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Microdensitometry to Identify Saline Rangelands on 70-mm Color-Infrared Aerial Film

Microdensitometer readings made on CIR film using white or blue light generally gave the best separation between saline and nonsaline range sites where differences in readings were caused by less plant cover on the saline sites.

Introduction

Aerial photography can be used successfully to identify, classify, inventory, and monitor changes in rangeland areas (Reid and Pickford, 1942; Colwell, 1961; Carneggie *et al.*, 1967; Driscoll, 1971).

Many of the world's rangelands are affected by salinty (Carter, 1975). The detection of these areas is important to range and resource managers who are concerned with productivity, condition, and animal carrying capacity. Microdensitometry has been shown to be a potentially useful tool to obtain quantitative measurements of wildland plant communities and components on both very small- and large-scale aerial photos (Driscoll *et al.*, 1974; Everitt *et al.*, 1977; Everitt *et al.*, 1980). Everitt *et al.* (1977) used microdensitometry on black-and-white Skylab imagery to distinguish saline from nonsaline rangelands; however, they could not distinguish them on color-infrared (CIR) film. Driscoll (1974) reported that CIR photos recorded more subtle differences among plant community systems than did other film types. Our objective was to test the possibility of using microdensitometry on 70-mm CIR aerial photos to distinguish between saline and nonsaline rangelands in south Texas.

Abstract: *Microdensitometry on 70-mm color-infrared (CIR) aerial film was tested for distinguishing saline from nonsaline sites on a rangeland in Starr County, Texas. Aerial photographs were taken in May 1976 (scale 1:19,000), June 1976 (scales 1:19,000 and 1:42,000), and June 1979 (scale 1:80,000). Optical density readings were made with white, red, green, and blue light. The saline sites were separated from the nonsaline sites by using white or blue light on the May 1976 photos. On the June 1976 photographs, the saline sites were separated from the nonsaline sites by using all four lights on the 1:19,000 scale photos, and by using white, green, or blue light on the 1:42,000 scale photos. The saline sites were also separated from the nonsaline sites using white, green, or blue light on the 1:80,000 scale photos taken in June 1979. The ability to differentiate saline from nonsaline sites was due to less plant cover on the saline sites. These data showed that automated photointerpretation could be used successfully to identify saline range sites on CIR aerial film.*

Materials and Methods

This study was conducted along a north-to-south flight line 24 km long and 1.6 km wide in Starr County, Texas, whose southern end is about 6.5 km north of Roma. This area is located in the South Texas Plains vegetational region (Gould, 1975).

Land use along this flight line was predominantly native rangeland; however, some of the native vegetation (brush) had been cleared and the

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land had been seeded to buffelgrass (*Cenchrus ciliaris* L.), or native grasses and herbs had been allowed to become reestablished. Everitt *et al.* (1977) described seven different native range sites (four nonsaline and three saline) along this flight line. These seven sites plus four improved sites (three nonsaline and one saline) were used in this study.

Herbaceous biomass production was measured for each of the 11 study sites at or near the time of each aerial photography date in May 1976, June 1976, and June 1979. Biomass production was measured by clipping all above ground herbaceous vegetation at ground level in 20 quadrats, each 50 by 50 cm in size (Stewart and Hutchins, 1936). Species composition by weight of herbaceous plants was determined by separating all species in each quadrat. Biomass production was expressed on a dry weight basis. The percent canopy cover of all woody plants was determined for each of the seven native sites using the line transect method (Canfield, 1941). Twenty 30.5-m transects were run on each of the seven sites. Woody canopy data were collected only in May 1976 because these data have been relatively constant for several years because generally, most woody plants grow slowly in the area. The line transect method was also used to measure herbaceous cover of the study sites; however, it was measured only for the two June dates.

