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A MULTITEMPORAL APPROACH FOR CLASSIFYING AND MAPPING RANGELAND VEGETATION

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A MULTITEMPORAL APPROACH FOR CLASSIFYING AND MAPPING RANGELAND VEGETATION

By R. H. Haas, J. A. Newcomer,
and E. H. Horvath

1983

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A MULTITEMPORAL APPROACH FOR CLASSIFYING AND MAPPING RANGELAND VEGETATION

By R. H. Haas, J. A. Newcomer, and E. H. Horvath

Technicolor Government Services, Inc.[1/]

ABSTRACT

Rangelands in the Western United States have relatively sparse ground cover and are occupied by a broad array of plant community types. The satellite view of landscapes occupied by rangelands is suitable for capturing the variations in brightness and greenness among plant community types. Principal component transformations of Landsat multispectral scanner (MSS) data were investigated as a means of obtaining brightness and greenness data for temporal analyses of rangelands. The objective was to use the transformed data to classify and map rangeland plant community types in the Grass Creek Resource Area near Worland, Wyoming.

The first and second principal components of Landsat MSS data acquired in June and September 1978, accounted for more than 98 percent of the spectral variation within the respective scenes. When multitemporal transformed data were classified with a maximum-likelihood algorithm, 29 spectral classes were identified.

Agricultural land and riparian vegetation were identified by 8 of the 29 spectral classes. Rangelands, comprising 89 percent of the land area, were identified by 16 spectral classes, which described 8 distinct and ecologically significant rangeland plant community types. Forest/woodland types were identified by two spectral classes and three classes were associated with clouds and cloud shadows.

Transformed variables from principal components analyses of Landsat MSS data were easily interpreted and readily applied to mapping rangeland vegetation. Only three variables, the first and second principal components from June and the second principal component from September data, were required to classify and map ecologically significant rangeland plant community types. The use of multitemporal brightness and greenness values obtained from Landsat MSS data proved to be an efficient means of mapping broad rangeland vegetation types over large areas.

[1/] Work done for the U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota, under Contract No. 14-08-0001-20129.

INTRODUCTION

Landsat multispectral scanner (MSS) data have proven useful for classifying and mapping rangeland vegetation types over large areas. Several studies have demonstrated the utility of MSS data for conducting rangeland inventories and for assessing biomass conditions (McLeod and Johnson, 1980). These studies indicate that the accuracy of Landsat-derived vegetation maps are generally acceptable for many uses, but that some ecologically important vegetation types may not be distinguished by spectral data from a single date.

Rangeland vegetation responds to seasonal weather conditions, yet few studies have investigated the impact of phenological change on spectral response of native plant community types. Rangelands in the Western United States characteristically have relatively sparse ground cover, and the physiognomy of plant community types comprising the ground cover varies greatly. Many of the plant communities have herbaceous vegetation components with definite seasonal growth patterns.

The satellite view of the landscapes occupied by rangeland is suitable for capturing variations in brightness and greenness among plant community types on respective overpass dates (Jenson and Waltz, 1979). It can therefore be hypothesized that brightness and greenness of the scene are important parameters for spectral classification of vegetative cover types. Brightness and greenness are usually highly correlated with the first and second principal components, respectively, of 4-band Landsat MSS data (Jenson and Waltz, 1979 and Kauth and Thomas, 1976). It is generally assumed that brightness, the first principal component, is a function of the amount and color of exposed soil, perennial vegetation cover, and other terrain features that change only slightly within a growing season. Greenness, as measured in the second principal component, normally depends on the seasonal growth characteristics of the plant community types, and is therefore seasonally dynamic.

The transformed variables from principal component analysis are (1) linear combinations of the input data; (2) mutually orthogonal, while explaining as much of the original variability as possible; and (3) equal in number to the input variables. Since the variance attributed to each of the transformed variables from principal components analysis is known, the transformed spectral data become an effective means of data compression (Kauth and Thomas, 1976).

The feasibility of using principal components transformations of MSS data for temporal analyses of rangeland scenes was investigated. The objective of the investigation was to use multitemporal transformed variables to classify and map plant community types that are dominated by warm and cool season vegetation.

