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Distinguishing Saline from Non-Saline Rangelands with Skylab Imagery

Differentiating between saline and non-saline rangelands was possible by using microdensitometry on black-and-white Skylab imagery exposed over narrow wavelength intervals.

Introduction

Many arid area soils are affected by salinity. Detecting these saline areas is very important to range scientists and wildland ecologists involved in using and managing these soils.

Rangelands are often so large and inaccessible that, in order to determine their characteristics and extent, photography or other imagery is necessary. The use of remote sensing to assess rangeland is well established (Colwell, 1969; Johnson, 1969; Poulton, 1970).

Several investigators have shown that rangelands could be classified with both color and infrared color photography (Carneggie *et al.*, 1967; Driscoll, 1971; Francis, 1970). Earth Resources Technological Satellite (Landsat-1) imagery has been used for mapping vegetation and monitoring changes in the range resources (Bentley, 1973; Seevers *et al.*, 1973; Tueller *et al.*, 1973).

Aldrich (1971) used microdensitometry to identify various land units on Apollo 9 color infrared photos. Driscoll *et al.* (1974) used microdensitometry to identify plant communities and components on infrared color aerial photos. This paper presents the result of a test on the feasibility of using microdensitometry on Skylab imagery for distinguishing between saline and non-saline rangelands in Starr County, Texas.

Abstract: *A flight line in Starr County, Texas, was used to test the feasibility of distinguishing saline from non-saline rangelands when using very small-scale (1:3,000,000) Skylab satellite imagery. Film optical density readings were made on six different films (four black-and-white, one conventional, and one infrared color) using various film/filter combinations. Differentiating between saline and non-saline rangelands was possible by using microdensitometry on black-and-white Skylab imagery.*

Study Area 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 (Figure 1).

Land use along this flight line was predominantly native rangeland with nearly level to gently undulating topography with a few hilly areas broken by caliche and gravelly ridges.

The climate is mild with short winters and

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FIG. 1. Location of study area in Starr County, Texas; South Texas Plains hatched.

relatively warm temperatures year around. Summer temperatures and evaporation rates are high. Average annual rainfall is about 43 cm. Heaviest rains are in May and September (Texas Almanac, 1974), and often there are months without precipitation.

Thompson *et al.* (1972) named seven soil types and six range sites for the study area:

Soil Types
Catarina soils
Copita fine sandy loam
Garceño clay loam
Maverick soils
Montell clay
Ramadero loam
Zapata soils

Range Site
Saline clay (saline)
Gray sandy loam (non-saline)
Clay loam (non-saline)
Rolling hardland (saline)
Saline clay (saline)
Ramadero (non-saline)
Shallow ridge (non-saline)

Botanical composition among the various range sites was similar in many instances, because many of the same grasses and woody plants were dominant on both saline and non-saline sites. Species* common to both sites were mesquite (*Prosopis glandulosa* Torr.), blackbrush (*Acacia rigidula* Benth.), guajillo (*Acacia berlandieri* Benth.), pricklypear cactus (*Opuntia lindheimeri* Engelm.), purple threeawn (*Aristida purpurea* Nutt.), red grama (*Bouteloua trifida* Thurb.), and Texas bristle grass (*Setaria texana* W. H. P. Emery).

* Plant names given are according to Correll and Johnston (1970).

Major species found only on saline sites included saladillo (*Varilla texana* Gray), guapilla (*Hechtia glomerata* Zucc.), dwarf screwbean (*Prosopis reptans* Benth.), curlymesquite (*Hilaria belangeri* (Steud.) Nash), and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.).

Some of the prevalent species found only on non-saline sites were granjeno (*Celtis pallida* Torr.), cenizo (*Leucophyllum frutescens* (Berl.) I. M. Johnst.), buffelgrass (*Cenchrus ciliaris* L.), hooded windmillgrass (*Choris cucullata* Bisch.), sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray), and four-flower trichloris (*Trichloris pluriflora* Fourn.).

FIELD METHODS

Three replications each of these seven soil types (21 sample sites) were chosen based on their ground area along the flight line being large enough to be discernible on Skylab imagery. Soil from each sample site was sampled at 15-cm increments to a 60-cm depth to determine its electrical conductivity (EC_e).

