Rangeland Vegetation Changes Measured from Helicopter-Borne 35-mm Aerial Photography

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ABSTRACT: Hand-held 35-mm color and color-infrared photographs were taken in 1981 and 1985 from helicopters over six rangeland study sites in northeastern Nevada. Changes in species (cover, density, frequency) and ground cover attributes were detected on large-scale (1:560 and 1:1,650) photo images using a variety of sampling techniques. Most shrub species were successfully identified and measured. Bunch grasses and forbs were not consistently identified or adequately sampled. No improvement was observed in imagery from a 107-m altitude compared to 198 m. Bare ground and litter cover were easily and consistently measured. Significant differences in plant and cover characteristics over time can be related to range condition and trend.

INTRODUCTION

PUBLIC LAND MANAGEMENT AGENCIES are required to manage rangelands for sustained yield and multiple use. Managers rely heavily on monitoring as a basis for management decisions. This monitoring process requires the capability to periodically detect and measure long-term or successional vegetation changes on these rangelands. Western rangelands are extensive and the dollars per unit area available for monitoring are relatively few. These considerations led us to evaluate large-scale vertical aerial photography as a means of monitoring vegetation changes for upland and wet meadow sites in northern Nevada. Our specific objective was to compare methods for monitoring vegetation and ground cover changes on six range sites between 1981 and 1985.

Various researchers have evaluated large-scale aerial photographs for their usefulness in providing data for forest management (Aldrich, 1959; Meyer *et al.*, 1982a; McCarthy *et al.*, 1982; Befort, 1986; Hagan and Smith, 1986), for the management of wetlands (Seher and Tueller, 1973; Hayes, 1976; Meyer *et al.*, 1982b), and for range resources management (Carneggie and Reppert, 1969; Francis, 1969; Wells, 1971; Tueller, 1977; Heintz et al., 1978; Waller *et al.*, 1978; Everitt *et al.*, 1980; Foran and Cellier, 1980; Meyer *et al.*, 1982b). However, few studies have tested a variety of sampling techniques or range plant communities.

An important consideration in the use of large-scale vertical aerial photography is the need to identify plant species. The representative fraction scales most often used are between 1:500 and 1:1,200. At these scales the resolution is in centimetres and many species and ground cover characteristics can be identified and measured. Trees (Heller *et al.*, 1964) and shrubs (Tueller *et al.*, 1972) are relatively easy to identify. Forbs and grasses are much more difficult. Often only large showy forbs and grasses are identifiable, although bunch grasses can sometimes be identified if sizes, tone, and texture differ. Thus, we considered it important to evaluate the techniques on a variety of study areas with varying mixes of shrubs, forbs, and grasses.

STUDY LOCATIONS

The six study areas used in this investigation are located on the Saval Ranch, approximately 53 km north of Elko, Nevada in sagebrush-grass vegetation. Each study area was characterized and classified as an ecological site based on the soil and annual precipitation criteria of the Soil Conservation Service (USDA, 1976). The study areas are as follows:

(1) A wet meadow ecological site with big sagebrush (*Artemisia tridentata*), meadow barley (*Hordeum brachyantherum*), mat muhly (*Muhlenbergia richardsonis*), sedges (*Carex* sp.), and cinquefoil (*Potentilla* sp.).
(2) A wet meadow ecological site with big sagebrush, rabbitbrush (*Chrysothamnus viscidiflorus*), sedges, and meadow barley. Although this area wetland ecological site is classified the same as Study Area No. 1 by the Soil Conservation Service system, it had greater amounts of rabbitbrush, suggesting a drier ecological condition.
(3) A loamy 10-12in precipitation zone (p.z.) ecological site with big sagebrush, rabbitbrush, bitterbrush (*Purshia tridentata*), Snowberry (*Symphoricarpos oreophilus*), cheatgrass (*Bromus tectorum*), bottlebrush squirreltail grass (*Sitanion histrix*), basin wildrye (*Elymus cinereus*), yarrow (*Achillia lanulosa*), goatsbeard (*Tragopogon* sp.), and mustards (*Brassica* sp.).
(4) A loamy slope 16in+ p.z. ecological site with serviceberry (*Amelanchier alnifolia*), bitterbrush, currant (*Ribes cereum*), snowberry, balsamroot (*Balsamorhiza sagittata*), bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), Thurber's needlegrass (*Stipa thurberiana*), penstemon (*Penstemon*), and hawksbeard (*Crepis* sp.).
(5) Clay pan 10-12in p.z. ecological site with low sagebrush (*Artemisia longiloba*), big sagebrush, sandberg bluegrass (*Poa secunda*), cheatgrass, phlox (*Phlox* sp.) and lupine (*Lupinus* sp.).
(6) A South slope 12-18in p.z. ecological site with big sagebrush, bitterbrush, rabbitbrush, basin wildrye, bluebunch wheatgrass, hawksbeard, stoneseed (*Lithospermum ruderale*), and phlox.

