richard s. driscoll

USDA FOREST SERVICE
RESEARCH PAPER RM-67
MARCH 1971

color aerial photography

a new view for range management

ABSTRACT

Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountainmahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

KEY WORDS: Aerial photography, infrared color photography, color photography, indicator plants, forest surveys, range surveys, land classification, forage plants, phenology.

USDA Forest Service
Research Paper RM-67

March 1971

COLOR AERIAL PHOTOGRAPHY--

A New View for Range Management

by

Richard S. Driscoll

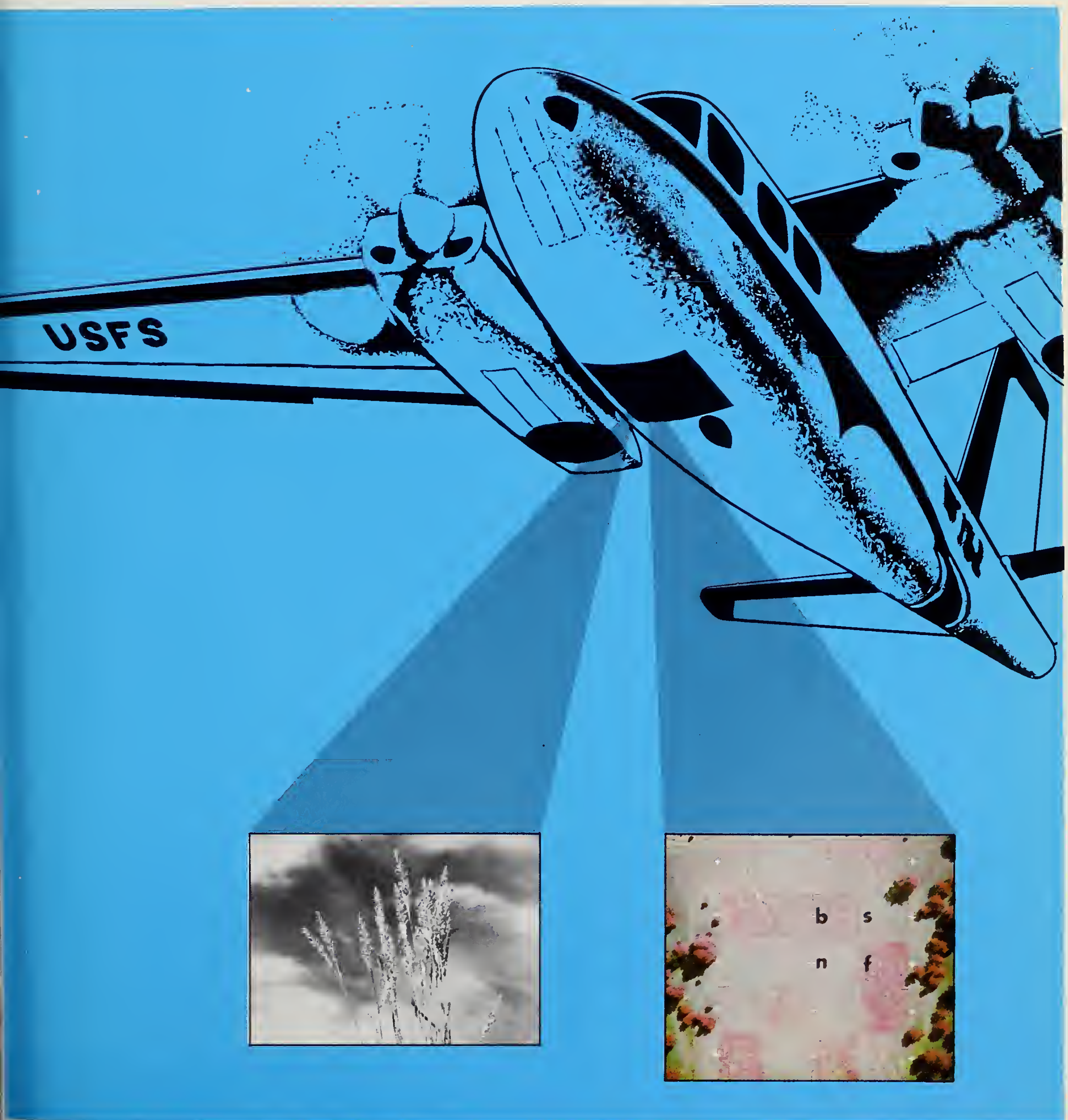
Principal Plant Ecologist

Rocky Mountain Forest and Range Experiment Station[1]

[1]Central headquarters maintained at Fort Collins in cooperation with Colorado State University. Trade names and commercial products are mentioned for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.

