and big game in a very broad mountain valley in northcentral Colorado at an elevation of about 8,000 feet. Big sagebrush (Artemisia tridentata), alkali sagebrush (A. longiloba, bitterbrush (Purshia tridentata), snowberry (Symphoricarpos sp.), three species of rabbitbrush (Chrysothamnus viscidiflorus, C. nauseosus, and C. parryi), and broom snakeweed (Gutierrezia sarothrae) were the most abundant shrubs.

4. An open woodland type at approximately 7,400 feet in northcentral Colorado in which pinyon pine (Pinus edulis) and Rocky Mountain juniper (Juniperus scopulorum) provide the general aspect to the area. Mountain-mahogany (Cercocarpus montanus) and big sagebrush are common shrub species. Herbaceous species are relatively minor. The area is grazed by livestock most of the year and deer yearlong.

RESULTS

The identification of an object in an aerial photograph must be based on characteristics of the object as imaged by the remotely placed sensor (aerial camera and film in this case) and not by characteristics of the object as viewed first-hand. The image characteristics used to differentiate plant species, community types, and other items were pattern, texture, relative size, shape, shadow, and color.

PLANT SPECIES IDENTIFICATION. Phenology, the change in growth and development of the plant in relation to weather and climate, was an important consideration when attempting to identify the individual plant species in the aerial photographs. For example, mid-July photography of the spruce-fir/grassland produced normal color photographs of vegetation a constant shade of green, and color infrared photographs a constant shade of red. At this date, all herbaceous species were growing vigorously, with foliage color, as noted with Munsell color notation, between 5 GY 4/6, 5 GY 6/4, and 7.5 GY 4/6. These color differences were so subtle they could not be discriminated in the aerial photographs, regardless of photo scale or film type.

Phenology changes at the same location by mid-August, however, provided the opportunity to differentiate individual species in the aerial photographs, primarily on the basis of color. By then, plant species were in different growth stages, which resulted in different foliage colors that were detectable in 1:750 scale aerial photographs. For example, the visual ground color of wild geranium foliage was red (5 R 4/10) and the resultant gold color in the color infrared photographs was easily discriminated from colors of all other species. On the normal color photographs taken at the same scale and date, this species could be identified only by careful searching under 4X stereo-magnification.

Somewhat similar phenological relationships existed for identifying shrubs in the aerial photographs. However, apparent height and stem leafiness, in addition to color, were important image characteristics for discriminating among these kinds of plants. For example, mid-July visual colors of bitterbrush and snowberry in the shrub type were very similar--5 GY 5/4 and 5 GY 5/6, respectively. Bitterbrush plants were taller, however, and stem leaf arrangements were vertical and less dense than snowberry. The height difference was discernable on 1:1000 scale photographs under 4X stereo. In addition, the stem leaf arrangement of snowberry provided a finer image texture than bitterbrush. Image color differences were not apparent between these two species in the normal color photographs, although the species could be discriminated on the basis of height differences. However, the image texture differences in the color infrared photographs, apparently influenced by the differences in stem leafiness, resulted in a lighter red color for snowberry than for bitterbrush. This provided a more positive photo identification characteristic for the former species.

Plant leaf structure influences the visible and near infrared energy reflection and hence the image signature of the species. Mountainmahogany and pinyon pine had the same visual foliage color (7.5 GY 4/6) in August. However, the relatively large, shiny, thick cuticled leaves of the mountainmahogany had higher infrared reflectance than the pine needles. This caused a bright red image for mountainmahogany, an important big game forage plant, and a brownish red image for the pine. Although height differences between mature specimens of the two plants could be used to differentiate them on both film types, image color differences in regular color aerial photographs were not apparent. Therefore, mature mountainmahogany plants and small pinyon pines were frequently misidentified in the color photographs.

Generally, the color infrared photography appears best for identifying both herbaceous and shrubby species in wildland environments (Table 1). With the photographs used (June 1) for herbaceous species in this test, identification percentages of blue grama (Bouteloua gracilis) and mountain muhly (Muhlenbergia montana) were low because they were late developing and had produced little green plant material at the time of photography. The other species initiate growth earlier and consequently discriminate image differences were visible at the time of photography. An exception to the "best" film type for identification was trailing fleabane (Erigeron flagellaris). This small, mat forming species had small immature green leaves and often was confused with bare soil in the color infrared photographs. The regular color film images were sufficiently different to provide better discrimination. Other photo interpretation tests involving the spruce-fir/grassland area indicate mid-August photographs to be best for identifying the largest number of herbaceous species.

