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LANDSAT-2 DATA FOR INVENTORYING RANGELANDS IN SOUTH TEXAS

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ABSTRACT

A 81,000-ha rangeland area in Kenedy and Willacy Counties, Texas, was used to test LANDSAT-2 MSS data from October 17 and December 10, 1975 for inventorying rangeland and various other land-use categories.

Computer land-use classification percentages of land cover for each overpass were compared with photo-estimated percentages from a ground correlated 1:100,000 scale LANDSAT color composite print. We found a highly significant correlation (r = 0.977**) between the photo- and computer-estimated hectarages for the October LANDSAT-2 overpass. The correlation was not significant for the December overpass largely because about half of the most extensive rangeland category (mixed brush) was misclassified as grassland, probably because the woody species were dormant and freeze damage had weakened the herbaceous vegetation reflectance.

Computer estimates of level I land-use (rangeland, wetland, agricultural land, water, and barren land) hectarage from both overpasses resembled photo-estimated hectarages, indicating the feasibility of estimating level I land-use categories in either October or December. Computer estimates of level II land-use (grasslands, mixed brush, and live oak rangelands) hectarages agreed with photo-estimated hectarages only in October, indicating that living vegetation is needed to spectrally discriminate between level II rangeland categories.

I. INTRODUCTION

To more efficiently manage natural resources, we must find better methods to determine their characteristics and extent. This applies particularly to our rangeland resources that are often inaccessible to ground observation. LANDSAT-2 (Earth Resources Technology Satellite) imagery offers the natural resource land planner or range manager the opportunity of examining landscape characteristics of large areas.

Several investigators have used LANDSAT-1 imagery for mapping vegetation types and monitoring changes in range resources[16,14,4,3,11]. This is a report of a test of the effectiveness of LANDSAT-2 multispectral scanner (MSS) data for inventorying rangelands in south Texas.

II. STUDY AREA

The specific study area is located between 26°28' and 26°42' north latitude and 97°25' and 97°49' west longitude, and includes approximately 81,000 hectares in Kenedy and Willacy Counties, in south Texas. It is a transition zone between the Texas Coastal Prairies and the South Texas Plains vegetational regions[8], with the Gulf of Mexico bordering the area on the east. The topography is flat to gently sloping with elevation ranging from sea level to 30 m above sea level.

The climate is mild, with short winters and relatively warm temperatures throughout the year. The average growing season exceeds 325 days[2]. The average annual rainfall is 70 cm. Heaviest rains occur normally in May and September.

Land cover is primarily native rangeland; however, some of the native vegetation has been cleared and the land has been seeded to grasses. A large portion of the eastern part of the study area is characterized by salt flats, tidal flats, and dune land. In addition, several large blocks of cultivated land are located in the southern part of the study area, where nonirrigated grain sorghum and cotton are grown. We used a modification of Anderson's land-use classification scheme for classifying the study area[1]. Five level I categories were identified (rangeland, wetland, agricultural land, barren land, and water) on the study area (Table 1). The rangeland area was further classified into three level II categories (grasslands, mixed brush rangeland, and live oak rangeland). Thus, seven different land units were identified.

III. MATERIALS AND METHODS

This study used the MSS computer compatible digital tapes and corresponding color images (1:1,000,000 scale) from LANDSAT-2 overpasses on October 17 and December 10, 1975. All four LANDSAT-2 MSS bands were used covering the 0.5- to 1.1-μm spectral region. These overpasses provided digital counts for a 185 km by 178.5 km area which included the study area in Kenedy and Willacy Counties. The October 17, 1975 overpass provided an image of the area with most vegetation in late-season growth. The December 10, 1975 overpass provided an image of the area when the vegetation was dormant from a freeze which occurred about one month earlier.

A seven class, area inclusive, ground truth correlated map of the 81,000-ha study area was traced onto a transparent overlay with 1:100,000 scale photo base enlarged from a 1:1,000,000 scale, 9.5 inch LANDSAT, color-composite, transparency[13]. A ground reconnaissance to verify land-use categories of the study area was made at or near each satellite overpass date. A photo-mosaic of the study area was constructed from 1:21,000 scale black-and-white aerial photographs from a June 1975 overflight of the area and was used as a map and a base on which data about the area were recorded. The photo-estimate process, used to produce the ground truth map, was similar to that described by Hardy and Hunt[9]. The percentage of the study area occupied by each land-use cover category 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 their ratio to that of the paper for the study area was determined. This photo-estimate was made for both overpasses. The several differences between the percentages of the land-use categories on the photo-estimates for the two dates are due to difficulties in delineating boundary lines between the various categories. During the two month interval between overpass dates the vegetation became dormant and obliterated sharp contrasts between the land-use categories.