STUDY AREA

The Grass Creek Resource Area (GCRA) in north central Wyoming, administered by the Bureau of Land Management, was selected as the study area. Elevation within the 603,000-hectare study area ranges from about 1,200 meters near Greybull, Wyoming, to greater than 3,200 meters along the east side of the Absaroka mountain range. The area extends from the Big Horn River on the east

to the Wood River on the west and contains part of what is called the Big Horn Basin.

Annual precipitation varies widely in the Big Horn Basin, ranging from about 155 mm at Basin, Wyoming, to 760 mm in the Upper Owl Creek region. The climate of the area is characterized by hot, dry summers and cold, dry winters. The study area encompasses irrigated agricultural lands along the rivers, highly eroded "badlands", and naturally occurring plant communities such as salt desert shrub, sagebrush/mixed grass, woodland and forest. The occurrence of plant communities correlates with annual precipitation zones and soils factors that influence plant/water relationships.

APPROACH

Principal components transformations were applied to geometrically corrected Landsat MSS data sets acquired on June 14, 1978 (scene 21233-16553) and September 9, 1978 (scene 30194-17184). Preprocessing of the data included registering to a Universal Transverse Mercator (UTM) map projection, resampling to a 50-m by 50-m pixel size, and masking the project area boundaries. A 1-percent random sample was extracted for both of the 4-band MSS data sets. Transformed images were created for the first and second principal components for both dates of coverage, using the eigenvector loadings derived from the sample data.

An additional principal components analysis was subsequently run on an 8-band image, consisting of the 4-band images from the two 1978 dates.

An unsupervised clustering routine was used to develop training statistics for a 3-band image of the transformed data, which included the first and second principal components from the June data set and the second principal component from the September data set. A maximum-likelihood algorithm was used to classify the scene into 29 spectral classes. These classes were aggregated to 13 land-cover classes based on separability and association with field data collected in June 1981.

A previous study had used nontransformed Landsat MSS data from June 1978 to classify and map 21 vegetation cover types for the GCRA (Haas, and others, 1982). Contingency tables were developed to compare the classes developed from the multitemporal principal components classification with the 21 classes developed previously from the June 1978 scene. The final 13-class cover map developed from transformed data was also compared to field data collected in June 1981.

RESULTS AND DISCUSSION

Principal components analyses of the 4-band June and September 1978 Landsat MSS data sets from the GCRA produced transformation (eigenvector) matrices that were very similar for the two dates (table 1). More than 98 percent of the variation within both spectral scenes was accounted for by the first and second principal components.

When principal components analyses were run on the 8-band image containing both data sets, it became apparent that the second principal component was

Table 1.--Eigenvectors and percent of variance for principal components from June 1978 and September 1978 Landsat MSS data (Grass Creek Resource Area, Wyoming).

MSS Band	Eigenvectors PC-1	PC-2	PC-3	PC-4
		-- June 1978 --		
4	0.4046	-0.2799	0.7384	0.4611
5	.6757	- .4948	- .2565	- .4824
6	.5187	.4031	.4895	.5734
7	.3326	.7171	.3864	.4752
Percent of Variance	87.1	11.8	0.62	0.47
		-- September 1978 --		
4	0.3695	-0.2992	-0.2215	0.8514
5	.6375	- .5448	- .1786	- .5146
6	.5539	.3292	.7612	.0733
7	.3876	.7108	.5827	- .0700
Percent of Variance	87.9	10.8	0.68	0.56

a temporal contrast between the two image dates (table 2). Since the first principal component from the 8-band image accounted for approximately the same amount of spectral variation (87 percent) as the separate 4-band images, it was assumed that the date contrast shown in the second principal component was due to an interaction of spatial greenness with time. Overall greenness in the 8-band image appears in the third principal component.

A decision was made to use a 3-band image, containing the first (PC-1 June) and second (PC-2 June) principal components from the June data set and the second (PC-2 September) principal component from the September data set, for vegetation classification. An unsupervised clustering of the 3-band data identified 29 spectral classes for the GCRA. Brightness/greenness contrasts for June and September are shown in figure 1. Some of the clusters were well separated by brightness (PC-1 June). There was, however, overlap among many clusters. Clusters 14, 19, and 25, for example, were not separated in either June nor September (figure 2). Yet greenness in June and September aided in the separation of the three ecologically important clusters (figure 3). Cluster 19 was confused with cluster 25 in June, while cluster 19 overlapped cluster 14 in September. All three were, however, well separated on the basis of greenness at the two dates.

