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AN APPLICATION OF REMOTE SENSING IN THE
MONITORING OF GRAZING SYSTEMS IN EASTERN MONTANA

By

Lynn Allen Herman

B.S. University of Maine, 1969


Presented in partial fulfillment of the requirements for the degree of


Master of Science in Forestry

UNIVERSITY OF MONTANA

1981

Approved by:


Chairman, Board of Examiners


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An Application of Remote Sensing in the Monitoring of Grazing Systems in Eastern Montana. (81 pp.)

Director: Frederick L. Gerlach *F.L.G.*

Recent judicial action requiring the Bureau of Land Management (BLM) to write environmental impact statements concerning the effects of livestock grazing on lands under their jurisdiction has prompted a need for current range trend data. Historically, time consuming rangeland evaluations have been very costly to conduct because of the need for extensive vegetation related field reconnaissance. Such studies often take years to complete because of the extensive land areas under the jurisdiction of the BLM. Because of the time constraints placed upon the BLM, an approach was needed which would provide general range trend information in a relatively short period of time. This study was conducted to investigate the validity of using a multistage imagery and sampling approach as an alternative method of collecting rangeland vegetation data obtained by field reconnaissance.

The overall multistage technique was designed to include three levels: Landsat imagery at a scale of 1:1,000,000, color infrared (CIR) positive transparencies at a scale of 1:31,680 and a ground based vegetation data system. Twenty-seven sample sites were randomly located on United States Geological Survey (USGS) topographic maps of a 29,956 acre study area located in the Missouri River Breaks region of eastern Montana. An evaluation of the relationships between imagery and ground characteristics was conducted using a discriminant analysis statistical technique. A nonmapping and hierarchical classification scheme was used to evaluate the effect that different grazing treatments had on various cover characteristics of the vegetation.

Results indicated that CIR imagery analysis using a manual density slicing technique, coupled with photo texture, ground aspect and ground configuration, could be used to predict various vegetation cover groups when the discriminant analysis technique was employed. A non-mapping procedure is a viable method of estimating vegetation cover groups and provides baseline data upon which future evaluations will result in inferences about range trend.

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my graduate advisor Professor Frederick L. Gerlach, for his continued support and encouragement on this project. His efforts on my behalf in securing financial support through teaching assistantships is also gratefully acknowledged.

I am also indebted to committee member Dr. E. Earl Willard for his guidance and direction, particularly in developing field techniques for this study. Dr. Darshan Kang was most helpful in serving as the third member of my graduate committee. Duane Whitmer and Fred Batson of the Bureau of Land Management provided advice and made imagery available for the project. Dr. Richard Helfman, Dr. Marten Smith, Dr. Nancy Boynton and Mrs. Margaret Gale of Michigan Technological University helped in reviewing preliminary drafts of this thesis and provided assistance in statistical and computer analysis of the data. Mr. Robert Nelson of Eastman Kodak Company assisted by supplying technical information. Dr. James P. Ludwig of Ecological Research Services, Inc. was most gracious in providing Mrs. Judy Ross to type the final draft of this paper.

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I. INTRODUCTION

During the past two decades, a program applying grazing systems has been implemented on Bureau of Land Management (BLM) lands in the western United States. In the early 1970's, this program was challenged by several environmental organizations. In effect, they claimed that the implementation of grazing programs was being carried out without assessment of the effects that these systems were having on various ecological factors. The resulting federal suit upheld the claims of the environmental groups and the BLM must now assess the environmental impact of various grazing programs. In the state of Montana, the BLM was directed to write environmental impact statements (EIS) for seven geographic regions, beginning with the Missouri Breaks area in 1978 (Appendix Figure 1). To assist the BLM in meeting their requirements, the University of Montana began a field investigation in this area in the summer of 1977.

The study consisted of an investigation in which vegetation differences were examined on various BLM management units. Fence line contrasts were used to compare the response of soil and vegetation subjected to different grazing treatments. These contrasts were defined entirely by using ground measurements of vegetation (Willard and Herman, 1978).

In recent years refinement of photo interpretation techniques and developments of high quality aerial imagery has given the resource manager a valuable tool to evaluate range resources. Studies using a multistage approach have shown success in the evaluation and monitoring of natural resources. Following this design, various scales of imagery

are examined. Successively larger scales are used to subsample the previous stage or smaller imagery scale. The final stage normally involves ground truth for calibration and verification of the system. Application of this approach in studying rangelands in northern Arizona has proven its importance as a management tool.

OBJECTIVES

The purpose of this study was to investigate the applicability of using a multistage imagery and sampling approach to monitor vegetation characteristics on BLM lands in eastern Montana. By comparing this technique to the already completed Missouri Breaks study (Willard and Herman, 1978), we could determine the effects on costs, time spent in the field and on the quality of information. The specific objectives of this study were:

1. To improve the methods of collecting information used to analyze grazing systems on BLM management units in eastern Montana;
2. To determine which vegetation characteristics may be monitored using imagery characteristics;
3. To develop a technique to monitor changes in range trend for vegetation subjected to different grazing treatments;
4. To provide a baseline study to be used as a basis for monitoring future range trends on selected BLM managements units;
5. To determine which interpretation variables may be correlated to range vegetation characteristics.

II. LITERATURE REVIEW

The range specialist has the responsibility to manage range ecosystems consistent with objectives outlined in current public policy doctrine. Increased pressures on the range resource have greatly expanded the manager's need for information upon which to base policy decisions. Technological advances in the field of remote sensing during the past 15 years have been outstanding. Noteworthy, was the launching of Landsat. These satellite platforms and the imagery they have provided, greatly expanded our perspective of the earth and our conscious effort at managing its resources. In discussing Landsat 1 and 2, Freedon (1976) states:

"Designed as a research and development tool to demonstrate the feasibility of systematic remote sensing from Earth orbit for resource and environmental monitoring, the two Landsats have already shown that the application of satellite-acquired data on the Earth's surface is a practical reality".

Inherent with such systems, however, are tremendous quantities of information which may or may not be available depending upon the current state of analytical technology available to the interpreter. Maxwell (1975, cited by Driscoll *et al.* 1978) suggested that the potential or theoretical information which is available from imagery may be far greater than that of the data which is collected on the ground.

The ever-increasing demand for rapid information about natural resources is a common requisite which is not unique to the range management field. Poulton *et al.*, (1975), stated:

"With intensification of the pressure by man upon his resources and the environment, there is a rapidly

growing need for more and better information for multidisciplinary decisions and action programs".

A review of the draft and final Environment Impact Statement for the Missouri Breaks (U.S.D.I., 1979a, 1979b) reinforces the fact that management programs for natural resources are rather complex.

Demands on rangelands have accelerated to the extent that information on the range resource must be continually updated in order to make sound management decisions. Unfortunately, the nature of the resource does not lend itself to rapid evaluation of the vegetative resources using current range resource inventories. Such techniques are time consuming and may require years to complete.

Research on grazing has often been conducted under carefully controlled conditions. Intensive studies have utilized fenced pastures where grazing treatment may be specified. By carefully controlling grazing over a number of years, vegetative responses may be monitored and final conclusions drawn based on the long term changes which have taken place. Most governmental range managers have not had such detailed research, and have had to make decisions based on more general range studies. By necessity, management decisions may be made using range inventory data which do not reflect current trends in the vegetation. BLM lands in eastern Montana are often scattered and not continuous, further complicating the monitoring of range trend and condition.

Area Management Plans (AMP's) have been developed in recent years with the intention being to regulate grazing for range improvements. In lieu of season-long grazing, other systems, such as rest-rotation grazing, deferred-rotation grazing, fall-winter grazing, etc., have been incorporated into the AMP's. The success of any grazing plan, however,

ultimately rests with the rancher or operators who have the federal lease for grazing on any specified area. While some operators may strive to follow a specific management plan, others may not be as conscientious. In periods of drought even the most diligent rancher may be forced to alter from a specified grazing plan. Obviously, there is a need for a monitoring system which will enable the range manager to protect as well as improve the vegetation resource before it is adversely affected.

Recent studies designed to evaluate the use of multistage imagery and sampling techniques to study rangelands have shown promise as a means which is highly adaptable and useful as an information source upon which to make range resource decisions. Colwell (1975) defined a multistage imagery sampling scheme as ". . . one in which progressively more detailed information is obtained for smaller subsamples of the areas being studied". Although its application in the field of range science has been limited, Poulton (1972), Driscoll and Francis (1972), Hironaka *et al.* (1976), Driscoll and Francis (1975), and Francis and Driscoll (1976) all used multistage imagery and sampling techniques to evaluate rangelands.

Poulton (1972) described a study conducted in Maricopa County, Arizona in which Apollo IX color infrared and high altitude color and color infrared photography were combined into a multistage technique. A general classification scheme was developed for use in evaluating each stage of the imagery. Apollo IX imagery was interpreted using primary surface feature classes.

Each primary surface feature class was then further subdivided and secondary classes were used to refine the original satellite image interpretations. The results showed that up to 93% accuracy of delineation

was possible using conventional interpretation techniques coupled with the multistage approach.

Driscoll and Francis (1972) investigated the application of four imagery scales in a multistage technique designed to estimate areas and structures of plant community systems near Roswell, New Mexico. Photography for this study included Apollo IX color infrared imagery enlarged to 1:750,000 as well as conventional aircraft color infrared photography at scales of 1:80,000, 1:20,000 and 1:2400. By subsampling each of the photo series beginning with the Apollo IX imagery, refinement of the interpretations at each stage allowed the investigators to quantify plant community parameters.

Although the number of stages is theoretically infinite, the number of levels of imagery actually chosen for any resource evaluation will, by necessity, be dictated by economic considerations coupled with the objectives of the specific study. If the objectives require generalized information, then fewer levels may be required and at smaller scales. Hironaka *et al.* (1976) used ERTS satellite imagery supplemented with limited high altitude small scale color infrared photography to classify and monitor rangelands in southern Idaho. Varied success was achieved in the delineation of native range types using this system. However, successful interpretation was possible using more generalized categories within such areas as land use mapping, cultivated versus non-cultivated land delineations, recognition of manmade features and in detecting changes in range trend. While visual interpretation techniques were used to derive this information, refinement of delineation was attained using image enhancement, sequential photography and multiband

black and white transparencies. The advantages of satellite imagery over conventional aerial photographs should encourage the use of satellite technology as it relates to generalized rangeland studies. Deficiencies which were overcome in this study by using ERTS frames in lieu of conventional photography included: the small area of coverage obtainable with larger scales of photography, displacements at the edges of the photographs which tended to reduce the effective area available for interpretation and the large amounts of time required to photograph a large area while trying to maintain uniformity of lighting.

Driscoll and Francis (1975) investigated the application of a multistage approach in classifying plant communities in Colorado. ECOCLASS provided a classification system designed to define ecological land units by integrating vegetational and land system hierarchies. ERTS color composites and various scales of color infrared photography were interpreted using conventional procedures. Results showed that the vegetational component of the ECOCLASS system could be refined to the habitat type level of discrimination.

Francis and Driscoll (1976) substituted Skylab color infrared imagery for ERTS frames as the small scale component of the multistage technique used in the 1975 study. Again, various scales of color infrared photography were used to subsample the Skylab imagery. The results indicated that more refined estimates of vegetation classification were possible using this imagery and the ECOCLASS scheme.

Although the multistage technique has shown promise as an important range management aid, to date the system has not been applied in eastern Montana. Various other techniques have been studied, however,

and provide a basis upon which to develop a multistage scheme. Meyer (1973), Cosgriffe *et al.* (1973), Meyer and Gerbig (1974), Batson and Elliott (1975), and Meyer *et al.* (1975) have studied and applied remote sensing techniques in analyzing rangelands in eastern Montana.

