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LARGE SCALE 70mm PHOTOGRAPHY FOR
RANGE RESOURCES ANALYSIS IN THE WESTERN UNITED STATES

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ABSTRACT

Large scale 70mm aerial photography is a valuable supplementary tool for rangeland studies. A wide assortment of applications have been developed varying from vegetation mapping to assessing environmental impact on rangelands. Color and color infrared stereo pairs are useful for effectively sampling sites limited by ground accessibility. They allow an increased sample size at similar or lower cost than ground sampling techniques and provide a permanent record.

1. INTRODUCTION

Rangelands cover almost 40 percent of the globe. These are lands that are not forests, agricultural, urban or industrial lands and are used for the purpose of providing forage for both domestic and wild animals, wildlife cover, recreation opportunities and vegetation for watershed protection. They are grasslands, shrublands, semi-arid deserts, marshlands and grazed forest and open woodlands. The broad expanses of these landscapes often coupled with relatively low productivity when compared with timberlands and intensive agricultural lands has precluded intensive analysis and monitoring. Remote sensing techniques including color and color infrared photography are rapidly being developed for rangeland applications and are proving to be extremely useful.

For the past 9 years this author has been involved in the obtaining and applications of large scale color and color infrared photography for evaluating range resources in the western United States. Large, intermediate and medium scales (Heller 1970) are represented here as this paper refers to representative fraction scales of approximately 1:15,000 up to as large as 1:600. At the largest scale this translates to 1 inch equals 50 feet. Emphasis of this paper is on these largest scale photographs.

These photographs have been obtained and interpreted in numerous ways. Most often these photographs have been used as an appropriate large scale subsample as part of a multistage sample while in other cases the data stand alone as a means of studying a small specific location with great detail. The various uses have included studies of the following: vegetation and species identification, plant species mapping, vegetation mapping, plant cover determination, plant density counts, biomass or range productivity determinations, vegetation utilization, plant vigor and phenology, range readiness, erosion determinations, rodent activity, off-road vehicle use and/or damage, evaluating herbicide applications, range condition and trend and evaluating and measuring environmental impact.

Numerous papers have described the applications and benefits of large scale color and color infrared photography for range resources management (Driscoll and Reppert, 1969; Carneggie, 1968; Lorain 1970; Carneggie, 1971; Carneggie et al., 1975; Tueller et al., 1972; Tueller and Swanson, 1973; Cosgriffe et al., 1973; Driscoll, 1969a and 1969b; Tueller and Booth, 1975; Tueller and Clark, 1976; Young et al., 1976; and Booth, 1974). Lorain (1970) and Francis (1970) have described techniques for marking transects for easy viewing from the air. Booth (1974) and Tueller and Booth (1975) describe procedures for systematically sampling range ecosystems.

2. METHODS

The equipment that we have used for the acquisition of these photographic data has consisted of a light single engine fixed wing aircraft (usually a Cessna 206, 185 or 180) equipped

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with an 18" camera hatch, two Hulcher 103, 70mm rapid sequence cameras, two 12-volt batteries, a dual camera mount (fabricated in our laboratory), a light meter and often an intervalometer. Applications and technology for large scale 70mm photography has been developed and successfully applied in the study of vegetation on rangelands, forests, and production agriculture (Aldrich et al. 1959; Heller 1959; Aldrich 1966; Heller 1970 and Reppert 1969).

The Hulcher^{1/} rapid sequence cameras are capable of being exposed singly, at five frames per second, ten frames per second, or pulsed at a given frame rate with an external intervalometer. Most photographs were taken with a 150mm Schneider-Xenotar F2-8 lens using one of three films: Aerochrome infrared film type 2443 (Kodak), color negative film type 2445, and Ektachrome MS aerographic film type 2448. Normally, color and color infrared films are used with simultaneous framing.

All photographs were obtained with stereo overlap for three-dimensional viewing. This was accomplished with each single camera by coordinating aircraft ground speed, altitude and frame rate. For example, to obtain between 60 and 80% stereo overlap and a 1:600 scale, it was necessary to fly the aircraft at 100 mph ground speed at 300 feet above terrain exposing each frame at 1/1500th of a second (Aldrich et al. 1959). Stereo viewing was found to be necessary for all our applications.

Our experience in the Great Basin suggests that the best results are obtained when the photography can be obtained on a clear day with the sun near its zenith. The data are usually studied directly in the roll as transparencies by stereoscopic viewing. Only if the range researcher or manager requires visual material for reports or public display is it necessary to process to prints. This is an important advantage since color prints at sizes larger than contact are relatively expensive. The 70mm or 2.25" format is more than adequate for evaluation although in some cases it has been necessary to project the transparencies before certain detailed measurements could be made.

