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INVENTORY OF SEMI-ARID RANGELANDS IN SOUTH TEXAS WITH LANDSAT DATA

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I. ABSTRACT

A 39,000-ha semi-arid rangeland test site in Starr and Zapata Counties, Texas, was used to compare rangeland inventory and other landuse categories estimated by digital pattern recognition methods (maximum likelihood ratio classification) with percentages estimated from a ground-correlated print enlarged to 1:100,000 scale from a LANDSAT color composite transparency. Five land-use categories were identified (grassland, mixed brush rangeland, saline rangeland, cropland, and water). We found a highly significant correlation (r = 0.997**) between the photo- and computer-estimated hectarage for the June LANDSAT-2 overpass. The correlation was not significant for the August overpass largely because a large percentage of the most extensive rangeland category (mixed brush rangeland) was misclassified as cropland. The misclassification was probably related to some of the spectra in the rangeland area resembling that of crop residue, and volunteer plants and weeds on the idle cropland. Computer-estimated hectarages for grassland, saline rangeland, and water were similar to the photo-estimated hectarages for both the June and August overpasses, indicating the feasibility of estimating these land-use categories for either date.

II. INTRODUCTION

The use of remote sensing techniques offers the range manager or wildland ecologist the opportunity to examine natural areas that are often inaccessible to ground observation. Although conventional aerial photographs have been an aid in resource surveys for several decades, recent developments have moved toward more sophisticated photographic and non-photographic remote sensors and computer-assisted data analysis techniques (Aldrich, 1976). LANDSAT-2 (Earth Resources Technology Satellite) imagery provides the natural resource land planner with very small scale space imagery of large land areas multiple times per year.

Previous studies have shown the usefulness of LANDSAT-1 imagery for mapping vegetation types and monitoring changes in range resources (Carneggie and DeGloria, 1974; Driscoll et al., 1974; Deering et al., 1975; Maxwell, 1976). This paper presents the results of a study on using LANDSAT-2 multispectral scanner (MSS) data for inventorying semi-arid rangelands in Starr and Zapata Counties in south Texas.

III. MATERIALS AND METHODS

The study area is located between 26°23' and 26°40' north latitude and 98°58' and 99°08' west longitudes and includes approximately 39,000 hectares (ha) in Starr and Zapata Counties of extreme south Texas. These counties border on Mexico. This area is located in the South Texas Plains vegetational region (Gould, 1975). The topography is level to gently undulating with a few hilly areas broken by caliche and gravelly ridges.

The climate is semi-arid and mild with short winters and relatively warm temperatures year around. Summer temperatures and evaporation rates are high. The average annual rainfall is 43 cm with heaviest rains occurring in May and September (Texas Almanac, 1975). Periodic droughts are common and often there are months with no rainfall.

Land-use is predominantly native rangeland. Some of the native vegetation has been cleared and the land seeded to buffelgrass (*Cenchrus ciliaris* L.), an introduced forage grass. Irrigated cropland is found on the flood plain of the Rio Grande River. We identified three level I categories (Anderson et al., 1976) (rangeland, cropland, and water) on the study area. The rangeland area was further classified into three level II categories (grassland, mixed brush rangeland, and saline rangeland). Thus, five different land units were identified.

Everitt et al. (1977) described the vegetation and soils of this area. They listed seven different native range sites (four non-saline and three saline). A ground site representative of each of these seven sites, plus three improved grassland sites were characterized by ground observation. Under the land-use classification scheme described by Anderson et al. (1976), the four non-saline native sites were classified as mixed brush rangeland, the three native saline sites were classified as saline rangeland, and the three sites where the brush had been controlled and the range improved by seeding with grass were classified as grassland.

Biomass measurements were taken at or near the time of each LANDSAT-2 overpass from these 10 different study sites. Total herbaceous biomass production was determined by clipping all vegetation about 3 cm above ground level in quadrats each 50 cm x 50 cm in size (Stewart and Hutchins, 1936). Twenty quadrats were taken on each of the seven native sites, while only 10 were taken on the three improved grassland sites because of the more homogeneous herbaceous cover of these areas. Line transects were run on each of the seven native sites to determine the percent canopy cover of woody plants (Canfield, 1941). Woody canopy data were collected only once because these data are relatively constant for several years.