We used a training-field classification approach for the LANDSAT digital data (Figure 1; this classification map is a 4 to 1 reduction of the original LANDSAT-2 data with a resolution of 1.9-ha/symbol). This approach consisted of obtaining over 1,000 training pixels from 27 training sites which intensive ground truth had indicated were representative of the land-use categories to be studied within the 81,000-ha study area (0.5% of total area). The entire study area was then classified using a maximum-likelihood classifier[7], implemented in a table look-up procedure, described by Eppler et al.[5]. Training sites were identified on gray maps of the study area, from which record and pixel coordinates were determined. The same training sites were used for both LANDSAT overpass dates.

For both LANDSAT overpass dates, the photo- and computer-estimated hectarage of each land-use category were compared using methods reported by Ray and Huddleston[12], Wigton[17], and Sigman et al.[15]. These methods were developed for the Statistical Reporting Service (SRS) to improve ground-estimated crop hectarages using LANDSAT crop classifications as an auxiliary variable. As concluded by Wigton[17], if there is a good linear relation between ground and computer hectarage estimates, then the sampling error will be reduced. Thus, for this study the higher the linear correlation the better the correspondence between photo and computer hectarage estimates will be. If these two independent land-use estimates are in good agreement, then the uncertainty of the land-use hectarage estimates is reduced even though the accuracy of both photo and computer hectarage estimates are subject to question in any remote sensing land-use inventory investigation.

A classification map of the 81,000-ha study area was produced for each LANDSAT overpass date to compare digital data land-use inventory with the hand-drafted, ground truth study area map. We could not verify the mapping accuracy between the photo and computer maps using statistical procedures described by Kalensky and Scherk[10], because we lacked computer-registering capabilities; thus, we visually assessed their classification and mapping accuracy.

IV. RESULTS AND DISCUSSION

A. SPECTRAL CHARACTERISTICS OF LAND-USE CATEGORIES

In Table 2 the mean digital counts and standard deviations of the various land-use categories for both October 17 and December 10, 1975 LANDSAT-2 overpasses are listed. All four MSS bands (4,5,6,&7) are presented, although we did not use band 4 (0.50 to 0.60 μm) for the computerized estimates. The photo estimates were made using a color-composite of bands 4, 5, and 7.

Most of the separability among the vegetation categories seemed to be based on bands 6 (0.70 to 0.80 μm) and 7 (0.80 to 1.10 μm), where plants are highly reflective[6]. The standard deviations were generally small in these channels.

Figures 2 and 3 are graphs of the mean digital counts for the various land-use categories for the two overpasses, respectively. Generally, differences were greater among the land-use categories for the October than for the December overpass, except for live oak versus mixed brush. Both had very similar mean digital counts in bands 6 and 7, so their separability would rely heavily on their difference in band 5.

The December 10 data had lower mean digital counts (relative reflectance) for all bands because incident solar energy was lower in December than in October. Seasonal senescence of green vegetation also lowered the response in bands 6 and 7. Live oak and grasslands had the same mean digital counts in band 7, hence, were not separable spectrally; in band 5 they were distinctive.

The level I categories seem to be distinctive on both dates, except possibly agricultural land versus mixed brush for the December 10 overpass. If grass was scarce, the bare soil sensed through the defoliated woody species would tend to resemble the predominately bare, fallow agricultural land.

B. OCTOBER AND DECEMBER LANDSAT-2 OVERPASSES

Table 3 shows a comparison between the photo- and computer-estimated hectarages for the various land-use categories for the October 17 and December 10, 1975 LANDSAT-2 overpasses, respectively.

The October photo-estimated percentages were larger than the computer-estimated percentages for four land-use categories (mixed brush rangeland, wetlands, barren land, and water), whereas the computer-estimated percentages were larger for three categories (grasslands, live oak rangeland, and agricultural land). However, we found a highly significant correlation ($r = 0.977^{**}$) for the comparison between photo- and computer-estimated hectarages.

The October photo- and computer-estimated percentages generally agreed for the five level I categories, and differed most for the level II category "mixed brush rangeland." The disagreement between the two estimated grassland percentages was probably due to the computer misclassifying as grasslands of some of the more open areas in the mixed brush rangeland or live oak rangeland.