Meyer (1973) discussed a 35 mm. aerial photographic system which was developed for use by the BLM in eastern Montana. Because the system is easily adaptable for use in light aircraft, it is currently being used by BLM area offices throughout the state. The simplistic nature of the system which includes a window camera mount and 35 mm. camera, provides an inexpensive way to obtain large scale photography of selected areas of interest to the manager. Using this system it was possible to delineate grazing differentials around cattle exclosures, monitor vegetation changes using photography obtained over subsequent years, and monitor stockpounds as well as browse condition for use in managing wildlife species.

Cosgriffe *et al.* (1973) and Batson and Elliott (1975) investigated the use of small scale color infrared photography to inventory surface resource features on coal lands of southeastern Montana. Batson and Elliott (1975) used 9 x 9 inch (22.9 x 22.9 cm.) color infrared transparencies at a scale of 1:80,000. This photography obtained at the height of green coloration of the vegetation and coupled with ground reconnaissance, enabled interpreters to delineate vegetation types. In addition, they were able to derive information on current land use, soil erosion information, general grazing use approximations, surface hydrology and wildlife habitat values.

Cosgriffe *et al.* (1973) also investigated the use of small scale color infrared transparencies at a scale of 1:40,000 to interpret surface resource features on the coal lands of southeastern Montana. Their vegetation classification scheme was used to type areas of 100 acres (40.5 hectares) or larger. Refinement of classification was possible by supplementing the small scale transparencies with low altitude 35 mm. color infrared photography and ground reconnaissance. They were also able to classify agricultural lands, identify soil erosion conditions, locate water resources, locate porcelonite or red baked shales caused by heat resulting from subsurface coal fires, analyze and monitor mineral extraction and exploration sites, locate burned areas of vegetation, delineate commercial forest stands, locate ranching facilities and identify potential archaeological sites and trails.

Meyer and Gerbig (1974) investigated the applicability of using ERTS imagery and small scale color infrared photography obtained at the height of green coloration in the vegetation to study rangelands in eastern Montana. Specifically, they studied the management potential of information gathered using this approach on the Malta District of the BLM. Various objectives which were investigated included: the feasibility of gathering resource data superior to that collected by ground reconnaissance, to provide management data in less time and at a lower cost by using the imagery in lieu of information collected in the field, to provide the range manager with data which would be more acceptable to the general public and to broaden the manager's understanding of the areas he manages. Results indicated that information obtained from ERTS imagery could be used to make extensive management decisions at the district and state

levels where more general resource decisions are made. Small scale color infrared photography obtained at the height of the green coloration of the vegetation and supplemented with 35 mm. oblique photos can be used to make more specific or intensive management decisions at the district and area levels in the BLM hierarchy.

Meyer *et al.* (1975) investigated the application of conventional interpretation techniques in evaluating surface resources on ERTS imagery of southeastern Montana. Three vegetation delineations were interpreted, including an open grassland and sagebrush type, a Ponderosa Pine type and a broadleaf and agricultural type. Variable results were obtained in attempting to map these types primarily due to commission and omission within any one vegetation type.

While this literature review is not complete with respect to using a multistage remote sensing approach to inventory natural resources, it summarizes the major efforts to date in the range science discipline. The literature reviewed for eastern Montana represents a cross section of important studies which have influenced the use of remote sensing techniques by BLM personnel in the state.

III. STUDY AREA DESCRIPTION

The study area, located in Phillips County Montana, is approximately 60 miles south of the town of Malta on U.S. Highway 191 (Figure 1). It is bordered on the west by the Little Rocky Mountains (Figure 2) and to the south by the Charles M. Russell Game Range which includes portions of the Missouri River and surrounding land commonly known as the Missouri River Breaks (Figure 3). Average annual precipitation is from 10 to 15 inches with most of the precipitation occurring between April and October. The topography of the area is variable and includes gently rolling upland plains to flat benches which gradually slope and integrate with steep sided intermittent drainages and tributaries of the Missouri River.

Grasslands, sagebrush and greasewood dominate as the principal vegetation types of the upland areas (Figure 4) with sparse stands of conifers occupying the drainages close to the Missouri River (Figure 5). Representative species of plants found on the area include: *Bouteloua gracilis*, *Agropyron smithii*, *Agropyron spicatum*, *Artemisia tridentata*, *Sarcobatus vermiculatus*, *Opuntia polyantha*, *Atriplex nuttallii* and *Pinus ponderosa* (A complete list of scientific and common names of plants found throughout the study area is presented in Appendix Table 1.).

The geological formations of the area include the Bearpaw, Judith River and Claggett Formations. The general drainage pattern is dendritic and radiates outward from the Little Rocky Mountains. Head-cutting and channel erosion occur due to thinned vegetation cover resulting from past livestock grazing (U.S.D.I., 1973).

Soils are variable and include: Litmus Clay Loams, Pierre Clay Loams, Laurel Loams, Phillips Loams and Badlands.

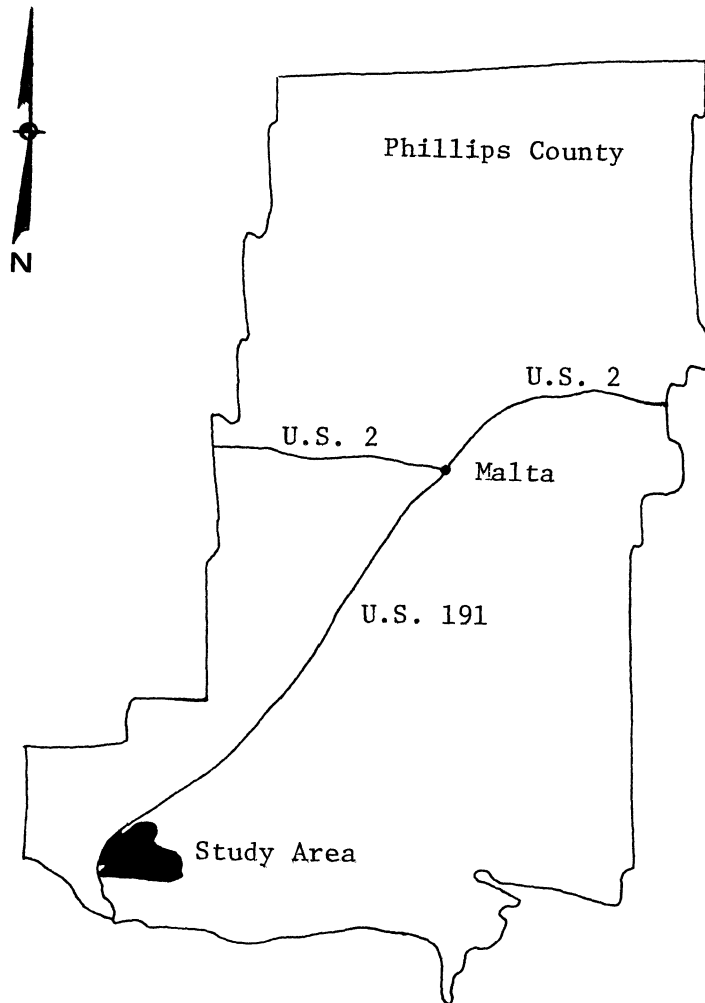
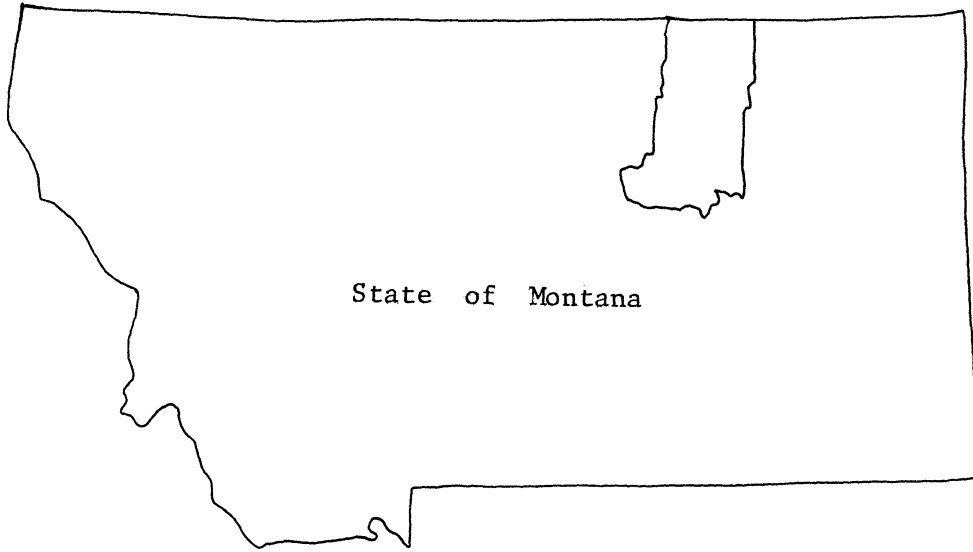


Figure 1. Location of the Missouri Breaks Study Area.

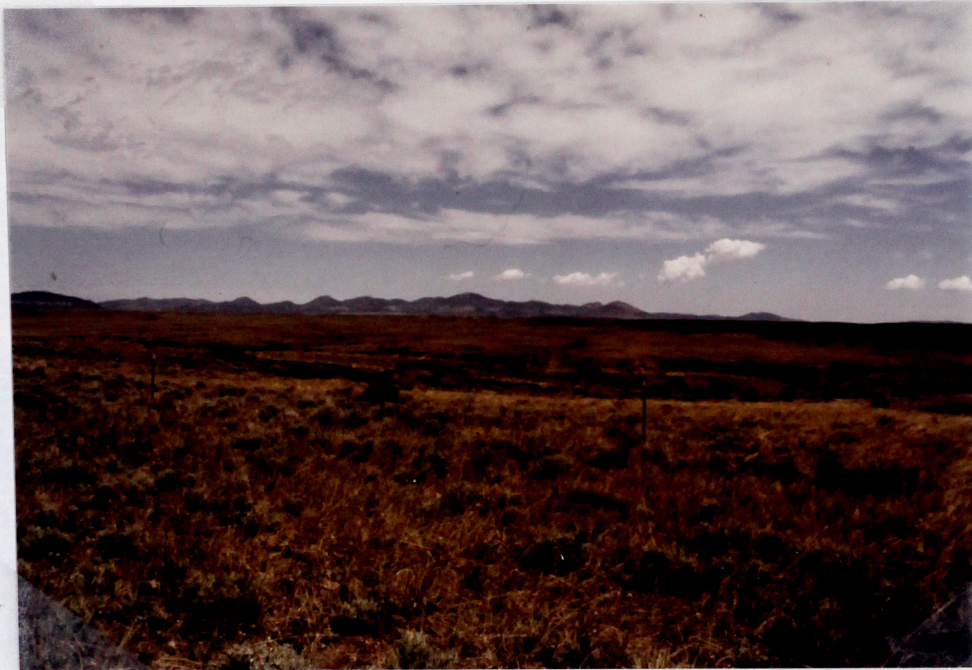


Figure 2. The Little Rocky Mountains located west of the Missouri Breaks Study Area.



Figure 3. The Missouri River Breaks located south of the Missouri Breaks Study Area.



Figure 4. Gently rolling upland plains of the Missouri Breaks Study Area.



Figure 5. Sparse conifer stands occupying drainages within the Missouri Breaks Study Area.

Encompassing approximately 29,956 acres (12,131 hectares), the area was selected for study because of the variety of vegetation types, the availability of existing imagery and diversity of grazing treatments within the boundaries. The area is divided into three BLM management units including Lavelle Creek Allotment, Rock Creek and East Sipperry Ann (Figure 6).

