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Using 70-mm Aerial Photography to Identify Rangeland Sites

Color-infrared photographs exposed during the summer were best for identifying range sites in south Texas.

Introduction

The management of rangelands requires accurate and current information concerning their resources. Because areas of rangeland are usually large and inaccessible, determining their extent with photography or other imagery may be necessary. Therefore, remote sensing techniques might help the range manager make inventories and management decisions (Johnson, 1969; Poulton, 1970).

Season is an important variable in inventorying rangeland with aerial photography. Hence, "multiseasonal photography" has been used, whereby photographs are taken at different seasons of the year for identification and measurement of specific items (Driscoll, 1974). Multiseasonal photography gives better results than one-time photography because the reflectance of an object varies from that of other objects at different times of the year. Photography in different seasons has been used successfully to identify shrub and tree species (Driscoll and Coleman, 1974; Sayn-Wittgenstein, 1961).

Abstract: *A south Texas rangeland area was used as a study site to test the use of microdensitometry on 70-mm color-infrared and black-and-white photographs (scale 1:19,000) for distinguishing among 11 range sites (two brushland, seven grassland, two barren land) during the winter (February), spring (May), and summer (August) of 1976. Color-infrared photographs were also taken at a scale of 1:42,000 for the summer date. Film optical density readings were made on one color-infrared film with white, red, green, and blue light, and on three black-and-white films using white light only. The best separations among density readings for all range sites were obtained using white light exposed on color-infrared film in the summer when vegetation was at peak foliage development. Results from this study indicate that 70-mm aerial color-infrared photography at a scale of 1:19,000 or 1:42,000 has good potential for identifying range sites in large and inaccessible areas, and could be a useful tool for range management.*

Aerial photography can be used for mapping and classifying rangeland (Reid and Pickford, 1942; Colwell, 1961; Carneggie *et al.*, 1967; Driscoll, 1971). Although numerous film types and scales have been used for mapping rangeland, Driscoll (1974) emphasized that plant communities should be mapped on color-infrared photographs at scales of 1:12,000 to 1:20,000, because color-infrared photography records more subtle differences among plant community systems.

Microdensitometry has been used to obtain quantitative measures for different land uses and to identify plant communities and components on color-infrared aerial photos (Doverspike *et al.*, 1965; Driscoll *et al.*, 1974). We present results of a test using microdensitometry on 70-mm black-and-white and color-infrared aerial photos to dis-

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tinguish quantitatively certain characteristics of 11 range sites at the different seasons in southern Texas.

Study Area and Methods

We conducted this study on the Yturria Ranch in Kenedy and Willacy Counties of southern Texas (Figure 1). This area is in a transition zone between the Texas Coastal Prairies and the South Texas Plains vegetational regions (Gould, 1975). The Gulf of Mexico borders the area on the east. The topography is flat to gently sloping; elevation ranges from sea level to 30 m above sea level (U.S. Geological Survey 7.5 minute topographical maps).

The climate is mild—winters are short and temperatures are relatively warm throughout the year. The average growing season exceeds 325 days (Texas Almanac, 1975). The average annual rainfall is 70 cm. Heaviest rains occur in May and September.

The vegetative cover in the study area was primarily native rangeland, although some of the native vegetation had been cleared and the land seeded to introduced grasses or native grasses and broad-leafed plants allowed to become reestablished. Eleven different rangeland study sites were used in this study except during the summer season, when part of the Alicia grass (*Cynodon* spp.) was harvested for hay, and this harvested site constituted a twelfth site. Table 1 describes each range site.

Ground truth data were collected in winter (February), spring (May), and summer (August), 1976 for the 11 study sites. Total biomass production and percent composition of herbaceous plants was determined for all three dates on all the study sites except the dune land and laguna sites. Because dune land is essentially bare soil and the lagunas are wetlands, no biomass samples were taken here. Biomass production was determined by clipping all vegetation at ground level in 20 quadrats, each 50 cm by 50 cm in area (Stewart and Hutchins, 1936). Species composition by weight of herbaceous plants was determined by separating all species in each quadrat. On two of the grassland sites, coastal sand (excess litter) and deep sand (native), herbaceous biomass measurements were taken monthly from March through October. The relative proportions of litter, standing green, standing brown, and seed head and stem biomass components were separated to determine the phenological variation of herbaceous plants of these range sites. On the two brushland sites (tight sandy loam and sandy mound), the botanical composition and percent canopy cover of woody plants were determined using the line transect method (Canfield, 1941). The line transect method was also used to determine herbaceous cover of the sample sites; however, herbaceous cover was determined only in August. Herbaceous cover was not determined on the dune land and laguna sites.