Relative plant height and color were the best discriminating characters for shrubs in August photographs. With big sagebrush, these characters could

Table 1.--Percent correct identification of species on 70 mm Anscochrome D-200 and Ektachrome Infrared Aero Film

Species	ANS-D-200	EIR
Herbaceous 1/		
Antennaria sp. (Pussytoes)	10	80
Bouteloua gracilis (Blue grama)	10	10
Muhlenbergia montana(Mountain muhly)	10	10
Festuca arizonica (Arizona fescue)	80	80
Artemisia frigida (Fringed sagebrush)	25	85
Erigeron flagellaris (Trailing fleabane)	85	60
Shrubs 2/		
Cercocarpus montanus (Mountainmahogany)	75	100
Purshia tridentata (Bitterbrush)	80	90
Artemisia tridentata (Big sagebrush)	95	95
Artemisia longiloba (Alkali sagebrush)	25	75
Symphoricarpos sp. (Snowberry)	25	75
Chrysothamnus sp. (Rabbitbrush)	25	75

1/ Based on June 1, 1968, photography, Colorado timber/grassland type, scale 1:600, one interpreter.

2/ Based on August 24, 1967, and August 3, 1968 photography, Colorado mixed shrub and open woodland types, scale 1:1,100, average of two interpreters.

be distinguished as easily on both film types. All other shrubs were more easily identified on the color infrared film.

SITE AND TREATMENT CLASSIFICATION. Site distinction is an important facet of any range management program involving measurement and interpretation of native vegetation. Aerial photographs provide a better perspective among sites if the vegetation or plant community is used as an indicator of sites. The photograph gives a greater synoptic view of an area compared to what can be seen from ground level.

Detailed interpretation of good quality black and white panchromatic aerial photographs at the usual scale (1:20,000) can provide discrimination among most sites on the basis of image texture and gray tones. The use of color photography, however, introduces additional descriptive dimensions which should increase the accuracy of discrimination among sites. There was no apparent advantage favoring either film type for general site or community differentiation. However, very small scale (1:135,000) color infrared photography showed more discrete differences among major plant communities and, when exposed in the late summer, provided information on grazing use patterns not discernible or easily overlooked in black and white panchromatic or regular color photography. The fine textured red images indicate areas of grassland that have been grazed by range cattle the entire grazing season, thereby reducing the accumulation of "rough" or dead plant material in the stand. This kind of information is valuable for making management decisions affecting use and surveillance of the grazing resource by defining areas used too much or too little.

The ponderosa pine/bunchgrass location included an investigation of effects of various fertilizer, herbicide, and grazing treatments on 75-square-foot blocks of native rangelands. Treatment effects could be differentiated by color in 1:2700 scale color infrared photographs taken in August, 2 months after treatments were applied. Intensive interpretation of the smallest scale (1:135,000) photographs procured in October also revealed differences between treated areas. This information introduces the possibilities of assessing effects of cultural treatments on native rangelands directly from color infrared aerial photographs.

IDENTIFICATION OF OTHER RANGELAND CHARACTERISTICS. Some rodents are often harmful to rangelands especially when population densities are high. For example, average populations of mountain pocket gophers in the vicinity of the spruce-fir/grassland location are estimated to consume 300 pounds per acre of air-dry herbage per year (Technical Committee, Colorado Cooperative Pocket Gopher Project 1960). When populations are high-twofold increases are expected in some years--herbage consumption by these rodents would represent a significant amount of the average 1,400 pounds of air-dry herbage produced per acre per year.

Gopher casts and mounds were easily identified in 1:600 scale photographs of both color film types. The casts, "ropes" of soil remaining on the ground surface after spring snowmelt, were most easily identified in early June Photographs. Fresh mounds, most conspicuous in late summer to early fall when young-of-the-year are establishing independent burrow systems, were easily identified in October photographs. They were more apparent in the color infrared film because some images of plants in the regular color photographs appeared similar to the mound images. Since mounding activity is closely related to population dynamics, this type of aerial photography could be used to monitor population changes over time on a broader synoptic basis than ground surveys.

Many other characteristics important to the grazing resource environment were identifiable in the photographs. Ant mounds, cone-shaped images which differed from the irregularly shaped gopher mounds, were easily discerned on both film types at a scale of 1:1000. Continuous herbaceous litter cover and dead shrub crowns were more consistently identified in the color infrared photographs due to the grayish white image colors. Deer carcasses were identifiable in both film types at scales up to 1:4600 regardless of when during the snow free season the photographs were taken. They appeared more obvious in the color infrared film due to greater color contrast between the carcass and surrounding vegetation and bare soil.

PHOTO MEASUREMENTS. A General Aniline and Film Cooperation Model 650 scanning microdensitometer, in-line with a Honeywell "Electronic" strip Chart Recorder as modified by GAF, was used to attempt to develop automated analytical interpretation of the photography. Since the color infrared photographs were most useful for species identification purposes, this film type was used with the microdensitometer.