Lavelle Creek Allotment

Lavelle Creek Allotment is a four pasture rest-rotation grazing system with an area of 10,802 acres (4375 hectares). The grazing system was designed to favor the key forage species of *Agropyron smithii*, *Stipa viridula* and *Atriplex nuttallii*. To accomplish this objective a four pasture rest-rotation grazing system was implemented by the BLM in 1969 and was designed to follow four steps. Annually each pasture receives one of the following:

- A. Livestock are turned into the pasture on May 1, and the pasture is grazed for maximum livestock production.
- B. Grazing is deferred until August 5, which is the approximate seed ripening date for *Agropyron smithii*.
- C. The pasture receives complete rest during the growing season.
- D. Grazing is deferred until July 1 to allow for seedling establishment.

During a four year cycle each pasture is grazed according to the formula presented in Figure 7. Pictorially this system is presented in Appendix Figure 2 for the years 1969 to 1980.

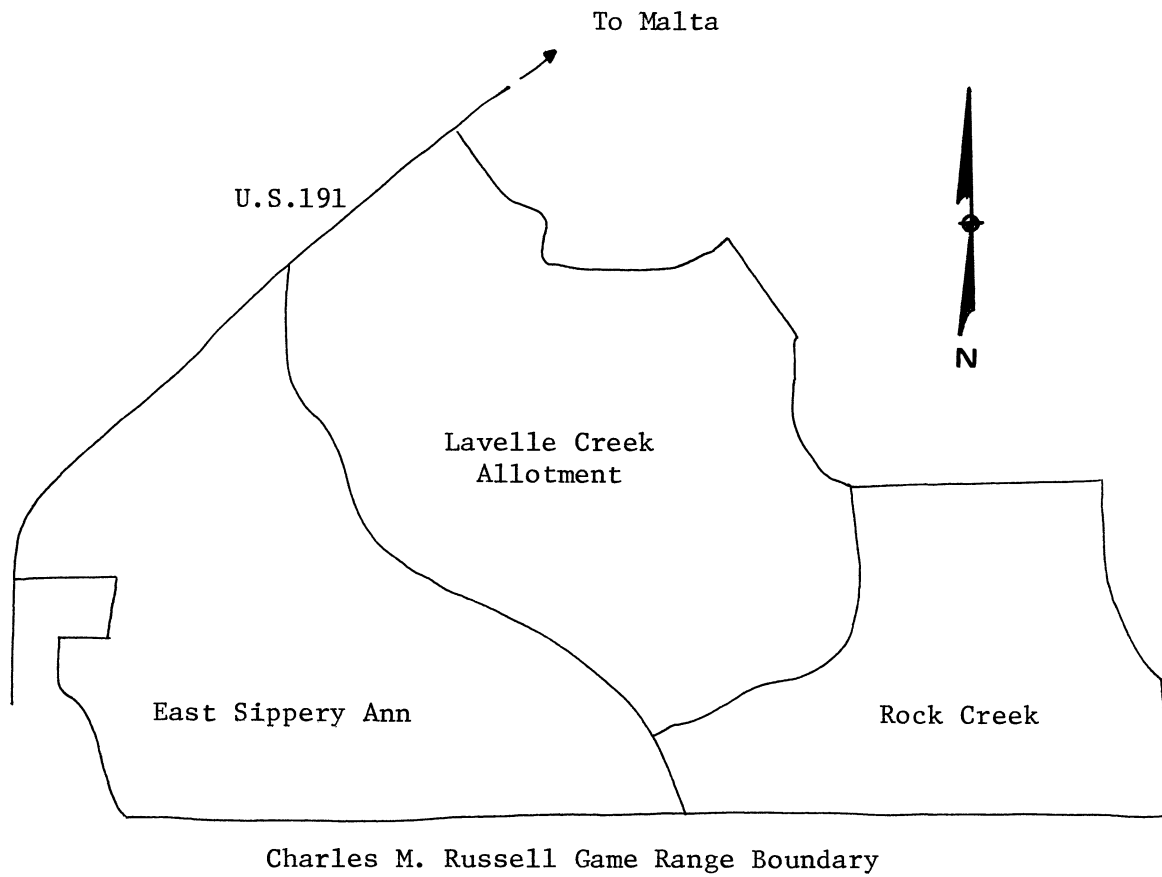


Figure 6. Lavelle Creek Allotment, Rock Creek and East Sipperry Ann BLM Management Units which comprise the Missouri Breaks Study Area.

May 1	July 1	August 5	October 31	
Graze		Rest		(A)
Rest		Graze		(B)
Rest				(C)
Rest	Graze	Rest		(D)

Figure 7. Four pasture rest-rotation grazing formula for Lavelle Creek Allotment.

Rock Creek

Limited information is available from BLM files for this grazing unit which covers an area of 7043 acres (2582 hectares). Licensed for seasonlong use, it has been grazed during the past 20 years from May 1 to October 1 for maximum livestock production. While BLM files do not provide detailed information on past grazing treatments, the severity of grazing has obviously been detrimental as a quick on-the-ground appraisal reveals.

East Sipperry Ann

This grazing unit has had a varied history of grazing treatments and covers an area of 12,111 acres (4904 hectares). Prior to 1973 the area was licensed for seasonlong use for an unspecified number of years. Since East Sipperry Ann lies adjacent to Rock Creek its grazing history prior to 1974 is probably quite similar. From 1974 to 1976 East Sipperry Ann was the third pasture in a three pasture rest-rotation grazing system. This three pasture system was designed to improve the vigor of two species, *Agropyron smithii* and *Stipa viridula*. To accomplish this objective the three pasture system was designed to follow three steps. During its short existence each pasture in the system was subjected to one of the following:

- A. Livestock were turned into the pasture on May 1 and the pasture was grazed through July 31.
- B. Grazing was deferred until July 15, the approximate date of seedripeness of *Stipa viridula*. Grazing was continued through October 31.
- C. The pasture was rested throughout the growing season.

The three pasture rest-rotation grazing formula for East Sipperry Ann pasture is presented in Figure 8. At the end of the 1976 grazing season the plan was discontinued because of difficulties encountered by the grazing association when cattle were moved from pasture to pasture. Since 1977, East Sipperry Ann has been licensed for seasonlong grazing which permits cattle to be grazed from May 1 to October 31.

	May 1	July 15	July 31	October 31	
1974	Graze		Rest		(A)
1975	Rest	Graze			(B)
1976	Rest				(C)

Figure 8. Three pasture rest-rotation grazing formula for East Sipperry Ann Pasture.

IV. METHODS

In designing this study it was felt that a nonautomated approach would be best if a multistage technique was to be of practical value to the range conservationists at local BLM offices. Manual interpretation of both Landsat imagery and 1:31,680 color infrared transparencies was conducted with the latter currently available at local BLM offices. Practical accepted methods of field reconnaissance were employed to collect ground data. All data was compiled in such a manner to make it ideally suited for computer analysis. This exception to the nonautomated design was necessary when it became obvious that manual analysis would have been too laborious. Although currently not available at local BLM offices, recent developments in small, low cost computer technology may make automated analysis at these offices possible in the near future.

Imagery Selection

For purposes of this study, major emphasis was placed upon utilizing existing imagery. Normally, research is proposed, objectives specified and then photography is designed and planned with the objectives in mind. However, financial constraints seem to be an ever increasing problem, and the flexibility to design aerial photography missions for specific projects may have to be altered in the future to accommodate changing economic trends. While imagery available for a specified land mass may not meet the needs of the researcher, the plethora of imagery available from most public agencies tends to minimize this problem. By utilizing existing imagery and designing studies within constraints of

existing photography, land managers may be more inclined to incorporate remote sensing projects into management programs.

A. Landsat

A computer search of Landsat imagery was requested for the months of April through October 1977 for the Missouri Breaks Study Area. This service provided by the EROS Data Center in Sioux Falls, South Dakota, is extremely valuable in that it provides a list of available imagery for a specified area in a relatively short period of time. In addition, the person making the request may specify the minimum quality of the imagery needed. The net result is a fairly concise list of quality imagery from which a person may obtain copies. For this study, a list of imagery with less than ten percent cloud cover was requested. In addition, imagery quality of 9 or better (on a scale of 1-10 with 10 being highest quality) was specified. From this list, multirate imagery in bands 5 and 7 (wavelengths 0.6 to 0.7 μ and 0.8 to 1.1 μ respectively) was purchased in a 7.3 x 7.3 inch paper format at a scale of 1:1,000,000. The five dates selected included: April 9, May 9, July 8, September 12, and October 4, 1977.

B. Color Infrared Photography

Color infrared transparencies (9 x 9 inch) at a scale of 1:31,680 taken in July of 1976 were available at the local BLM office in Malta. These were selected as the second stage because the photography was used frequently by BLM personnel and it was suggested that positive contact transparency copies could be easily made. Precision Photo Laboratories of Dayton, Ohio was contacted and copies were obtained.

Coverage of the study area was secured at a cost of less than one hundred dollars and processing was completed in approximately 2½ weeks. This meant that the BLM transparencies were unavailable for use by the agency for a relatively short period of time.

C. Sampling Scheme and Sample Point Location

A random sampling scheme was used to locate 27 sample points on the study area. It was felt that randomization of sampling units would allow for statistically reliable inferences. Each sampling point was evaluated in the field to provide the basis for relating image data to ground information.

Initially, United States Geological Survey (USGS) 7½ minute quadrangle sheets were obtained for the study area. A mosaic was prepared and an X-Y grid superimposed over the map. A table of random digits provided X and Y coordinates for locating sample points on the USGS sheets. Once located, points were transferred to the color infrared transparencies using a Bausch and Lomb Zoom Transfer Scope. Points were placed on frosted acetate overlays which were registered using the fiducial marks of the color infrared transparencies. By avoiding placement of points directly on the transparencies, obscuring of detail by the marked point was eliminated.

The design of this study necessitated that the same sample point should be interpreted on both stages of photography. Therefore, a grid was prepared and superimposed over the Landsat frames. This grid, based on state plane coordinates, was prepared by locating easily identifiable landmarks on the Landsat frames and relating their location

and position to a small scale map (1"-7.4 miles). Once the grid was completed, location of any sample point was accomplished by calculating its position within the grid system. Again, as with the color infrared transparencies, points were located on frosted acetate overlays to eliminate obscuring of detail by the marked point.

Ground Sampling

Field investigation of the 27 sample points was conducted during mid-June, 1979. Location of sample areas was accomplished by using USGS quadrangle sheets. The location of easily verifiable landmarks such as fence corners and trail intersection, permitted the use of compass and pacing as a means of physically locating each sample point in the field. Once located, two techniques were used to obtain percent shrub cover and to acquire frequency and cover estimates of all species within a sample area.

A. Percent Shrub Cover

A 100 foot (30.5 meter) metal tape was suspended on the over-story shrub canopy at each field located sample point. Intercept by species was recorded along the length of the tape. One trial per sample point was conducted and summations yielded percent shrub cover by species.

B. Species Frequency and Cover Classification

A 7.9 x 19.7 inch (20 x 50 cm) Daubenmire Frame was used to obtain frequency and cover estimates of all species. At each sample area, 10 plots were randomly located along the length of the 100 foot tape. Occurrence by species was recorded for each plot as well as cover

by classes. Visual approximations of cover by species were categorized into one of five groups for each of the 10 sample plots (Table 1).

C. Physical Classification

In addition to vegetative information, various physical classifications were completed for each sample point (Table 1). A Ranger Silva Compass was used to acquire aspect for each area. A Suunta Clinometer was used to obtain percent slope for each sample site. Configuration for each sample area was also recorded. Eight configurations were found to occur among the sites that were sampled. An estimate of soil erosion classes based upon a visual approximation of the percent of surface soil removed from the site was noted. Five soil erosion classes were recognized. And, finally, grazing treatments and the allotment or grazing unit was recorded for each sample area.