Fig. 1. General location of study area in south Texas.

We used four Hasselblad* cameras (80 mm lens, 5.7 by 5.7 cm format) with variable exposures and film/filter combinations, which are shown in Table 2. Aerial photographs (scale 1:19,000) were taken between 1100 and 1500 hours under clear sunny conditions in February, May, and August of 1976, at an altitude of 1,525 m. Aerial photographs (scale 1:42,000) were also taken at an altitude of 3,300 m during August.

We made film density readings with a Joyce, Loebl and Company (England) microdensitometer, equipped with an automatic scanning attachment made by Tech/Ops (Burlington, Massachusetts, 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. The microdensitometer output is an optical count (reciprocal of transmission) that is related to optical density (O.D.) by the relation:

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

One scan line was run from each of three random locations on each range site, giving three scans per site for each season. There were 40 to 50 readings (data bits) for each scan line on the film. All measurements of density were made 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, which provided 3.63 m^2 of ground area. On those photos taken at an

* 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.

TABLE 1. GENERAL DESCRIPTION OF THE ELEVEN RANGELAND STUDY SITES IN KENEDY AND WILLACY COUNTIES OF SOUTH TEXAS

Range site	Description
Brushland sites	
Tight sandy loam (native)	A mixed brush site that supports a variety of woody plants, grasses, and forbs. It typically supports a stand of woody plants with about 80% canopy cover. Mesquite (*Prosopis glandulosa* Torr.) is the dominant woody plant.
Sandy mound	A moderately open brushy site with motts of live oak trees (*Quercus virginiana* Mill.) breaking the landscape. This site has about a 50% woody canopy. Several species of grasses and forbs dominate the herbaceous plant community.
Grassland sites	
Deep sand (native)	This site is best characterized as a savanna with large, mature mesquite trees scattered in small motts or singly distributed over grasslands. It supports a ≤10% woody canopy, and a variety of grasses and forbs.
Laguna	This site occurs in depressional areas ranging from 0.5 to 4 ha. It serves as a catchment for runoff from the surrounding terrain. The plant community is an open grassland subjected to varying degrees of wetness.
Coastal sand (excess litter)	This is a coastal, open grassland. A variety of grasses, forbs, and sedges make up the plant community. Grazing had been deferred for a prolonged period, and an excessive amount of litter had built up.
Coastal sand (burned)	This area had burned just before this study began.
Tight sandy loam (improved)	The brush had been controlled on this site and the range reseeded with buffelgrass (*Cenchrus ciliaris* L.). Native grasses and herbs had also become reestablished.
Deep sand (improved)	The brush had been controlled on this site and native grasses and herbs had become reestablished.
Grassland sites	
Alicia grass	An improved tight sandy loam site where the brush had been controlled and the range reseeded with Alicia grass (*Cynodon* spp.). This site was periodically cut for hay during the growing season.
Barren land sites	
Salt flat	These sites are nearly level areas along the coast only a few feet above the mean high tide. They are characterized by large areas of bare soil or salt slicks. Only a few salt-tolerant herbaceous plant species grow on these sites.
Dune land	Areas near the coast of deep, unstable sand, usually bare of vegetation. Some are partially stabilized by vegetation around the outer edges of the areas.

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.

Analysis of variance was conducted to determine significant differences for each color light density on color-infrared film and for each black-and-white film. Duncan's multiple range test was used to test the statistical significance of individual means of the study sites (Steel and Torrie, 1960). Correlation analysis between herbaceous biomass measurements and mean optical counts was calculated for the grassland sites. Herbaceous cover was also correlated with mean optical counts.

TABLE 2. FILM/FILTER COMBINATION, SENSITIVE WAVELENGTH, AND EXPOSURE FOR THE FOUR HASSELBLAD CAMERA SENSOR SYSTEM

Film	Filter	Film Wavelength (μm)	Exposure
IR Color (EK 2443)	CB-12	0.50–0.90	F 8 at 1/250 sec.
IR B&W (EK 2424)	89-b	0.76–0.89	F 11 at 1/500 sec.
PAN B&W (Tri-X 5063)	93 green	0.51–0.59	F 2.8 at 1/125 sec.
PAN B&W (Tri-X 5063)	92 red	0.62–0.72	F 2.8 at 1/125 sec.