Contents

New and improved color aerial films, coupled with high-speed aerial cameras, enable us to identify individual plant species as well as other features of the range environment. These photo systems, linked with potential automated photo interpretation techniques guided by ground sampling, provide possibilities for updating range inventories at less cost than conventional ground surveys alone. Imaged below on a 1:2,400 scale color infrared photograph are blocks of native range 75 feet square, treated with herbicide (s), fertilizer (f), a combination of herbicide and fertilizer (b), and neither (n). The herbicide/fertilizer treatments induce a nonnormal physiological effect which should provide clues to detection of stressed vegetation.



Color Aerial Photography--
A New View for Range Management

Richard S. Driscoll

Black-and-white panchromatic aerial photographs were first documented as an integral part of range inventory procedures in 1937 (U. S. Inter-Agency Range Survey Committee 1937). In an appraisal of range survey methods, aerial photography was recommended over other methods to provide more accurate vegetation type maps and to obtain more dependable forage estimates (Reid and Pickford 1942).

The application of a sampling procedure for range inventories based on aerial photography has been described by Harris (1951). Lord and McLean (1969) discussed how some characteristic aerial-photo patterns of vegetation and land forms were used in soils survey and land classification.

Primarily, black-and-white aerial photography has been used for mapping broad vegetation types—such as grassland versus shrubland versus timberland—and to locate cultural features including roads, fences, seeded areas, or special situations such as rodent infestations. The photographs were usually of medium scale (1:15,840 to 1:30,000) and of average quality on 9-inch by 9-inch format. In addition, photographs available for use had most likely been taken during some previous year. Consequently, image characteristics observed represented current ground conditions only in a gross fashion such as the apparent boundary between generalized vegetation types.

For the above reasons, and because of the experiences of foresters with color aerial photography (Sayn-Wittgenstein 1960, 1961; Heller et al. 1964, 1967; Aldrich 1966), research was started at the Rocky Mountain Forest and Range Experiment Station in 1967 on the feasibility of large-scale (1:600 to 1:4,600), 70 mm (2¼-inch by 2¼-inch format) color aerial photography flown at different times during the growing season for detecting and identifying plant species, communities, and other habitat features in different range environments in Colorado. This Paper reports some early findings at the Rocky Mountain Station. Carneggie and Reppert (1969) have reported on use of this kind of photography for northeastern California grasslands and shrublands.

The Study

Test Sites

Four test sites representing contrasting vegetation types were selected for this research.

Black Mesa is located approximately 30 airline miles west of Gunnison, Colorado, on a spruce-fir/grassland cattle summer range at an elevation of approximately 9,800 feet. It is also grazed by deer and elk from spring through fall. Thurber fescue, Idaho fescue, aspen fleabane, and Fremont geranium are the most common herbaceous species in the grassland areas.[2]

Manitou is located approximately 25 airline miles northwest of Colorado Springs, Colorado, on a ponderosa pine/bunchgrass cattle summer range. Deer use the area yearlong. The specific study location occurs in a parklike opening at about 7,700 feet elevation. Blue grama, Arizona fescue, pussytoes, and fringed sagebrush are the most abundant species on this test site.

Kremmling is located on a deer winter range approximately 10 airline miles northeast of Kremmling in north-central Colorado in a mixed-shrub type. Cattle graze this area lightly at various times from spring through fall. The site is in a very broad mountain valley, locally known as Middle Park, at an elevation of about 8,000 feet. Big sagebrush, alkali sagebrush, antelope bitterbrush, snowberry, rabbitbrush, and broom snakeweed are the most abundant shrubs.

McCoy is located approximately 25 airline miles southwest of Kremmling, Colorado, in the pinyon-juniper type. It is used by livestock most of the year, and is an important deer winter range. The site is within a complex, rolling to hilly topographic pattern of the upper Colorado River drainage at an elevation of approximately 7,400 feet. Pinyon pine and Rocky Mountain juniper provide the general aspect to the area. True mountainmahogany and big sagebrush are common understory species; herbaceous species are relatively minor.

[2] *Common and botanical names of plants mentioned are given inside back cover.*

Aerial Photography

Flight lines from 250 feet to 4,500 feet long were established and marked on the test locations to assure photographic coverage of specific kinds of plants, plant communities, and other items in the range environment. These items were marked on the ground, usually with wood surveyor stakes or some arrangement of wood lath so they could be detected and positively identified in the aerial photographs (Francis 1970).