Botanical composition and percent canopy cover of woody plants were determined for each range site (Canfield, 1941). Average woody plant height was obtained by measuring all plants intercepted by the point-centered quarter method (Dix, 1961). Botanical composition of herbaceous plants was determined with a point frame (Tothill and Peterson, 1962). Sixteen of the 21 sample sites were brush-infested native rangeland; however, the brush had been partially controlled on five sites (two gray sandy loam, two clay loam, one Ramadero) and the range reseeded to "introduced" grasses. The Catarina and Montell Soils are saline soils that have the same associated range site (saline clay site). However, since these were two separate soil types, their botanical composition and characteristics were determined separately.

LABORATORY METHODS

The EC_e of the saturated soil extracts for each of the seven soil types was determined using the method of Richards (1954).

The Skylab imagery used was from film exposed at 2:45 CST on May 30, 1973, at a scale of 1:3,000,000 and processed to positive transparencies. Table 1 lists the film/filter combinations and the wavelengths used.

Film density was determined using a

TABLE 1. FILM/FILTER COMBINATION AND SENSITIVE WAVELENGTH FOR THE SKYLAB S-190A MULTISPECTRAL PHOTOGRAPHIC CAMERA SENSOR SYSTEM.

Wavelength (μm)	Film	Filter (NASA designation)
0.50 – 0.60	Pan-X B & W (SO-022)	AA
0.60 – 0.70	Pan-X B & W (SO-022)	BB
0.70 – 0.80	IR B & W (EK-2424)	CC
0.80 – 0.90	IR B & W (EK-2424)	DD
0.50 – 0.88	IR Color (EK-2443)	EE
0.40 – 0.70	HI—RES color (SO 356)	FF

Joyce, Loebl and Company† (England) microdensitometer, equipped with an automatic scanning attachment made by Tech/Ops (Burlington, Mass., USA). For color photos, film 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). For black-and-white photos, film density readings were made with white light only. Each density reading represents the density of 0.0015 mm^2 of film, with 100 readings/2.54 mm of film.

The various sample sites were located on an isodensitracing (gray map) of each film type.

Density readings were grouped by soil type, color light density, and film type, and fed into a computer by sampling sites. In order to eliminate unusually high or low density readings from disturbed areas and manmade objects, such as field roads, fence rows, cleared land, stock ponds, dams, etc., we calculated a mean and standard deviation and then the computer eliminated all density readings outside the interval of the mean ± 1 standard deviation, and then we recalculated a mean for each sample site (Figure 2).

The recalculated mean density readings for each sampling site were used as replications for each soil type and range site. For color and color infrared film, we calculated an analysis of variance for each color light density with one analysis of variance for each black-and-white film.

RESULTS AND DISCUSSION

GROUND TRUTH DATA

Table 2 presents the EC_e values of the soil extracts from the seven different soil types. The EC_e values, as related to their effect on plant growth by the U. S. Salinity Laboratory staff (Richards, 1954), are as follows: above 4.0 mmhos/cm limits production of most forage crops; above 8.0 mmhos/cm, only moderately salt-tolerant species grow well; and above 12.0 mmhos/cm, only the most salt-tolerant species survive. Based on these guidelines, three soils (Catarina, Montell, and Maverick) had EC_e values in the high salinity range and the other four soils had low EC_e values in the non-saline category.

Although many of the same plant species are found on both saline and non-saline sites, they vary considerably in growth forms and productivity. On the saline sites the grass is usually shallow-rooted sod grasses and other short grasses whereas on the non-saline sites short and midgrass species are intermixed. Although herbaceous biomass production was not determined for any of the saline or non-saline range sites at the time of the Skylab overpass, the saline sites generally have lower production. The appreciable concentration of soluble salts in the upper soil profiles of the saline range sites limits plant growth (Davis and Spicer, 1965; Fanning *et al.*, 1965). These saline sites have large bare soil areas or "slicks" with surface deposits of sodium and calcium salts which decrease herbaceous biomass (Figure 3) (Fanning *et al.*, 1965; Thompson *et al.*, 1972). Woody species are "stunted." The percent canopy cover and average woody plant height for the seven range sites are presented in Table 2. The three saline range sites [saline clay (Catarina soils), saline clay (Montell clay), and rolling hardland] had comparatively low woody plant canopy covers whose average height was lower than 70 cm whereas on the non-saline range sites (clay loam, gray sandy loam, Ramadero, and shallow ridge) the woody plant canopy covers were taller (up to 140 cm) and denser (up to 63 percent ground cover) with more vigorous plants.