METHODS

It is feasible to acquire large-scale vertical aerial photographs using either a low, slow flying helicopter or fixed wing aircraft and hand-held rapid-sequence cameras with fast shutter speeds and low *f*-stops. Because of concern for safety at low altitudes, all photographs were obtained from a helicopter. A Bell B-1

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helicopter was chosen because of its good forward visibility, maneuverability, and relatively modest cost. All photos were taken hand-held with motor driven 35-mm cameras with 120-mm lenses. These cameras allowed acquisition of five to ten photographs on each pass over a study area. The 120-mm lens provided photographs of a suitable scale taken vertically between the bubble of the helicopter and the skid, without the skid showing in the scene.

Photographs were taken from altitudes of 107 m (350 ft) and 198 m (650 ft), giving representative fraction scales of 1:960 and 1:1,650. The aerial photography was taken on 6 July 1981 and 26 June 1985 between 10:00 A.M. and noon local time. Each study area was photographed with both color (Kodachrome II) and color infrared (Kodak Ektachrome Infrared) film with a Wratten-12 filter. This entailed at least two and sometimes three or four passes, depending on how successfully the pilot was able to place the photographer directly over the area. Yellow plexiglass markers (0.65 m by 1.30 m) fixed to the ground made the areas easy to relocate from the air. They had not deteriorated after four years in the field (Figure 1). The markers also served as reference points for locating specific plants and ground cover features on the ground and on the photographs.

We tested six sampling methods for each of the two film types flown at two different altitudes. Thus, a total of 288 samples was possible, 24 samples for each year from each of the six study areas. However, because of various problems, including loss of film by processors, loss of film by investigators, and poor focus on some imagery, only 240 of these 288 samples were available. Ground frequency data were available for five of the study areas. The transects for Study Area No. 2 were wiped out by flooding after 1981.

A table was prepared for each study area showing each statistically significant change detected between years for each available film type, altitude, and sampling method. An example for Study Area 3, which had a full data set, is reproduced here (Table 1).

Aerial Photographic Sampling

All analyses and measurements were done from projected positive transparencies (slides). A grid was drawn on clear paper and placed onto a wall to serve as a screen for 35-mm slide projection. The focused image sizes were changed using an adjustable focal length lens so that the projected image of each slide had the same scale. All sampling was done from an area on each image representing 32.26m by 9.68m (100 ft by 30 ft) on the ground. Thus, the size of the sample from each photograph varied depending upon the scale used. The equivalent scales among transects averaged 0.82 m per cm on the projected images for the 107-m flight altitude, and 1.67 m per cm for the 198-m flight altitude when projected for analysis. The original photographs were viewed steroscopically only to identify species. All counts and measurements were made on single images.