The 29 clusters were aggregated to 13 cover classes using the mean brightness/greenness values for each cluster and by comparing the data with field data collected in June 1981. Eight of the 29 cover classes were associated with sites having relatively high green biomass in either June or September. They were classified either as being cultivated agriculture or as riparian vegetation (table 3). No attempt was made to label the individual spectral clusters associated with agricultural and riparian vegetation. Since the riparian areas were so small, they were pooled into a single class with the agricultural vegetation.

Thirteen clusters were associated with rangeland vegetation. When aggregated, the clusters defined eight ecologically important plant community types (table 4). Many of the rangeland community types could have been separated by brightness in June; however, slight variations in greenness in June and September were important in the final partitioning of the 13 clusters into 8 plant community types.

Five clusters were associated with forest/woodland plant communities (table 5) and were generally characterized by low PC-1 June brightness values. Snow and cloud cover had very high brightness values and cloud shadow had very low brightness values. Clouds and cloud shadows occupied less than 1 percent of the total area of the scene in June and were not present at all in September 1978.

The final 11 land cover and plant community types identified by the 3-band temporal brightness/greenness image were well separated spectrally (figure 4). The 10 classes of natural vegetation were separated mostly by brightness, and were generally correlated with the amount of standing biomass characteristic of the type. However, the relatively minor variations in greenness were also important to achieve spectral distinction of the broader vegetation classes.

Table 2.--Eigenvectors and percent of variance for first four principal components derived from an 8-band image (June and September 1978) Landsat MSS data (Grass Creek Resource Area, Wyoming).

Date	MSS Band	Eigenvectors			
		PC-1	PC-2	PC-3	PC-4
June 1978	4	0.3307	-0.2893	-0.2782	0.1818
	5	.5357	- .3081	- .4594	.2619
	6	.4375	- .2941	.3542	- .1813
	7	.2929	- .2555	.6268	- .2476
September 1978	4	.2163	.2709	- .1519	- .2807
	5	.3769	.4942	- .2090	- .5317
	6	.3111	.4690	.1470	.2965
	7	.2020	.3635	.3239	.5956
	Percent of Variance	87.1	6.6	4.4	0.9

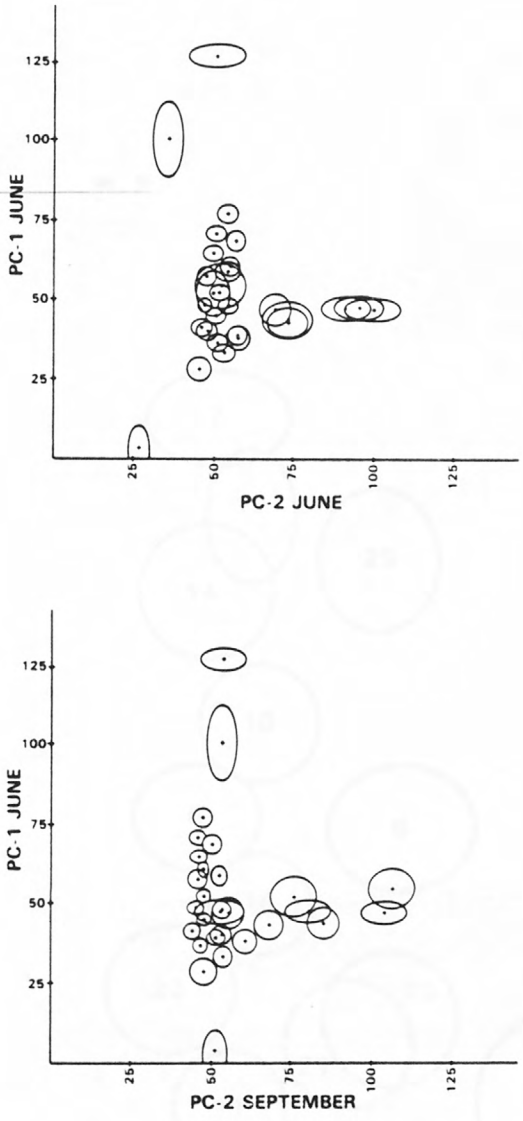

Figure 1. Scatter diagram showing the mean ± one standard deviation (relative values) for 29 brightness/greenness clusters from June and September 1978 principal component images of the Grass Creek Resource Area.