Image Interpretation

A. Landsat

A Kodak Gray Scale No. Q-13 was used to quantify information obtained from the Landsat imagery. This scale, with 19 shades of gray, permits the matching of photo tones with those of the scale. Each multi-date frame in both bands 5 and 7 was interpreted using this manual technique. Therefore, each sample point had a total of 10 quantified gray tones.

B. Color Infrared Photography

A variety of manual interpretation techniques were attempted using the color infrared transparencies. While machine processing of

TABLE 1. GROUND SAMPLING CLASSIFICATION SCHEMES USED FOR THE MISSOURI BREAKS STUDY AREA IN 1979.

Species Cover Classes:

- 1 = 0 - 5 %
- 2 = 6 - 25 %
- 3 = 26 - 50 %
- 4 = 51 - 75 %
- 5 = 76 - 100%

Aspect Classes:

- 1 = North
- 2 = South
- 3 = East
- 4 = West
- 5 = Northeast
- 6 = Northwest
- 7 = Southeast
- 8 = Southwest

Slope Classes:

- 1 = 0 - 10%
- 2 = 11 - 50%
- 3 = > 50%

Land Configuration Classification:

- 1 = Flat Upland Bench
- 2 = Side Slope
- 3 = Streambottom
- 4 = Convex Bench
- 5 = Basin
- 6 = Ridge Top
- 7 = Flat Lowland Bench
- 8 = Intermittent Drainage

Soil Erosion Estimates:

- 1. <5 % Low
- 2. 6-15 % Moderate
- 3. 16-25 % High
- 4. >25 % Extreme
- 5. Rodent Disturbance

Grazing Treatments:

- 1 = Seasonlong Grazing
- 2 = Four Pasture Rest-
Rotation Grazing

Allotment or Grazing Unit:

- 1 = Lavelle Creek Allotment
- 2 = Rock Creek Grazing Unit
- 3 = East Sippery Ann Grazing
Unit

imagery often yields more refined information than does a manual approach, automated image analysis is generally not available to the natural resource manager at the local level.

A manual density slicing technique was used to quantify reflectance values in green and red wavelengths of light. Three sheets of centroid color chips were obtained. These sheets: red pink, reddish orange reddish brown, and green were chosen as a basis upon which to make color comparisons. Two chips, vivid red and vivid green, were selected as a standard. Mr. Robert Nelson of Eastman Kodak Company was contacted and a request was made to match the two centroid color chips selected as a standard with two red and green Kodak Wratten Gelatin Filters. Spectrophotometer analysis was conducted by Eastman Kodak Company of the vivid red and vivid green centroid chips. Each chip was analyzed using incandescent tungsten light (2856 K) passed through a #11 filter (Illuminant A) and daylight (6774 K) passed through a #139 (Illuminant C) filter. Trichromatic coefficients ($X_A Y_A$ and $X_C Y_C$) were obtained for both the vivid red and vivid green centroid color chips. Eastman Kodak Company (1978) discussed trichromatic coefficients:

"The trichromatic coefficients X and Y, when used as coordinates of a point in a plane, provide a useful representation of a filter color....The diagram that results, called a chromaticity diagram, is useful for comparing the color of filters that are related to the same standard illuminant."

Trichromatic coefficients for the centroid chips were then compared to those supplied by Eastman Kodak Company for their Wratten Gelatin Filters. A #24 red and a #66 green filter 5 x 5 inches (125 x 125 mm) were selected as having trichromatic coefficients similar to those obtained

for the chips. Table 2 summarizes data supplied by Eastman Kodak Company for both the centroid chips and Kodak Wratten Gelatin Filters.

TABLE 2. SPECTROPHOTOMETER COMPARISONS OF CENTROID COLOR CHIPS AND A #24 RED AND #66 GREEN WRATTEN GELATIN FILTER BY THE EASTMAN KODAK COMPANY IN 1979.

	Illuminant A (Incandescent tungsten light)	Illuminant C (Daylight)
Vivid red centroid chip	X _A 0.6632	X _C 0.5983
	Y _A 0.3168	Y _C 0.3029
#24 Wratten Gelatin Filter	X _A 0.6735	X _C 0.6675
	Y _A 0.3263	Y _C 0.3322
Vivid green centroid chip	X _A 0.3158	X _C 0.2394
	Y _A 0.5442	Y _C 0.4731
#66 Wratten Gelatin Filter	X _A 0.3333	X _C 0.2486
	Y _A 0.5050	Y _C 0.4169

(All X and Y values are trichromatic coefficients.)

The two Wratten Gelatin Filters suggested by the Eastman Kodak Company were purchased in the format previously mentioned. The color infrared transparencies were placed on a light table and each sample point was interpreted by viewing it through the #24 red filter and the #66 green filter. Centroid color chips were then matched to the color observed for each filter. It was soon apparent that the red pink sheet was of little value while the reddish orange reddish brown sheet proved to be superior in matching site colors as observed through the #24 red filter.

Although the number of color chips on the reddish orange reddish brown and green sheets (18 and 20 respectively) were adequate, it

became obvious that the interpreter could distinguish more colors than were available on the centroid color chip sheets. Therefore, a second series of colors was obtained for matching sites viewed through each of the Wratten Gelatin Filters. Paint chip cards for DuPont Lucite Designer I paints provided more colors which could be used in the interpretation technique. Over 80 colors in various shades of red and green provided the improved capability. Each sample point was evaluated again using the set of DuPont paint chips. No attempt was made to try to standardize any of the paint chips with Kodak Wratten Gelatin Filters.

An analysis of texture was conducted using a series of 35mm slides obtained by photographing various grades of sandpaper spray painted a uniform gray color. Kodachrome 64 color slide film was used to produce the texture series. Table 3 summarizes texture classes (including the various sandpaper grits photographed) used to interpret the color infrared transparencies while Appendix Figure 3 shows examples of each of the texture classes.

Various other parameters were estimated and evaluated with respect to the ground data obtained for each sample site (Table 1). Ground aspect classes were obtained from the transparencies. Slope estimates by classes were also determined following the slope classes presented in Table 1. No attempt was made to use photogrammetric techniques to measure slope for any of the sample areas. Site configuration was also interpreted and classified according to the plan presented in Table 1. A purely subjective estimate of soil erosion classes (Table 1) was attempted for each site. And finally, grazing treatment and grazing allowance or unit were recorded for each sample area (Table 1).

TABLE 3. TEXTURE CLASSES USED TO INTERPRET 1:31,680 COLOR INFRARED TRANSPARENCIES OF THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

	<u>Sandpaper Grit Photographed</u>	<u>Texture Class</u>
1 =	600 A	Extra Fine
2 =	80 D	Fine
3 =	40½	Medium
4 =	36 D	Coarse
5 =	24 E	Extra Coarse

Data Analysis

Analysis of the data for this study was conducted using a Univac 1100 Exec. 8 computer located at Michigan Technological University in Houghton, Michigan. A series of programs known as SPSS (Statistical Package for the Social Sciences), has been developed by the National Opinion Research Center of the University of Chicago. This package of preprogrammed options is available at most major universities and provides the research scientist with a choice in selecting an appropriate analytical technique without having to actually design the program.

For purposes of this study, a technique was needed which would: analyze and compare imagery data in conjunction with vegetation data obtained from field reconnaissance, determine the relationship and calculate a function which would express imagery data in relation to the vegetative data, and then using this relationship, predict vegetation characteristics when only imagery data is known. The discriminant analysis program contained within the SPSS package is ideally suited for this type of analysis.

In the introduction to discriminant analysis, Klecka stated:

"Discriminant analysis begins with the desire to statistically distinguish between two or more groups

of cases.... To distinguish between the groups the researcher selects a collection of discriminating variables that measure characteristics on which two groups are expected to differ."

Initially 14 of the 27 sample sites were randomly selected and values for both the discriminating variables and vegetation characteristics were entered into the computer.

In the Landsat analysis, 10 discriminating variables were used in conjunction with one characteristic or vegetation type. Four major groups were defined, coded and evaluated with respect to the 10 variables (Table 4). Each discriminating variable consisted of one coded gray value (1-19) which was obtained by matching Landsat imagery gray tones for each sample site with those available on the Kodak Gray Scale. The analysis of the five multirate Landsat images in bands 5 and 7 in this fashion provided the 10 discriminating variables used in this portion of the program.

TABLE 4. VEGETATION GROUPS WHICH WERE ANALYZED WITH LANDSAT DATA USING DISCRIMINANT ANALYSIS FOR THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

<u>Vegetation Characteristic</u>	<u>Coded Value*</u>	<u>Group</u>
1. Vegetation Type	1	Open Grassland
	2	Grassland/Shrubland
	3	Grassland/Woodland
	4	Non-vegetated

*Coded values for each group are entered into the computer

In the analysis of the color infrared data a variety of discriminating variables were evaluated in conjunction with several vegetation characteristics or groups. Table 5 summarizes the discriminating variables used in this portion of the program, while Table 6 identifies the various vegetative characteristics or groups which were available for analysis in conjunction with these variables.

Once the discriminating variables and groups or vegetation characteristics have been entered into the computer for the 14 sample sites previously mentioned, only discriminating variables are entered for the remaining 13 sites. The SPSS program was then initiated. Outputs from the first portion of the program are linear functions which express the relationship between the variables and groups. Concerning this relationship Klecka, 1975, stated:

"The mathematical objective of discriminant analysis is to weigh and linearly combine the discriminating variables in some fashion so that the groups are forced to be as statistically distinct as possible."

Output from the second phase of the program is the classification of vegetation groupings for the 13 sites in which only the discriminating variables have been entered. Diagrammatically, the discriminant analysis program as it has been applied in this project is outlined in Figure 9.

Evaluation of group predictions for the 13 sites was then carried out by comparing known group values (group values are known for all 27 sites) with those predicted by the computer analysis.

In the final stage of this technique, acreage estimates for each group of interest are calculated. A nonmapping approach after Marcum and Loftsgaarden (1977) permits an investigator to obtain acreage estimates

TABLE 5. DISCRIMINATING VARIABLES OBTAINED FROM 1:31,680 COLOR INFRARED TRANSPARENCIES OF THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

<u>Discriminating Variable</u>	<u>Coded Values*</u>
1. Red Centroid Color Chip Series	1-18 Red Shades
2. Green Centroid Color Chip Series	1-20 Green Shades
3. DuPont Red Paint Chip Series	1-40 Red Shades
4. DuPont Green Paint Chip Series	1-40 Green Shades
5. Texture	1 = Extra Fine 2 = Fine 3 = Medium 4 = Coarse 5 = Extra Coarse
6. Aspect	1 = North 2 = South 3 = East 4 = West 5 = Northeast 6 = Northwest 7 = Southeast 8 = Southwest
7. Configuration	1 = Flat Upland Bench 2 = Side Slope 3 = Stream Bottom 4 = Convex Bench 5 = Basin 6 = Ridge Top 7 = Flat Lowland Bench 8 = Intermittent Drainage

* Coded Values for each group are entered into the computer.

TABLE 6. VEGETATION GROUPS WHICH WERE ANALYSED WITH DATA FROM 1:31,680 COLOR INFRARED TRANSPARENCIES USING DISCRIMINANT ANALYSIS FOR THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

<u>Vegetation Characteristics</u>	<u>Coded Values*</u>	<u>Group</u>
1. Relative Grass Cover	1	0-10%
2. Relative Forb Cover	2	11-20%
3. Relative Ground Cover	3	21-30%
	4	31-40%
	5	>40%
4. Relative Shrub Cover	1	0- 5%
	2	6-10%
	3	11-15%
	4	16-20%
	5	>20%
5. Percent Shrub Cover	1	0-10%
	2	11-15%
	3	16-20%
	4	21-30%
	5	>30%

* Coded Values for each group are entered into the computer.