The large difference in hectarage between the two October estimates for the mixed brush rangeland arises because "mixed brush" is a highly variable category, ranging from 5 to 80% ground cover by woody vegetation. The range sites that constitute this category grade from one site to another, so that boundary lines drawn based on images are highly subjective. The computer classification is based on discrete spectral classes, and a decision is made concerning each pixel representing a 0.47-ha ground area. Much of the 7% threshold (unidentified) category is the boundary pixels between agricultural land, rangeland, access roads, and urban areas, where the signatures are composites of natural and man-made features. Others are single or small groups of pixels within the rangeland itself that differ spectrally from the typical range sites for the category.

For the December overpass (Table 3), the computer over-estimated percentages for grassland, wetland, and agricultural land, whereas the photo over-estimated percentages for mixed brush rangeland, live oak rangeland, barren land, and water. The correlation ($r = .633$) between photo- and computer-estimated hectarages was not significant.

Most December photo- and computer-estimated percentages for the level I categories agreed well. However, the wetland category was considerably larger for the computer-estimated percentages. Figure 3 showed that the wetlands (lagunas) were not spectrally very different from the live oak rangeland and mixed brush categories which may account for the higher computer-estimated percentages. The computer-estimated percentages for the level II categories "grasslands" and "mixed brush rangeland" were considerably different from the photo-estimated percentages, and the agreement was much poorer than for the October overpass. As a result of a severe mid-November frost, many of the woody species like mesquite trees had lost their leaves. The defoliation of the woody species allowed much more light to penetrate to the herbaceous understory, so that the spectral signatures of the mixed brush rangeland and grassland categories were similar. The spectra presented in Table 2 show that the standard deviation of the mean training sample signature of the two categories overlapped in each of the spectral bands.

C. CLASSIFICATION ACCURACY

Figure 1 presents a black-and-white print (MSS 5) and a line printer classification map of the 81,000-ha study area for the October 17, 1975 LANDSAT-2 overpass. Even though errors may be present, overall classification results appear good between the print and classification map for agricultural land (M overprinted with a W), barren land (+), wetlands ($), live oak rangeland (W), grassland (-), mixed brush rangeland (/), and water (•).

V. CONCLUSIONS

This study showed that LANDSAT-2 data can be successfully used to identify level I land-use (rangeland, wetland, agricultural land, water, and barren land) categories in both October and December in south Texas. However, level II rangeland land-use (grassland, mixed brush, live oak rangeland) categories could be best identified in October, indicating that living vegetation is needed to spectrally discriminate between level II rangeland categories. These data indicate that useful range inventories are possible using spectral measurements from space.

VI. ACKNOWLEDGEMENTS

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Table 1. Land-use categories and their descriptions on the 81,000-ha study area in Kenedy and Willacy Counties of south Texas. Categories are listed using a modification of Anderson's land-use classification system.

Land-use Categories	Descriptions
01. Rangeland	
01. Grasslands	Improved grasslands, reestablished to introduced grasses, or native grasses and herbs.
02. Mixed brush rangeland	Brush infested rangelands with woody canopies varying from 5 to 80%. Dominant woody species include mesquite (*Prosopis glandulosa* Torr.), bluewood (*Condalia hookeri* M.C. Johnst.), lime pricklyash (*Zanthoxylum fagara* Sarg.) and granjeno (*Celtis pallida* Torr.)
03. Live oak rangeland	Characterized by motts of live oak trees (*Quercus virginiana* Mill.) breaking the landscape. The canopies of these live oaks may exceed 60% in some areas.
02. Wetland	Lagunas or depressions that are dispersed throughout the study area and range in size from 0.5 to 4 ha. They serve as catchments for runoff from surrounding terrain. The plant community is an open grassland subjected to varying degrees of wetness.
03. Agricultural land	Idle cropland, bare soil.
04. Barren land	Sand dunes, tidal flats, and salty flats (predominantly bare soil).
05. Water	

Table 2. LANDSAT-2 MSS (MSS bands 4, 5, 6, & 7) mean digital counts ($\bar{x}$) and standard deviations ($s_{\bar{x}}$) of the various land-use categories (training sites) in the 81,000-ha study area in Kenedy and Willacy Counties, Texas.