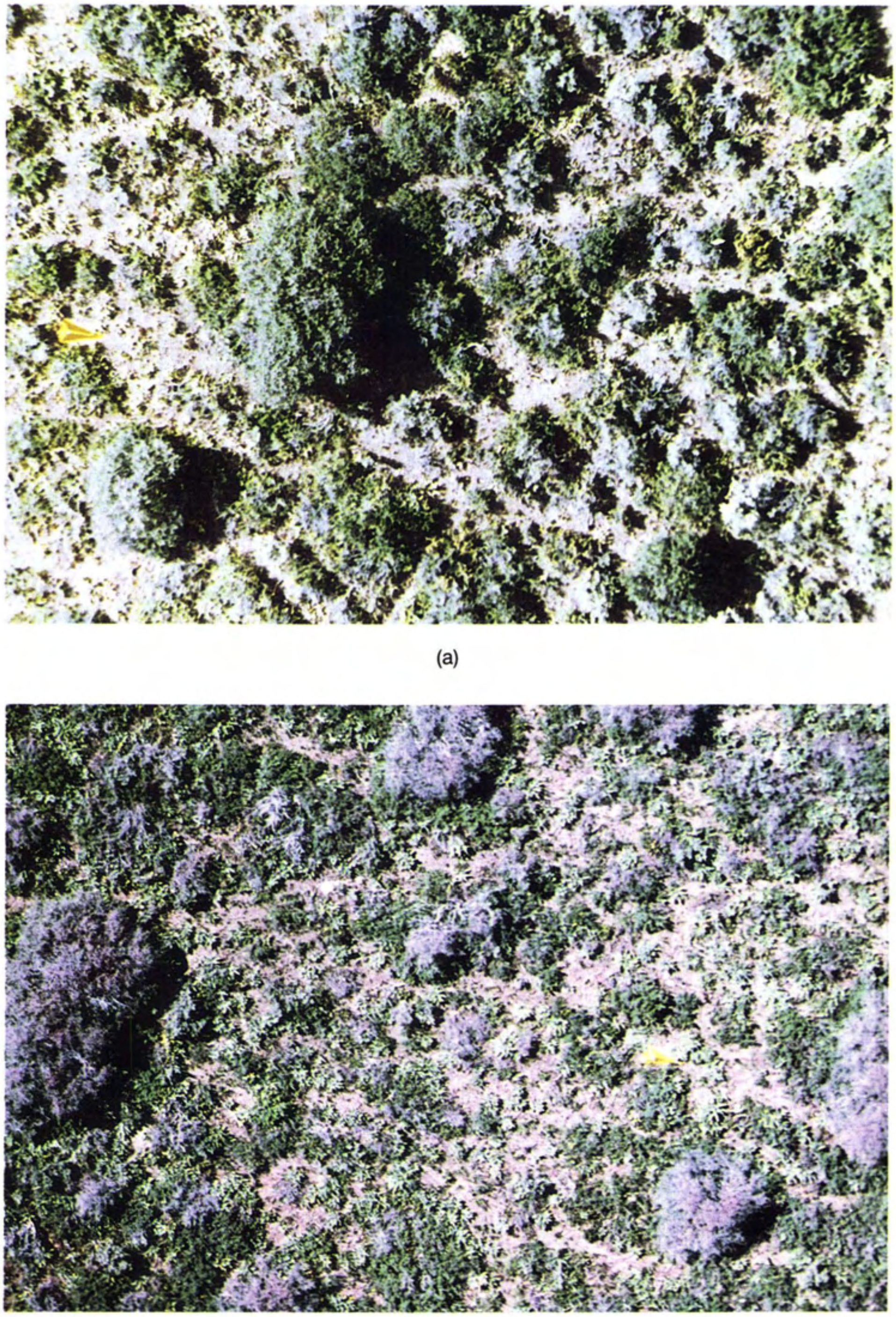
Density of plant species was determined by projecting images onto three belt transects, each having ground dimensions of 0.92 m by 30.4 m (6 ft by 100 ft). Nested frequency was determined from ten regularly placed transects, each comprised of ten contiguous sample frames. The ground dimensions of the nested frames were 0.46 m by 0.46 m (1.5 ft by 1.5 ft), 0.46 m by 0.92 m (1.5 ft by 3 ft), and 0.92 m by 0.92 m (3 ft by 3 ft). Also within this area, dot grids and ocular estimates were used to estimate cover of plant species and ground cover attributes. A 36 dot/6.25 cm^2 (36 dot/in^2) dot grid was selected because it was easy to see individual points in relation to ground features. We estimated cover of species in five regularly places transects,

Table 1. Significant Changes in Species and Ground Cover Attributes between 1981 and 1985 for Study Area 3.