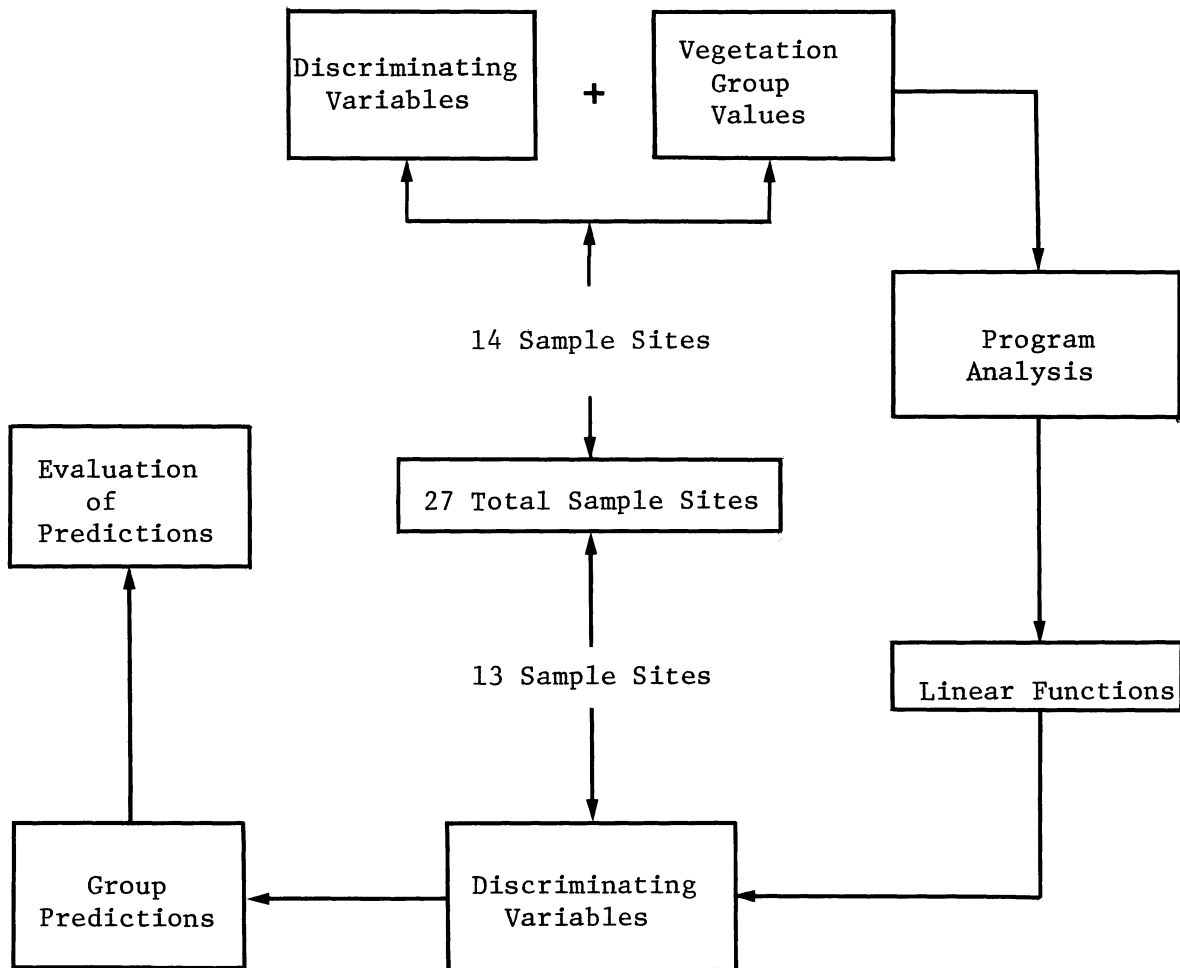


Figure 9. Diagram of the discriminant analysis program as it has been applied to the 1979 Missouri Breaks Study in Montana.

for various environmental situations by calculating proportions for each class within any specified group of interest. For example in the Landsat analysis, the number of sites which fell into each vegetation type (Table 4) was determined from the 27 total sites sampled. These proportions are based on values obtained from the 14 ground verified sites and those predicted by the discriminant analysis procedure for the remaining 13 sites.

After initial acreages were calculated from the Landsat data for each of the four vegetation groups, refinement of each type was carried out according to the hierarchy presented in Figure 10. Note that subgroupings below the Landsat classifications are obtained from data provided by the 1:31,680 color infrared transparencies. The same nonmapping procedure described for Landsat is followed for the color infrared groupings.

In this study, the determination of the various relative cover acreages was used as a measure of grazing response. Comparisons of these cover estimates permitted us to make inferences about each grazing treatment found on the study area. Obviously, the number of subdivisions refined below the Landsat classification is dependent upon the overall objectives of the study which is being conducted. While we collected data on a variety of ecological parameters, the scope of this study restricted the number which were used in the final analysis of this technique. It is interesting to note, however, that by using the hierarchical approach presented above we can compare, for example, the relative grass cover of a shrubland/woodland vegetation type on a north aspect and ridge configuration which has been subjected to seasonlong grazing with another area of similar characteristics but differing only in the grazing treatment.

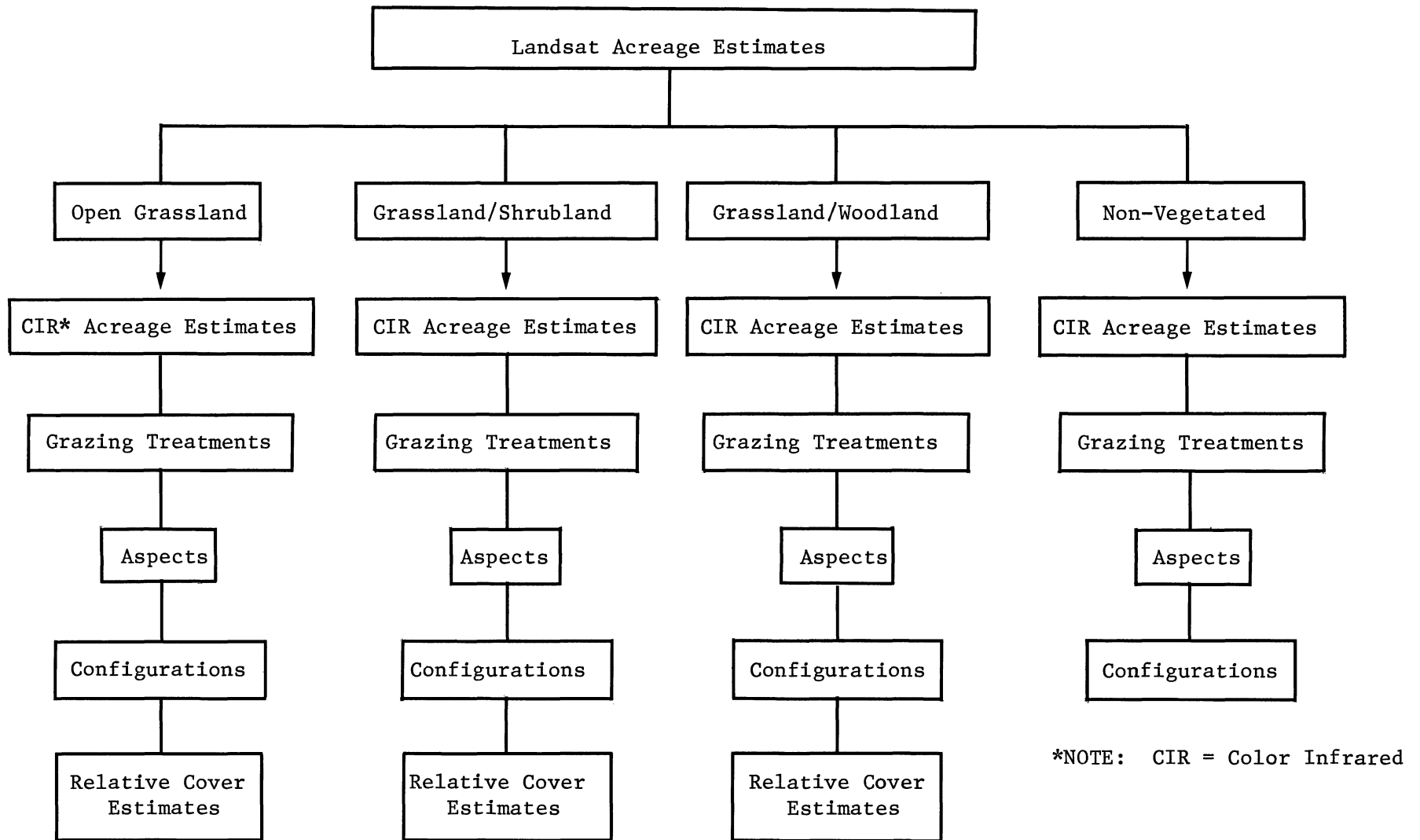


Figure 10. Refinements of Landsat vegetation acreage estimates using data obtained from 1:31,680 color infrared transparencies of the Missouri Breaks Study area, Montana, in 1979. 37

V. RESULTS AND DISCUSSION

In analyzing the data in this study, two options were available in the SPSS discriminant analysis program. In retrospect, because of the limited number of sample sites, a baseline analysis approach might have been more appropriate. Using this technique, all 27 sample sites could have been evaluated without any prediction capability. This, then, would have provided a baseline study with additional research work needed to evaluate the success or reliability of such an approach.

The second method which was used in this study involves an immediate prediction capability (A sample computer printout is presented in Appendix Figure 4.). As previously discussed, the 27 sample sites were randomly divided into two groups (14 and 13 sites respectively). The 14 sites or prediction data were used as a basis for developing prediction functions of groups for each vegetation characteristic (Table 6) within the discriminant analysis program. The remaining 13 sites or test data were then evaluated with respect to these functions. The reliability of the prediction data is expressed as a percentage. This percentage is calculated by taking the prediction functions and reevaluating the prediction data from which each function was originally derived. Reliability of the test data is also expressed as a percentage of correct classification. Whereas, the prediction data classification is calculated by the computer program, test data classification must be manually calculated because the predicted group categories are purposely not available in the data file.

A. Landsat Data Analysis and Results

The most important component of the Landsat analysis technique was the preparation of a grid system which could be used to locate sample points on the Landsat imagery. As you recall, it was desired to evaluate the same sample points on all levels of the multistage approach (i.e. Landsat, color infrared and ground sampling). Therefore, a means was needed whereby sample points could be located on the Landsat frames.

Specially processed Landsat imagery is available from the EROS Data Center, where imagery has been processed and corrected with respect to ground control. The greatest disadvantage to this type of imagery is that it is very expensive to obtain and, therefore, was not considered practical for this project. In lieu of this, "unprocessed" imagery (the standard product from EROS) was obtained at a reasonable expense. The obvious disadvantage to this product is the lack of registration to ground control on the individual frames.

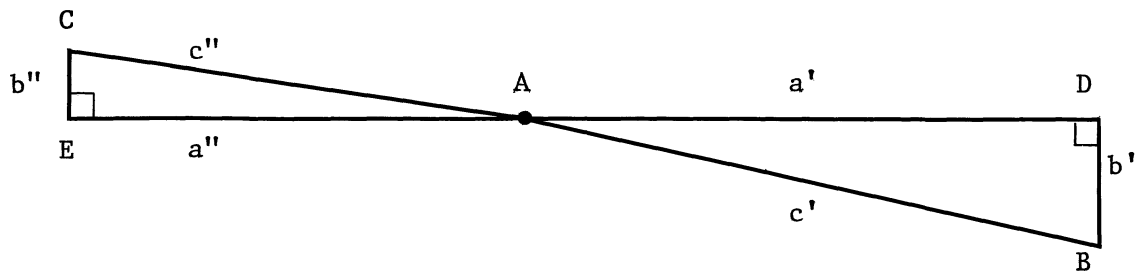
In order to investigate the validity of using a grid system to locate sample points, an artificial grid was superimposed over one of the Landsat frames. An acetate overlay facilitated this process and eliminated the need to write directly on the imagery. Initially, the X axis was placed on the southernmost border of the image with the Y axis perpendicular to it. Note that orientation was not done using geographic coordinates provided at the sides of the imagery because these coordinates are not registered with respect to the imagery.

