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Assessment of Landsat for Rangeland Mapping, Rush Valley, Utah

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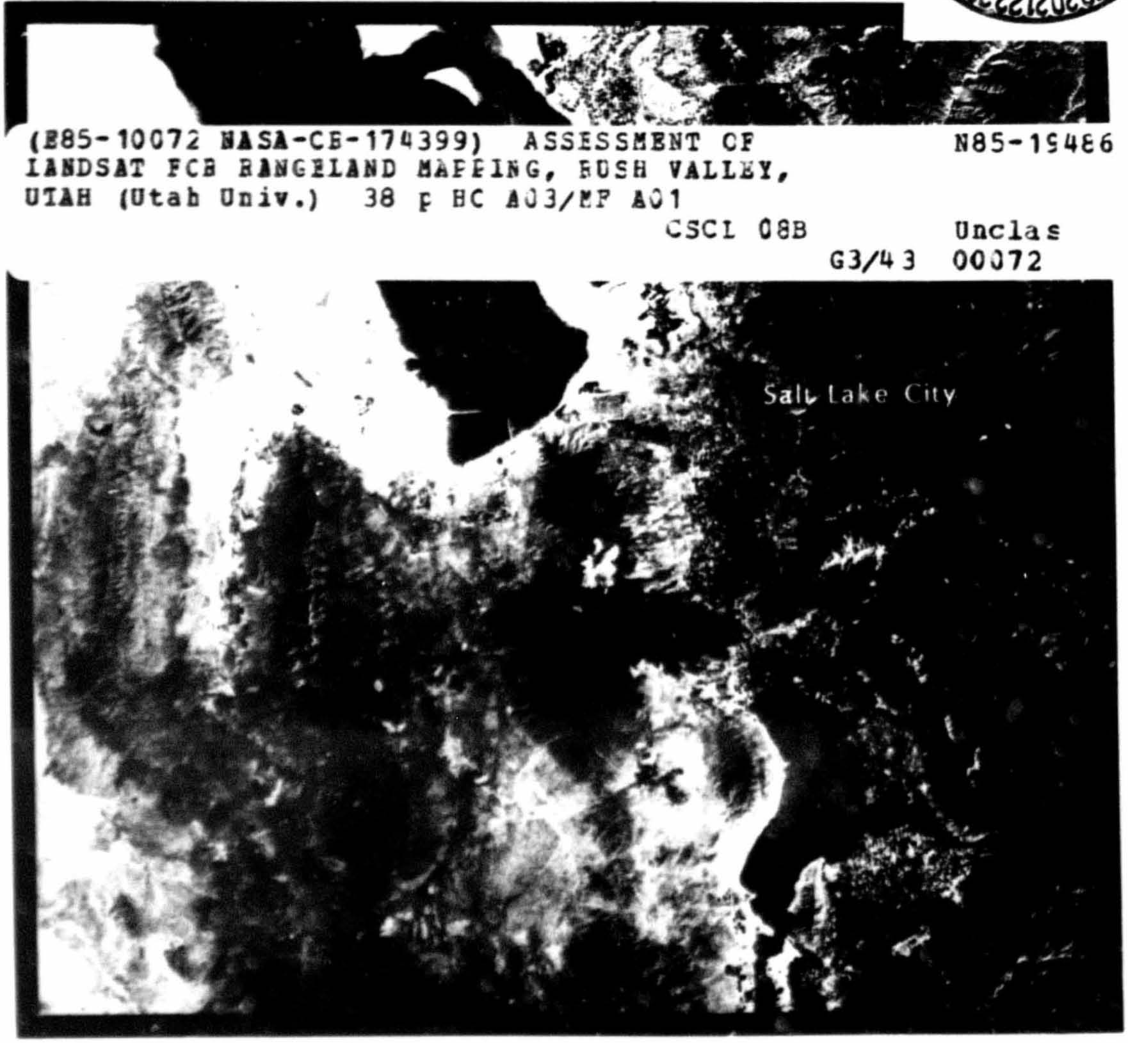
CSCL 08B Unclas
G3/43 00072



UNIVERSITY OF UTAH RESEARCH INSTITUTE

Salt Lake City

ASSESSMENT OF LANDSAT FOR RANGELAND MAPPING,

RUSH VALLEY, UTAH

CRSC Report 84-9

by

Merrill K. Ridd, Kevin P. Price, and Gordon E. Douglass

December 1984

Center for Remote Sensing and Cartography
University of Utah Research Institute
391 Chipeta Way, Suite D
Salt Lake City, Utah 84108

Supported by

Utah Department of Agriculture
and
National Aeronautics and Space Administration (Grant NAGW-95)

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INTRODUCTION

The objective of this investigation is to assess the feasibility of using Landsat MSS (multispectral scanner) data to identify and map cover types for rangeland, and to determine comparative condition of the ecotypes. A supporting objective is to assess the utility of various forms of aerial photography in the process.

If rangelands can be efficiently mapped with Landsat data, as supported by appropriate aerial photography and field data, then uniform standards of cover classification and condition may be applied across the rangelands of the state. Further, a foundation may be established for long-term monitoring of range trend, using the same satellite system over time.