A circular aperture scanning a 416 square-micron area on the transparency was used. The circular configuration was selected since it conformed most closely to the shape of the plant image on the film. Preparatory research indicated a green filter rather than red, contrary to theory (Fritz 1969), would provide the best opportunity to discriminate among selected plant species.

The prime objective of this research was to relate ground measurements of vegetation along a line transect to densitometry along the same line premarked for identification in the transparencies. Before this could be done, the optical density of specific imaged species was determined, to assess the degree of discrimination possible among the species. Although the mean densities of the selected species appear to separate, the density ranges indicate the method may not be feasible for automatic image interpretation (Table 2). An exception might be for the discrimination of sagebrush from bitterbrush, as genera, where they occur in the same stand--which they frequently do. The image density differences between bare soil and cover of live vegetation indicate the method is capable of automatically separating these two categories.

To test the separation of plant communities, scan lines were generated to span various communities on 1:4200 and 1:350,000 scale color infrared film exposed in August and October respectively. The communities could be separated on the basis of image density and density frequency amplitudes of the images. Therefore, this system, in conjunction with direct input to a computer, may provide an analytical approach for determining the amount and kinds of plant communities. This is a new area of research in which new concepts must be developed and tested.

Table 2.--*Means and ranges of film density values of color infrared images of five shrubs and bare soil, scale 1:1,100, photo mission 3 August 1968.*

Species or object	Film density values	
	Mean	Range
Cercocarpus montanus (Mountainmahogany)	3.676	3.15-4.42
Pinus edulis (Pinyon pine)	3.655	3.26-4.12
Juniperus scopulorum (Rocky Mountain juniper)	3.266	3.04-3.56
Purshia tridentata (Bitterbrush)	3.169	2.97-3.53
Artemisia tridentata (Big sagebrush	2.805	2.56-3.00
Artemisia longiloba (Alkali sagebrush)	2.768	2.62-2.72
Bare soil	2.497	2.44-2.58

DISCUSSIONS AND CONCLUSIONS

Color aerial photographs, in particular color infrared photos, have potential value for improving grazing resource inventories. Individual herbaceous and shrub species can be identified with acceptable accuracy on large scale photographs (1:600-1:1100). Plant communities, grazing use patterns, and cultural treatments can be discerned on smaller scale photographs (1:135,000 for community and grazing use discrimination). Other grazing resource influences, including rodent and insect activities, can be assessed by detailed photo interpretation.

The success of using this kind of photography to augment grazing resource inventories depends on season of the year as related to phenology, size of the plant of interest, associated vegetation, and stand density. Due to the complexity of the vegetation, frequently over 100 plant species on an acre of ground, and the varying growth habits of each species, there is no one optimum time during the growing season to procure photography for species identification. It is not expected that all species would be identifiable or even detectable in the photographs because of small size. A problem, then, is to determine the plant or plant grouping size that can be resolved in the photographs and when during the growing season the plant of interest can be consistently identified with an acceptable degree of accuracy. For example, if an objective is to monitor population changes of wild geranium in spruce-fir/grasslands, mid-August photography is satisfactory. It is also probable that the photographic image of a species differs among locations where it occurs. This needs to be determined.

More latitude regarding seasonal procurement of photographs for plant community or site delineation might be tolerated. Since the images of plant species groupings, rather than individual species, are of interest, the image signatures of these groupings may be sufficiently different that changes in phenology will have less influence on differentiating characteristics among communities as compared to individual plants. Additional research is needed to define the most acceptable time of year and photographic scale for community distinction. In all cases, ground sampling in conjunction with photo interpretation cannot be overlooked. It is conceivable that the rapid data acquisition through photography, coupled with potential automated interpretation controlled by ground sampling, can provide grazing resource information at less cost than ground sampling alone.

Perhaps the most fundamental problem regarding use of sophisticated aerial photography for grazing resource inventory is replication, in time and space, of the scene recorded as photographic imagery. An important aspect in grazing resource management is to monitor changes in vegetation over time from place to place. This information is paramount for making management decisions to integrate grazing with other resource uses. However, quality control is not yet adequate in the exposing, processing, or reproduction of the aerial photographs to assure that image color characteristics of an object can be duplicated in time and space. This forces the photo interpreter to lay aside the most interpretable image features--color hue, value, and chroma. Electronic aids to the human interpreter are of minimum advantage until this problem can be solved.

The 70 mm camera system used for the research reported herein must be regarded as a sampling tool. The small film format and the narrow view-angle of the lens does not provide the synoptic view of the landscape otherwise recorded by conventional aerial cameras. Sampling techniques need to be developed whereby 70 mm photographs are used to sample strips of the landscape photographed simultaneously on conventional format film.

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