Land-use categories	MSS4		MSS5		MSS6		MSS7	
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
October 17, 1975 LANDSAT-2 overpass								
Grasslands	17	1	18	2	45	3	24	2
Mixed brush rangeland	17	2	19	3	36	3	18	2
Live oak rangeland	15	1	15	2	37	2	20	1
Wetland	13	1	13	2	17	8	6	5
Agricultural land	21	3	27	5	30	7	13	3
Barren land	52	18	77	30	81	26	32	9
Water	23	5	22	9	16	12	4	5
December 10, 1975 LANDSAT-2 overpass								
Grasslands	15	2	20	3	28	4	14	2
Mixed brush rangeland	14	1	17	2	23	2	11	1
Live oak rangeland	12	1	13	2	25	2	14	1
Wetland	12	2	14	4	21	5	10	3
Agricultural land	14	2	18	4	19	6	8	3
Barren land	38	10	57	18	60	17	24	7
Water	17	1	15	4	10	7	2	2

Table 3. Comparison of photo- and computer-estimated percentages for the various land-use categories (using LANDSAT-2 MSS digital data of Kenedy and Willacy Counties study area) surveyed on October 17 and December 10, 1975 overpasses (MSS bands 5, 6, and 7), respectively.

Land-use categories[1]	October				December			
	Photo		Computer		Photo		Computer	
	Size ha	Study area %	Size ha	Study area %	Size ha	Study area %	Size ha	Study area %
01. Rangeland								
01. Grasslands	2,916	3.6	5,508	6.8	2,025	2.5	19,962	24.6
02. Mixed brush rangeland	43,416	53.6	33,372	41.2	45,303	55.9	21,789	26.9
03. Live oak rangeland	12,150	15.0	15,066	18.6	12,668	15.6	12,370	15.3
02. Wetland	3,159	3.9	2,268	2.8	1,401	1.7	5,641	6.9
03. Agricultural land	11,259	12.9	12,636	15.6	11,535	14.2	12,456	15.4
04. Barren land	4,374	5.4	3,321	4.1	4,010	5.0	3,474	4.3
05. Water	3,726	4.6	3,159	3.9	4,058	5.0	2,795	3.5
Threshold	-	-	5,670	7.0	-	-	2,513	3.1
Total	81,000	100.0	81,000	100.0	81,000	100.0	81,000	100.0