STUDY AREA

The study area, selected in cooperation with Utah Department of Agriculture personnel, is in Rush Valley, Utah, immediately south of Tooele Army Depot (South Area), 110 kilometers southwest of Salt Lake City. The study area covers 21,062 acres and occupies a desert basin, in the Basin and Range Province. Physiographically the area includes Lake Bonneville bottom sediments and delta deposits, interrupted by alluvial deposition. Figure 1 shows the study area and the 7½-minute USGS quadrangles that are represented.

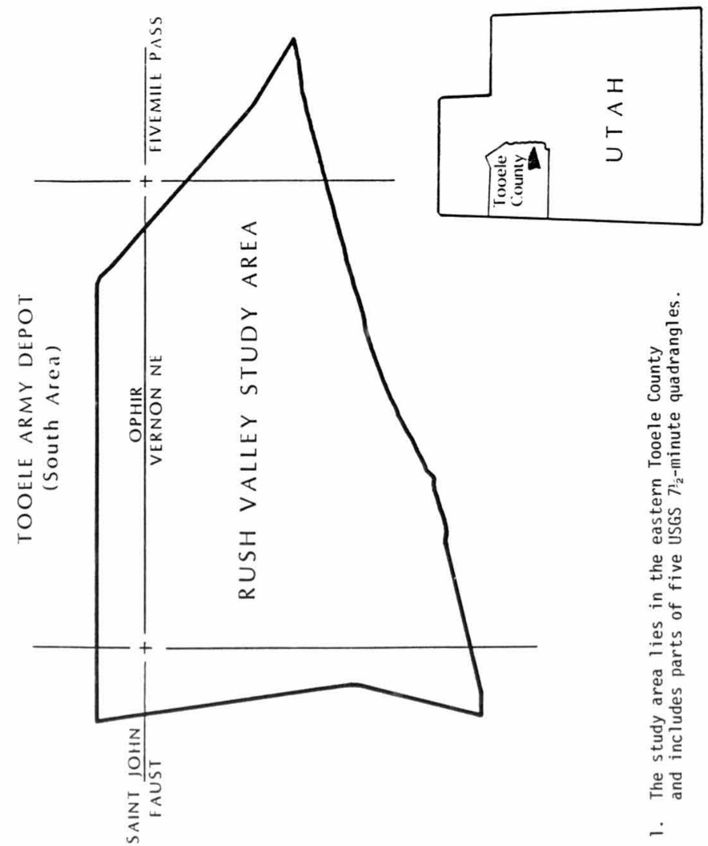

Figure 1. The study area lies in the eastern Tooele County and includes parts of five USGS 7½-minute quadrangles.

MATERIALS AND FACILITIES

Three dates of Landsat imagery were examined to determine the optimal season for differentiation of cover types: May 18, 1979; June 17, 1980; and August 14, 1982.

Five forms of aerial photography were evaluated:

- CIR (color infrared) at ~ 1:30,000 scale, from BLM.
- B/W (black and white) at ~ 1:24,000 scale, from BLM.
- Enviropod panoramic natural color film, from CRSC.
- 35mm Ecktachrome at various elevations, from CRSC.
- Orthophotoquads at 1:24,000 scale, from USGS.

Computing facilities at CRSC (Center for Remote Sensing and Cartography) were used for all digital analysis. Landsat data were processed with NASA/ELAS software on a PRIME computer, and displayed on an AED color monitor, Zeta plotter, and line printer. Digitizing of soil and geomorphic units was done on a Tektronix digitizer, interfaced with the PRIME computer.

METHODOLOGY

Quite often, Landsat investigators find they must go beyond the spectral data to classify environmental features, to the desired degree of class separation. Additional data, such as soil categories, may be digitally entered to separate classes that cannot be separated by spectral data alone. Such additional layers of data are often called ancillary data. In our investigation, we desired to "push" Landsat as far as possible in defining cover types. If further breakdown was needed, we would digitize soil and/or geomorphic data to assist in distinguishing the desired categories of cover.

Following an initial reconnaissance visit to the field, the basic strategy was to:

1. Run a preliminary digital analysis of the three Landsat data sets and select the best date.
2. Obtain Enviropod photography and 35mm slide photography of the study area.
3. Prepare a preliminary Landsat classification map of the selected date for use in the field.
4. Gather field data and ground photography.
5. Analyze the data in the laboratory, and return to the field as needed.
6. Add ancillary data as needed.
7. Prepare a final classification of cover types, and prepare a report.

Highlights of these steps are presented below.

Selecting Best Date for Landsat

The three dates of Landsat data were compared by running a four-channel classification and a Kauth-Thomas greenness-brightness transformation, and comparing results. The May date was too early, and the August date too late to provide the desired differentiation of cover types observed during field reconnaissance. The date with maximum separability was June 17, 1980. The four-channel classification of raw data was superior to the Kauth-Thomas transformation, and was used from this point on throughout the analysis. The four channels of data are green, red, and two wavelengths of infrared light values.