A. ANALYSIS OF LANDSAT DATA

This study used the system-corrected, MSS computer compatible digital tapes (CCT) and corresponding color images (1:1,000,000 scale) from LANDSAT-2 overpasses on June 3, 1977 and August 16, 1975. All four LANDSAT-2 MSS bands were used covering the 0.5- to 1.1-um spectral region. These overpasses provided digital counts for a 185- by 185-km area. The June 3, 1977 overpass provided an image of the area when the vegetation had been exposed to normal climatic conditions. The August 16, 1975 overpass provided an image of the area during flush foliage development following heavy rains.

The LANDSAT data analysis process involved a software system developed at Weslaco, Texas which uses the maximum likelihood ratio pattern recognition technique for analyzing remote sensing data (Wiegand et al., 1977). The procedure involved: (1) developing a photo-estimated classification map of the study area; (2) selecting 27 study sites for collection of LANDSAT digital count training data; (3) specifying the LANDSAT training data for the maximum likelihood ratio statistical algorithm for five land-use categories; (4) classifying each LANDSAT data pixel within the 39,000-ha study area according to the five training categories; and (5) displaying these computer-estimated classification results in map and tabular form.

B. PHOTO-ESTIMATED CLASSIFICATION MAP

A five class, area inclusive, photo-estimated classification map (Reeves et al., 1976) of the 39,000-ha study area was traced onto a transparent overlay with a 1:100,000 scale photo base enlarged from a 1:1,000,000 scale, 9.5 inch LANDSAT, color-composite, transparency. A ground reconnaissance was made to verify land-use categories of the study area at or near each satellite overpass. A photo-mosaic of the study area was constructed from 1:24,000 scale black-and-white aerial photographs used by the Soil Conservation Service. Soil types were mapped out on to these photos from published (Thompson et al., 1972) and unpublished soil survey information. Thus we were able to delineate the various range sites that comprised the rangeland categories. The photo-estimate process, used to produce the photo-estimated classification map, was similar to that described by Hardy and Hunt (1975) and Elifrits et al. (1977). The percentage of the study area occupied by each of the five land-use categories was determined by cutting the tracing paper overlay on which the boundary lines between land-use categories had been traced into areas corresponding to each category. These portions of tracing paper were weighed on an analytical balance and the ratio of each category to the weight of the paper for the study area was determined. The photo estimate was an average of both dates since land-use was very similar for the two satellite overpasses.

C. SELECTION OF TRAINING SITES

The accuracy of the classification results are highly dependent upon the training data selected. Thus, our approach consisted of locating 21 rangeland sites within the 39,000-ha study area that were representative of the various rangeland categories. Ten of these sites were the sites we took ground measurements from with the other 11 being additional representative sites of the three rangeland categories. Five sites were used to represent grasslands, five sites represented mixed brush rangeland, and eleven sites represented saline rangeland. Aerial photography and knowledge of local cropping practices were used to select three training sites for cropland. LANDSAT color composite imagery was used to select three training sites for a water category. Therefore, a total of 27 training sites represented the five land-use categories.

D. SPECIFICATION OF TRAINING STATISTICS

Plant, soil, and water line printer or gray maps of the study area for both June and August were generated using a table look-up process that allows automatic delineation of any LANDSAT scene into vegetation cover stages, degrees of soil brightness, and water (Richardson and Wiegand, 1977). The 27 training sites were located on both gray maps and the LANDSAT CCT record and pixel coordinates of the site boundaries were determined.

A principal component analysis (Richardson et al., 1972; Wiegand et al., 1977) was performed on over 800 training pixels (0.9% of total area) selected from within the 27 training sites' boundaries and a scatter diagram of the first two principal components generated to assess the separability of the five categories before the 39,000-ha study area was classified.

Mean vector and covariant matrix training statistics were calculated to represent each of the five categories from the training pixels selected from the training sites. These training pixels were classified using the maximum likelihood ratio pattern recognition algorithm (Fu et al., 1969) to further evaluate the adequacy of the training statistics.

E. COMPUTER-ESTIMATED CLASSIFICATION MAP

The final mean vector and covariant matrix training statistics were used to classify the entire 39,000-ha study area using the maximum likelihood classifier (Fu et al., 1969) implemented in a table look-up procedure described by Eppler et al. (1971). Computer-estimated classification maps of the study area were produced from this classification for both the June and August LANDSAT overpass dates. These classification maps were used to visually compare the mapping accuracy of the computer-assisted inventory of the study area with the photo-estimated classification map.