	Aerial photo sampling																								Ground sampled freq. spp. occurrence
	Density				Dot grid				Est. % Cover				Frequency of species occurrence												
	107		198		107		198		107		198		0.46×0.46m Plot				0.46×0.92m Plot				0.92×0.92m Plot				
													170		198		170		198		170		198		
Species	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	C	CIR	
Squirreltail grass																									
Cheatgrass																									
Bluebunch wheatgrass																									
Basin wild-rye																									
Lupine		+3		+3						+1				+1				+1							
Misc. Forbs	+2	+3							−3																+3
Balsamroot																									
Snowberry																	+2				+2				
Bitterbrush															−1	−1		−1			−1	−1	−1		
Rabbitbrush							−2	−2				−2				−1							+2	−1	−3
Big sage-brush	+2	−1			−1	−2	+1	−2	−2		−3	−2		−3				−3		−2		−2		−2	
Dead sage-brush					+2	+2					+1		+3		+2	+1	+3		+2		+3		+3		
Dead bitter-brush													+2				+2	+1		+1	+2	+1	+1	+1	
Dead rabbit-brush																									
Ground litter	−3							+3	+2												−2				
Total litter[1]					+3	+2	+3	+2	+3	+2	+3	+3			+3				+1				+3		
Bare ground						+3		+3		+3		+3		+2	+1	+3		+3		+3		+3		+3	

C = color, CIR = color infrared; 107 = 107-m flight altitude, 198 = 198-m flight altitude; + indicates significant increase; − indicates significant decrease; significance levels: 1 = P≤.05, 2 = P≤.01, 3 = P≤0.001.

[1]Ground litter plus standing dead plant material.



(a)

(b)

FIG. 1. (a) Study Area No. 4 (loamy slope 16+ in ecological site) in 1981. Note the live serviceberry (largest shrubs) and the bare ground between the shrubs. (b) Study Area No. 4 in 1985. Note the dead serviceberry plants and reduced bare ground components. Also, an increase in balsamroot (the large green forb shown on the left interspersed among the shrubs) is visible. Changes in total litter, bare ground, and balsamroot were statistically significant.

each consisting of ten contiguously placed samples, giving a sample size of 1800 dots. Ground dimensions of each sample were 1.83 m by 1.83 m (6 ft by 6 ft). In all five transects, a total area of 16.75 m^2 was sampled. Hits on each species or ground cover attribute were recorded for each dot on the grid. The total number of hits on each species divided by the total number of dots and multiplied by 100 gives and estimate of percentage cover. Cover was also ocularly estimated for the same species and attributes in 50 regularly placed quadrants each with ground dimensions of 1.83 m by 1.83 m. Estimates were made to the nearest percentage point with the help of estimation guides of 2 and 5 percent of the plot area.

TABLE 2. NUMBER OF SPECIES IDENTIFIED ON LARGE-SCALE AERIAL PHOTOGRAPHY, IN SPECIES-FREQUENCY PLOTS ON GROUND AND IN TOTAL SEARCH OF EACH STUDY AREA.

Study Area No.	No. of species identified in photos	No. of species in ground frequency plots	No. species identified in total study area
1	6	19	30
2	2	*	30
3	8	12	27
4	6	24	33
5	4	12	23
6	7	11	25
Mean	7.1	15.6	28

*Study Area 2 was not ground-sampled for species frequency.

Means for each attribute measured at each study area were compared for equality between the two years of observation using a t-test for significance at 90, 95, and 99 percent confidence levels (Steel and Torrie, 1960). Separate comparisons were made for all data using each method and film type at the two altitudes. Statistical comparisons were not made among methods, film types, or altitudes. Methods, film types, and altitudes were compared by observing which attribute consistently reported statistically significant increases or decreases.

GROUND SAMPLING

Frequency of occurrence data were collected on the ground in the same years on five study areas to compare with the aerial data. Frequency percentages were the mean of ten transects each with 20 presence or absence determinations. Mean frequency percentage for each species was tested for significant change between years using an Analysis of Variance and F-test (Steel and Torrie, 1960). The collection and analysis of plant frequency data generally followed the procedures in use by the Bureau of Land Management, USDI, in Nevada (Nevada Range Studies Task Group, 1984; USDI, 1985). Smith *et al.* (1986) confirmed experimentally that use of such frequency plots is a highly sensitive methodology for detecting change in range communities.

Following the second photo mission, color prints were taken to the field sites. By using the yellow markers for orientation, many specific individual shrubs, both dead and alive, and some larger bunch grasses visible on the prints could be located on the ground. Thus, species identifications could be tested and confirmed. At the same time experienced observers traversed each study area to record all species present.

RESULTS

SPECIES IDENTIFICATION

We were able to consistently identify and measure attributes for an average of 7.1 species per study area on the photographs, whereas ground sampling for species frequency encountered an average of 15.6 species per study area. Trained observers searching each area were able to identify an average of 28 vascular plant species per study area (Table 2).