Aerial Photography

The earliest opportunity to obtain suitable aerial photography was during mid-summer 1984. Using a Cessna 172, 35mm slides were obtained from various altitudes at 500 to 5,000 feet above ground level. Oblique and near-vertical photos were taken of the various environmental/community types of the study area. Some 150 slides were thus obtained, and potential ground visit sites observed. Limited Enviropod photography was obtained. It was found that 35mm hand-held photography was sufficiently flexible and inexpensive to use as the dominant aid to interpreting cover types.

High-altitude CIR photography from the NHAP (National High Altitude Photography) program was found to have limited value in determining any more than general environmental patterns. For any dependable differentiation of cover types for grazing evaluation, the 35mm slides were much more diagnostic.

A large-scale B/W print of the study area (~1:20,000), obtained from ASCS (Agricultural Stabilization and Conservation Service), was found to be very useful in the laboratory throughout the project. While it was not useful in detecting specific cover types, it was a constant aid in general orientation and a guide to field access.

More useful, still, were the orthophotoquads, in the laboratory and field. Orthophotoquads have many advantages. First, they are scaled to 1:24,000, the desired scale of the final classified map. They are photographic and, therefore, represent the field conditions as seen from above. Because of this, they are an ideal base on which to overlay and accurately register printmaps of classification from preliminary to final versions. This is a great benefit because accurate registration is essential to accurate classification of ecotypes.

Preliminary Classification

A preliminary printmap classification, scaled to the 1:24,000 quadrangle, is a great asset to guiding field site selection. To prepare a printmap, several steps are involved which have become routine at CRSC for Landsat data (Figure 2). Beginning with SEARCH, a program that generates spectral signatures from the varied cover conditions over the whole area, and then running through principal components, cluster analysis, and discriminant analysis, a scatter plot of all the SEARCH signatures is made. Figure 3 shows the scatter plot of the original 58 signatures. Each point on the plot represents some combination of brightness and greenness that is representative of the cover conditions. The next step is to decipher the cover type for each class shown on the scatter plot.

Briefly, a baseline, often called the "soil line," runs from the darkest signature, extreme left, to the brightest signature, upper right. The transition along this direction is a measure of brightness. Reaching out to the lower right from this line is increasing greenness. Alfalfa, for example, would appear at the "green point."

A printmap made from this data is the next step. A maximum likelihood classifier is used. It "looks at" each Landsat pixel in the study area and assigns it to the most likely one of the signatures (or classes) shown in the scatter plot. Then, the whole set is georeferenced to the map and scaled to 1:24,000 (Figure 2). A clear diazo of the printmap is overlaid on the orthophotoquad (and/or regular USGS quadrangle) and registered to fit. An example of the printmap is shown as Figure 4.

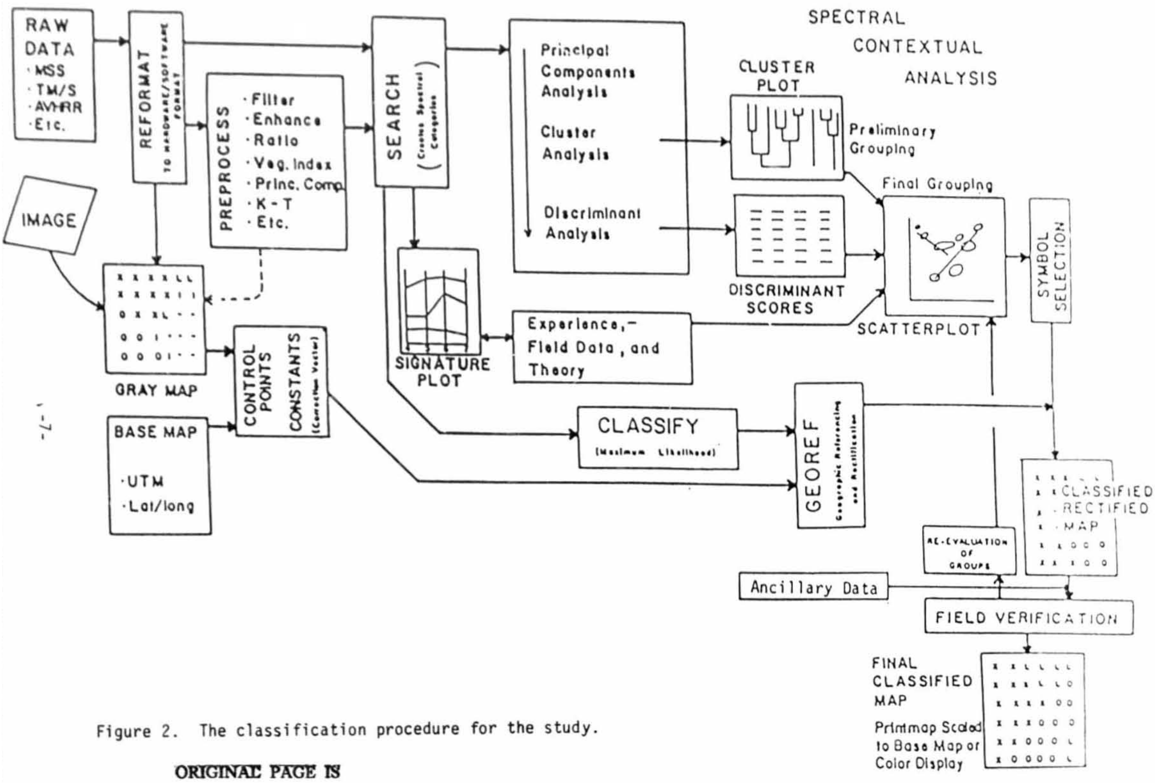

Figure 2. The classification procedure for the study.