Results and Discussion

WINTER

On color-infrared film, blue light gave the best separation among the 11 range sites in winter (Table 3). With the exception of the two coastal sand grassland sites (excess litter and burned), the grassland sites were separated into one group. Correlation between herbaceous biomass and film optical counts was not statistically significant.

Of the two brushland sites, the winter spectra of the evergreen live oak trees (*Quercus virginiana* Mill.) on the sandy mound was completely different from those of all other sites. Because many of the woody species on the tight sandy loam brushland site had lost their leaves during winter, the spectra for this site closely resembled those of the litter and dormant biomass on the coastal sand (excess litter) grassland site rather than those of the evergreen live oak trees on the sandy mound site. Also, the spectra of the salt flat closely resembled those of these two sites.

Readings on the dune land and coastal sand (burned) sites were distinguished using white, red, green, and blue light. The coastal sand (burned) site had burned two weeks before the area was photographed, and thus the spectra of this site were that of black ash which absorbed a high percentage of the incident light and resulted in high film density (low light reflectance). Dune land absorbed very little incident light, resulting in low film density (high light reflectance).

Although several separations were obtained among the density readings on all three black-and-white films, the highest number was obtained on black-and-white Tri-X 5063 (0.51–0.59 μm). However, no general separation was possible among the readings for brushland, grassland, and barren land sites. The two brushland sites separated together but were in the same group as the two coastal sand grassland sites. This may be attributed to the altered appearance of the two coastal sand sites. These sites looked dark on this film, as did the two brushland sites. The dune land site could be distinguished from all other sites on all three black-and-white films.

SPRING

Numerous separations were obtained among the density readings using white, red, green, and blue light on color-infrared film. It was difficult to determine which colored light gave the overall best separations in spring (Table 4). On white light, the two brushland sites were differentiated from each other, but the tight sandy loam brushland site and the coastal sand (excess litter) grassland site could not be differentiated. The two barren land sites could be differentiated, but several of the grassland sites could not be distinguished from the salt flat barren land site.

On red light, the two barren land sites could be differentiated from each other and from the grassland and brushland sites. The brushland sites were separated together, but the coastal sand (burned) grassland site was not separable from the brushland sites. Although the vegetation burned in February had partially reestablished by May, there was still considerable black ash on the soil surface, which gave the surface a darker appearance similar to that of the brushland sites.

Using green light, the brushland sites were differentiated from both grassland and barren land sites, as well as from each other. The two barren land sites were differentiated from each other, but several of the grassland sites could not be distinguished from the salt flat barren land site.

Blue-light density readings gave the least meaningful separations. The brushland and barren land sites could not be separated from the grassland sites, although they were separated from each other. Only the laguna and the dune land sites could be differentiated from all other sites.

Although there were several separations among the density readings for grassland sites using all four colored lights on color-infrared film, there was no significant correlation between biomass measurements and film optical counts.

Complete separations were obtained among density readings for all 11 range sites on each of the three black-and-white films, but there was no general grouping among brushland, grassland, and barren land sites. Thus, meaningful separations were minimal on black-and-white photography during the spring season.

SUMMER

Although several separations were obtained for all four colored lights on color-infrared film, the best separations were made with white and blue light in summer (Table 5). With white light, complete separations were obtained for all 12 range sites. The barren land sites could be distinguished from the grassland and brushland sites. The brushland sites could be distinguished also, but the coastal sand (excess litter) grassland site was included into the same group as the brushland sites. There were several separations among the different grassland sites.

On blue light, there were 11 complete separations among density readings for the 12 sites. The two barren land sites differentiated from each other and from the grassland and brushland sites. The two brushland sites were in the same group, but we could not distinguish the sandy mound site from the coastal sand (excess litter) grassland site. There was no overlap between any of the other grassland sites with either the barren land or brushland sites.

There was no significant correlation between herbaceous biomass or herbaceous cover and film

Table 3. Microdensitometer Readings with White, Red, Green, and Blue Light on Aerial Color-Infrared Film and White Light on Three Black-and-White Films Exposed on Hasselblad 500 EL Cameras for 11 Range Sites in Kenedy and Willacy Counties, Texas, in February 1976. Scale of Photography was 1:19,000.