F. COMPUTER-ESTIMATED AREA AND PROPORTION ESTIMATES

Area measurements for each of the five categories were determined by counting the number of pixels from the entire 39,000-ha study area that were classified into each category. The area measurement in hectares (ha) was calculated as the total pixels classified into each category multiplied by 0.467 ha/pixel. Proportion estimates were then calculated as the number of hectares for each of the five categories divided by the total number of hectares for the entire study area. Some of the pixels within the study area did not statistically resemble any of the five training categories according to the maximum likelihood classifier and so they were assigned to an unidentified category called threshold.

G. EVALUATION OF AREA AND PROPORTION ESTIMATES

Photo- and computer-estimated area and proportion estimates were compared using methods reported by Wigton (1976), Sigman et al. (1977), Hoffer and Fleming (1978), and Bauer et al. (1978). As shown by Bauer et al. (1978) this technique may be used for evaluating classification accuracy by comparison with some standard using correlation analysis. To test the hypothesis of no difference between the photo- and computer-estimates the correlation coefficient should be significant, the slope of the correlation line should not be significantly different from unity, and the intercept should not be significantly different from zero.

IV. RESULTS AND DISCUSSION

A. GROUND TRUTH DATA

The average herbaceous biomass production and percent woody plant canopy cover for the 10 rangeland study sites for both LANDSAT-2 satellite overpasses are presented in Table 1. Biomass measurements were generally low and similar in magnitude for the seven mixed brush and saline rangeland sites. However, biomass measurements were high on the grassland sites. Biomass production was higher during the August 1975 period because of heavy rains in late July and early August that caused flush foliage development. The greatest difference in plant cover between the mixed brush and saline rangeland sites was in their woody plant canopies. Woody canopies for the saline sites ranged from 20 to 30% while on the mixed brush sites they ranged from 43 to 61%. Everitt et al. (1977) reported similar findings and also reported that the woody plants were "stunted" on these saline sites with average heights less than 70 cm compared with average heights up to 140 cm on the mixed brush sites. The saline sites have appreciable concentrations of soluble sodium and calcium salts in the upper soil profiles and low plant cover (Davis and Spicer, 1965; Fanning et al., 1965; Thompson et al., 1972). Extremely saline areas are barren and may have a salt crust on the surface.

B. SPECTRAL CHARACTERISTICS OF LAND-USE CATEGORIES

The mean digital counts and standard deviations of the training sites used for the various land-use categories for the June 3, 1977 and August 16, 1975 LANDSAT-2 overpasses are presented in Table 2. All four MSS bands (4, 5, 6, & 7) are presented, although band 4 (0.50 to 0.60 um) was not used for the computerized estimates. The photo-estimate was made using a color composite of bands 4, 5, and 7. Figures 1 and 2 are graphs of these mean digital counts for the various land-use categories for the two overpasses, respectively. The best separability among the vegetation categories was obtained on the digital counts for the June overpass for which spectral contrast among classification categories was greater than for August. The mean digital counts were similar for several of the different vegetation categories for the August overpass. Cropland and mixed brush rangeland had very similar digital counts in bands 6 and 7, therefore their separability depended on their difference in band 5. Grassland and mixed brush rangeland had similar counts in band 5 but were greatly separated in bands 6 and 7 while saline rangeland and cropland had nearly identical counts in band 7 but were well separated in bands 5 and 6.

C. JUNE AND AUGUST LANDSAT-2 OVERPASSES

A comparison between the photo- and computer-estimated hectarages for the five land-use categories for the June 3, 1977 and August 16, 1975 LANDSAT-2 overpasses, respectively, is presented in Table 3.

In June, the photo-estimated percentages were larger in two categories (mixed brush rangeland and saline rangeland), whereas the computer-estimated percentages were larger for three categories (grassland, cropland, and water). However, we found a highly significant correlation ($r = 0.997^{**}$) for the comparison between photo- and computer-estimated hectarages. The slope ($b = 1.11$) was not significantly different from unity nor was the intercept ($a = -0.84$) significantly different from zero. Thus we accept the hypothesis of no difference between photo- and computer-estimates.