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

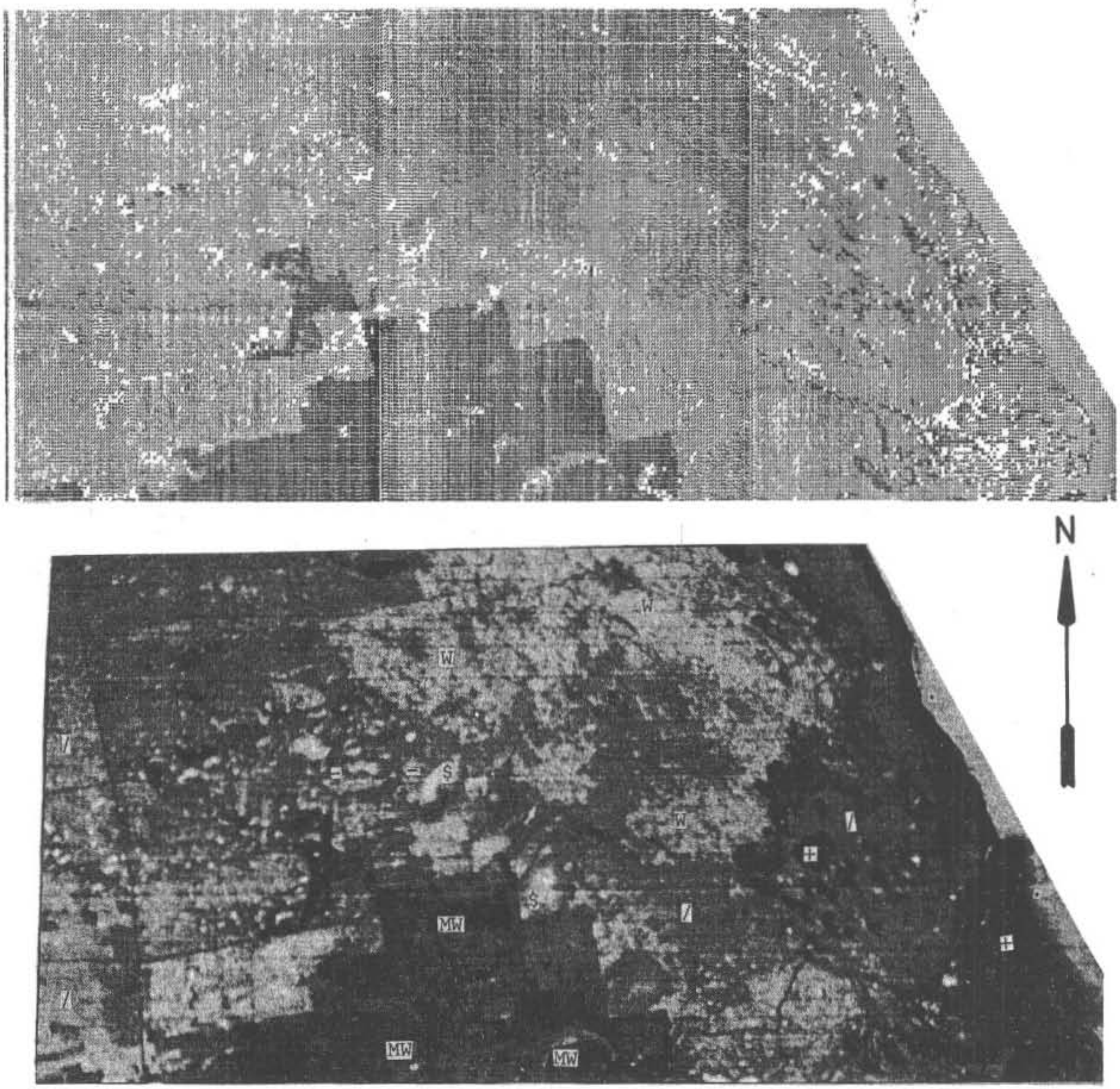

Figure 1. Black-and-white print using MSS 5 (lower) and line printer classification map (upper) of the 81,000-ha rangeland area in Kenedy and Willacy Counties of south Texas for the October 17, 1975 LANDSAT-2 overpass. Resolution of classification map is 1.9 ha/symbol. Definition of land-use category symbols are: live oak rangeland (W), mixed brush rangeland (/), grasslands (-), barren land (+), wetland ($), agricultural land (M overprinted with a W), water (•), and threshold (blank).