Dual 70 mm format aerial cameras were mounted in a Forest Service-owned Aero Commander 500 B aircraft to obtain simultaneous imagery with two different film types. Photo scales ranged from 1:600 to 1:4,600.

The 70 mm camera systems used for this work have several significant advantages over conventional aerial camera systems. The 70 mm systems have fast shutter speeds and rapid pulse rates which, when coupled with high-speed small-format film, make possible low-level airplane photography of high resolution for stereo viewing. Other advantages include relatively low cost, small size and light weight, and variable lenses interchangeable in flight.

The film types were Anscochrome D-200, type 7230, exposed with a Wratten 1-A skylight filter, and Kodak Ektachrome Infrared Aero, type 8443, exposed with a Wratten 12 filter. These color film types were selected for two reasons: (1) the greater possibility of identifying individual items in color rather than in black and white, and (2) the ability of color infrared film to portray, in discriminate color images, differences among subjects in their reflectance of near-infrared radiation not observable to the unaided eye.

Anscochrome D-200 is an ordinary color reversal aerial film constructed with a three-layer emulsion sensitized to red, green, and blue light. When exposed and processed properly, the activated dyes form color images that closely match the color of the objects photographed.

The infrared color film is a false-color, reversal film. It differs from ordinary color film in that the three sensitized layers are sensitive to green, red, and near-infrared radiation, instead of the usual blue, green, and red. Since all three layers are also sensitive to blue light, we used a yellow Wratten 12 filter to absorb that part of the spectrum. When exposed and processed properly, this combination of sensitizations and dyes produces false colors for most natural objects. For example, rapidly growing green vegetation produces an image in shades of magenta or red because of relatively strong near-infrared reflectance. Bare soil or mature, drying vegetation appears as shades of cyan or blue because of little near-infrared reflectance. Heller (1970) describes in more detail the light/film physics involved when using this film type.

All film was processed to color transparencies to avoid potential loss of resolution and color balance which often occur when the film is processed to prints.[3]

Photo missions were flown over the test sites when (1) the growing season was starting, (2) the growing season was at its peak, (3) the most abundant species were starting dormancy, and (4) most species were dormant, but prior to snowfall. In addition, the overflights of the Manitou test site were planned to provide before-and-after photos of native range treated with herbicides and fertilizers. This selection of photo missions was planned because no single time period could be expected to provide optimal data about the many items in the complex range environment.

Some Interpretive Comparisons of the Film Types

The identification of an object in an aerial photograph must be based on characteristics of the object as imaged by the camera and film, not by the usual characteristics of the object as viewed firsthand. The photo-image characteristics used for identifying specific items include color, pattern, texture, relative size, shape, and shadow.

Plant Identification

Phenology, or the stage of plant development, is an important consideration when attempting to identify individual plant species in aerial photos.

[3] *All photography was procured and film developed cooperatively with the Forest Remote Sensing Project, Pacific Southwest Forest and Range Exp. Sta., USDA Forest Serv., Berkeley, Calif.*

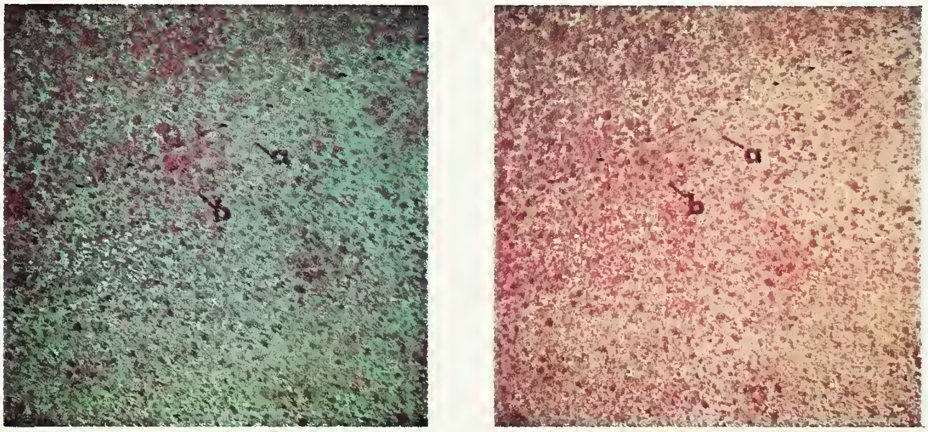


Figure 1.--Ektachrome Infrared Aero (left) and Ansochrome D-200 (right) exposed simultaneously August 24, 1967; Scale 1:750. Wild geranium (a) and orange sneezeweed (b) are identified without error in the Ektachrome Infrared photographs. The two species are difficult to identify in the color photo.