Range Site	Herbaceous Biomass (kg/ha)	EK-2443 Color IR Film (0.50–0.90 μm)				Black-and-White Films		
		White* light	Red* light	Green* light	Blue* light	Tri-X-5063* (0.51–0.59 μm)	Tri-X-5063* (0.62–0.72 μm)	EK-2424* (0.76–0.89 μm)
Brushland sites								
Tight sandy loam	284	95h	54e	57e	66d	32d	31g	92f
Sandy mound	280	149b	94bc	101b	115b	33d	26g	116c
Grassland sites								
Deep sand (native)	426	134cd	98b	97bc	104c	60c	58de	111c
Laguna	—	140bc	95bc	89c	100c	61c	56de	101de
Coastal sand (excess litter)	1664	104gh	79d	66de	71d	37d	36fg	47h
Coastal sand (burned)	—	161a	135a	124a	126a	43d	46ef	64g
Tight sandy loam (improved)	2100	127de	94bc	93bc	103c	63c	61d	124b
Deep sand (improved)	700	113fg	98b	91bc	94c	81b	76bc	97ef
Alicia grass	1632	119ef	86bcd	90bc	100c	73bc	67cd	113c
Barren land sites								
Salt flat	414	79i	83cd	72d	69d	87b	88b	109cd
Dune land	—	44j	82f	38f	40e	117a	111a	199a

* Means followed by a common letter are not significantly different at the 5% probability level.

TABLE 4. MICRODENSITOMETER READINGS WITH WHITE, RED, GREEN, AND BLUE LIGHT ON AERIAL COLOR-INFRARED FILM AND WHITE LIGHT ON THREE BLACK-AND-WHITE FILMS EXPOSED ON HASSELBLAD 500 EL CAMERAS FOR 11 RANGE SITES IN KENEDY AND WILLACY COUNTIES, TEXAS, IN MAY 1976. SCALE OF PHOTOGRAPHY WAS 1:19,000.

Range Site	Herbaceous Biomass (kg/ha)	EK-2443 Color IR Film (0.50–0.90 μm)				Black-and-White Films		
		White* light	Red* light	Green* light	Blue* light	Tri-X-5063* (0.51–0.59 μm)	Tri-X-5063* (0.62–0.72 μm)	EK-2424* (0.76–0.89 μm)
Brushland sites								
Tight sandy loam	408	119b	50d	90b	115b	126b	57e	73b
Sandy mound	394	109c	48d	84c	102c	113c	79c	78b
Grassland sites								
Deep sand (native)	858	88de	34g	78de	96cd	133a	47f	76b
Laguna	—	135a	68c	98a	123a	123b	58e	59c
Coastal sand (excess litter)	1592	123b	89a	100a	113b	91e	80c	27d
Coastal sand (burned)	1160	85de	46de	76de	86e	102d	90b	79b
Tight sandy loam (improved)	2660	93d	35g	80d	99c	137a	68d	74b
Deep sand (improved)	1677	74f	38fg	70f	80f	137a	66d	75b
Alicia grass	2498	87de	41ef	75e	91de	133a	65d	72b
Barren land sites								
Salt flat	504	83e	81b	74e	76f	110c	89b	27d
Dune land	—	25g	20h	23g	27g	120b	118a	105a

* Values in a column followed by a common letter are not significantly different at the 5% probability level.

TABLE 5. MICRODENSITOMETER READINGS WITH WHITE, RED, GREEN, AND BLUE LIGHT ON AERIAL COLOR-INFRARED FILM AND WHITE LIGHT ON THREE BLACK-AND-WHITE FILMS EXPOSED ON HASSELBLAD 500 EL CAMERAS FOR 12 RANGE SITES IN KENEDY AND WILLACY COUNTIES, TEXAS, IN AUGUST 1976. SCALE OF PHOTOGRAPHY WAS 1:19,000.