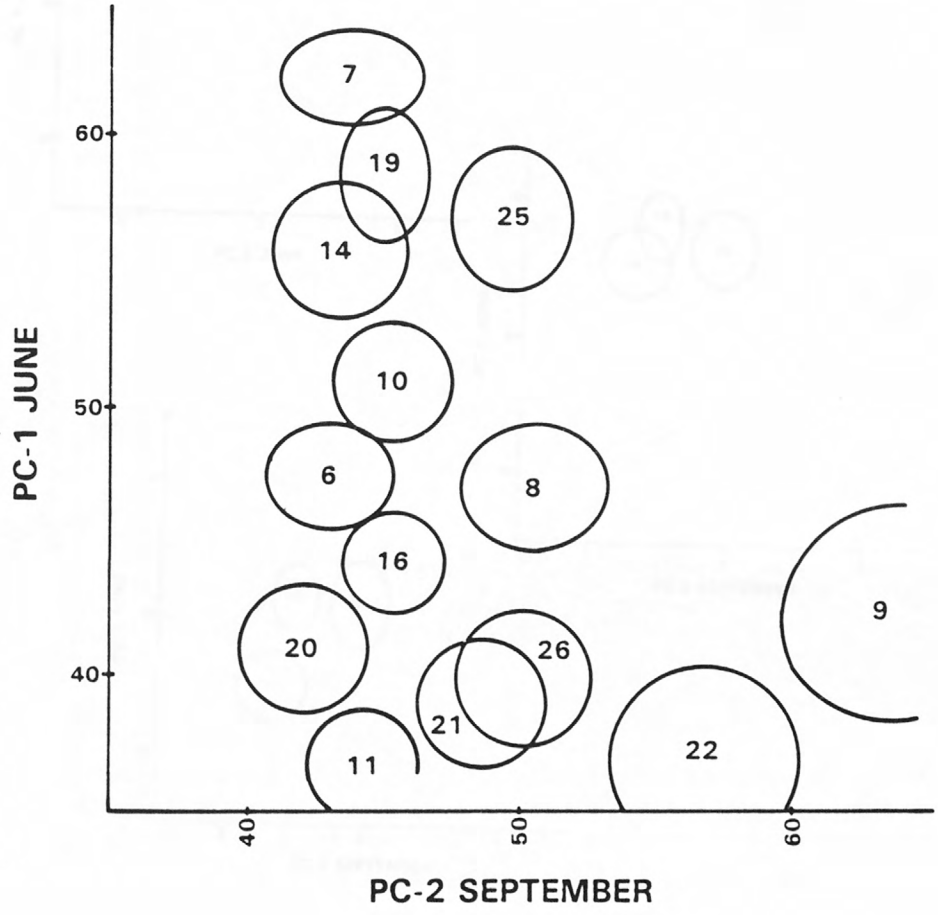

Figure 2. Partial display showing separation of specific clusters (relative values) for a PC-1 June and PC-2 September 1978 comparison.