† Mention of company or trademark is for the readers' benefit and does not constitute endorsement of a particular product by the U. S. Department of Agriculture over others that may be commercially available.

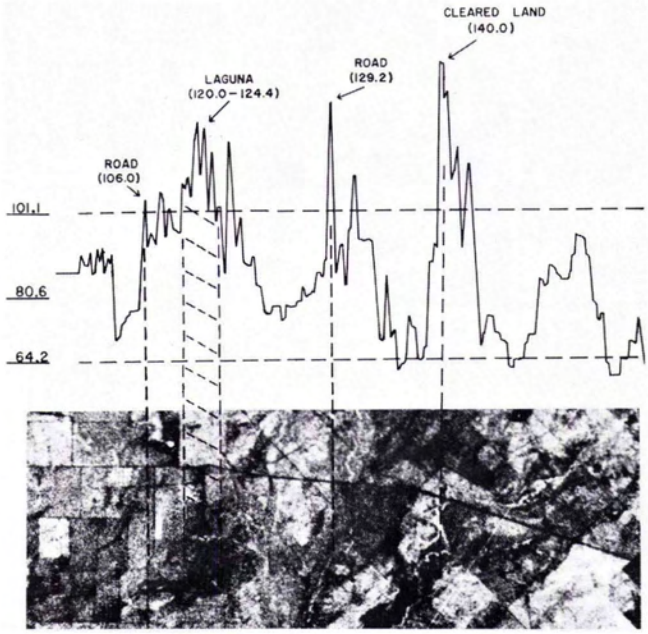

FIG. 2. Isodensitracing of a single scan line through a rangeland area along the flight line in Starr County, Texas, taken from black-and-white film [SO-002(0.60-0.70 μm)] illustrating the range in optical counts encountered and their correspondence to surface features. Unusually high optical counts associated with disturbed areas or manmade objects are indicated. The mean and standard deviation values of optical counts are given on the figure.

FILM DENSITY RESULTS

Black-and-White Films. Table 3 shows statistically significant differences (Duncan's Multiple Range Test) among the seven range sites for mean optical density readings of photos taken with three black-and-white films [SO-022 (0.50 to 0.60 and 0.60 to 0.70 μm) and EK-2424 (0.70 to 0.80 μm)]. These seven sites can be divided into essentially two main groups for each film.

TABLE 2. EC_e VALUES MMHOS/CM OF THE SOIL EXTRACTS, WOODY PLANT CANOPY (%) COVER, AND AVERAGE HEIGHT (CM) OF WOODY PLANTS FOR SEVEN RANGE SITES ON A FLIGHT LINE IN STARR COUNTY, TEXAS.

Range site and soil type	EC_e (mmhos/cm)	Woody plant canopy cover (%)	Average height of woody plants (CM)
Rolling hardland (Maverick soils)	6.4	32	66
Saline clay (Catarina soils)	9.4	31	56
Saline clay (Montell clay)	12.6	18	33
Clay loam (Garceno clay loam)	0.9	63	140
Gray sandy loam (Copita fine sandy loam)	0.6	56	94
Ramadero (Ramadero loam)	0.6	58	135
Shallow ridge (Zapata soils)	0.6	38	114