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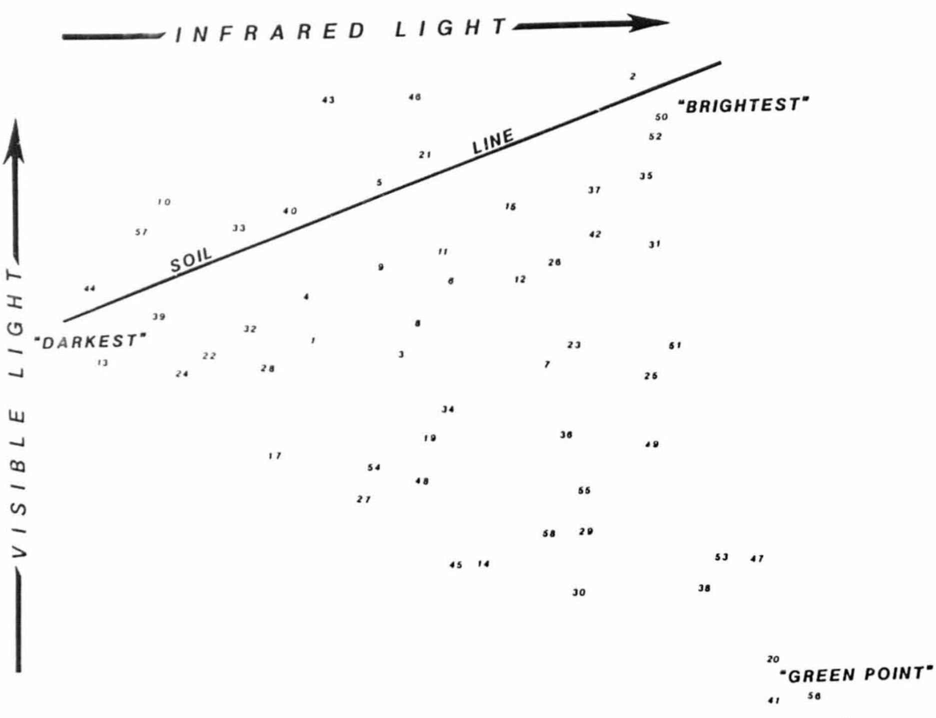

Figure 3. The scatter plot exhibits increasing brightness along the axis of the soil line and increasing greenness outward to the lower right.

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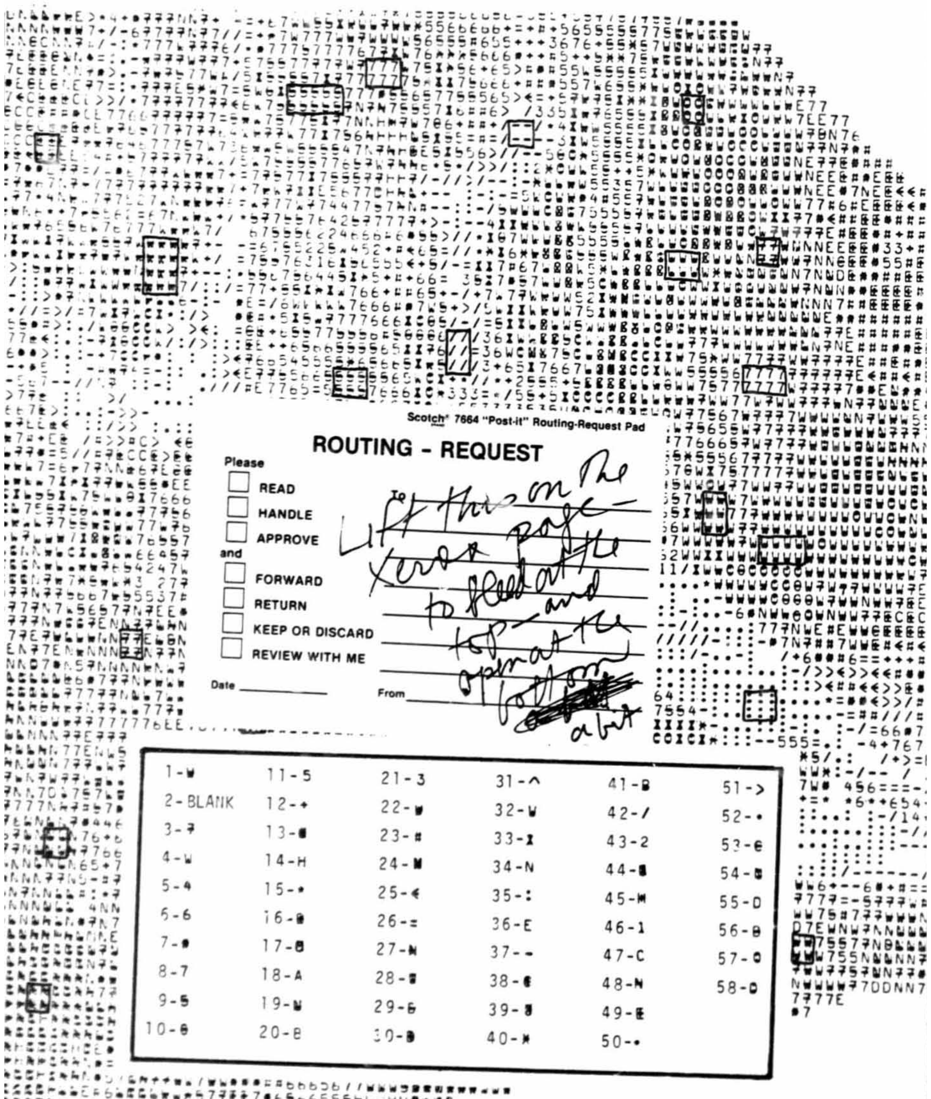