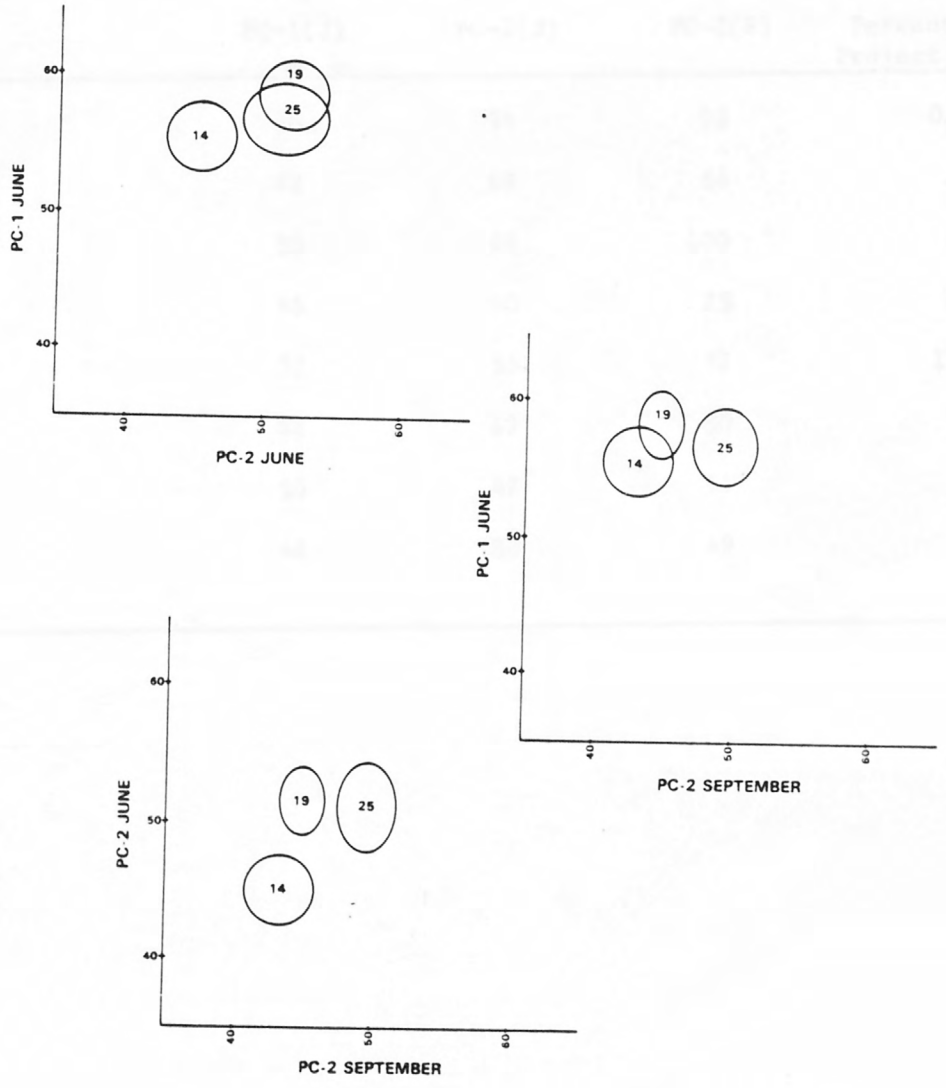

Figure 3. Partial display showing the unique separation of clusters 14, 19, and 25 by greenness in June and September 1978 (relative values).

Table 3.--Mean brightness values for agricultural land and riparian classes and the percentage of each class in the Grass Creek Resource Area.

Class Number	Image Bands			Percent of Project Area *
	PC-1(J)	PC-2(J)	PC-2(S)	
3	46	94	98	0.26
9	42	69	64	.99
13	53	49	100	.35
18	46	90	75	.56
22	37	55	57	1.34
24	42	69	80	.36
28	50	47	71	.77
29	46	86	49	.76

* Project area encompassed 603,000-hectars in the Big Horn Basin, Wyoming.

Table 4.--Mean brightness values for rangeland vegetation classes and the percentage of each class in the Grass Creek Resource Area.

Plant Community Type	Class Number	Image Bands PC-1(J)	PC-2(J)	PC-2(S)	Percent of Project Area*
Low Cover Range	12	75	51	44	6.67
	17	69	48	43	7.73
Low Shrub/Grassland	4	67	54	47	6.21
	7	63	47	43	7.51
Mixed Grass	25	57	51	49	4.13
Bluegrama/Sagebrush	10	51	49	45	9.83
Mixed Grass/Sagebrush	14	56	45	43	7.50
	19	59	52	44	6.25
Sagebrush/Mixed Grass	16	44	48	45	6.60
	21	38	54	49	3.32
Other Shrub/Grass	8	47	52	50	3.55
	27	45	65	52	1.56
Dense Sagebrush	6	47	45	43	8.92

* Project area encompassed 603,000-hectars in the Big Horn Basin, Wyoming.

Table 5.--Mean brightness values for shrub/woodland, forest/woodland vegetation, and cloud shadow classes and the percentage of each class in the Grass Creek Resource Area.

Cover Type	Class Number	Image Bands PC-1(J)	PC-2(J)	PC-2(S)	Percent of Project* Area
Shrub/Woodland	11	36	48	44	3.29
	20	40	43	42	3.74
	26	39	45	50	2.63
Forest/Woodland	2	33	50	51	2.49
	15	28	43	45	1.95
Snow and Cloud Cover	1	122	48	50	.26
	23	97	33	50	.25
Cloud Shadow	5	4	25	49	.21

* Project area encompassed 603,000-hectares in the Big Horn Basin, Wyoming.