Although there were differences between the photo- and computer-estimated percentages for June, they were minimal. Some of these differences may be attributed to the photo-estimates where highly subjective boundary lines are drawn due to the grading of range sites from one to another that constitute the rangeland categories. Other differences can be attributed to the computer classification technique that are based on discrete spectral classes, wherein a decision is made concerning each pixel representing a 0.47-ha ground area. The computer classified 6.2% of the study area as threshold (unidentified). The threshold category is comprised of boundary pixels between cropland, rangeland, access roads, and other man-made objects. Another portion of the threshold category is comprised of single or small groups of pixels within the rangeland itself that differ spectrally from the typical range sites for the category (drainage ways, etc.).

For the August overpass (Table 3), the computer-estimated percentages did not agree as well with the photo-estimates as they did in June. The correlation ($r = 0.730$) between the photo- and computer-estimated hectarages was not significant. Also the slope ($b = 1.41$) was significantly different from unity and the intercept ($a = -5.84$) was significantly different from zero. Thus, we reject the hypothesis of no differnece between photo- and computer-estimates.

The major difference between the photo- and computer-estimates in August was in mixed brush rangeland and cropland. Although cropland was confined to a small area in the southern part of the study area, the computer classified a large portion of the mixed brush rangeland as cropland. The spectra for mixed brush rangeland and cropland were similar which may account for the misclassification of mixed brush and cropland (Figure 3). We feel this may be the result of some of the spectra in the rangeland area resembling that of the crop residue, and volunteer plants and weeds on the idle cropland. It was also observed that many of the woody plants had sprouted new leaves at the time as the result of 20 cm of rain three weeks prior to the overpass. This may have also contributed to this misclassification.

In August the computer-estimated percentages for grassland, saline rangeland, and water were similar to those of the photo-estimates and were not greatly different from the computer-estimates for the same categories in June. The computer-estimates for threshold were in general agreement for both the June and August overpasses. The ability to differentiate the saline rangeland is in agreement with the finding of Everitt et al. (1977) who were able to identify these areas on Skylab photography.

V. CONCLUSIONS

This study demonstrated that LANDSAT-2 MSS data can be successfully used to identify rangeland types (grassland, mixed brush rangeland, and saline rangeland) in a semi-arid area of south Texas. A comparison between two dates (June and August) during the growing season showed the best identification was obtained in June. These data indicate that useful range inventories are possible using spectral measurements from space; however, select conditions or possibly time series data may be required to classify mixed brush rangeland without the possibility of large error.

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Table 1. Woody plant canopy cover and herbaceous biomass production for ten rangeland study sites in a 39,000-ha study area in Starr and Zapata Counties, Texas.

Range site and soil type[1]	Woody plant[2] Canopy Cover (%)	June 1977 Herbaceous Biomass Production (kg/ha)	August 1975 Herbaceous Biomass Production (kg/ha)
Mixed brush rangeland			
Sandy loam (Copita fine sandy loam)	52	212	315
Shallow ridge (Zapata soils)	43	138	177
Clay loam (Garceno clay loam)	61	244	376
Ramadero (Ramadero loam)	58	354	448
Grasslands			
Sandy loam - Buffelgrass (Copita fine sandy loam)	—[3]	3,150	6,624
Sandy loam - Buffelgrass (Copita fine sandy loam)	—	2,971	6,128
Clay loam - Buffelgrass (Garceno clay loam)	—	3,349	6,302
Saline rangeland			
Saline clay (Catarina soils)	29	207	313
Saline clay (Montell clay)	20	233	363
Rolling hard land (Maverick soils)	30	280	291

1 A description of the soil and vegetational characteristics of these sites is presented by Everitt et al. (1977).

2 Woody canopy data was collected only once because these data are relatively constant for several years.

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

Table 2. LANDSAT-2 MSS (MSS bands 4, 5, 6, and 7) mean digital counts ($\bar{x}$) and standard deviations ($s_{\bar{x}}$) of the five land-use categories (training sites) in the 39,000-ha study area in Starr and Zapata Counties, Texas.