	Herbaceous		EK-2443 Color IR Film (0.50–0.90 μm)				Black-and-White Films		
Range Site	Biomass (kg/ha)	Cover (%)	White* light	Red* light	Green* light	Blue* light	Tri-X-5063* (0.51–0.59 μm)	Tri-X-5063* (0.62–0.72 μm)	EK-2424* (0.76–0.89 μm)
Brushland sites									
Tight sandy loam	411	18	108a	47b	78abc	98b	26h	15e	79d
Sandy mound	356	27	111a	48b	79ab	99ab	27gh	55c	67e
Grassland sites									
Deep sand (native)	1117	46	87b	36cd	70cd	92c	51cd	48cd	91c
Laguna	—	—	92b	34d	71bcd	94c	36fg	38d	96bc
Coastal sand (excess litter)	2422	86	114a	78a	86a	102a	35fg	58c	50f
Coastal sand (burned)	1600	60	73c	41bc	63de	85d	57c	89b	81d
Tight sandy loam (improved)	5284	78	61d	17f	55e	74e	54c	84b	106a
Deep sand (improved)	2636	61	89b	44bc	71bcd	93c	45de	85b	77d
Alicia grass	4944	91	88b	34d	70cd	93c	38ef	48cd	79d
Alicia grass (cut for hay)	1720	70	73c	34d	62de	87d	58c	87b	80d
Barren land sites									
Salt flat	487	17	33e	26e	30f	35f	68b	106a	91c
Dune land	—	—	27e	20ef	23f	28g	82a	113a	101ab

* Means followed by a common letter are not significantly different at the 5% probability level.

optical counts using either white or blue light on color-infrared film.

Several complete separations were obtained among density readings on each of the three black-and-white films. The best grouping among sites, however, was obtained on black-and-white film Tri-X 5063 (0.51–0.59 μm). On this film, the barren land sites could be differentiated from each other and from the brushland and grassland sites. The two brushland sites were in the same group, but the sandy mound brushland site did not separate completely from two of the grassland sites. On black-and-white film Tri-X 5063 (0.62–0.72 μm), the barren land sites were differentiated from the brushland and grassland sites into one group. The tight sandy loam brushland site could be differentiated, but the sandy mound brushland site was in the same group as three of the grassland sites.

Because the best separation among density readings for the study sites was obtained on color-infrared film exposed in summer at a scale of 1:19,000, we further compared these sites for the summer season using all four colored lights on color-infrared film with a scale of 1:42,000. Statistically significant differences among the study sites were found for mean optical density readings with white, red, green, and blue light (Table 6). However, the best separations were obtained using white light, which is in agreement with the findings on the 1:19,000 scale photography (Table 5). Again, the barren land sites could be distinguished from the grassland and brushland sites. The brushland sites also could be distinguished, but the coastal sand (excess litter) grassland site could not be differentiated from the tight sandy loam brushland site. These data indicated that changes in photography scale did not significantly effect the relationship among the white light optical density readings for these rangeland sites. There was no significant correlation between herbaceous biomass or herbaceous cover and film optical counts using white light on color-infrared film.

PHENOLOGICAL VARIATION OF RANGELAND HERBACEOUS BIOMASS

We measured the amounts of litter, standing green, standing brown, and heads and stem biomass components making up the total biomass for the deep sand (native) and the coastal sand (excess litter) grassland sites for the 1976 growing season (Figure 2 and 3). Standing green biomass peaked in July on both sites and remained high through August. Heavy rains in the area in late June and July resulted in a flush of foliage development. This peak in standing green biomass corresponds with our best separation among range sites on the film coverage in early August. These

TABLE 6. MICRODENSITOMETER READINGS WITH WHITE, RED, GREEN, AND BLUE LIGHT ON AERIAL COLOR-INFRARED FILM (SCALE 1:42,000) EXPOSED ON A HASSELBLAD 500 EL CAMERA FOR 11 RANGE SITES IN KENEDY AND WILLACY COUNTIES, TEXAS, IN AUGUST 1976.

Range Site	Herbaceous		EK-2443 Color IR Film (0.50–0.90 μm)			
	Biomass (kg/ha)	Cover (%)	White* light	Red* light	Green* light	Blue* light
Brushland sites						
Tight sandy loam	411	18	122a	66b	93a	109a
Sandy mound	356	27	111b	55cd	90a	109a
Grassland sites						
Deep sand (native)	1117	46	88de	49def	76de	96cd
Laguna	—	—	101c	43f	84bc	104b
Coastal sand (excess litter)	2442	86	119a	81a	94a	108ab
Coastal sand (burned)	1600	60	92d	59bc	79cd	99c
Tight sandy loam (improved)	5284	78	100c	58bc	85b	110a
Deep sand (improved)	2636	61	92d	52cde	78d	96cd
Alicia grass**	4944	91	—	—	—	—
Alicia grass (cut for hay)	1720	70	83d	46ef	72e	93d
Barren land sites						
Salt flat	487	17	46f	44ef	46f	48e
Dune land	—	—	27g	15g	24g	31f

* Values in a column followed by a common letter are not significantly different at the 5% probability level.