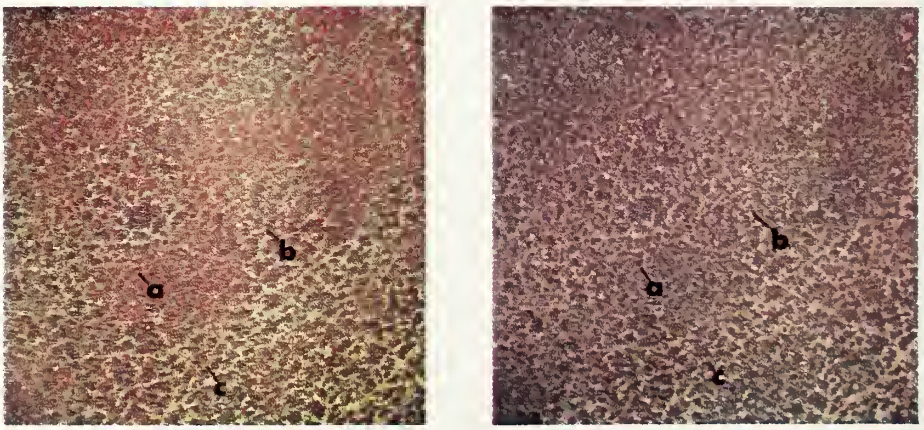


Figure 2.--Bitterbrush (a), big sagebrush (b), and snowberry (c) are more easily detected and identified on color infrared (left) as compared to normal color aerial photography (right) at a scale of 1:1,000 exposed in mid-July. Automated photointerpretation techniques which discriminate between color density differences could be used to determine the amount (cover or numbers) of these species on an area basis.

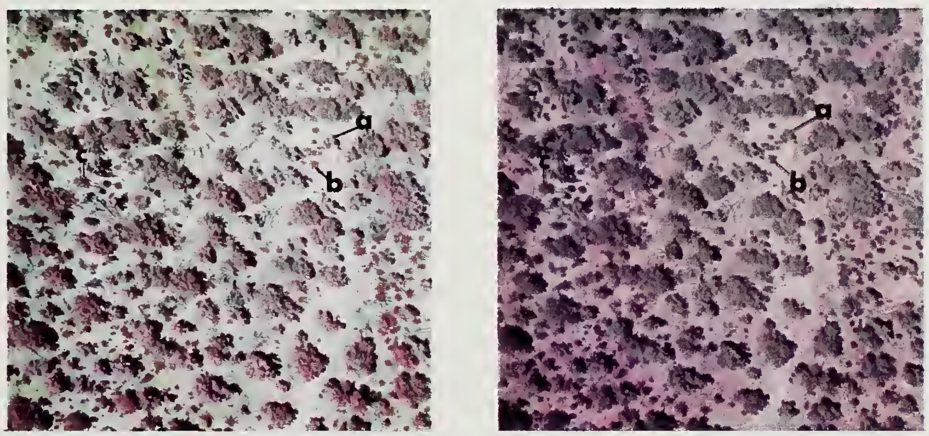


Figure 3.--One hundred percent correct identification of small juniper (a), mountainmahogany (b), and pinyon pine (c) is possible on the color infrared photos (left) at 1:1,200 scale, exposed in July or August. These species are frequently misinterpreted on color photos (right) at the same scale.

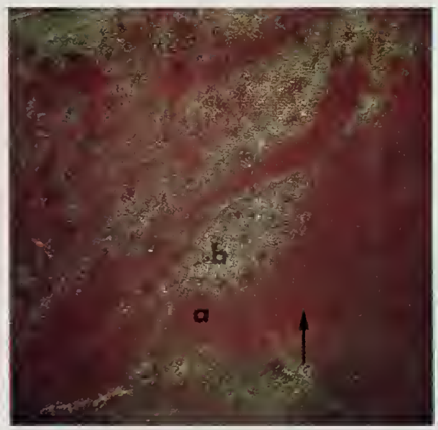


Figure 4.--Bitterbrush/snowberry sites (a) are more precisely delineated from sagebrush sites (b) in this 1:4,600 scale color infrared photo than they would be on regular color photos, although the general community boundaries are equally interpretable on both film types. Individual specimens of large shrubs, serviceberry at the tip of the arrow, can be identified at this photo scale if photos are taken at the right time of year: in this case, mid-August.

