# 70-MM. Aerial Photography—A Remote Sensing Tool for Wild Land Research and Management[1]

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New remote sensing techniques will be widely used in wild land research and management in the years ahead. A review of our initial efforts with one facet of remote sensing—large-scale 70-mm. color aerial photography—will stimulate appreciation of its vast potential. This potential can be categorized into possibly valuable applications with unique advantages. This system can ultimately be related to more powerful sensor systems, whose efficient use awaits only research and development.

## EMERGENCE OF 70-MM. AERIAL PHOTOGRAPHY

While applications of many facets of remote sensing—radar, thermal sensors, etc.—are relatively new to range and related fields, photography is not. In past years, small-scale (1:15,000 to 1:20,000 and smaller) aerial photography has been used, mostly to delineate only very broad vegetation types and physical features. And even that part of the three-step procedure for determining range condition trend that requires oblique ground photography every 5 years depends partly on remote sensing.

Few range and wildlife researchers have appreciated and fully used the potential within conventional aerial photography. We left it to the foresters with the thought "it's difficult enough to detect, identify, and measure a pine tree, not to mention a bitterbrush or Idaho fescue plant."

The breakthrough that now permits detection of small grassland and shrubland features centers around recent technological advances in camera systems and films that permit large-scale, overlapping aerial photographs of high resolution to be obtained. In 1953, Losee called for the use of large-scale photographs to obtain more efficient timber estimates. Seventy-mm. camera systems with rapid film transport and fast shutters (1/1,000 second or faster) were suggested as the best solution to the image motion problem associated with large-scale photographs (Heller et al. 1964).[3] Aldrich (1966) lists several other advantages of 70-mm. camera systems; these include low cost, light weight, interchangeable lens, narrow angles of view, and film easy to process and use in the roll.

High-speed color film, adaptable to the 70-mm. camera system and exposed at large scales, has more potential for species differentiation than ordinary black and white film because there are about 20,000 color combinations distinguishable to the human eye, versus 200 shades of gray on black and white film. More differentiation can be obtained by using color infrared film, which is sensitive to green, red, and near infrared wave lengths of light (blue light is omitted by using a Wratten 12 filter). Resulting photographs exhibit a false color effect. For example, reddish brown soil appears green on the film, and healthy, vigorous, green vegetation appears as some shade of pink or red.

Large-scale photography can be used for (1) tree species identification (Sayn-Wittgenstein 1960, Heller et al. 1964), (2) tree volume estimates (Kippen and Sayn-Wittgenstein 1964, Lyon 1967, and Weber 1965), and (3) forest health determination (Aldrich 1966).

Because of this successful use of large-scale photography in forestry, it is only natural that such a system might prove to be a useful sampling tool for shrublands and grasslands (Carneggie and Reppert 1969).

## NEW STUDIES STARTED

In 1967, three feasibility studies were started. The objective was to find the usefulness of two types of aerial film (Anscochrome D–200 and Ektachrome Infrared Aero) taken at various times during the growing season at large scales (1:650 to 1:4,600) for detection, identification, and measurement of herbaceous and shrubby species and other range features. If the system showed promise for these purposes, a procedure could be developed to use this photography system in range inventory procedures.

One study was located at Harvey Valley,

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Calif., on grass and shrub sites within the ponderosa pine bunchgrass area, Lassen National Forest, Calif. (Carneggie and Reppert 1969). A second study was started at Black Mesa on sites within the high-elevation Thurber fescue grassland, Gunnison National Forest, Colo. A third was on shrub sites used primarily as deer winter range in Middle Park, Colo.

In 1968, two more studies were started: one in a pinyon juniper area near McCoy, Colo., and another on sites within the ponderosa pine bunchgrass area at the Manitou Experimental Forest, Colo.

Preflight ground procedures consisted of marking certain plant species and other ground features with arrows (surveyor stakes laid horizontally on the ground) for quick comparative reference on aerial photographs (fig. 1). Rectangular plots were laid out, and the vegetation therein was mapped or photographed from the ground for future comparison with aerial photographs. Line-chart intercept of vegetation, and other ground features along transects within these plots, were measured for comparison with the scan-line output of image color densities produced by a microdensitometer. This instrument, which measures light transmission through photographic transparencies, is affected by the image density of small areas; it is described in more detail by Doverspike et al. (1965). The ground targets were photographed from a stepladder at or near the time of flight, and extensive notes were taken about plant phenology, plant and soil colors, and other factors (fig. 2).