In order to evaluate the validity of this grid system, three points (A, B, and C with A selected as the origin of the coordinate system) were selected which could be easily interpreted and precisely

located on both the Landsat frame and on a small scale (1"=7.4 miles) map of eastern Montana. These points were located as close as possible to the center of the Landsat frame. Geographic coordinates were obtained for each of the points and state plane coordinates (a Lambert Conformal Projection) were calculated using a Hewlett Packard 97 calculator. Because the points selected were located within the overlap of the North and Central zones, state plane coordinates were calculated twice; once using the North zone constants and once using the Central zone constants (Figures 11 and 12). These same figures (11 and 12) graphically represent the location of points A, B, and C with respect to each other. Initial measurements were obtained for the image distances between A and B (c') as well as between A and C (c''). Right triangles were formed with respect to the superimposed XY grid, and a' , a'' , b' and b'' measurements were obtained directly from the imagery. Landsat measured values for all sides are presented in Figures 11 and 12.

Ground distances were next calculated from the state plane coordinates. Angles CAE and DAB were then determined using these ground distances and the tangent trigometric function (Figures 11 and 12).

In order to check the spatial relationships of B and C with respect to A, distances a' , a'' , b' and b'' (X and Y values) were calculated. Since angles CAE and DAB were known (calculated from state plane coordinates) and Landsat distances c' and c'' were measured directly from the imagery, sides a' , a'' , b' and b'' were calculated using the trigonometric functions of sine and cosine. Lines c' and c'' were selected as a basis upon which to calculate a' , a'' , b' and b'' . because it was initially expected that the orientation of the grid to the imagery would have to be changed.

Geographic Coordinates

A = 47° 37' 41"
 108° 41' 14"
 B = 47° 27' 13"
 107° 54' 05"
 C = 47° 43' 47"
 108° 58' 26"

State Plane Coordinates (feet)

469423.630
 2197897.591
 472429.040
 2389213.789
 468814.870
 2128100.511

Ground Distance
(feet)

a' = 191316.198
 b' = 3005.410
 c' = 191339.803
 a'' = 69797.080
 b'' = 608.760
 c'' = 69799.735

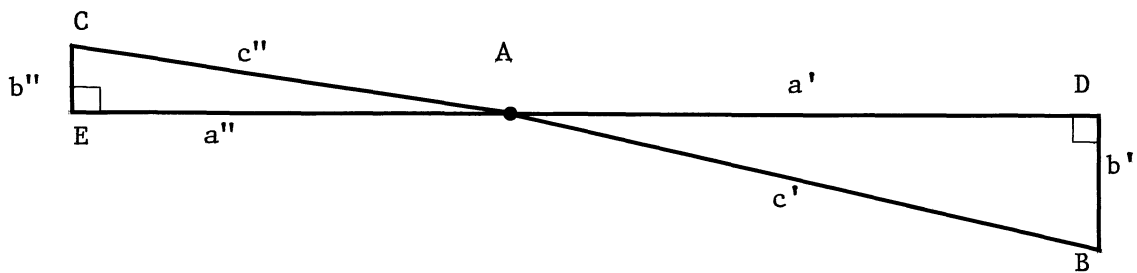
Calculated Landsat
Distance (inches)

2.43
 .03
 2.43
 .87
 .01
 .87

Measured Landsat
Distance (inches)

2.42
 .23
 2.43
 .75
 .26
 .87

Figure 11. Landsat grid control using state plane coordinates calculated from North zone constants for the Missouri Breaks Study Area, Montana, in 1979.

Geographic Coordinates

A = 47° 37' 41"
 108° 41' 14"

B = 47° 27' 13"
 107° 54' 05"

c = 47° 43' 47"
 108° 58' 26"

State Plane Coordinates (feet)

487918.150
 2202159.166

490934.410
 2397595.956

487307.200
 2130859.009

Ground Distance
(feet)

a' = 195436.790
 b' = 3016.260
 c' = 195460.054
 a'' = 71300.157
 b'' = 610.950
 c'' = 71302.774

Calculated Landsat
Distance (inches)

2.43
 .04
 2.43
 .87
 .01
 .87

Measured Landsat
Distance (inches)

2.42
 .23
 2.43
 .75
 .26
 .87

Figure 12. Landsat grid control using state plane coordinates calculated from Central zone constants for the Missouri Breaks Study Area, Montana, in 1979.

Any rotation of the imagery with respect to the grid at the origin A would change X and Y values but not distances c' and c'' . Calculated values for a' , a'' , b' and b'' are presented in Figures 11 and 12.

An evaluation of calculated ground distance values (and extrapolated calculated Landsat distances) obtained using both the North and Central zone constants, indicates that similar data were obtained for both sets of constants (Figures 11 and 12). This is not unexpected because as you integrate between zones or have state plane coordinate points which occur in the overlap region, both sets of constants should yield similar results.

A comparison of calculated and measured Landsat distances reveals some interesting relationships between the values calculated using the state plane coordinates as a basis, and those measured directly from the XY Landsat grid. Because of the geometry of the Lambert Conformal Projection, scale variation in an east-west or X direction is minimal. A comparison of these values in Figures 11 and 12 (a' and a'') obviously supports this fact. Scale variation in the north-south or Y direction with this type of projection should increase particularly as you approach the overlap regions between zones. Comparison of values for b' and b'' again supports this statement. Values for c' and c'' would be variable depending on the distances b' and b'' . If this is true as you increase values in the Y distance, you would expect greater disagreement between calculated and measured c' and c'' values. Note that Y values are relatively small and, therefore, there is relative agreement between c' and

These results are not unexpected and as previously mentioned, no attempt was made initially to orient the XY grid with respect to geographic coordinates on the Landsat frames. As you may recall, it was thought that rotation of the grid about the origin A might be necessary. In this respect, if you rotate the grid in a clockwise fashion thus reducing b' you increase the value of b'' . Similarly, if you rotate the grid about the origin in a counterclockwise direction to decrease b'' , you automatically increase the value for b' . Thus, these rotations in a two dimensional plane do not permit you to match values for the measured and calculated data for b' and b'' . It appears, therefore, that orientation of the map grid and orientation of the Landsat grid are different and simple rotation in a two dimensional plane is not a solution.

Although other options were available for sample point locations on the Landsat imagery, no further attempt was made to investigate their accuracy or validity. In retrospect, if the coordinate system had proven successful a minimum of five orientations would have been necessary; one for each of the five multigate frames. Such an approach would have been time consuming, but certainly not prohibitive.

One alternative would have been to have mathematically adjusted the Landsat coordinate values had orientation parameters been known for the state plane coordinate system. But perhaps the best approach in lieu of a coordinate system would have been to have used a monocular transfer instrument such as a vertical sketchmaster or zoom transfer scope. With Landsat scales of 1:1,000,000 and a map scale of 1:500,000, transfer of

points between the two would certainly be within the capabilities of these instruments provided ground features identified on Landsat could be located on the map.

Because a monocular transfer instrument was not available for use in sample point location at the time when this portion of the study was completed, an evaluation of the relationships between Landsat imagery gray tones and the broad vegetation categories presented in Table 5 was not possible.

B. Color Infrared Data Analysis and Results

As previously mentioned there were five vegetation characteristics (Table 6) which were of interest in this study including: relative grass cover, relative forb cover, relative ground cover, relative shrub cover and percent shrub cover. Each characteristic was then subdivided into five groups and analysis for each site was then based on these groups for each of the five vegetation characteristics.

Five computer programs were developed according to the SPSS format, and each discriminant analysis program was evaluated three times using different discriminating variables for a total of 15 program runs. The first run (Run 1) for each of the five programs involved data for five discriminating variables: a red filter matched with the NCIC color chip series, a green filter matched with the NCIC color chip series, texture, aspect and configuration. The second run (Run 2) also included five discriminating variables where data for the NCIC color chips was replaced by data from the DuPont paint chip series. The third run (Run 3) involved data for seven discriminating variables including both the NCIC and DuPont chip series as well as texture, aspect, and configuration. The ultimate goal then was to predict to which group a site belonged for each of the five broad vegetation characteristics (Table 6).

Table 7 summarizes classification results for prediction data obtained for this study. Keep in mind that these percentages represent correct group classifications based upon a reevaluation of the same data from which the prediction functions were derived. These percentages are, therefore, a measure of the "reliability" of this portion of the discriminant analysis program.

In reviewing Table 7, it is interesting to note that percent success increases as we compare Runs 1, 2, and 3. Recalling that after the initial interpretation work with the NCIC color chips in which the interpreter felt he could differentiate more colors than were available in the series, the differences between Runs 1 and 2 are not surprising. The DuPont paint chip series provided more alternatives and thus improved the reliability of the discriminating variables for Run 2. Run 3 which shows the best reliability was evaluated using seven discriminating variables rather than five as in Runs 1 and 2. Worth noting is that by combining both the NCIC and DuPont paint chip series data, a higher percent success classification is realized in Run 3 than in Runs 1 and 2 where the series are evaluated separately.

In evaluating the vegetation characteristics individually in Runs 1, 2 and 3, it is obvious that the relative forb cover groups were most successfully discriminated. In fact, in Runs 2 and 3, the reevaluation resulted in 100% success. When the vegetation structure of forbs is considered, the reasons for this apparent high success may be explained. Generally, forbs have large leaf surface areas which provide a greater reflectance surface for both the green and near infrared wavelengths. Indeed, in the year 1976 when the photography was taken and in 1979 when ground data was collected, both of these years were considered to have had above average precipitation on the study area. Many forbs and, in particular, *Melilotus officinalis*, occur only during wet years. In 1978, when some preliminary work was done in the area, the Missouri Breaks experienced below average precipitation and *M. officinalis* was not present. Therefore, the occurrence of greater numbers of forbs during

wet years and, in particular, during 1976 and 1979 certainly influenced the high discriminating success of the forb cover groups.

Relative grass cover group discriminations show the general trend of increasing reliability when the three runs are compared. Because most of the vegetation types that occur in the Missouri Breaks Study Area are dominated by grasses, it probably is second only to forbs as the most important component in reflectivity within the stands. The photography which was flown in July, 1976, was timed to coincide with the height of green coloration (i.e. peak maturity of the grasses). This, then, may account for the high success with which the relative grass cover groups were discriminated.

Relative ground cover figures appear to be unusually high when you consider that only the litter component was used to provide the data base for the groups. On many of the sites, litter was minimal and certainly provided the least amount of reflectance of any of the vegetation characteristics. However, because the total amount of vegetative cover seldom approached 100% on any of the Missouri Breaks Study Area, there was a considerable amount of bare soil surface area which undoubtedly accounted for a major portion of the reflectivity of this component. On areas where high litter cover occurred, lesser amounts of bare soil were exposed and conversely on areas with low litter cover, larger soil surface areas were exposed. However, reflectance in the green and near infrared wavelengths probably would be similar and the actual photo reflectance measured included both bare soil as well as litter cover. This, then, would account for the high success of the relative ground cover groups. Perhaps a more appropriate

TABLE 7. CLASSIFICATION RESULTS FOR THE COLOR INFRARED PREDICTION DATA FROM THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

SPSS Discriminant Analysis Program Runs

	Run 1	Run 2	Run 3
	5 Discriminating Variables Including: NCIC Color Chips (red and green filters) Texture Aspect Configuration	5 Discriminating Variables Including: DuPont Paint Chips (red and green filters) Texture Aspect Configuration	7 Discriminating Variables Including: NCIC Color Chips (red and green filters) DuPont Paint Chips (red and green filters) Texture Aspect Configuration
Relative Grass Cover	78.57%	85.71%	92.86%
Relative Forb Cover	92.86%	100.00%	100.00%
Relative Ground Cover	71.43%	85.71%	92.86%
Relative Shrub Cover	64.29%	64.29%	71.43%
Percent Shrub Cover	78.57%	71.43%	92.86%

ground measurement might have been total surface area not covered by living material in lieu of only a little component assessment.