Photographic equipment used included (i) Hasselblad camera (80-mm lens, 5.7 by 5.7-cm format); (ii) filter packet of Hasselblad 4 × 0-2 (orange) and 3.5 × CB 12-1.5 (blue filters); and (iii) Eastman Kodak Aerochrome CIR type EK-2443 film. The camera exposure used was *f*7 at 1/250 sec. Aerial photographs were taken between 1100 and 1500 hours under clear sunny conditions on three dates: 15 May 1976, 23 June 1976, and 21 June 1979. The May 1976 photographs (scale 1:19,000) were taken at an altitude of 1,525 m, whereas the June 1976 photographs (scales 1:19,000 and 1:42,000) were taken at altitudes of 1,525 and 3,300 m, respectively. The June 1979 photographs (scale 1:80,000) were taken at an altitude of 5,606 m.

Film density readings were made on CIR film with a Joyce, Loebl and Company (England) microdensitometer*, equipped with an automatic scanning attachment made by Tech/Ops (Burlington, Mass., USA). Density readings were made with four different light sources: white (no filter), red (Wratten 92 filter), green (Wratten 93 filter), and blue (Wratten 94 filter). The microdensitometer output is in optical counts that are punched onto paper tape. The paper tape microdensitometer output consists of a base line count corresponding to the standard optical densities of the first step of the calibrated step wedge in use, plus added counts that depend on the particular step on the wedge that balances the light transmission by the film being analyzed in the second light beam. The distance the uniformly graduated step wedge travels to balance the transmission by the film determines the count registered by the encoder. The optical count is related to the optical density (O.D.) by the relation

$$\text{O.D.} = [(\text{optical count} - \text{base readings})(\text{wedge factor})] + (\text{step wedge density}).$$

One scan line was run from each of three random locations on each range site, giving three scans per site for each photography date. There were 40 to 50 readings (data bits) for each scan line on the film. Density readings were made only in a small area around the center of each photograph to avoid the effects of lens fall-off. For the aerial photographs taken at an altitude of 1,525 m, the area of a data bit on film was about 0.01 mm^2, and the ground area was 3.63 m^2. On those photos taken at an altitude of 3,300 m, the area of a data bit on film was about 0.005 mm^2 and the ground area was 8.68 m^2. For those photos taken at an altitude of 5,606 m, the area of a data bit on film was about 0.0025 m^2 and the ground area was 16.00 m^2.

Analysis of variance was conducted to determine significant differences for each color light density on each film. Duncan's multiple range test was used to test the statistical significance among means for the study sites (Steel and Torrie, 1960). Coefficients were calculated for linear correlations between herbaceous biomass measurements and mean optical counts and between herbaceous and woody plant cover and mean optical counts.

Results and Discussion

Ground Control Data

Ground control measurements for the 11 study sites are given in Table 1. The generally higher herbaceous biomass measurements for the two June dates were caused by the higher rainfall shortly before these dates. Unfortunately, herbaceous cover measurements were taken only for the two June sampling periods. Herbaceous biomass and cover were generally low for the seven native sites with little differences among saline and nonsaline sites. The slightly higher herbaceous biomass and cover of the Ramadero site was due to its more fertile soils and its location in an upland drainageway that received greater soil moisture from runoff. Both herbaceous biomass and cover were considerably higher on the improved sandy loam (buffelgrass I and II) and clay loam (buffelgrass III) sites than on the improved saline clay site. The lower productivity of

* Trade names are included for the benefit of the reader and do not imply an endorsement of or a preference for the product listed by the U.S. Department of Agriculture.