Figure 5.--Mountain pocket gopher mounds (brownish spots) in a 1:600 scale color infrared photograph exposed in mid-September. The mound indicated was missed in the companion normal color photograph. Evidence of gopher activity was reasonably discernible in 1:2,400 scale photos exposed on the same date.

For example, mid-July photographs of the Black Mesa site showed the vegetation a constant shade of green on normal color film, and a constant shade of red on color infrared. At this date, all herbaceous plants were growing vigorously with colors (National Bureau of Standards ISCC-NBS system of color designations) between 125 (medium olive green) and 122 (grayish yellow green). These color differences were so subtle they could not be distinguished in the aerial photographs, regardless of photo scale or film type. Because of phenological changes by mid-August, however, individual species could then be differentiated in aerial photographs, primarily on the basis of color. The plant species were in different growth stages, foliage colors were changing, and these differences were detectable in 1:750 scale aerial photographs. For example, the visual ground color of geranium foliage was 16 (dark red). The resultant 69 (deep orange yellow) color imaged on the color infrared photographs provided easy detection and positive identification of the species (fig. 1) since no other species had this color. The population density could thus be accurately determined if this were an objective of a resource inventory. On the color photographs at the same scale and date, the species could be detected and identified only by careful searching under 4x stereo-magnification.

Other relationships were found for identifying shrubs from the aerial photos of the Kremmling test site flown in mid-July. Apparent height and stem leafiness were the important image characteristics, in addition to color, for discriminating between bitterbrush and snowberry. Bitterbrush plants were taller and leaf arrangements on the stems were more vertical and less dense than snowberry. The height difference, which provided a shadow difference, was discernible on 1:1,000 scale photographs under 4x stereo, and the difference in leaf arrangements provided a more discrete image texture for snowberry. With these characteristics, the two species could be distinguished on both film types.

Actual colors of these two species in mid-July were very similar, 127 (grayish olive green) and 125 (medium olive green), respectively. However, image colors in photos taken at that time provided discriminatory differences between the two species, especially in the color infrared. In these photos, bitterbrush was usually 15 (medium red) while snowberry was generally a 13 (deep) to 16 (dark red). On the color photos, bitterbrush was usually 125 (medium olive green) and snowberry 150 (grayish green). The color differences between these species, apparently caused by leaf size and arrangement on the stems, were more obvious in the color infrared photographs.

Image differences between bitterbrush and big sagebrush at the Kremmling site were sufficiently discrete on mid-July photos at 1:1,000 scale that they could be distinguished on both film types. However, the difference between 15 (medium red) of bitterbrush versus the 240 (light reddish purple) of big sagebrush was more apparent in the color infrared photographs than were the green color differences between the two species in the color photograph (fig. 2).

Mountainmahogany, pinyon pine, and juniper could be discriminated well on 1:1,200 scale color infrared photographs on the McCoy site taken August 3, 1968 (fig. 3). Although apparent ground colors of the foliage of mountainmahogany and pine were the same, 125 (medium olive green), the relatively large, shiny, thick-cuticled leaves of mountainmahogany apparently reflected more infrared than the pine needles. This caused an 11 (very red) to a 13 (deep red) image for mountainmahogany and a 43 (medium reddish brown) image for the pine. Because of relative height differences, mature specimens of the two plants could be differentiated on both film types, but identification errors would be frequent when attempting to differentiate mature mountainmahogany and small pines in the same size range on the color photographs.

Fringed sagebrush is usually classed as an undesirable livestock forage. Surveillance of population changes of the species would be important in evaluating range trend or for potential plant control projects. In 1:600 scale color infrared photographs taken June 1, 1968 at the Manitou test site, the species imaged 12 (slightly red) to 11 (very red), and was easily differentiated from other items in the area. At this time, few other plant species had initiated growth and consequently produced minimal infrared reflectance. Fringed sagebrush could be detected and identified in the color photographs, but image character differences were not as unique as in the color infrared film.

Site and Treatment Classification

Site distinction is an important facet of any range management program involving measurement and interpretation of vegetation. With aerial photographs, sites can be better differentiated if vegetation is used as an indicator. The synoptic view of an area afforded by an aerial photograph is much superior to the limited low-angle oblique view seen from the ground.