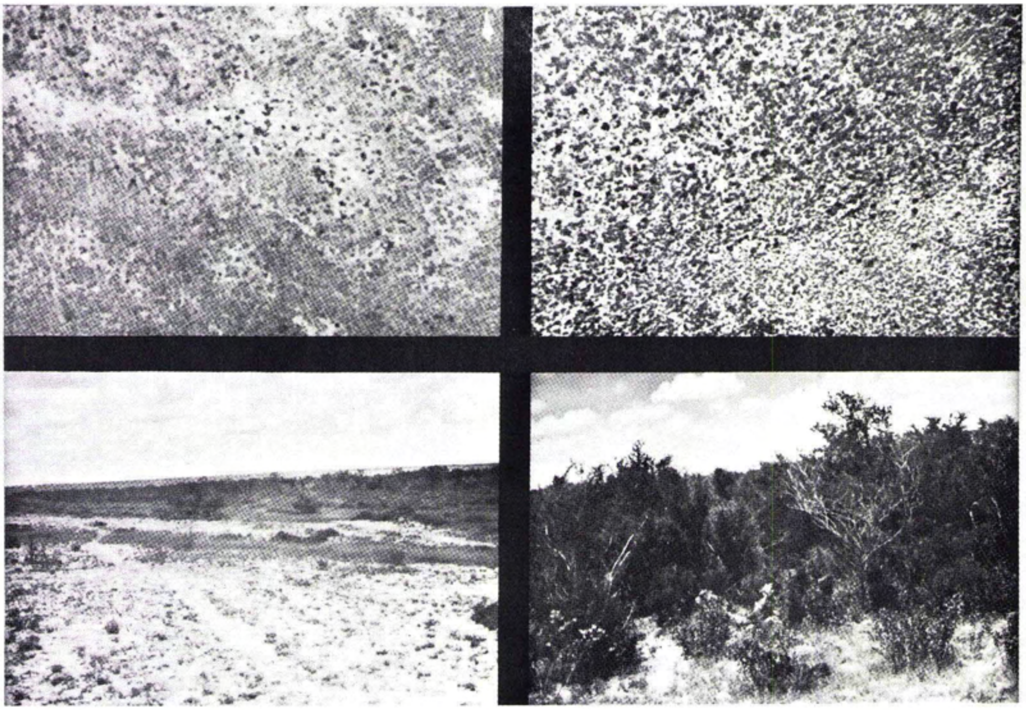

FIG. 3. (Left). Aerial (upper) and ground (lower) photographs of a typical saline clay range site having large bare soil areas (slicks) and surface deposits of soluble salts which limit the growth form of woody species to a "stunted" type. (Right). Aerial (upper) and ground (lower) photographs of a gray sandy loam range site characterized by dense spreading woody canopy covers and taller plants.

No significant difference ($P < 0.05$) was found among mean optical density readings for the seven range sites on infrared black-and-white film [EK-2424 (0.80 to 0.90 μm)], which seemed to be overexposed, and, therefore, the data are not shown.

TABLE 3. MICRODENSITOMETER READINGS[1] WITH WHITE LIGHT ON SO-022 (0.5 TO 0.6 AND 0.6 TO 0.7 μM) AND EK-2424 (0.7 TO 0.8 μM) AERIAL BLACK-AND-WHITE FILMS EXPOSED ON THE SKYLAB S-190A MULTISPECTRAL PHOTOGRAPHIC CAMERA FOR SEVEN RANGE SITES ON A FLIGHT LINE IN STARR COUNTY, TEXAS.

Range site	EC_e (mmhos/cm)	Film SO-022[2] (0.5−0.6 μm)	Film SO-022[2] (0.6−0.7 μm)	Film EK-2424[2] (0.7−0.8 μm)
Rolling hardland (Maverick soils)	6.4	79.64ab	72.12a	108.90ab
Saline clay (Catarina soils)	9.4	73.40ab	70.15a	107.81ab
Saline clay (Montell clay)	12.6	84.31a	68.20ab	104.01a
Clay loam (Garceno clay loam)	0.9	64.38 bc	63.49 bc	123.98 c
Gray sandy loam (Copita fine sandy loam)	0.6	51.15 c	60.90 c	127.31 c
Ramadero (Ramadero loam)	0.6	54.58 c	60.87 c	124.46 c
Shallow ridge (Zapata soils)	0.6	53.22 c	58.33 c	120.05 bc

[1] Microdensitometer readings (OC) are convertible to film optical density (OD) values in these data set using the formula: (optical counts − 30) (0.0111) + 0.39 = optical density.
[2] Means followed by a common letter are not significantly different at the 5 percent probability level according to Duncan's Multiple Range Test.

The three saline range sites could be distinguished from non-saline range sites with microdensitometry on black-and-white films exposed in the 0.50 to 0.60, 0.60 to 0.70, and 0.70 to 0.80 μm wavelengths. Although we could not separate completely all saline sites from all non-saline sites on any of the three black-and-white films (Table 3), the seven sites could be separated into two main groups on all three films. Black-and-white film [SO-022 (0.60 to 0.70 μm)] had the least overlap between range sites with low and high salinity with five absolute separations among the seven sites. With SO-022 (0.50 to 0.60 μm) and EK-2424 (0.70 to 0.80 μm), four absolute separations were found on each film.