TABLE 1. GROUND CONTROL DATA FOR 11 RANGE SITES ON A FLIGHT LINE IN STARR COUNTY, TEXAS, IN MAY 1976, JUNE 1976, AND JUNE 1979

Range Site and Soil Type	Woody Plant Canopy Cover (%)	May 1976 Herbaceous Biomass (kg/ha)	June 1976 Herbaceous Biomass (kg/ha)	June 1976 Herbaceous Cover (%)	June 1979 Herbaceous Biomass (kg/ha)	June 1979 Herbaceous Cover (%)
Nonsaline sites						
Sandy loam-native (Copita fine sandy loam)	52	160	273	15	226	15
Shallow ridge-native (Zapata soils)	43	154	186	15	205	14
Clay loam-native (Garceno clay loam)	61	183	274	14	211	13
Ramadero-native (Ramadero loam)	58	300	822	27	477	22
Sandy loam-buffelgrass I (Copita fine sandy loam)	—*	1,347	3,866	61	2,800	55
Sandy loam-buffelgrass II (Copita fine sandy loam)	—	1,490	4,946	66	3,125	52
Clay loam-buffelgrass III (Garceno clay loam)	—	1,910	3,800	63	3,760	64
Saline sites						
Saline clay-native (Catarina soils)	29	125	188	14	167	13
Saline clay-native (Montell soils)	20	127	162	12	200	11
Saline clay-improved (Montell soils)	—	632	724	20	521	17
Rolling hardland-native (Maverick soils)	30	239	249	12	170	10

* These are improved sites where the brush has been controlled.

the improved saline clay site was caused by the lack of buffelgrass and the presence of large bare soil areas or "slicks" with surface deposits of Na and Ca salts that decreased herbaceous biomass production and cover (Fanning *et al.*, 1965; Thompson *et al.*, 1972). The greatest difference in plant cover among the native sites was in their percentage of woody plant canopies. For the saline sites, woody plant canopies ranged from 20 to 30 percent, whereas, for the nonsaline sites it ranged from 43 to 61 percent.

FILM DENSITY RESULTS

Several separations were obtained among density readings using all four colored lights on CIR film (scale 1:19,000) exposed in May 1976, but the separations were best with white light (Table 2). Complete separations were obtained for all 11 range sites, with the four saline sites separating into one group. Among the nonsaline sites, the three improved buffelgrass sites were in the same group as the sandy loam and shallow ridge native sites, whereas the clay loam and Ramadero native sites were in another group. The saline sites appeared as more barren areas on the film, which made them easily discernible from the nonsaline sites that had greater amounts of plant cover and less soil background. The improved buffelgrass sites could be visually distinguished from the native nonsaline sites by their rather smooth image appearance. In contrast, the native nonsaline sites had a rough image appearance due to the canopy configuration of woody plant species. Evidently, the improved buffelgrass and native nonsaline sites had similar film densities. The microdensitometer measures only film density; therefore, sites with equal densities are included in the same group, regardless of image appearance. The density readings for the saline sites were also separated from those of the nonsaline sites using blue light; however, the saline sites did not all separate into a single group. The nonsaline sites separated into the same groups that were obtained using white light.

Many separations were obtained among density readings using all four colored lights on both CIR films (scales 1:19,000 and 1:42,000) exposed in June 1976 (Table 3). On the 1:19,000 scale photography, the saline sites were separated into one group using white, red, or green-colored lights. The saline sites could also be differentiated from the nonsaline sites using blue light, but they did not separate into a single group. On the 1:42,000

TABLE 2. MICRODENSITOMETER READINGS WITH WHITE, RED, GREEN, AND BLUE LIGHTS ON EK-2443 (0.50-0.90 μm) AERIAL COLOR INFRARED FILM (SCALE 1:19,000) EXPOSED ON A HASSELBLAD 500 EL CAMERA FOR 11 RANGE SITES ON A FLIGHT LINE IN STARR COUNTY, TEXAS, IN MAY 1976