Figure 4. A portion of the classified printmap showing some polygons of cover types to be visited in the field. Each print character represents 1.15 acres. Print symbols represent the 58 classes shown in Figure 3.

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Also shown on Figure 4 are some polygons. These are selected in the laboratory as representative sites to be visited in the field. Presumably each different symbol conveys diagnostic characteristics of brightness and greenness of the field site, indicative of the cover type (and soil conditions, etc.) Only polygons of 2x2 pixels or larger are targeted for field visit. This is to avoid boundary pixel problems and possible misregistration.

Field Data

Field data were gathered for as many of the original 58 classes as possible. At each site a data sheet is filled out showing the percent cover by life form and by species. Additional data pertinent to soil, terrain, and other environmental features were also recorded. Ground level photographs were taken for further reference in the laboratory, and to relate to the aerial slides taken earlier. The field data sheet is shown in Appendix A.

Laboratory Analysis

The next step was to examine and correlate the field data (by cover type) with the scatter plot position and the printmap. On this basis, a new classification and printmap were made. However, a number of inconsistencies emerged, wherein a given spectral signature represented quite different types of cover in different physical settings. For example, the bright class group shown at the upper right in the scatter plot was greasewood (*Sarcobatus vermiculatus*) and saltbush (*Atriplex falcata* and *tridentata*) in low, playa areas, but was little rabbitbrush (*Chrysothamnus viscidiflorus*) on higher land. This spectral confusion led to the need for ancillary data.

Ancillary Data

It was determined that soil differences and geomorphic differences were influencing the spectral signature, and needed to be entered into the classification decision. Using SCS (Soil Conservation Service) soil data, a simple separation of coarse from fine soils was distinguished. A map of coarse vs. fine soils was digitized and entered into the classification. Figure 5 shows the map distinguishing the two.

Likewise, geomorphic units were seen to influence the signature. Thus, five categories of geomorphic units were identified from photographic and field observation, as shown in Figure 6. A decision algorithm was prepared, which stratified the spectral signatures by combinations of soil and geomorphic type, ready for a final classification.

Final Classification and Map

A final printmap of classification was prepared (Figure 7). The original 58 classes were thus synthesized into 12 classes of cover type. The process of grouping and regrouping was constantly guided by the fitness of the range to grazing.

Table 1 shows the final classification of range cover types, with a brief description of each class. The symbols for each class correspond to those on the printmap, Figure 7. Table 2 shows the percent cover by species within life form categories for each range cover class. In this table, the two mixed shrub types (low diversity and high diversity) are grouped together. Scientific names are given in Appendix B.

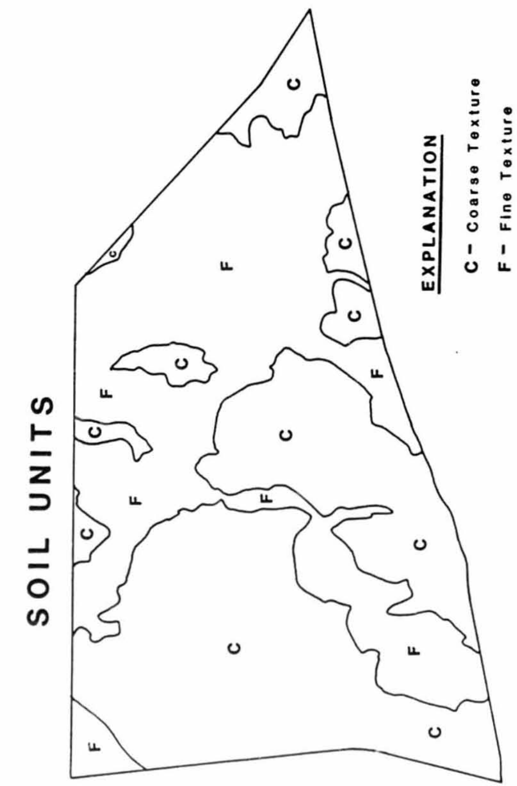

Figure 5. The pattern of coarse and fine soils was digitized and entered into the classification decision.