The aerial photographs were taken from an Aero Commander 500B by personnel of the

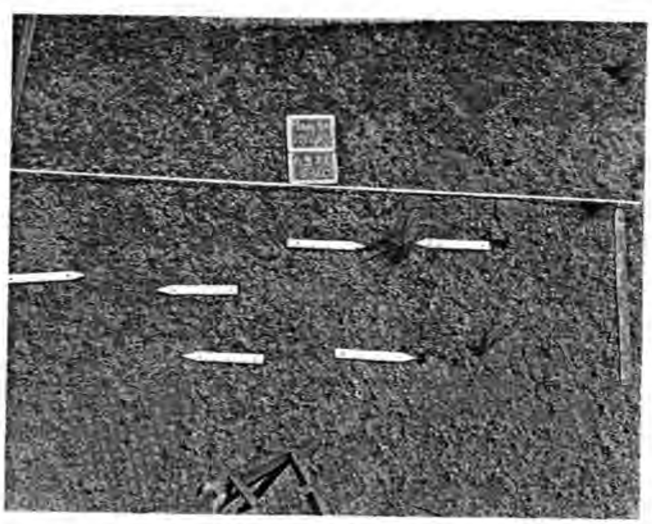

FIGURE 1.—Photo from a stepladder, showing arrows pointing to four species, bare soil, and a rodent burrow entrance. Long lath on right points to zero end of a 20-foot permanent line transect; 10 feet of this transect is shown in the photograph.

FIGURE 2.—Near-vertical ground photographs of marked targets are taken on or near the day of the photo mission, and make up a vital part of the ground truth. Note low-flying photo plane.

Forestry Remote Sensing Project, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, Calif. Twin-mounted KB 8A Maurer cameras, equipped with 150-mm. Schneider Xenotar lenses, were used with 70-mm. Anscochrome D–200 filtered with a 1-A Skylight filter, and with Ektachrome Aero Infrared with a Wratten 12 filter. The cameras were impulsed simultaneously with an Abrams CP–3 intervolometer to provide identical photo coverage on the two film types. Shutter speeds were set at 1/2,000th second, with the airplane flying 100 miles per hour, to reduce image motion and to obtain 60-percent overlap for stereoscopic coverage. The photo missions were flown rather close to the ground, some as low as 300 feet, to obtain the large scales desired.

## EARLY RESULTS

Several results have been obtained from this first work. Obtaining large-scale color aerial photographs was not an end in itself. In fact, if aerial photographs are taken without regard to season, they may be nearly unusable for desired objectives (see color plate II D and E in accompanying paper by D. M. Carneggie). However, if the necessary time is first expended to find out why things are happening to features shown on the photographs, one can then hope to prescribe situations when color or color infrared aerial photography will be useful.

The best time or season for photography depends upon what range feature is of interest and its stage of development, if it is a plant. For example, at Harvey Valley, Calif., in late July, both color and color infrared film were good for identifying *Eriogonum* spp., which at that date had many showy yellow flowers. However, infrared was much better for separating *Purshia tridentata* from *Artemisia tridentata* (see color plate II B in accompanying paper by D. M. Carneggie). On the other hand, *Carex exerta*, a low-growing sedge, was only faintly visible in outline on color infrared in July when it was mature and dry; however, it stood out in a bright pink outline on June 10, when it was in a green vegetative stage. The two previously mentioned shrubs—both in early leaf stages—were not so easily distinguished on June 10. The identification relationship between the two shrubs was similar at the Middle Park, Colo., test site.

At the Black Mesa, Colo., test site, photographs taken in July, when all herbaceous vegetation was growing vigorously, provided minimum differentiation among species with either kind of film. However, by late August, when some species were completing their summer growth, species were more readily differentiatable. For example, *Geranium fremontii*, which had developed seed and leaves turning red, appeared gold in the color infrared photographs. No other image with this color characteristic was detected. *Helenium hoopesii* appeared as a pink rosette, brighter in the center than around the edges, on the color infrared. These and other species were not as easily identified in the color photographs (see color plate II C in accompanying paper by D. M. Carneggie).

While it will take several conclusive photo interpretation tests to fully determine how much more useful one film type is over the other, we do have some indication that color infrared has distinct advantages in differentiating species. On three dates, for instance, *Cirsium* spp. consistently showed as unique brilliant red spots on color infrared. For the three dates, *Purshia tridentata* and *Artemisia tridentata* both appeared a very similar shade of green on color film, but on color infrared photos *Purshia tridentata* tended to be a brighter red than *Artemisia tridentata*. A deer carcass, which was placed along the flight line at the Kremmling, Colo., site, tended to show a brighter whitish tone on color infrared photographs taken in August. Thus, it contrasted more with nearby vegetation than with the image characteristic on color film, thereby indicating the feasibility of this film type in assessing winter deer losses.

This initial work with large-scale aerial photography has shown that many features—some surprisingly small—can be detected. A complete list of these detectable features would include the following:

1. Individual shrub, grass, and forb plants.
2. Flowers on forbs such as *Eriogonum*.
3. Larger seed heads on some grasses such as *Bromus inermis*.
4. Colonies of tiny annuals such as Gayophytum spp.
5. Cattle tracks and droppings.
6. Soil surface erosion and surface moisture.
7. Rocks as small as 1 or 2 inches in diameter.
8. Dead deer and shed antlers.
9. Rodent holes and casts.
10. Anthills.

## POTENTIAL USES

Because so many features can be seen on large-scale aerial photography, as compared to small-scale photography, prospects are good for developing techniques to:

1. Identify many plant species and soil surface features.

2. Better classify grass and shrub communities into specific habitat types or sites.

3. Measure herbaceous and shrub vegetation parameters such as cover, density, height, spatial distribution, and utilization.