Given good quality black and white panchromatic aerial photographs of the usual scale (1:20,000), a careful interpreter can discriminate among most sites on the basis of image texture and gray tone. The addition of color introduces another dimension which should decrease interpretation errors and increase the accuracy of discrimination among sites. There was no apparent advantage favoring one or the other of the color photographs for this purpose. On 1:4,600 scale photographs, however, site delineations may be more accurate and the possibility of identifying individual plants may be increased by using color infrared (fig. 4).

At Manitou, the test site included an investigation of various fertilizer, herbicide, and grazing treatments on vegetation. Blocks of land 75 feet square were used for the treatments. Color differences between treatments could be distinguished in 1:2,700 color infrared photographs taken in August, 2 months after treatments were applied (see page one). Comparisons with normal color film were not possible because camera malfunctions resulted in atypical photographs. The facts that differences among treatments could be discriminated in the color infrared photos, and that individual species could be identified in larger scale photographs of the same type, suggest treatment effects might be assessed directly from aerial photographs. Ground conditions at an instant in time could be recorded on film and later analyzed in the office, which would alleviate the perpetual problem of time-dependent field measurements confounded by seasonal changes in the vegetation.

Other Habitat Features

Rodents are often harmful to rangelands, especially when population densities are high. For example, average populations of northern pocket gophers (22 per acre) in the vicinity of the Black Mesa site have been estimated to consume nearly 300 pounds of air-dry herbage per acre each year (Colorado Cooperative Pocket Gopher Project 1960). During expected population increases, common on the test site, these rodents would consume a significant amount of the total herbage production.

Gopher casts and mounds were easily detected on the 1:600 scale photos of the Black Mesa test site. The casts, "ropes" of soil deposited 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 photos taken October 1, 1968. They seemed more apparent in the color infrared film, since some images of plants in the regular color photographs appeared similar to the mound images (fig. 5). The vegetation at that time of year still reflected sufficient infrared that it registered pink in the infrared film, compared with the brownish image color of the mounds. Since pocket gopher mounding is closely related to population dynamics (Reid et al. 1966), this type of photography could be used to monitor population changes on a broader basis than ground surveys. Relative amounts of mounding activity were also identifiable in 1:2,400 scale photographs.

Many other items in the range environment were identifiable in the photographs. Ant mounds 12 inches in diameter appeared cone shaped, different from irregularly shaped gopher mounds, in 1:1,000 scale photos. Surface entrances to burrow systems of ground squirrels at the Manitou test site were identifiable in 1:600 scale photographs. Continuous herbaceous litter cover and dead shrub crowns were generally easier to detect on the color infrared photos, due primarily to the light gray image color.

Deer carcasses at the Kremmling site were identifiable in both film types at scales up to 1:4,000 regardless of when, during the growing season, the photographs were taken. They were more obvious on the color infrared compared to color photos because of greater contrast between (1) the reddish-imaged vegetation and the nearly white-imaged carcass versus (2) greenish-imaged vegetation and the light yellowish-brown-imaged carcass. In addition, carcasses of the current year could be distinguished from carcasses of the previous year on color infrared photographs taken in late spring or early summer. Decay of the carcass over a year coupled with winter-spring moisture apparently fertilized plants immediately adjacent to the carcass. This enhanced the infrared reflectance of the vegetation, and resulted in a bright red halo around the year-old carcass, a phenomenon not found with a fresh carcass. Thus, large-scale color infrared photography may be feasible for sampling current winter deer mortality.

Projections

Color aerial photography adds a new view to measurement and interpretation of range vegetation. Interpretation of color infrared photos appears to offer most promise for detection and identification of individual plants. Neither film type shows a definite advantage over the other for discriminating among sites or vegetation types.

Successful interpretation of aerial color photos depends on season of year the photos were taken, which is related to phenology, size of the plant, associated vegetation, and denseness of the stand. Time of day (sun angle) and growth-habit variations among species also affect image characteristics, and need additional investigation. Equally important is the fact that there is no one optimum time during the growing season to procure photography for interpretation of the many items in the complex range environment. The selection of a time or times for photo missions depends on the objective of a job. For example, if the object is to monitor population changes of geranium on Black Mesa, mid-August photography is satisfactory. If the object is to determine the degree, extent, or changes in pocket gopher activities, however, aerial photographs should be taken in late summer or early fall.