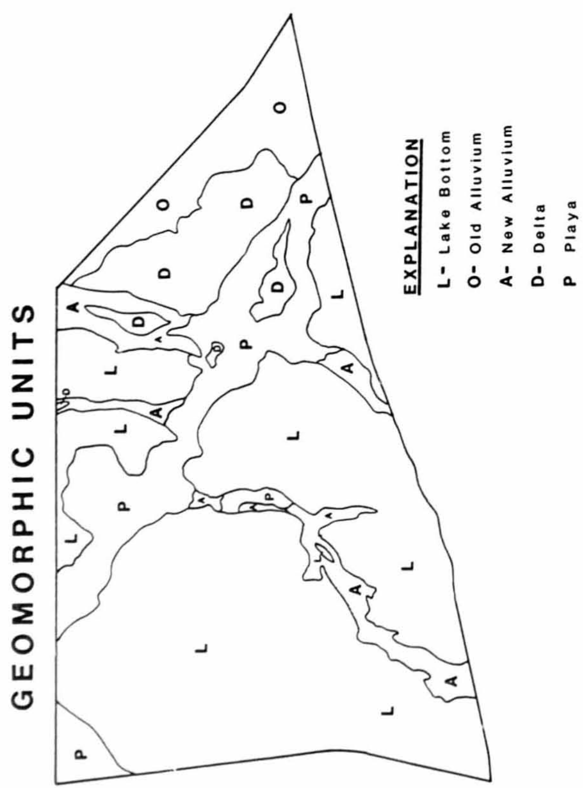

Figure 6. Five geomorphic types were digitized and entered into the classification decision.

Table 1. Twelve Final Classes of Range Cover Types

Map Symbol	Range Cover Classes	Site Description
M.	Mixed Shrub (high diversity)	Coarse textured soils, shadscale, winterfat, bud sage, big sage, little rabbitbrush, perennial grasses.
M	Mixed Shrub (low diversity)	Coarse textured soil, big sagebrush, little rabbitbrush, some bud sage.
W	Winterfat	Finer textured soil, pure winterfat with cryptogamic crust interspace.
Blank	Saltbush	Two species Atriplex falcata on fine textured soils with cheatgrass, and A. tridentata on very fine textured soils on playa bottom.
S	Shadscale	Highly variable community type. Fine to coarser textured soils. Pure stands or mixed with other shrub types.
OX+	Big Sagebrush	Coarse textured soils, almost pure sagebrush with some cheatgrass and little rabbitbrush.
C:	Cheatgrass - shrub mix	Predominantly cheatgrass with interspersion of winterfat, or saltbrush (A. falcata) or big sagebrush and bud sage. Soils fine to moderately coarse. Cheatgrass most dominant on fine soils.
K	Summercyprus	Finer textured soils on disturbed sites. Dominated by exotic annuals. Predominately Kochia with mixes of tumbleweed, prickly lettuce, and species of mustard.
.	Greasewood	Soils fine to very fine. Pure stand or mixed with A. tridentata (Saltbush) Suaeda fruticosa (Alkali seepweed) and some exotic annuals.

Table 1. Twelve Final Classes of Range Cover Types (continued)

Map Symbol		
C	Cheatgrass	Finer to moderately coarse soils. Mostly pure cheatgrass with some interspersion of annuals.
-	Little Rabbitbrush	Fine to coarse soils. Very dry sites usually southern exposure. Little rabbitbrush with some dwarfed big sage. Cover sparse.
H	Halogeton	Usually fine textured soils. Sites highly disturbed. Pure stands or mixed with other invading annuals.

Table 2. Percent cover by species and life form for each range cover class.

* Species by Life Form	Range Cover Classes: Sagebrush T	Mixed Shrub Mt and M	Little Rabbitbrush -	Cheatgrass Shrub Mix C:	Cheatgrass C	Shadscale S	Winterfat W	Falcate Saltbush □	Greasewood .	Halogeton H	Kochia K	Total Cover	%
SHRUBS													
Big sagebrush	27	9	2	2							2	42	6.3
Greasewood						2	1	1	33	8	2	47	7.1
Winterfat		7	1				33			2		43	6.5
Shadscale	3	4	4	4		27	1	5	1	5		54	8.1
Little rabbitbrush	2	6	18	3								29	4.3
Saltbush				5				13				18	2.7
Bud sage		6										6	1.0
Seepweed								10	5	8		23	3.5
PERENNIAL GRASSES													
Indian ricegrass	1	2	2	T								5	0.8
Bottlebrush squirreltail		6	1	1					1			9	1.4
ANNUAL GRASS													
Cheatgrass	20	18	6	51	82	15	5		7	8	15	227	34.0
FORBS													
Summercyprus											26	26	3.9
Halogeton									1	36		37	5.6
Tumblemustard	T				2	2	3				T	7	1.1
Tumbleweed						2	1		T	5	10	18	2.7
Prickly lettuce											5	5	0.8
CRYPTOGAMS	5	8	5	4	3	14	14	3	7	8		71	10.7
TOTAL LIVING COVER	58	66	39	70	87	62	58	32	55	81	60	668	
BARE GROUND	28	18	42	18	6	31	23	68	40	8	22	304	
ROCK	8	9	16	5								38	
LITTER	6	7	3	C	7	7	19		5	11	18	91	

*Appendix B indicates the scientific names of each species.