Land-use cagegories	MSS4		MSS5		MSS6		MSS7	
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
June 3, 1977 LANDSAT-2 overpass								
Grassland	29.8	1.6	36.6	2.4	54.6	2.2	24.7	0.9
Mixed brush rangeland	28.0	2.5	32.9	5.1	47.5	4.2	20.9	1.7
Saline rangeland	35.8	3.1	46.8	5.1	55.4	4.3	22.9	1.6
Cropland	25.5	2.7	24.8	4.7	62.0	5.7	31.3	2.9
Water	27.6	2.9	21.9	9.3	16.4	1.2	3.1	3.2
August 16, 1975 LANDSAT-2 overpass								
Grassland	37.6	2.5	28.6	4.1	63.4	5.2	30.3	2.5
Mixed brush rangeland	34.7	3.9	29.0	5.6	48.5	7.0	22.9	3.7
Saline rangeland	42.2	4.7	39.8	7.7	53.4	5.0	23.6	2.0
Cropland	32.7	1.7	26.2	3.2	49.1	4.9	24.0	2.6
Water	27.2	1.6	15.1	1.1	9.5	0.7	1.9	0.6

Table 3. Comparison of photo- and computer-estimated percentages for the various land-use categories (using LANDSAT-2 MSS digital data of Starr and Zapata Counties study area) surveyed on June 3, 1977 and August 16, 1975 overpasses (MSS bands 5, 6, and 7), respectively.

Land-use categories[1]	Photo		June Computer		August Computer	
	Size ha	Study area %	Size ha	Study area %	Size ha	Study area %
01. Rangeland						
01. Grassland	4,793	12.3	5,448	14.0	6,404	16.4
02. Mixed brush rangeland	20,685	53.0	19,079	48.9	10.042	25.8
03. Saline rangeland	12,499	32.1	10,811	27.7	12,094	31.0
02. Cropland	702	1.8	1,080	2.8	7,110	18.2
03. Water	319	0.8	148	0.4	183	0.5
Threshold	-	-	2,434	6.2	3,167	8.1
Total	39,000	100.00	39,000	100.00	39,000	100.00

[1] Categories are listed using a modification of Anderson's land-use classification system.