The 70-mm photographic system used for this study must be considered a sampling tool. The camera system was developed primarily to take photographs from low-flying aircraft. Due to the relatively small film format, 70-mm by 70-mm (2¼-inch by 2¼-inch), and the narrow angle of view of the lens, a single frame does not provide the synoptic view of the landscape otherwise recorded with conventional aerial camera systems. Consequently, sampling techniques need to be developed whereby 70-mm photography is used to sample strips of the landscape photographed simultaneously on film of conventional format.

The use of color aerial photography, especially large scale, for rangeland vegetation inventory and surveillance is new. Many problems are yet to be solved. It is not expected that all plant species would be identifiable or even detectable in the photographs because of small plant size and resolution of the photographic system. The resolution threshold for individual plants or plant groupings, and when during the growing season specific plants can be consistently identified with an acceptable degree of accuracy, need to be determined. We also need to determine whether the photographic image of a species differs among locations where it grows.

More latitude may be tolerated in seasonal procurement of photographs to identify plant communities or sites, since images of the total community system rather than individual species are of interest. Additional work is needed to determine when during the year community systems might best be differentiated.

Perhaps the most fundamental problem in use of color aerial photography at any scale for rangeland vegetation inventory and measurement is replication. To be completely useful, such photography should monitor changes in vegetation over time from place to place. However, quality control is not yet adequate in the manufacture, exposing, processing, or reproduction of the aerial photograph to assure consistent duplication of image color. In all cases, ground sampling is essential in conjunction with photointerpretation.

It is conceivable that the use of color aerial photography to provide rangeland resource information is a new area of research, in which new concepts must be developed and tested. It is conceivable that rapidly acquired color aerial photographs could be coupled with automated interpretation and quantification systems controlled by ground sampling to provide better information at less cost than ground sampling alone.

Driscoll, Richard S.
1971. Color aerial photography--a new view for range management. USDA Forest Serv. Res. Pap. RM-67, 11 p., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountainmahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

KEY WORDS: Aerial photography, infrared color photography, color photography, indicator plants, forest surveys, range surveys, land classification, forage plants, phenology.

Driscoll, Richard S.
1971. Color aerial photography--a new view for range management. USDA Forest Serv. Res. Pap. RM-67, 11 p., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountainmahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

KEY WORDS: Aerial photography, infrared color photography, color photography, indicator plants, forest surveys, range surveys, land classification, forage plants, phenology.

Driscoll, Richard S.
1971. Color aerial photography--a new view for range management. USDA Forest Serv. Res. Pap. RM-67, 11 p., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountainmahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

KEY WORDS: Aerial photography, infrared color photography, color photography, indicator plants, forest surveys, range surveys, land classification, forage plants, phenology.

Driscoll, Richard S.
1971. Color aerial photography--a new view for range management. USDA Forest Serv. Res. Pap. RM-67, 11 p., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountainmahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

KEY WORDS: Aerial photography, infrared color photography, color photography, indicator plants, forest surveys, range surveys, land classification, forage plants, phenology.

Aldrich, R. C.
1966. Forestry applications of 70 mm color. Photogram. Eng. 32: 802-810.

Carneggie, D. M., and J. N. Reppert.
1969. Large-scale 70 mm aerial color photography. Photogram. Eng. 35: 249-257.

Colorado Cooperative Pocket Gopher Project.
1960. Pocket gophers in Colorado. Report by technical committee. Colo. Agr. Exp. Sta. Bull. 508-S, 26 p.

Francis, Richard E.
1970. Ground markers aid in procurement and interpretation of large-scale 70 mm aerial photography. J. Range Manage. 23: 66-68.

Harris, Robert W.
1951. Use of aerial photographs and sub-sampling in range inventories. J. Range Manage. 4: 270-278.

Heller, R. C.
1970. Imaging with photographic sensors. p. 35-72. In Remote sensing with special reference to agriculture and forestry. Wash. D. C.; Nat. Acad. Sci.

________, G. D. Doverspike, and R. C. Aldrich.
1964. Identification of tree species on large-scale panchromatic and color aerial photography. U. S. Dep. Agr. Agr. Handb. 261, 17 p.

________, J. H. Lowe, R. C. Aldrich, and F. P. Weber.
1967. A test with large-scale aerial photographs to sample balsam woolly aphid damage in the northeast. J. Forest. 65: 10-18.

Lord, T. M., and A. McLean.
1969. Aerial photo interpretation of British Columbia rangelands. J. Range Manage. 22: 3-9.