Note that cheatgrass (Bromus tectorum) is quite abundant in several classes, making up 82% cover in its own class and 51% in the cheatgrass-mixed shrub class. Perennial grasses are very limited in the study area, with a maximum of 6% in the mixed shrub class. Forbs are limited except in the two classes of Halogeton (36%) and Summercyprus (26%). In the Halogeton class, there is a 23% shrub cover, with some cheatgrass, while the Summercyprus type has 15% cheatgrass, 10% tumbleweed (Salsola kali) and limited shrubs.

Among the shrub types, winterfat (Eurotia lanata) and greasewood are the most "pure" at 33%, with small amounts of cheatgrass and forbs. Shadscale (Atriplex confertifolia) stands are relatively pure at 27% on the average, as are sagebrush (Artemesia tridenta) stands, also at 27% for the dominant species. These typically are found on the lake bottom sediments in the central and western part of the area. The rabbitbrush sites (18% rabbitbrush) are typically on the higher ground in the area. Falcate saltbush and greasewood are typically in the playa depressions stretching from southeast to northwest across the area.

Table 3 lists the 12 classes by acreage, hectares, square miles, and the percent of the total study area that each type represents. The column marked "frequency" simply counts the number of print characters of that class on the final printmap. Each print character covers 1.15 acres. This is, incidentally, about the size of the original Landsat pixels, although they are not directly related.

Table 3. Frequency and Area Coverage of Range Cover Types in the Study Area.

CLASS	PIXEL FREQUENCY	% FREQUENCY	CUMMULATIVE % FREQUENCY	ACRES	SQUARE MILES	HECTARES
MIXED SHRUB (High diversity)	853	4.7	4.7	980	1.5	397
MIXED SHRUB (Low diversity)	750	4.1	8.8	862	1.4	349
WINTERFAT	677	3.7	12.5	778	1.2	315
SALTBUSH	727	4.0	16.5	836	1.3	338
SHADSCALE	1,428	7.8	24.3	1,641	2.6	664
BIG SAGEBRUSH	2,339	12.8	37.1	2,688	4.2	1,088
CHEATGRASS-SHRUB	4,786	26.1	63.2	5,501	8.6	2,226
SUMMERCYPRUS	754	4.1	67.3	867	1.4	351
GREASEWOOD	2,155	11.8	79.1	2,477	3.9	1,002
CHREATGRASS	1,371	7.5	86.6	1,576	2.5	638
LITTLE RABBITBRUSH	1,651	9.0	95.6	1,898	3.0	768
HALOGETON	835	4.6	100.0	960	1.5	388
TOTALS	18,326			21,064	33.1	8,524

GRAZING ASSESSMENT

For purposes of evaluating the 12 range types for sheet grazing, each type was rated on a scale from one to ten for spring (actually late winter-early spring) and fall (actually fall-early winter). Cover classes were ranked as to their overall forage quality based on plant nutrition, seasonality of plant vigor, dormancy, reproduction, and seed maturity. Also considered was the prevalence of poisonous plants on the site. Table 4 shows the ratings.

Figure 8 shows a printmap of the spring rating, and Figure 9 shows the fall rating. In comparing the two maps, it is evident that the ratings generally run higher in the spring than the fall. This is also evidenced in Table 5, where area calculations show a significant shift in forage value. Total percent of area for spring forage shows the highest percentages predominantly rated in the good to fair range. Fall ratings show a change to predominantly fair.

Table 4. Rating of Range Cover Types for Spring and Fall Grazing for Sheep.

SPRING
(LATE WINTER-EARLY SPRING)

	Excellent		Good		Fair		Poor		Poison	
	1	2	3	4	5	6	7	8	9	10
Mixed Shrub (High Diversity)	X									
Mixed Shrub (Low Diversity)				X						
Winterfat		X								
Saltbush		X								
Shadscale				X						
Big Sagebrush					X					
Cheatgrass-Shrub				X						
Summercypress				X						
Greasewood						X				
Cheatgrass					X					
Little Rabbitbrush							X			
Halogeton										X

FALL
(LATE FALL-EARLY WINTER)

	Excellent		Good		Fair		Poor		Poison	
	1	2	3	4	5	6	7	8	9	10
Mixed Shrub (High Diversity)		X								
Mixed Shrub (Low Diversity)					X					
Winterfat		X								
Saltbush		X								
Shadscale			X							
Big Sagebrush					X					
Cheatgrass-Shrub					X					
Summercypress						X				
Greasewood					X					
Cheatgrass								X		
Little Rabbitbrush							X			
Halogeton										X

Table 5. Rating of the Range Types for Spring and Fall Sheep Grazing.