Photographic costs are variable and generally the aircraft operation or rental is the major cost. Suitable light aircraft presently rent without pilot for from \$40-85/hour while prices including a pilot are normally \$10-20/hour higher. A 100-ft. roll of color or color infrared film now costs approximately \$160 to purchase and process to the transparency. A 100-ft. roll will cover approximately 72 acres at a scale of 1:800 although this kind of continuous coverage is rarely accomplished or required for most 70mm work. A single roll can usually provide up to 450 single frame or over 150 stereo pairs. In other words, numerous areas can be sampled for range resource analysis with a single roll of film.

The promoter of large scale color photography for rangeland uses should be the first to strongly state that these photographic data, good as they are, do not constitute a panacea or final solution to some of our range sampling problems. Rather, they, in my opinion, provide an excellent cost-effective supplement for our range analysis and monitoring problems. They, ideally, should be used by trained range resource managers and scientists to supplement their field work. Those intimately familiar with the field problems will find 70mm color photography a valuable supplementary tool for their work.

Of even greater importance is the fact that photographs provide a permanent record that can be reevaluated and reinterpreted 5, 10, and 50 years from now if the need arises. Field notes and measurements, while required, cannot be re-measured due to the dynamic nature of our range resource. Also, acquisition of the data is not dependent on ground accessibility.

We have spent considerable time developing dichotomous keys for use in aerial photo interpretation. The keys use most of the various photo interpretation factors such as texture, shape, size, tone and pattern to distinguish range resource features. Color has been used as a criterion but found wanting due to the extreme variation found from date to date in color and especially in the color infrared film. These keys seldom work if used by untrained range managers or scientists without field experience or someone outside the field. On the other

^{1/} I do not wish to particularly endorse one camera over another. However, the Hulcher 103 camera was within our price range, accomplished our tasks and after gaining some experience they have performed up to and often beyond our expectations.

hand, they do strongly aid the knowledgeable range person as he tries to familiarize himself with the aerial photography. Several of these keys are available for use and review (Tueller et al. 1972); Tueller et al. 1975; Seher and Tueller 1973; Lorain 1970; Tueller and Lorain 1971; Parkin 1977).

2. APPLICATIONS

Species Identification

The accurate identification of species is almost always a necessary first step before other plant association or soil surface parameters can be assessed photographically. Most, if not all, trees and shrubs on all range sites can be correctly identified (Tueller et al. 1972). Only certain species of forbs and grasses can be correctly identified and subsequently measured (Driscoll and Reppert 1968; Carneggie et al. 1971; Poulton et al. 1975). Normally these latter species must be either those that are abundant or large and showy or both. Dichotomous keys utilize several interpretation factors such as color, texture of individual plants or plant clumps, pattern of the distribution of individuals and shape of certain species are very valuable for photo interpreters involved in species identification (Lorain 1970; Tueller et al. 1972). Color and color infrared are likewise important in the species identification process and in every case additional species are identified as the second film type is interpreted. On some sites color alone is preferable to color infrared (e.g. Sonoran Desert sites).

Plant Cover

In a range vegetation context the reference here is to foliar projection of shrub and forb vegetation onto the ground and usually to the basal area of grasses. Several methods have been used: planimeter, point method or dot grid, estimation, line intercept and direct measurements involving the measurement of two radii and then computing cover with the ellipse formula. The point method or dot grid has perhaps been the most useful and most accurate (Tueller and Lorain 1973). For the future we can expect to use an electronic planimeter, an area evaluator circuit with a color density slicing apparatus, or a scanning microdensitometer (Driscoll et al. 1974) to rapidly obtain and record cover data.

Cover data by species can be as much as 30 times slower using routine field procedures when compared with the same data from large scale aerial photographs by dot grid (Tueller et al. 1972). Ground and photo data is often very comparable by species and for total plant cover (Table 1 and Tueller and Lorain 1973).

Plant Density

Density (plants/unit area) is obtained with ease for some species, especially those that are readily identified. However, the ground density data cannot be duplicated on the aerial photographs as readily as can cover measurements (Table 2 and Lorain 1970). In some cases, individual specimens cannot be distinguished, e.g., some shrubs occur as clumps averaging one to several specimens. In this case it is often possible to enumerate clumps and then, using supplemental ground data, arrive at density by knowing the average number of plants per clump. The data is derived simply by counting an entire frame or, more commonly, a subsample of a given area.