Mean optical density differences among saline and non-saline rangelands can be attributed to the difference between the saline and non-saline range sites in amount of exposed soil, because of the differences between their woody plant percent canopy covers and average heights (Figure 3). On the saline sites the lower percent canopy cover and shorter plants allowed more light to be reflected. The black-and-white films had higher optical density values at the 0.50 to 0.60 μm and 0.60 to 0.70 μm wavelengths for the saline sites which exposed more soil, and lower optical density values at the 0.70 to 0.80 μm wavelengths than did the non-saline sites.

Color and Color Infrared Films. Table 4 shows statistically significant differences among the seven range sites for mean optical density readings with white, red, green, and blue light for color film [SO-356 (0.40 to 0.70 μm)] and color infrared film [EK-2443 (0.50 to 0.88 μm)]. Only white light on color film (SO-356) had a partial separation among saline and non-saline range sites; however, differentiation was inconsistent. The mean densities for all other film/filter combinations on color film (SO-356) and color infrared film (EK-2443) had statistical differences among range sites, with no definite relationships between film optical densities and range site salinity levels.

Mean optical density values on color and color infrared film showed minor differences among the various range sites, with no definite relationship between film optical densities and range site salinity levels.

Since differentiation between saline and non-saline range sites on color and color infrared film was ineffective or not accomplished, the narrow wavelength exposure of film could be superior to exposure by wider bands of light. Evidently the mixture of soil and vegetation responses over a wide bandpass filtration interval obscures useful tonal (film density) responses obtained by narrow band exposure.

Conclusions

This study showed that differentiating between saline and non-saline rangelands was

Table 4. Microdensitometer Readings with White, Red, Green, and Blue Lights on SO-356 (0.40–0.70 μm) Aerial Color and EK-2443 (0.50–0.88 μm) Aerial Color Infrared Films Exposed on the Skylab S-190A Multispectral Photographic Camera for Seven Range Sites on a Flight Line in Starr County, Texas. EC_e Values are Expressed in Millimhos/Centimeter.

		SO-356 Color Film (0.40–0.70 μm)				EK-2443 Color IR Film (0.50–0.88 μm)			
Range site	EC_e (mmhos/cm)	White[1] light	Red[1] light	Green[1] light	Blue[1] light	White[1] light	Red[1] light	Green[1] light	Blue[1] light
Rolling hardland (Maverick soils)	6.4	85.09a	81.88a	78.74a	61.48a	70.89a	102.66ab	79.72ab	47.58ab
Saline clay (Catarina soils)	9.4	102.32abc	93.55ab	92.39abc	78.25b	70.38a	97.08a	74.02a	41.44a
Saline clay (Montell clay)	12.6	92.14ab	87.66ab	84.34ab	64.72a	81.85b	110.34bc	88.97bc	54.36bc
Clay loam (Garceno clay loam)	0.9	108.61bcd	95.18ab	92.10abc	78.17b	81.59b	112.75bc	89.81bc	54.17bc
Gray sandy loam (Copita fine sandy loam)	0.6	111.90cde	105.37bc	100.06bcd	82.12bc	85.89b	106.83ab	88.67bc	60.36cd
Ramadero (Ramadero loam)	0.6	129.50e	118.87c	190.55d	91.85c	82.75b	111.95bc	92.27c	57.90cd
Shallow ridge (Zapata soils)	0.6	123.17de	119.86c	108.35cd	85.54bc	90.84b	120.60c	99.04c	65.34d

[1] Means followed by a common letter are not significantly different at the 5% probability level according to Duncan's Multiple Range Test.

possible by using microdensitometry on very small-scale (1:3,000,000) black-and-white Skylab satellite imagery, exposed over narrow wavelength intervals.

Mean optical density differences among saline and non-saline rangelands could be attributed to the difference between saline and non-saline range sites in amount of exposed soil and to differences in woody plant canopy cover and average height since on the saline sites lower percent woody plant canopy cover and shorter woody plants allowed more light to be reflected.

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