SPRING

(Late winter - early spring)

		Pixel Frequency	Acres	Hectares	% of Area	Total % of Area
Excellent	1	853	980	397	4.7	12.3
Excellent	2	1,404	1,613	653	7.6	
Good	3	0	0	0	0	42.1
Good	4	7,718	8,867	3,588	42.1	
Fair	5	3,710	4,262	1,725	20.3	32.0
Fair	6	2,155	2,476	1,002	11.7	
Poor	7	1,651	1,897	768	9.0	9.0
Poor	8	0	0	0	0	
Poison	9	0	0	0	0	4.6
Poison	10	835	959	388	4.6	
Totals		18,326	21,059*	8,521*	100.0	100.0

FALL

(Late fall - early winter)

		Pixel Frequency	Acres	Hectares	% of Area	Total % of Area
Excellent	1	0	0	0	0	12.3
Excellent	2	2,257	2,593	1,049	12.3	
Good	3	1,428	1,641	664	7.8	7.8
Good	4	0	0	0	0	
Fair	5	10,030	11,523	4,663	54.7	58.8
Fair	6	754	866	351	4.1	
Poor	7	1,651	1,897	768	9.0	16.5
Poor	8	1,371	1,575	637	7.5	
Poison	9	0	0	0	0	4.6
Poison	10	835	959	388	4.6	
Totals		18,326	21,054*	8,521*	100.0	100.0

*Differences in area estimates between Tables 3 and 4 due to rounding error.

CONCLUSIONS

This has been an experimental research effort. A number of conclusions can be drawn from the results:

1. Landsat data provide an objective and quantitative means for distinguishing range ecotypes to a more refined degree than is typically mapped through conventional means.
2. Ancillary data, especially the simple soil division of coarse vs. fine texture, assist in providing greater accuracy of map units.
3. Now that this test is completed, large areas could be mapped with a fraction of the effort and time in digital processing, ancillary data use, and aerial photo acquisition and interpretation.
4. This Landsat-based system provides an objective and uniform method for identifying and mapping range cover types on a broad and consistent basis.
5. A Landsat-based system provides a potential foundation for monitoring range trend over time.
6. Classified rangeland maps from Landsat are in digital form and may be readily entered into a data base for resource management.

This analysis has sought to differentiate rangeland types to a fairly refined level, both in terms of cover classes and in terms of spatial pattern. For the land manager, the spatial detail could be easily generalized by running a "spatial" filter through the classification map. This would create larger spatial patterns that are more consistent with a management scale.

APPENDIX

Appendix A: A Sample of the Field Data Form Used by CRSC.

SITE CHARACTERISTICS/ LOCATION FORM

PROJECT: ______________ REGION: ______________
(State or area)
QUADRANGLE: ______________ GENERAL LOCATION: ______________ DATE: ________

GENERAL SITE INFORMATION • • • • • • • FIELD SITE # ________ • • • • • • • •

TOPOGRAPHY		PRINT MAP INFORMATION	
ELEVATION (m):		GENERAL COVER TYPE:	
SLOPE (%):		CLASS SYMBOL:	
ASPECT (deg.):		CLASS NUMBER:	

COVER COMPONENTS	OBSERVATION POINTS A	B	C	D	E	GENERAL
LIFE FORM: SHRUB COVER (%)............						
LIFE FORM: PERENNIAL FORB COVER (%)....						
LIFE FORM: PERENNIAL GRASS COVER (%)...						
LIFE FORM: ANNUAL COVER (%)...........						
TOTAL LIVING COVER– ..						
CRYPTOGAM COVER (%).........						
Total Living Cover						
LITTER COVER (%)................						
SURFACE ROCK COVER (%)..........						
BARE SOIL (less than 1 cm diam.).						
Total to 100%						
PREV. SPP. 1. DOMINANT (code/%).......	/	/	/	/	/	/
PREV. SPP. 2. SUBDOMINANT (code/%)....	/	/	/	/	/	/
PREV. SPP. 3. SUBDOMINANT (code/%)....	/	/	/	/	/	/
PREV. SPP. 4. SUBDOMINANT (code/%)....	/	/	/	/	/	/
PHOTOGRAPH LOG						
PHOTO #1 (roll/#, direction).....						
PHOTO #2 (roll/#, direction).....						
PHOTO #3 (roll/#, direction).....						

COMMENTS: SOIL/EROSION--

LAND FORM--

OTHER--

Appendix B. Common and Scientific Names of Prevalent Species Found in the Study Area.

Big Sagebrush	*Artemesia tridentata*
Greasewood	*Sarcobatus vermiculatus*
Winterfat	*Eurotia lanata*
Shadscale	*Atriplex confertifolia*
Little Rabbitbrush	*Chrysothamnus viscidiflorus*
Saltbush	*Atriplex tridentata* and *A. falcata*
Bud Sage	*Artemesia spinescens*
Alkali Seepweed	*Suaeda fruticosa*
Indian Ricegrass	*Oryzopsis hymenoides*
Bottlebrush Squirreltail	*Sitanion hystrix*
Cheatgrass	*Bromus tectorum*
Summercyprus	*Kochia scoparia*
Halogeton	*Halogeton glomeratus*
Tumblemustard	*Sisymbrium altissimum*
Tumbleweed	*Salsola kali*
Prickly Lettuce	*Lactuca serriola*