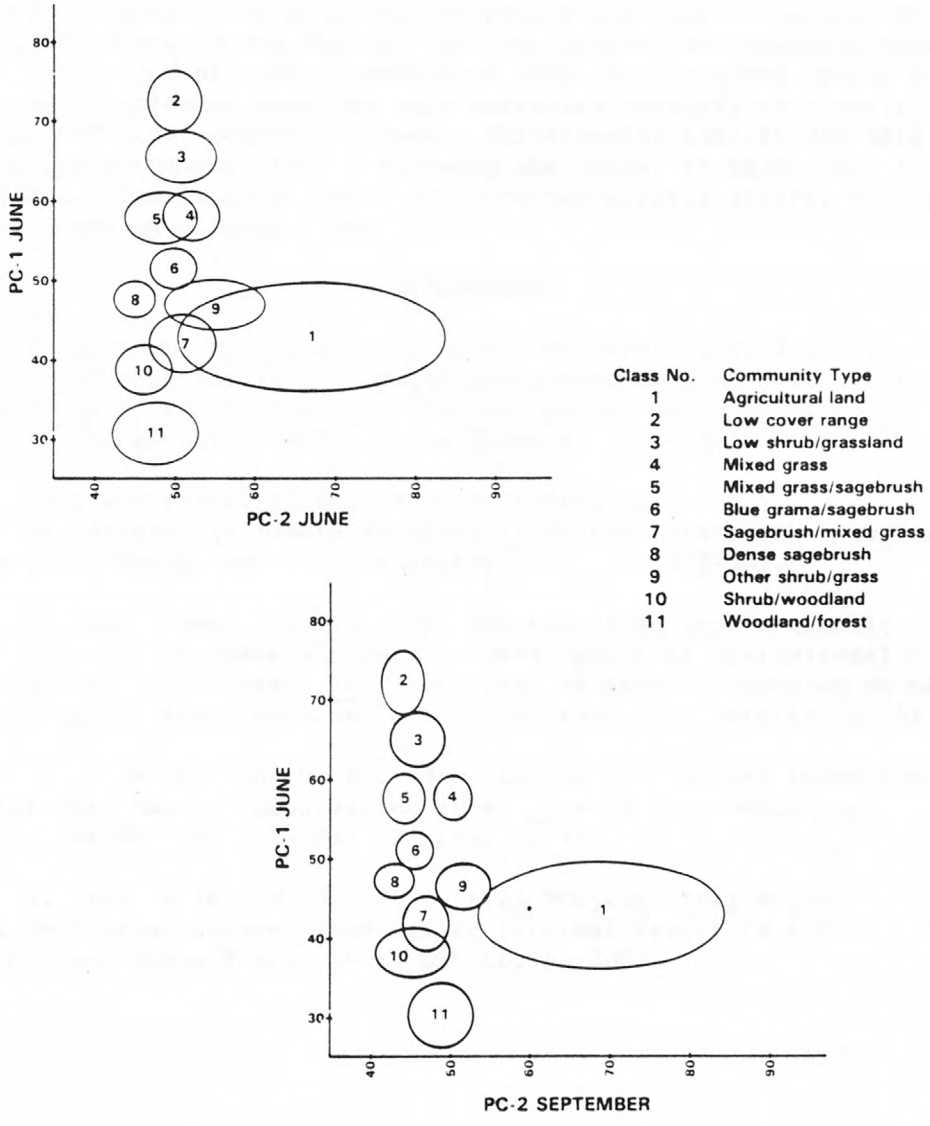

Figure 4. Scatter diagrams showing the relative separation of 11 land cover and plant community types in the Grass Creek Resource Area, Wyoming.

SUMMARY

Scene brightness and greenness, derived from transformed Landsat MSS data collected in June and September 1978 were used to classify and map vegetation in the GCRA near Worland, Wyoming. Eleven land cover and natural vegetative classes were identified and mapped. Eight distinct and ecologically significant rangeland plant community types were described by the multitemporal data.

Transformed variables from principal component analyses of Landsat MSS data were easily interpreted and readily used in classifying rangeland vegetation. The first and second principal components from June, and the second principal component from September were the only variables required to classify the major rangeland plant community types. Transforming Landsat MSS data to brightness and greenness aids in reducing the number of bands used in spectral data analyses. The results appear adequate for mapping general rangeland vegetation types over large areas.

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