Range Site and Soil Type	Color IR Film (scale 1:19,000)			
	White* light	Red* light	Green* light	Blue* light
Nonsaline sites				
Sandy loam (Copita fine sandy loam)	84 b	47 b	64 c	73 b
Shallow ridge (Zapata soils)	81 b	50 b	67 bc	83 b
Clay loam (Garceno clay loam)	113 a	62 a	79 a	99 a
Ramadero (Ramadero loam)	114 a	47 b	76 ab	103 a
Sandy loam-buffelgrass I (Copita fine sandy loam)	72 b	42 bc	61 c	76 b
Sandy loam-buffelgrass II (Copita fine sandy loam)	75 b	40 bc	64 c	76 b
Clay loam-buffelgrass III (Garceno clay loam)	76 b	34 cd	62 c	81 b
Saline sites				
Saline clay (Catarina soils)	47 c	28 d	83 a	52 cd
Saline clay (Montell clay)	48 c	30 d	43 de	56 cd
Saline clay-improved (Montell clay)	52 c	33 cd	46 d	59 c
Rolling hardland (Maverick soils)	42 c	29 d	36 e	46 d

* Mean values followed by a common letter do not differ significantly at the 5% probability level, according to Duncan's multiple range test.

TABLE 3. MICRODENSITOMETER READINGS WITH WHITE, RED, GREEN, AND BLUE LIGHTS ON EK-2443 (0.50–0.90 μm) AERIAL COLOR INFRARED FILM (SCALES 1:19,000 AND 1:42,000) EXPOSED ON A HASSELBLAD 500 EL CAMERA FOR 11 RANGE SITES ON A FLIGHT LINE IN STARR COUNTY, TEXAS, IN JUNE 1976

Range Site	Color IR Film (scale 1:19,000)				Color IR Film (scale 1:42,000)			
	White* light	Red* light	Green* light	Blue* light	White* light	Red* light	Green* light	Blue* light
Nonsaline sites								
Sandy loam (Copita fine sandy loam)	96 b	60 b	90 b	110 b	80 bcd	57 c	74 c	92 cd
Shallow ridge (Zapata soils)	72 c	45 d	68 d	80 d	84 bc	65 b	79 bc	98 bc
Clay loam (Garceno clay loam)	97 b	53 c	91 b	111 b	92 b	63 b	85 b	104 b
Ramadero (Ramadero loam)	114 a	69 a	101 a	119 a	112 a	73 a	97 a	115 a
Sandy loam-buffelgrass I (Copita fine sandy loam)	71 c	44 d	64 e	77 d	70 d	47 d	63 d	84 d
Sandy loam-buffelgrass II (Copita fine sandy loam)	76 c	50 c	76 c	95 c	77 cd	57 c	71 cd	90 cd
Clay loam-buffelgrass III (Garceno clay loam)	76 c	46 d	68 d	82 d	80 bcd	62 bc	74 c	90 cd
Saline sites								
Saline clay (Catarina soils)	53 d	40 e	50 f	52 ef	51 e	44 d	47 e	47 e
Saline clay (Montell soils)	52 d	39 e	50 f	54 ef	53 e	43 d	50 e	47 e
Saline clay-improved (Montell soils)	54 d	39 e	49 f	57 e	50 e	42 d	47 e	47 e
Rolling hardland (Maverick soils)	53 d	40 e	49 f	50 f	52 e	44 d	48 e	48 e

* Mean values followed by a common letter do not differ significantly at the 5% probability level, according to Duncan's multiple range test.

TABLE 4. MICRODENSITOMETER READINGS WITH WHITE, RED, GREEN, AND BLUE LIGHTS ON EK-2443 (0.50–0.90 μm) AERIAL COLOR INFRARED FILM (SCALE 1:80,000) EXPOSED ON A HASSELBLAD 500 EL CAMERA FOR 11 RANGE SITES ON A FLIGHT LINE IN STARR COUNTY, TEXAS, IN JUNE 1979