It is rather surprising to note that of the five vegetation characteristics, both relative shrub cover and percent shrub cover have the least discriminating success. Only in Runs 1 and 3 did percent shrub cover approach the discriminating ability of the other three vegetation characteristics. When a vegetation stand is first viewed, particularly in a grassland region, the shrubs appear to be the most obvious vegetation component in the stand. This perception by the observer is the result of the large woody surface area, the large form or crown of the shrub, and the height of each shrub plant above the grass canopy. If, however, you look at the leaf surface area of most plains shrubs which accounts for most of the reflectivity, it becomes obvious that this area is relatively small. The principle shrub species which occurs on the study area is *Artemisia tridentata*. Not only is the leaf area small, but in most instances, the number of leaves on each *A. tridentata* plant is relatively sparse. This, coupled with the fact that individual plants are scattered intermittently throughout most stands, would reduce the ability to discriminate these two vegetation characteristics on small scale color infrared photography which was used in this study. Another factor which undoubtedly influenced the reflectivity and the subsequent interpretive success of these two characteristics is the fact that the key vigor of most shrub species occurs in late summer. Since the photography was flown in mid-July, this time period did not coincide with the height of vigor for most of the shrub species on the area. This certainly would be apparent in the reflectivity of the green and near infrared wavelengths

and possibly reduce the value of the discriminating ability. There are minor differences in Table 7 between relative shrub cover and percent shrub cover and this is not unexpected when you recall that these two characteristics were obtained using different sampling techniques.

A review of Table 8 reveals that the ability to use discriminant analysis to successfully predict group memberships for each of the vegetation characteristics is relatively poor. The discriminant analysis program provides a first highest and second highest probability that a site belongs to a specified group for each of the characteristics. Percentages presented on the left side of each run represent the success of correct classification for only the first highest probability in each case. Numbers in parentheses represent the success of correct classification when a group has been correctly identified in either the first or second highest probability. Results presented in Table 8 for the first highest probabilities are obviously unacceptable where the highest success realized is only 46.15%. By looking at the combination of probabilities, however, moderate success was achieved and will be discussed with respect to each of the vegetation characteristics.

Perhaps the single most important factor influencing the results presented in Table 8 was the limited number of sample sites that were used in this study. It was apparent from the onset that 27 sites would not be a sufficient number for a complete and thorough evaluation of this technique. While the number of photo sites obviously could have been increased without much additional effort, the number of ground sites visited proved to be the limiting factor. While field work is by necessity expensive and time consuming, 27 field sites were completed within the

TABLE 8. CLASSIFICATION RESULTS FOR THE COLOR INFRARED TEST DATA FROM THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

SPSS Discriminant Analysis Program Runs

	Run 1	Run 2	Run 3
	5 Discriminating Variables Including: NCIC Color Chips (red and green filters) Texture Aspect Configuration	5 Discriminating Variables Including: DuPont Paint Chips (red and green filters) Texture Aspect Configuration	7 Discriminating Variables Including: NCIC Color Chips (red and green filters) DuPont Paint Chips (red and green filters) Texture Aspect Configuration
Relative Grass Cover	30.77% (46.15%)*	38.46% (61.54%)	38.46% (61.54%)
Relative Forb Cover	23.08% (38.46%)	23.08% (30.77%)	23.08% (38.46%)
Relative Ground Cover	30.77% (53.85%)	23.08% (53.85%)	23.08% (61.54%)
Relative Shrub Cover	38.46% (76.92%)	46.15% (76.92%)	46.15% (76.92%)
Percent Shrub Cover	23.08% (46.15%)	30.55% (53.85%)	15.38% (53.85%)

*(%) means combined first and second highest probability of correct classification within each vegetation group.

constraints available on the project. As previously mentioned, a more appropriate approach would have been to have used the 27 sites as prediction data and then evaluated the classification success (as presented in Table 7).

A second factor which influenced the results was that while sample sites were evaluated in a random fashion, vegetation groups may not have had a random distribution on the study area. The application, therefore, of a randomized study technique to a non-randomized set of data influenced the results which were obtained in this portion of the study.

A third factor which undoubtedly influenced the test data results presented in Table 8, was the fairly specific group categories which were assigned to each vegetation characteristic (refer to Table 6). While the discriminant analysis programs were not rerun with more generalized categories, reliabilities may have been increased in the classification portion of this study.

A final factor which influenced the results was the selection of discriminating variables which were used in the discriminate analysis program. The seven variables selected were chosen because it was felt that they provided the most reliable data of any obtained in the study. This is not to say, however, that other variables might not have provided more discriminating capability.

It is difficult at best to discuss the results of Table 8 when the best reliability obtained was 76.92% correct classification. While predictions based upon the first highest probability of belonging to a specific vegetation characteristic group are unacceptable, when the

first and second predictions are combined, some interesting results are available for discussion.

Relative grass cover, relative ground cover and percent shrub cover show relatively similar results with Runs 2 and 3 showing the best results. Again, as in Table 7, the use of the DuPont paint chip series seems to improve the classification success.

Interesting to note are the results for relative forb cover and relative shrub cover. Both appear to have contradictory results when compared with prediction data success in Table 7. Relative forb cover shows the lowest success in the test data while having the highest reliability in Table 8. Relative shrub cover, on the other hand, shows the best reliability in Table 8 while having the poorest reliability in the prediction data evaluation. When both tables are considered, it would appear that relative shrub cover has the most consistent discriminating ability while forb cover has the most unreliable.

C. Nonmapping Results

A nonmapping technique after Marcum and Loftsgaarden (1977) was used to estimate various acreages within the study area. Because all 27 sample sites have verifiable ground data, it solely will be used to predict acreages. In a large scale application of this technique, however, nonverified sample sites (predictions of ground characteristics using discriminant analysis) would be combined with those verified to make predictions.

To illustrate the general application of this approach, it was desired to estimate the number of acres which occurred in each of the three grazing units; Lavelle Creek (LC), Rock Creek (RC), and East Sippery Ann (ESA). The probability (P) that a random sample point falls into any one of the three grazing units is:

$$P_{(LC)} + P_{(RC)} + P_{(ESA)} = 1$$

These probabilities are determined by taking the number of sample points falling in each unit and dividing it by the total number of sample units (27). Acreage estimates are calculated by multiplying the probabilities for each unit times the total known acreage of the study area. Table 9 summarizes data obtained using this procedure.

A review of Table 9 indicates that acreage estimates are relatively satisfactory (the greatest difference is Rock Creek with a 3700 acre error) when you consider that these estimates are based only on 27 sample sites. An increase in the number of sites would certainly reduce this difference and as Marcum and Loftsgaarden, 1977, stated:

"During actual field studies (Marcum, 1975) estimates of areas of habitat categories obtained by the random points method were compared with areas determined by using a planimeter; no significant differences were found. In highly diverse environments, the random points method is probably superior to mapping due to the difficulty in obtaining good planimeter estimates."

In a full scale application of this procedure, the next step would be to refine each of the acreage estimates presented in Table 9. This process would follow the scheme previously presented in Figure 10 with the final estimates being made for the various cover groups. While no attempt was made to do this (27 sample sites was not enough to make accurate estimates), the procedure is valid and would provide a baseline data base upon which future evaluations could be compared and inferences about range trend drawn. For example, if shrub cover estimates increased on an area subjected to seasonlong grazing and decreased on an area grazed using a rest-rotation system, inferences could be drawn about the grazing pressures. Obviously other factors would be considered but this simple example does show the potential value of this technique.

One disadvantage to using this system is that as you refine each acreage estimate in the hierarchial system (Figure 11), there is a tendency to compound the error with each subsequent level. It is not felt that this would be prohibitive because all reevaluation comparisons would be done using the same approach and differences would be relative with respect to each other.

In looking at the overall multistage technique, two other problems need mentioning which provided some difficulties in this study. First, it is very difficult to expect to locate the same sample point

TABLE 9 . GRAZING UNIT ACREAGE ESTIMATES FOR THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

	<u>Lavelle Creek</u>	<u>Rock Creek</u>	<u>East Sippery Ann</u>	<u>Totals</u>
Number of Sites	12	3	12	27
Probabilities (P)	.444	.112	.444	1.000
Known Acreages	10,802	7,043	12,111	29,956
Acreage Estimates (P x total area)	13,313.8	3,328.4	13,313.8	29,956

through all levels of the system. Field location, in particular, was difficult when only the USGS maps were used. Black and white photos of the color infrared in a paper format which could have been used in the field would have been very valuable in this regard. A second problem was the difficulty encountered in color matching the chips with the imagery colors under the red and green filters. The main problem was that the interpreter could differentiate more colors than were available even using the DuPont Paint Chip series.

It was not the intent of this research effort to over-simplify interpretation procedures in a complex application of a remote sensing technique. All too often research investigations result in procedures and techniques which are of little practical value at management levels of resource organizations. Emphasis, therefore, was placed on evaluating manual interpretation approaches in lieu of potentially more reliable automated processing of imagery. While results obtained in this study are less than optimum, it is felt that further investigations and subsequent refinement of the multistage technique would provide a viable alternative to laborious and costly field related range studies.

In reviewing this study, there are several areas where improvements could have been made which would have improved the validity of this research effort.

1. An increase in the number of sample sites would have improved the reliability of the results considerably. A total of 27 sample sites is less than satisfactory and was the weakest point of this study. Statistical techniques should be used to delineate the appropriate number of sample sites.
2. The size of the study area should have been increased to take full advantage of the Landsat and color infrared coverage. This technique lends itself toward a large scale application and 29,956 acres is simply too small an area on which to evaluate its potential. On the Landsat frame, the study area covered approximately one square inch out of the 50 available.

3. A monocular transfer instrument should have been used to locate sample sites on the Landsat imagery. This would have permitted an evaluation of the relationships between image gray tones as measured by a Kodak Q-13 Gray Scale and the Landsat vegetation groups using the discriminant analysis procedure. This also would have provided the opportunity to investigate the value of the multirate and multiband Landsat frames.
4. A third imagery stage of large scale photography would have permitted additional refinement and discriminations of vegetation parameters.
5. Soil types should have been evaluated and included within the system. Inclusion of soil types as a discriminating variable would have improved the results of the color infrared classification. This would have been particularly valuable when you consider that changes in vegetation parameters are often closely associated with changes in soil types.
6. The study should also have been broadened to determine to what extent other factors such as soil erosion, soil compaction, livestock concentration areas, etc. could have been evaluated with respect to imagery characteristics.

VI CONCLUSIONS

In this study we have looked at the feasibility of applying a multistage image sampling technique in the evaluation of grazing systems in eastern Montana. In order to accomplish this objective, the following technique was developed which permitted a comparison of imagery characteristics with various vegetation parameters obtained by generalized field sampling:

1. Landsat and 1:31,680 color infrared imagery was used in conjunction with ground reconnaissance in a multistage photographic study;
2. Sample sites were randomly located and evaluated in each stage of the process;
3. Evaluation of the relationships between imagery and ground characteristics was conducted using a discriminant analysis statistical technique;
4. A nonmapping and hierarchial classification scheme was used to evaluate the effect that different grazing treatments have on various relative cover characteristics of the vegetation.