4. Monitor changes in vegetation and in soil surface conditions in relation to time.

5. Monitor natural causal agents of vegetation changes such as rodent, insect, and plant disease outbreaks; and livestock and big-game concentrations, etc.

6. Increase the accuracy of interpretations made from small-scale surveillance systems, such as earth orbital satellite photography, or conventional small-scale aerial photography, within a multiple sampling procedure where interpretations from large-scale photography and ground truth (fig. 2) can be extrapolated to small-scale photography (see color plate I in accompanying paper by D. M. Carneggie). Factors such as precipitation, wildfire, and plant die-off, which often occur uncontrolled over extensive areas, could be monitored by such a system.

7. Relate wildlife dynamics to habitat conditions. Also, by tying in early nighttime thermal sensing of campfires, hunter density and distribution might be related to big-game distributions.

8. Obtain early detection of situations which may have serious management implications, such as influx of noxious plants, unbalanced distribution of livestock, rodent concentrations, and environmental deterioration caused by recreational malpractice such as off-road vehicular travel and littering near hunter camps.

## ADVANTAGES OF A PROVEN 70-MM. SYSTEM

An effective technique based on large-scale 70-mm. aerial photography would have many advantages, most of which would apply to other remote sensing systems:

1. Pictorial backup for ground treatments and measurements. This is the obvious and currently the most common use of photography.

2. A photographic base upon which to make measurements similar to on-ground measurements. For example, line intercept measurements or shrub distribution maps can be made from aerial photographs.

3. Provide a photographic base for new measurements unique to the photograph. An example is the measurement of optical density of specific imaged objects to relate photo image characteristics to species identification or the estimation of some vegetation parameters such as foliar cover, by means of automatic data processing.

4. Provide a permanent photographic record for later examination to evaluate the reasons for unsuspected change or reaction of vegetation to some factor(s). For example, a small colony of annuals, even though unnoticed now, is preserved on film for future viewing should it become widespread and obvious in later years.

5. Eliminate measurement variation due to personnel changes or changing measurement standards by allowing today's photo interpreter to return to yesterday's scene and to simultaneously remeasure both situations by an identical procedure.

6. Shorten the season of field data collection and partially solve the changing phenology problem as it affects measurement of vegetation parameters.

## CONCLUSIONS

Our current efforts have been directed toward (1) developing identification techniques and tests for plant species and other wild land features, (2) determining optimum film types and dates for taking photos, and (3) perfecting herbaceous shrub photogrammetry techniques. Included were preliminary efforts to relate microdensitometer measurements to on-ground line-intercept values.

Many problems have been encountered. More intensive ground truth was needed, and will be incorporated into future studies. We found it very difficult to describe color on the photographs, even using Munsell color chips. Thus, the description of photo images based on noncolor characteristics (texture, height, shape, shadow, etc.) may be of equal or greater value in identification than color descriptors. However, the use of color descriptors still offers greater potential for identification purposes because the color combinations are greater than the number of gray tones in panchromatic photographs.

There is need for fundamental research into such factors as the physiological causes of different shades of color of plant species as shown on the photographs. There is also a need to develop automated interpretation and analyses by use of a device such as a scanning microdensitometer coupled to a computer system, which would reduce the volume of data in the aerial photographs into usable forms.

Finally, there is need for continued cooperation and open interchange of ideas and developments. This includes contact with scientists and others working with the various sensor systems.

## LITERATURE CITED

Aldrich, R. C.
1966. Forestry applications of 70 mm color. Photogramm. Eng. 32(5): 802–810.

Carneggie, David M., and Reppert, Jack N.
1969. Large scale 70-mm. aerial color photography. Photogramm. Eng. 35(3): 249–257.

Doverspike, George E., Flynn, Frank M., and Heller, Robert C.
1965. Microdensitometer applied to land use classification. Photogramm. Eng. 31(2): 294–306.

Heller, R. C., Doverspike, G. E., and Aldrich, R. C.
1964. Identification of tree species on large-scale panchromatic and color aerial photographs. U.S. Dep. Agr., Agr. Handb. 261. 17 pp.

Kippen, F. W., and Sayn-Wittgenstein, L.
1964. Tree measurements on large-scale vertical, 70 mm. air photographs. Forest Res. Br. Dep. Forest., Can., Publ. 1053, 16 pp.

Losee, S. T. B.
1953. Timber estimates from large-scale photographs. Photogramm. Eng. 19(5): 752–762.

Lyons, E. H.
1967. Forest sampling with 70 mm fixed airbase photography from helicopters. Photogrammetria 22(6): 213–231.

Sayn-Wittgenstein, L.
1960. Recognition of tree species on air photographs by crown characteristics. Forest Res. Br., Dep. Forest., Can., Tech. Note 95, 56 pp.

Weber, Frederick P.
1965. Aerial volume table for estimating cubic foot losses of white spruce and balsam fir in Minnesota. J. Forest. 63(1): 25–29.

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