Range Site	EK-2443 Color IR Film (scale 1:80,000)			
	White* light	Red* light	Green* light	Blue* light
Nonsaline sites				
Sandy loam (Copita fine sandy loam)	99 b	103 b	91 b	80 b
Shallow ridge (Zapata soils)	78 cd	70 c	77 c	67 cd
Clay loam (Garceno clay loam)	87 bcd	72 c	86 b	77 bc
Ramadero (Ramadero loam)	139 a	115 a	110 a	103 a
Sandy loam-buffelgrass I (Copita fine sandy loam)	76 d	55 d	76 c	64 d
Sandy loam-buffelgrass II (Copita fine sandy loam)	89 bc	66 c	89 b	74 bc
Clay loam-buffelgrass III (Garceno clay loam)	95 b	71 c	90 b	79 b
Saline sites				
Saline clay (Catarina soils)	44 e	52 d	43 d	36 e
Saline clay (Montell soils)	43 e	50 d	42 d	36 e
Saline clay-improved (Montell soils)	45 e	51 d	45 d	38 e
Rolling hardland (Maverick soils)	47 e	50 d	48 d	42 e

* Mean values followed by a common letter do not differ significantly at the 5% probability level, according to Duncan's multiple range test.

scale photography, the saline sites could be separated from the nonsaline sites using white, green, or blue light. On red light, the four saline sites separated into one group, but the improved buffelgrass I site also was included in this group. Although the improved buffelgrass and native nonsaline sites could be visually distinguished on the two June 1976 films, their density readings could not be separated using any of the colored lights on either film. The Ramadero site was the only native nonsaline site that could be differentiated from the improved buffelgrass sites using all four colored lights on both films.

TABLE 5. COEFFICIENTS OF DETERMINATION FOR LINEAR CORRELATIONS OF PERCENT WOODY CANOPY COVER WITH OPTICAL DENSITY READINGS ON COLOR-INFRARED FILM FOR SEVEN NATIVE RANGE SITES (THREE SALINE AND FOUR NONSALINE) ON A FLIGHT LINE IN STARR COUNTY, TEXAS.

Photography Date and Scale	Light Source			
	White light	Red light	Green light	Blue light
May 1976 scale 1:19,000	0.91**	0.80**	0.36$^{N.S.}$	0.81**
June 1976 scale 1:19,000	0.90**	0.74*	0.92**	0.92**
June 1976 scale 1:42,000	0.84**	0.78**	0.85**	0.88**
June 1979 scale 1:80,000	0.77**	0.65*	0.88**	0.87**

* Significant at the 5% level.
** Significant at the 1% level.
N.S. Not significant level.

On the 1:80,000 scale CIR film exposed in June 1979, density readings of the saline sites were separated from those of the nonsaline sites using white, green, or blue-colored lights (Table 4). The saline sites were separated into the same group using red light but the improved buffelgrass I site was also included in this group. Though several separations were obtained among density readings for the improved buffelgrass and native nonsaline sites using all four colored lights, no general grouping could be made between these sites; however, these sites were visually discernible on film.

RELATIONSHIP BETWEEN GROUND CONTROL DATA AND DENSITY READINGS

There were no significant coefficients for linear correlations between herbaceous biomass or cover measurements with film optical density readings using any of the colored lights on CIR film for the three photography dates; however, coefficients were significant for linear correlations of percent woody canopy cover with film optical density readings. The coefficients of determination for the linear correlations of the percent woody canopy covers of the seven native sites with film optical density readings ranged significantly from 0.65 to 0.92, except for the nonsignificant coefficient of 0.36 for green light on the May 1976 photos (Table 5).

Summary and Conclusions

This study showed that photointerpretation by microdensitometry could be used to identify saline range sites quantitatively on CIR (0.50 to 0.90 μm) aerial film (scales 1:19,000, 1:42,000, and 1:80,000) exposed in May 1976, June 1976, and June 1979. Microdensitometer readings made on CIR film using white or blue light generally gave the best separation between saline and nonsaline range sites. These data showed that changes in photography scale did not significantly affect the relationships among optical density readings for saline range sites. However, among the nonsaline sites, the improved buffelgrass sites could not be distinguished from the native brush-infested sites, even though visual differences were apparent.

The differences in microdensitometry readings among saline and nonsaline range sites were caused by less plant cover on the saline sites.

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