DETECTION OF TREND

Grasses. Significant changes in one or more species of grasses were detected by ground frequency sampling in four of five study areas. No changes were detected with the aerial imagery and sampling methods. However, on Study Area 6 an increase in the large bunchgrass, basin wildrye, was consistently recorded at various levels of significance with all photographic sampling methods.

Forbs. Ground frequency sampling showed consistent increases in frequency of two or more species of forbs on four of the five study areas so sampled. The increases were mostly highly significant ($p = 0.001$). The only significant change detected from aerial photographs was an increase in the large showy forb, lupine, on Study Area No. 6.

Shrubs. The most common shrub species, big sagebrush, was easily identified, and photographic sampling methods were internally consistent in all study areas (Table 3). In Study Areas 3, 4, and 5 these results were not consistent with ground frequency samples. However, a highly significant decrease in rabbitbrush in Study Area No. 3 was also significant in density sampling and in the largest photographic frequency frame as well as in cover and dot grid with medium altitude color infrared (CIR). A significant increase in ground frequency of rabbitbrush in Study Area No. 4 was not detected in any aerial sampling.

Ground Cover Attributes. Significant changes in ground litter were consistently samples in Study Areas 1 and 3. When total litter was sampled, significant increases were consistently seen in Study Areas 2, 3, and 4 (Table 4). Bare ground increased in most samples of Study Area No. 3. Significant changes occurred in some samples on areas 1, 4, 5, and 6. With the exception of Study Area No. 4, these significant changes were sampled only on CIR imagery.

DISCUSSION

PHOTOGRAPHIC ALTITUDE

No dramatic improvement in ability to detect trends was apparent in comparisons of the low altitude with the medium altitude imagery. Photographic interpretation was ineffective with forbs and small bunch grasses at these altitudes. Ability to detect change in wildrye, a large bunch grass, was similar on photographs exposed at both altitudes. In view of the greater equipment demands and safety considerations, it is recommended that the lower altitude not be used for monitoring these vegetation types.

FILM TYPE

Color infrared film was generally superior for change detection involving green shrubs such as serviceberry and bitterbrush with strong infrared reflectivity. Low reflecting shrubs such as big sagebrush and rabbitbrush were easier to identify and sample on color film. The CIR film was clearly more sensitive for bare ground and dead shrubs, and marginally so for litter. The use of both film types is recommended for optimum monitoring.

PHOTOGRAPHIC SAMPLING METHODS

Overall, species density counts provided fewer consistent results and the least conformity with ground frequency samples. Species cover estimates were more consistent.

Our information suggests that the dot grid method is more sensitive and presumably more objective. However, it takes significantly more time than ocular estimates. Dot count data from 58 cm^2 could be acquired by an interpreter in 30 minutes but, in the same length of time, cover estimations could be made on a nearly 1290 cm^2 sample plot, thus giving a much larger sample size and, thus, possibly greater precision and accuracy. An advantage of the dot grid method is that only a single identification of each point at a time need be made, rather than integrating numerous points over the entire plot area at one time as is required by cover estimations. Consistent with our results, Edinger (1983) found dot grid sampling on aerial photographs to provide the best results with lowest standard deviations when sampling shrubs.

TABLE 3. SIGNIFICANT CHANGES DETECTED IN BIG SAGEBRUSH (*ARTEMISIA TRIDENTATA*).

Sampling Technique	Imagery		Study Area No. 1	2	3	4	5	6
Density	Low Alt.	C	n.a.	−2	+2	n.a.		
		CIR	n.a.	−2	−1			−1
	Med. Alt.	C		n.a.				
		CIR		−3				−2
Dot Grid	Low Alt.	C	n.a.	−3	−1			
		CIR	n.a.	−3	−2	−1		
	Med. Alt.	C		n.a.	+1	−3		
		CIR		−3	−2			
Est. % Cover	Low Alt.	C	n.a.	−2	−2			
		CIR	n.a.	−3		−2		
	Med. Alt.	C		n.a.	−3			
		CIR	−1	−3	−2			
Frequency 0.46×0.46m Plot	Low Alt.	C	n.a.	−1				−2
		CIR	n.a.	+3	−3			
	Med. Alt.	C		n.a.				
		CIR	−1	−2				
Frequency 0.46×0.92m Plot	Low Alt.	C	n.a.	−2				
		CIR	n.a.	−3	−3			
	Med. Alt.	C		n.a.				
		CIR	−3	−3	−2			
Frequency 0.92×0.92m Plot	Low Alt.	C	n.a.					
		CIR	n.a.	−3	−2	−2		
	Med. Alt.	C		n.a.				
		CIR	−3	−3	−2			
Species freq. measured on ground			−1	n.a.		+2		+2