Condition and Trend

On any given range site the vegetation possesses a set of characteristics including a given species composition. This is referred to as the range condition. These sets of characteristics tend to change over time. These changes, their direction, magnitude and speed are referred to as range trend. Species composition, either changes in the relative proportion of species or changes in the occurrence of certain species, can be readily measured on large scale 70mm photographs (Lorain 1970; Tueller et al. 1972; Carneggie et al. 1971; Driscoll and Reppert 1968). Both long and short term changes can be measured. The adequacy of the permanent record becomes apparent in range condition and trend studies.

Large scale 70mm photography is useful for identifying and measuring litter, rocks, bare ground, other soil surface features (Carneggie and Reppert 1969; Driscoll and Reppert 1969; Carneggie et al. 1971; Lorain 1970). These factors are also very useful for assessing range condition and trend. In addition, accurate shrub measurements may be sufficient on many ranges to evaluate trend since their increase or decrease is highly correlated with changes in the herbaceous species. A reciprocal relationship has often been found. Fecal droppings can be counted or used as an index to range utilization.

Table 1. Ground and photo cover in percent in the Sonoran Desert near Casa Grande, Arizona and in the Mojave Desert near Mercury, Nevada.

	Species	Ground	Aerial Photography		
			1:800	R	1:2,000
<u>Casa Grande</u>					
Palo Verde	<u>Cercidium sp.</u>	6.7	8.0	.80	8.7
Creosote Bush	<u>Larrea tridentata</u>	6.3	4.7	.81	
Giant Saguaro	<u>Carnegia gigantea</u>	.01	.05		trace
Ironwood	<u>Olneya tesota</u>	.12	.07	.77	trace
Bur Sage	<u>Ambrosia dumosa</u>	3.2	3.6	.74	
Mesquite	<u>Prosopis juliflora</u>	5.6	5.7	.89	
Whitethorn	<u>Acacia constricta</u>	7.2	8.2	.94	
<u>Mercury</u>					
Bur Sage	<u>Ambrosia dumosa</u>	8.0	2.5		
Joint fir	<u>Ephedra nevadensis</u>	1.8	1.5		
Range Ratany	<u>Krameria parviflora</u>	3.4	4.8		
Creosote Bush	<u>Larrea tridentata</u>	4.4	4.4		
Lycium	<u>Lycium andersoni</u>	3.7	6.1		
	Total	21.7	19.3		

Table 2. Ground and photo derived density (plants/hectare) data at Casa Grande, Arizona and Mercury, Nevada.

Species	Photo Density		Ground Density
<u>Rock Valley</u> Scale: 1:600			
<u>Ambrosia dumosa</u>	1403		2674
<u>Ephedra nevadensis</u>	496		651
<u>Krameria parviflora</u>	1092		1496
<u>Larrea tridentata</u>	829		891
<u>Lycium andersoni</u>	922		1233
<u>Casa Grande</u> Scale: 1:800, 1:2,000			
<u>Cercidium sp.</u>	106	102	106
<u>Larrea tridentata</u>	76		177
<u>Carnegia gigantea</u>	4.5	4.1	4.5
<u>Olneya tesota</u>	0.4	0.4	0.4
<u>Ambrosia dumosa</u>	209		258

Plant Biomass

On many range sites plant biomass (above ground productivity) has been found to be highly correlated to plant cover and other parameters measurable on the aerial photographs. Spectrophotometric techniques (Tucker et al. 1975; Pearson et al. 1976) have application on short grass prairie range sites and other relatively homogeneous types. However, this latter

technique does not hold as much promise on heterogeneous shrub types where the correlation method holds greater promise. We approached this problem hopeful of finding easily measured characteristics on 70mm large scale stereo pairs that are highly correlated with range productivity. For example, we have recently found high correlations between shrub crown cover and productivity of grasses. Unfortunately, the measurements we have made do not yet extend to estimates of range utilization.

Plant Phenology

It has been widely stated that color infrared film has the capability of providing excellent data on plant vigor. This is only true to a certain extent. Mostly, the expectations are beyond the capability of the color infrared film. Vegetation maturation was followed weekly through an entire growing season in Hot Creek Valley, Nevada for a shrub type (Tueller and Swanson 1973). A color densitometric technique was unsuccessfully used to follow changes in plant vigor. Tone differences from date to date did not follow a prescribed pattern of changes even though many precautions were taken, mainly, all the film was purchased in a single batch from Kodak in Rochester and frozen until use, all photographs were taken at or near high noon and all processing was done in Kodak's Versamat processor under exacting conditions. The changes are thought to be a result of date and exposure differences and were most apparent in the tone recorded for the nonvegetation component.

However, relative vigor differences of a somewhat large magnitude can be easily assessed on the large scale color infrared film. With proper sampling techniques certain management problems related to plant vigor (e.g., range readiness, fire fuel estimates, and time for recreational use) may be solved or partially solved.