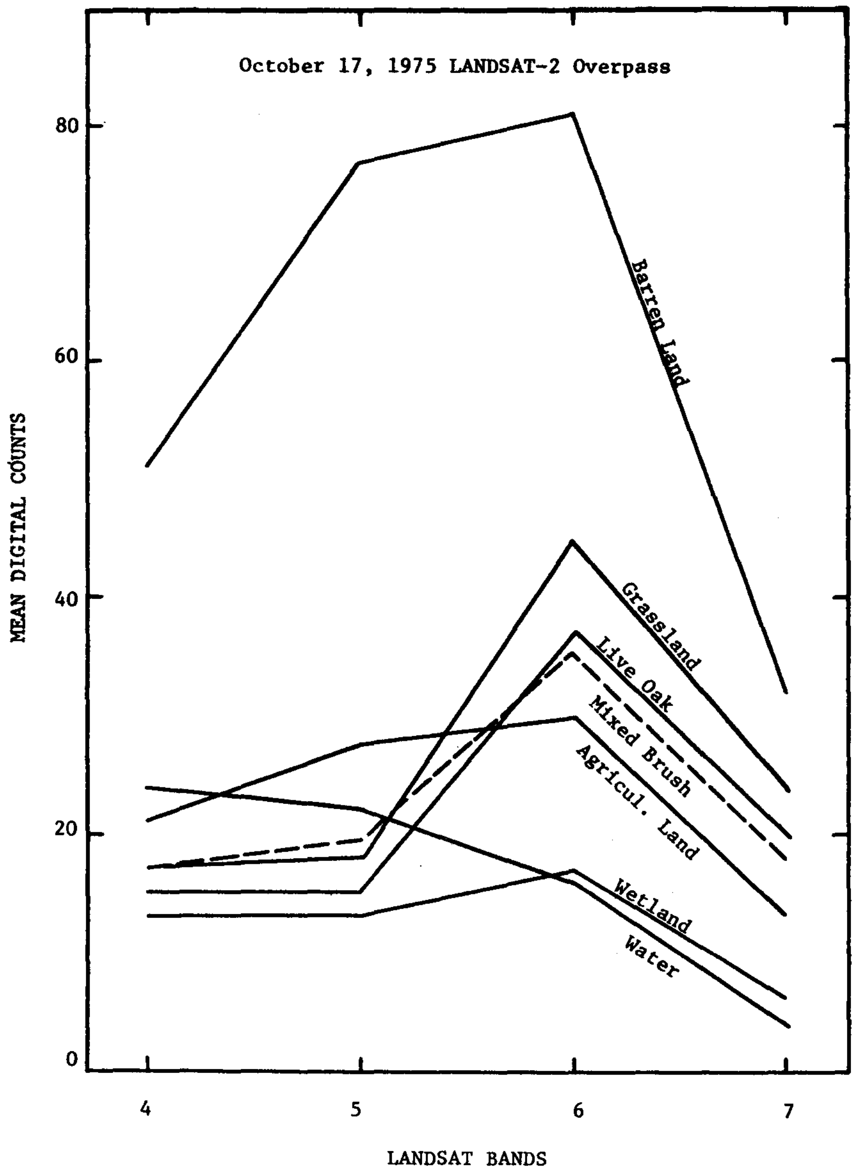

Figure 2. Mean digital counts for the various land-use categories (training sites) for the four MSS bands from the October 17, 1975 LANDSAT-2 overpass.

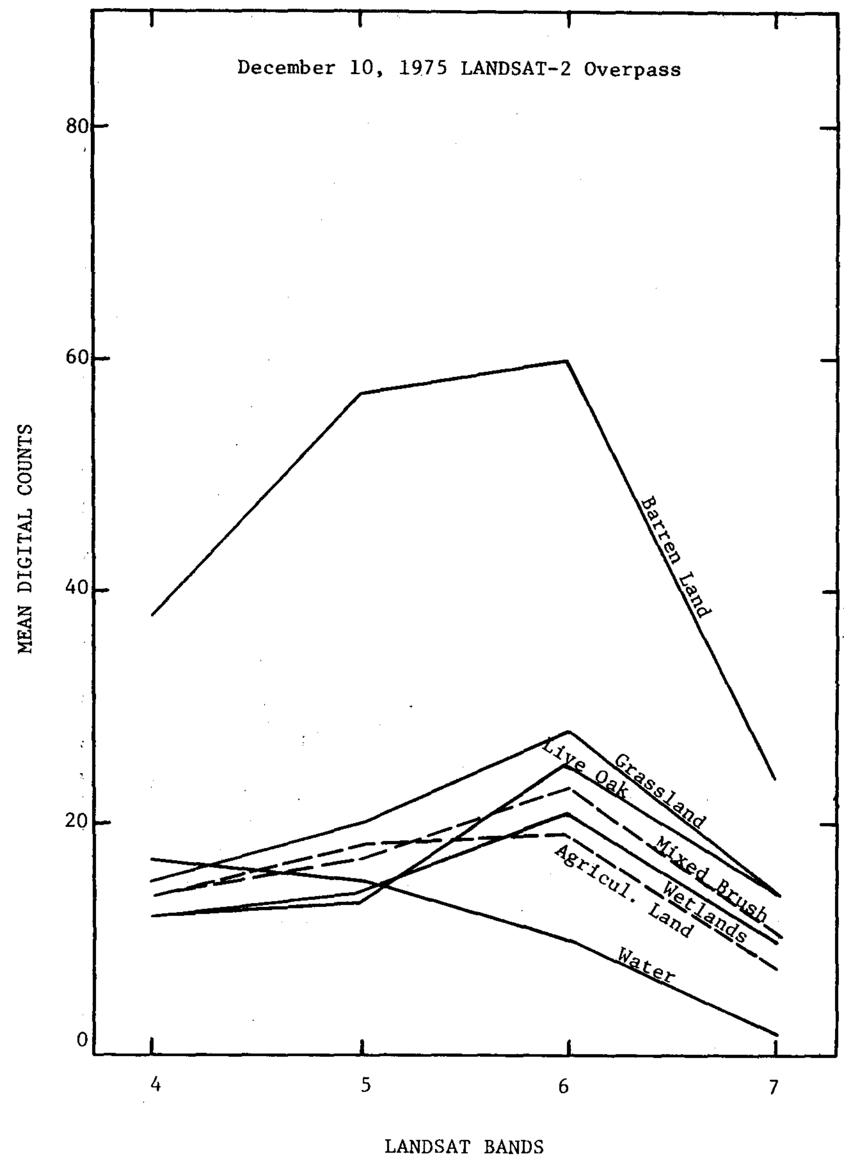

Figure 3. Mean digital counts for the various land-use categories (training sites) for the four MSS bands from the December 10, 1975 LANDSAT-2 overpass.