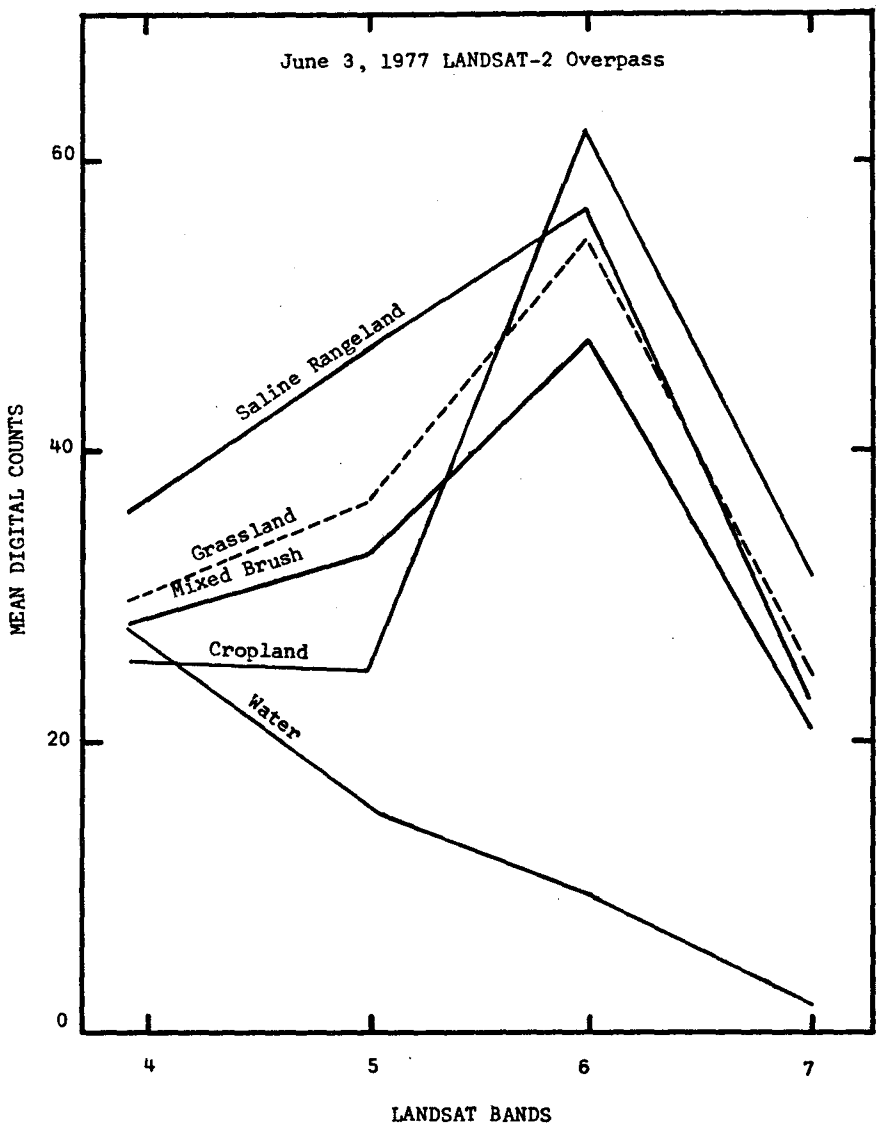

Figure 1. Mean digital counts for the various land-use categories (training sites) for the four MSS bands from the June 3, 1977 LANDSAT-2 overpass.

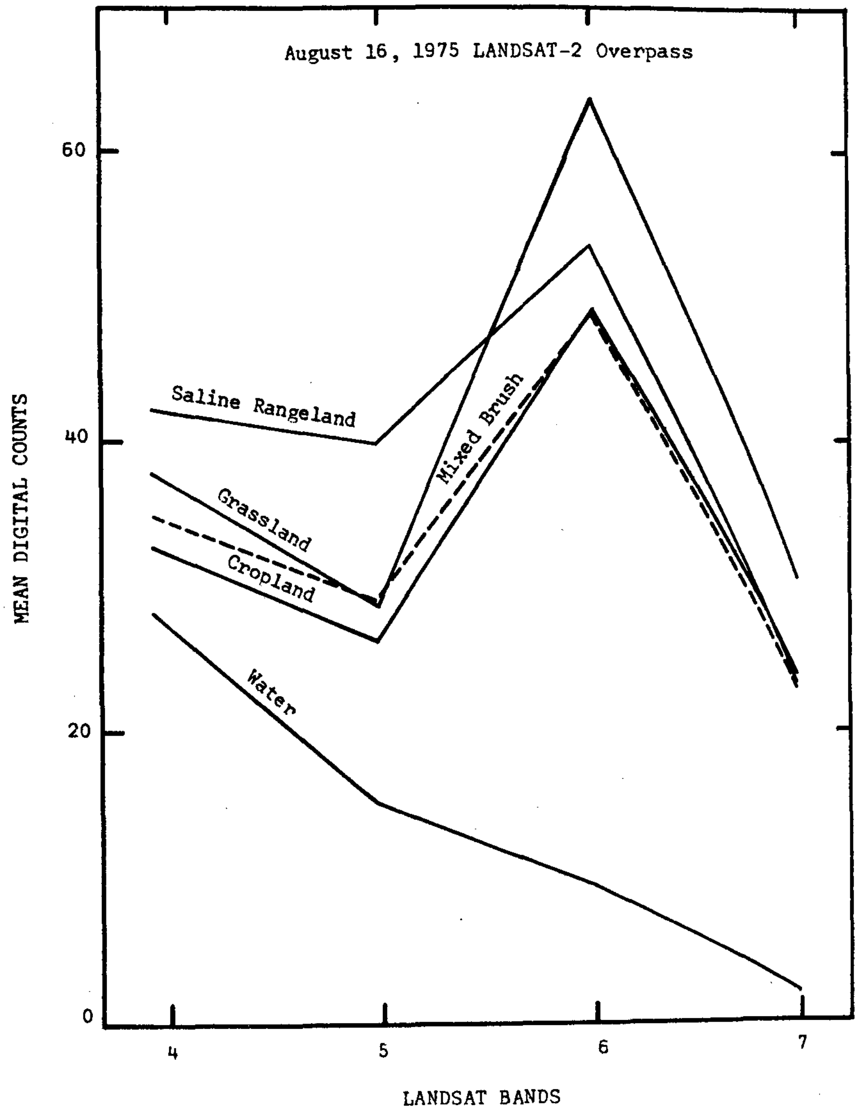

Figure 2. Mean digital counts for the various land-use categories (training sites) for the four MSS bands from the August 16, 1975 LANDSAT-2 overpass.

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