Erosion and Surface Soil Features

We have completed detailed work and developed specific procedures for using large scale 70mm color or color infrared stereo pairs to evaluate erosion features on rangelands. We have found it to be possible to duplicate Bureau of Land Management watershed evaluations directly from the stereo photography with greater ease and reliability than field efforts (Tueller and Booth 1975). Costs involved in flight time over the watershed, film and processing costs and labor for the evaluation were found to be less than \$0.02/ha (\$0.01/acre). Also, many off-road sites can be easily studied providing a very efficient sampling procedure. The criteria were changed somewhat to conform with information available from the stereo pairs, bare ground, vesicular crusts, litter, wind erosion, flow patterns, rills and gullies.

Other soil surface features such as cattle droppings and rodent disturbance for some species of small mammals can be easily evaluated and related to range utilization and condition and trend.

Vegetation Mapping

Vegetation maps depicting exact locations of ecotones between important range habitat types can be easily developed from large scale photographs. However, plant community or habitat type mapping is normally accomplished on smaller scale photographs. We have been working with 1:10,000 photography for this purpose and find it to be about optimum (Parkin 1977) although 4-inch to the mile (1:15,840) resource photography has great utility in this regard. The 1:10,000 scale frames were especially useful for differentiating shrub type from shrub type and for successfully differentiating topographic detail necessary for delineating certain habitat types.

Off-Road Vehicle Use

We have studied the effects of off-road vehicle use on several sites. At the Silver Bell (Tucson) IBP site photographs were taken before and after treatment with 4-wheel drive vehicles driving 40 km on approximately 51 hectares. Results showed only limited damage to vegetation (Table 3). Heavy damage was recorded from Bay Area motorcycles in the Pinoche Hills of the California Coast Range. The number, location, and relative depth of vehicle tracks can be easily evaluated.

Table 3. Density (plants/hectare) before and after off-road vehicle use in the Sonoran Desert near Tucson, Arizona obtained from 1:1500 scale 70mm color photography.

<u>Species</u>	<u>Before Treatment</u>	<u>After Treatement</u>
Palo Verde (<u>Cercidium</u> sp.)	21	15
Bur-sage (<u>Ambrosia dumosa</u>)	750	625
Ironwood (<u>Olneya tesota</u>)	4	4
Creosote Bush (<u>Larrea tridentata</u>)	180	130

Pinyon-juniper Chaining Evaluation

Age class distribution of the stand prior to treatment often determines the success of pinyon-juniper chaining, a control measure. Color IR film allows detailed investigation of this plus post-treatment evaluation of dead, damaged, and healthy trees of various sizes.

Environmental Impact

Numerous environmental impact applications are possible with the large scale 70mm format. These include vegetation inventories, plant damage assessment and measurements of accelerated erosion caused by various land use activities.

Vertical color aerial photographs were excellent for assessing damage to trees and shrubs. Mortality counts of single needle pinyon (Pinus monophylla) and Utah juniper (Juniperus osteosperma) on the Nevada Test Site (ERDA facility) on sequential color infrared photographs showed a sequential or residual increase in mortality (Tueller and Clark 1976). Total mortality could not be assessed until the growing season after detonation. This constitutes a unique example of many uses for environmental impact purposes.

Evaluating Herbicide Applications

Color infrared reflectiveness of a green rabbitbrush community has been used to determine optimum date for application of herbicides (Evans et al. 1973; Young et al. 1976). A single frame of 70mm film at a scale of 1:600 captures more than 250 green rabbitbrush plants and permits easy interpretation. When first a pink tinge is seen on rabbitbrush margins on CIR then there are only 2 weeks to the start of the optimum period for herbicide application.

Aquatic Vegetation

This imagery is excellent for marsh vegetation analysis, primarily due to the difficulty of ground access. The best time of year to photograph marsh vegetation was found to be late summer (Aug.-Sept.) when the submerged and floating plants were at a stage of maximum vegetative development. Keys were found to be especially useful for this application (Seher and Tueller 1973).

3. CONCLUSIONS

A large scale 70mm system is a simple, cost effective tool for obtaining range resources data over vast acreages. Exclusive ground sampling techniques have been biased by being restricted to sites along roads or navigable streams. Aerial sampling allows these biased samples to be expanded to objectively located sites on recognizable ecological habitat types far removed from roads. These techniques can now be used by range resource managers, although, for reasons hard to understand, primary emphasis continues on small scale, low resolution systems (e.g., Landsat II). Systematic use of supplementary large scale procedures, however, should be further tested and used in ongoing range management programs.

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