Reid, Elbert H., and G. D. Pickford.
1942. An appraisal of range survey methods from the standpoint of effective range management. U. S. Dep. Agr. Forest Serv., Pac. Northwest Forest and Range Exp. Sta. Range Res. Rep. 2, 66 p., Portland, Oreg.

Reid, V. H., R. M. Hansen, and A. L. Ward.
1966. Counting mounds and earth plugs to census mountain pocket gophers. J. Wildl. Manage. 30: 327-333.

Sayn-Wittgenstein, L.
1960. Recognition of tree species on air photographs by crown characteristics. Can. Dep. Forest. Tech. Note 95, 55 p.

____
1961. Phenological aids to species identification on air photographs. Can. Dep. Forest. Tech. Note 104, 26 p.

U. S. Inter-Agency Range Survey Committee.
1937. Instructions for range surveys as formulated by the Inter-Agency Range Survey Committee and adopted by the Western Range Survey Conference, April 24, 1937, 30 p., mimeo.

Common and Botanical Names of Plants Mentioned

.ACK MESA:

Fescue, Idaho	*Festuca idahoensis* Elmer
Fescue, Thurber	*Festuca thurberi* Vasey
Fleabane, aspen	*Erigeron macranthus* Nutt.
Geranium, Fremont	*Geranium fremontii* Torr.
Sagebrush, alkali	*Artemisia longiloba* (Osterhout) Beetle
Sagebrush, big	*Artemisia tridentata* Nutt.
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Snowberry	*Symphoricarpos* sp.

NITOU:

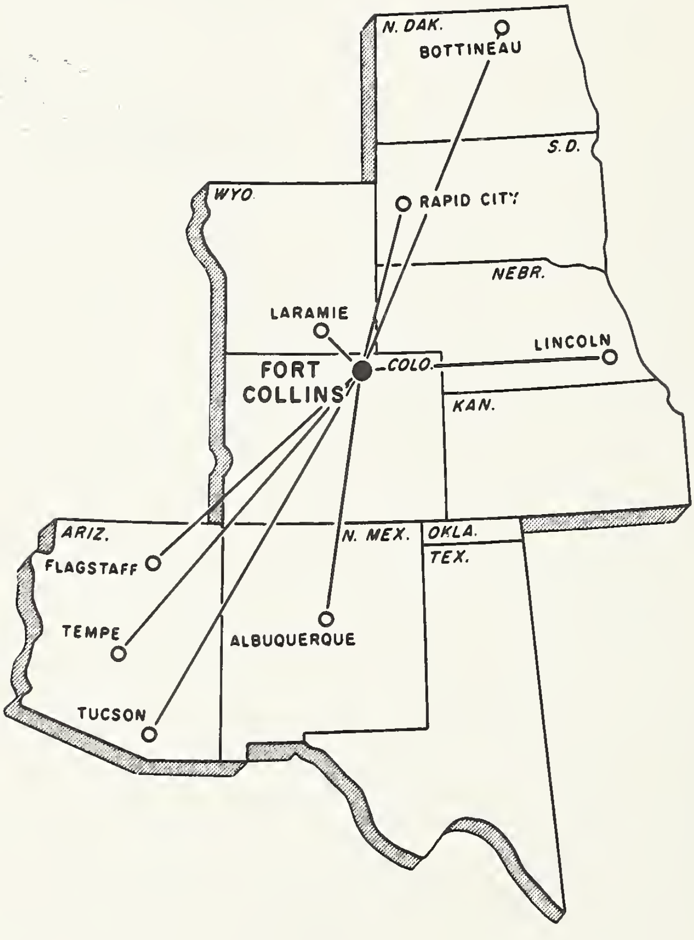
Fescue, Arizona	*Festuca arizonica* Vasey
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag.
Pussytoes	*Antennaria* sp.
Sagebrush, fringed	*Artemisia frigida* Willd.

REMMLING:

Bitterbrush, antelope	*Purshia tridentata* (Pursh) DC.
Rabbitbrush	*Chrysothamnus* sp.

McCOY:

Juniper, Rocky Mountain	*Juniperus scopulorum* Sarg.
Mountainmahogany, true	*Cercocarpus montanus* Raf.
Pine, pinyon	*Pinus edulis* Engelm.
Sagebrush, big	*Artemisia tridentata* Nutt.


N. DAK.
BOTTINEAU
S. D.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
TUCSON