C = Color, CIR = Color Infrared, Low Alt. = 107m, Med. Alt. = 198m; n.a. = not available; + indicates significant increase, − indicates significant decrease; significance levels: 1 = P≤.05, 2 = P≤.01, 3 = P≤.001.

TABLE 4. SIGNIFICANT CHANGES IN TOTAL LITTER DETECTED ON AERIAL PHOTOGRAPHS.

Sampling Technique	Imagery		Study Area No. 1	2	3	4	5	6
Density	Low Alt.	C	n.a.			n.a.		
		CIR	n.a.					
	Med. Alt.	C						
		CIR						
Dot Grid	Low Alt.	C	n.a.	+3	+3	n.a.		
		CIR	n.a.	+3	+3	+3		+1
	Med. Alt.	C		n.a.	+3	+3		
		CIR		+3	+2	+3		
Est. % Cover	Low Alt.	C	n.a.	+3	+3	n.a.		
		CIR	n.a.	+3	+2	+3		+3
	Med. Alt.	C		n.a.	+3	+3		
		CIR		+3	+3	+3		
Frequency 0.46×0.46m Plot	Low Alt.	C	n.a.	+3		n.a.		
		CIR	n.a.	+3		+2		
	Med. Alt.	C		n.a.	+3	+3		
		CIR		+3		+2		
Frequency 0.46×0.92m Plot	Low Alt.	C	n.a.	+3		n.a.		
		CIR	n.a.	+3		+3		
	Med. Alt.	C		n.a.	+1	+3		
		CIR		+3		+3		
Frequency 0.92×0.92m Plot	Low Alt.	C	n.a.	+3		n.a.		
		CIR	n.a.	+3		+3		
	Med. Alt.	C		n.a.	+3	+3		
		CIR		+3		+3		

C = Color, CIR = Color Infrared, Low Alt. = 107m, Med. Alt. = 198m; n.a. = not available; + indicates significant increase, − indicates significant decrease; significance levels: 1 = P≤.05, 2 = P≤.01, 3 = P≤.001.

Comparison of Ecological Sites

Monitoring trends with low level aerial photography can be successful on some ecological sites. Generally, sites with large shrub components or sites with trends in litter cover or bare ground are most successfully monitored. For example, changes on Study Area No. 2, a wet meadow with a strong shrub component, were easily detected. The increase in dead sagebrush, total litter, and bare ground were all consistent with an observed rise in water table level. Big sagebrush is easily killed by water saturation of soils (Ganskopp, 1986). Similarly, a "die-off" of serviceberry and bitterbrush as a result of a tent caterpillar (*Eroga websteri*) infestation (Lent, pers. obs.) was easily and consistently detected on Study Area No. 3. In contrast, the clay pan site (Study Area No. 5) showed several highly significant increases in forbs and grasses in ground sampling but only a consistent decrease in bare ground was significant in photo sampling.

Thus, in general, the aerial photography will prove more useful for monitoring riparian communities and other ecological sites important for browse.

CONCLUSIONS

Use of low level aerial photography was found to be an effective procedure for monitoring changes in shrubs and ground cover attributes on various range communities. The techniques, especially dot matrix sampling or use of the largest aerial frequency plots, appeared to be particularly sensitive for detecting changes in larger shrubs. This is in keeping with conclusions of other workers (RISC, 1983; West, 1985; McCarthy *et al.*, 1982). However, significant changes in small bunch grasses and forbs were not consistently detected. With improved understanding of the management significance of changes in litter and bare ground, more use could be made of aerial monitoring of these parameters. Use of these parameters as indicators of effects of grazing pressure is currently feasible (Risser, 1984) if aerial photography is used to identify potential problem areas, and ground samples are then used to aid in detailed interpretation of the changes. For these parameters, use of color infrared film had clear advantages. It is recommended that more use be made of monitoring systems that provide a mix of aerial photo documentation and sampling with conventional ground techniques.

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