** This site was obscured by cloud cover, thus microdensitometer readings were not made.

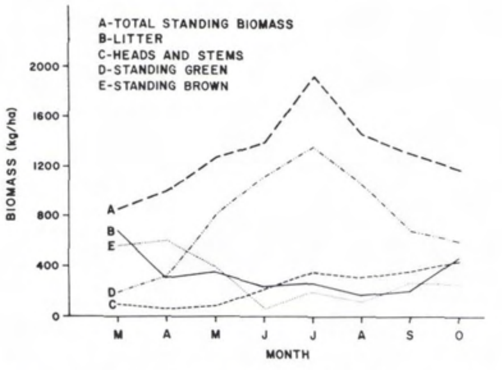

FIG. 2. Total biomass and standing green, standing brown, heads and stems, and litter biomass components collected for the deep sand (native) grassland site in south Texas during the 1976 growing season.

results are in general agreement with those of Carneggie (1972) who reported that the best differentiation between the greatest number of plant species was obtained when the plants were at or near peak foliage development.

The large amount of litter on the coastal sand (excess litter) site justified its being included with the brushland sites throughout this study. This darkened litter absorbed a high percentage of the incident light, which resulted in a high film density (low reflectance).

SUMMARY AND CONCLUSIONS

Results from this study indicated that color-infrared photographs (scales 1:19,000 and 1:42,000) exposed during the summer were best for identifying range sites in south Texas. Microdensitometer readings made on color-infrared film using white light gave the best separation among a variety of range sites (two barren land, eight grassland, two brushland) when the vegetation was at peak foliage development.

During the dormant winter season, microdensitometer readings made with blue light on color-infrared film gave the best separation among the range sites. A freshly burned rangeland area could be distinguished from all the other study sites using white, red, green, and blue light.

During the spring, microdensitometer readings made using white, red, and green colored light on color-infrared film gave about equal results.

Although several separations were obtained among density readings for all three black-and-white films during each of the three seasons, the best separations were obtained during the summer season on black-and-white film Tri-X 5063 (0.51–0.59 μm).

The results indicate that the potential is good for using 70-mm aerial color-infrared photography in the summer to identify and perhaps inventory large and inaccessible range sites as a tool in range management decision making.

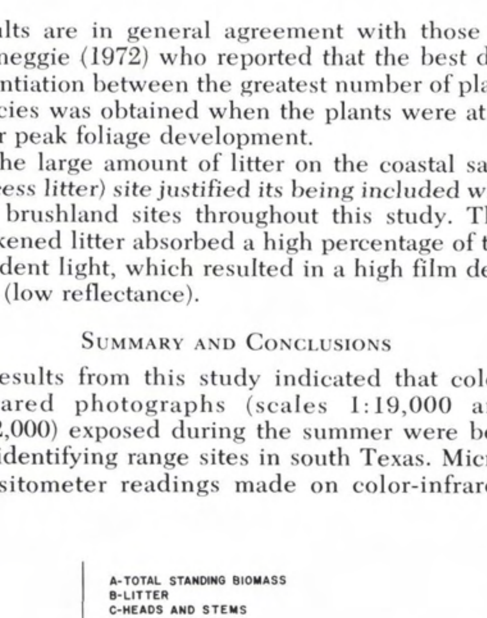

FIG. 3. Total biomass and standing green, standing brown, heads and stems, and litter biomass components collected for the coastal sand (excess litter) grassland site in south Texas during the 1976 growing season.

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1. Manuscripts should be typed, double-spaced on 8½ × 11 or 8 × 10½ white bond, on *one* side only. References, footnotes, captions—everything should be double-spaced. Margins should be 1½ inches.
2. Ordinarily *two* copies of the manuscript and two sets of illustrations should be submitted where the second set of illustrations need not be prime quality; EXCEPT that *five* copies of papers on Remote Sensing and Photointerpretation are needed, all with prime quality illustrations to facilitate the review process.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
5. Illustrations should not be more than twice the final print size: *glossy* prints of photos should be submitted. Lettering should be neat, and designed for the reduction anticipated. Please include a separate list of captions.
6. Formulas should be expressed as simply as possible, keeping in mind the difficulties and limitations encountered in setting type.

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