In the strict sense of the word, this study was not a true multistage approach because of the difficulties encountered in sample point location on Landsat imagery. The manual development of a Landsat grid coordinate system on bulk processed Landsat imagery was not possible when related to a small scale map coordinate system based upon state plane coordinates (Lambert Conformal Projection). Color infrared imagery at a scale of 1:31,680 however, provided the necessary imagery

characteristics for comparison to ground related vegetation parameters.

These characteristics included:

1. Near infrared reflectance as measured by matching sample site colors with an NCIC color chip and DuPont paint chip series;
2. Green wavelength reflectance as measured by matching sample site colors with an NCIC color chip and DuPont paint chip series;
3. Texture as measured by comparing transparency textures with a standard made by photographing various sandpaper grits;
4. Sample site aspect as determined on the color infrared transparencies;
5. Ground configuration as evaluated on the transparencies.

This research effort shows that it is possible to evaluate grazing systems as well as to provide baseline data for future reevaluations of these systems. The basis for these evaluations is a nonmapping approach which can be used to estimate acreages for the following vegetation cover groups:

1. Relative grass cover;
2. Relative forb cover;
3. Relative ground cover;
4. Relative shrub cover;
5. Percent shrub cover.

Changes in these cover estimates would also permit inferences about range

trend on areas subjected to specific types of grazing treatments. The basis for this nonmapping procedure is the use of a discriminant analysis statistical technique. This is a viable method of relating vegetation parameters to imagery characteristics. Inherent within this system is the ability to predict vegetation parameters when only the imagery characteristics are known. In a widespread application of this method a minimum of ground sampling would be needed to calibrate the system thus allowing the rapid evaluation of large land areas of interest which might not otherwise be possible.

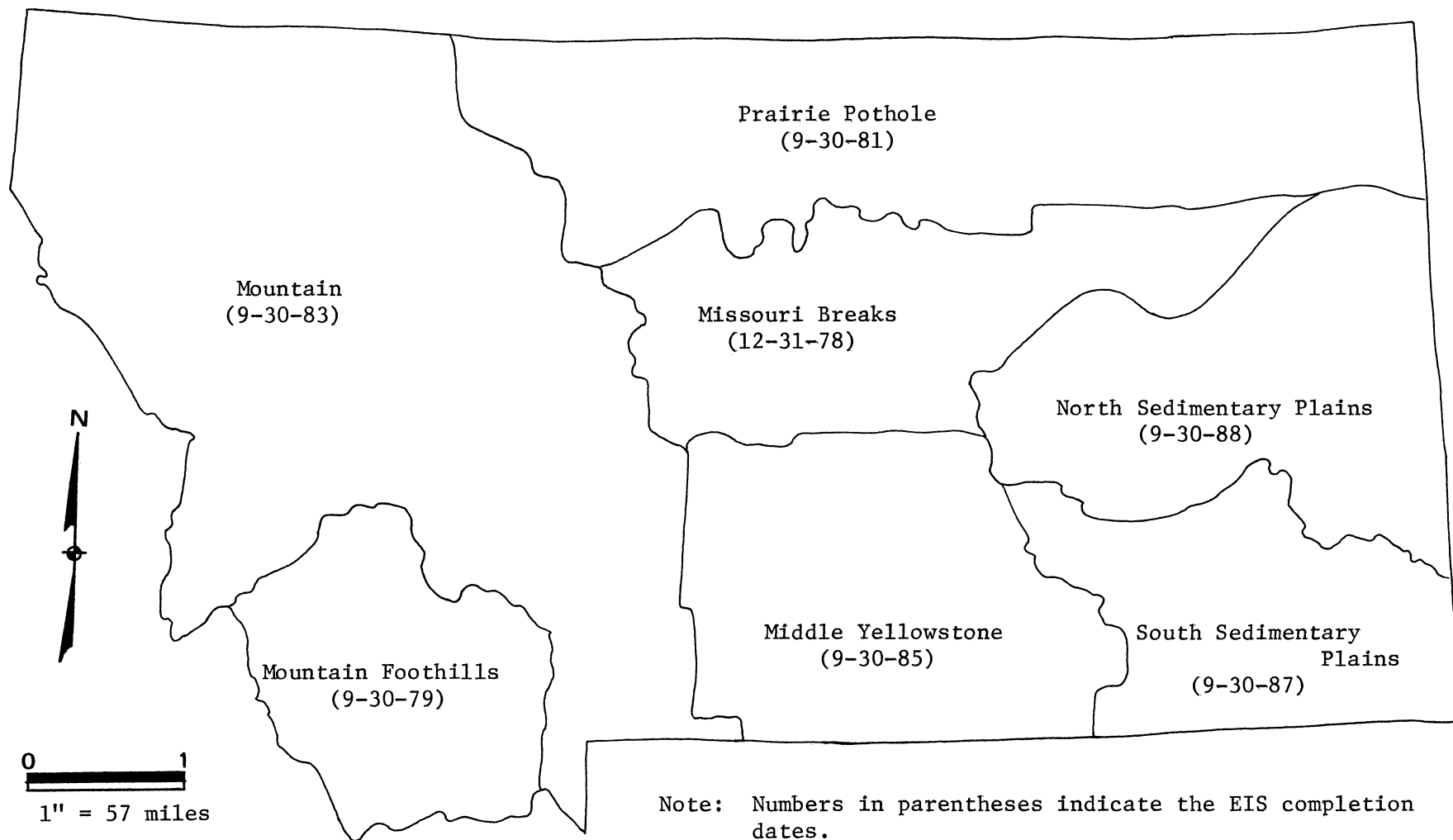
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APPENDIX



APPENDIX FIGURE 1. BLM EIS REGIONS AND EXPECTED COMPLETION DATES FOR THE STATE OF MONTANA.

APPENDIX TABLE 1. SCIENTIFIC AND COMMON NAMES OF PLANTS FOUND
THROUGHOUT THE STUDY AREA.

Grasses:

<i>Agropyron smithii</i>	Western wheatgrass
<i>Agropyron spicatum</i>	Bluebunch wheatgrass
<i>Bouteloua gracilis</i>	Blue grama
<i>Calamovilfa longifolia</i>	Prairie sandreed
<i>Hordeum jubatum</i>	Foxtail barley
<i>Koeleria cristata</i>	Prairie junegrass
<i>Poa secunda</i>	Native bluegrass
<i>Schedonnardus paniculatus</i>	Tumblegrass
<i>Stipa viridula</i>	Green needlegrass

Sedges:

<i>Carex filifolia</i>	Threadleaf sedge
------------------------	------------------

Shrubs:

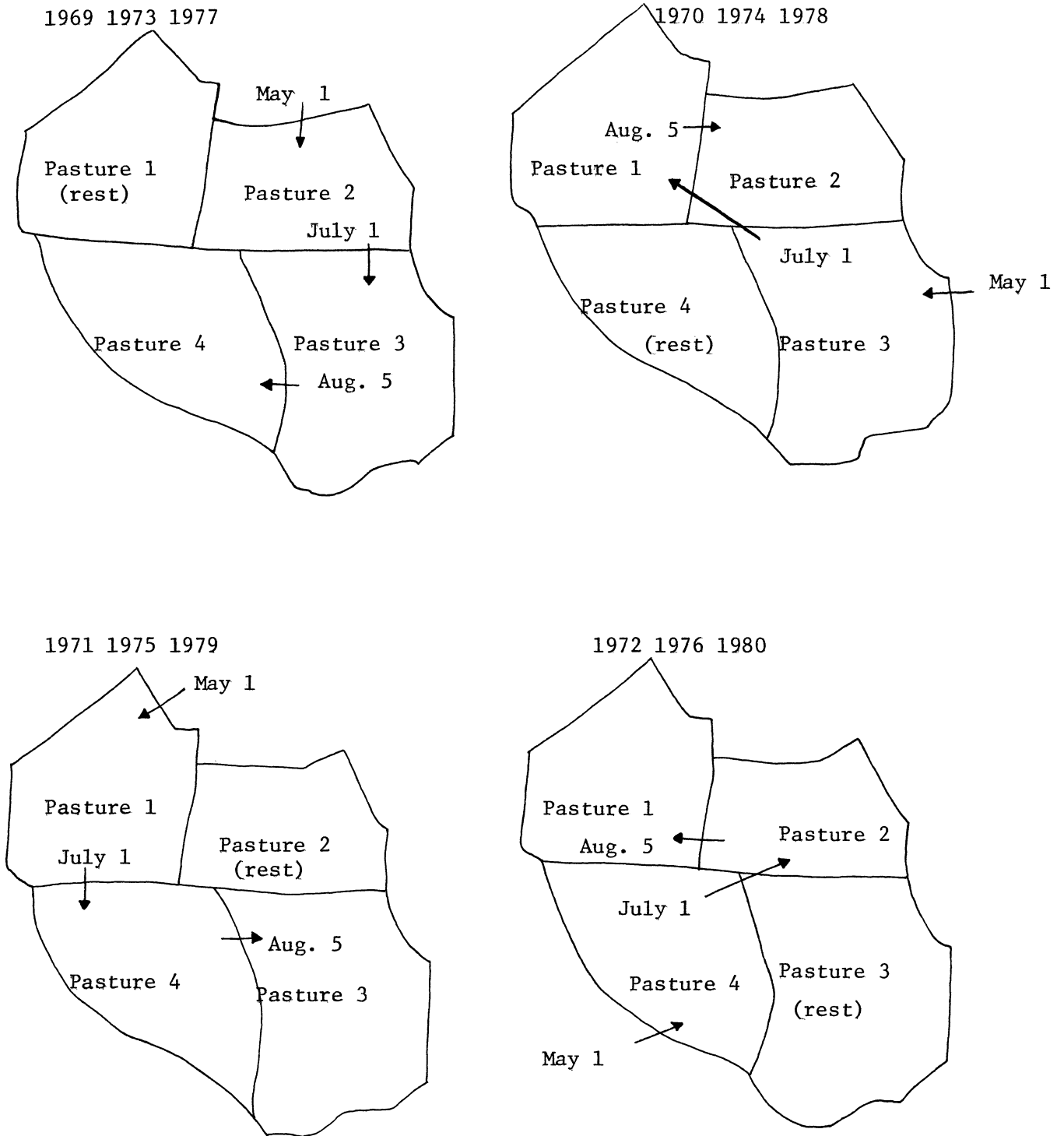
<i>Artemisia cana</i>	Silver sage
<i>Artemisia tridentata</i>	Big sage
<i>Atriplex nuttallii</i>	Nuttall saltbush
<i>Chrysothamnus viscidiflorus</i>	Little rabbitbrush
<i>Gutierrezia sarothrae</i>	Broom snakeweed
<i>Opuntia polycantha</i>	Plains pricklypear
<i>Rhus trilobata</i>	Skunkbush
<i>Rosa sp.</i>	Rose
<i>Sarcobatus vermiculatus</i>	Greasewood

Forbs:

<i>Achillea millefolium</i>	Western yarrow
<i>Artemisia frigida</i>	Fringed sage
<i>Aster canescens</i>	Hoary aster
<i>Comandra umbellata</i>	Pale bastard toadflax
<i>Eriogonum pauciflorum</i>	Eriogonum
<i>Hymenoxys richardsonii</i>	Hymenoxys
<i>Melilotus officinalis</i>	Sweet clover
<i>Phlox hodii</i>	Hood's phlox
<i>Sphaeralcea coccinea</i>	Scarlet globemallow
<i>Taraxacum officinale</i>	Dandelion
<i>Thermopsis rhombifolia</i>	Prairie thermopsis

Trees:

<i>Juniperus scopularum</i>	Juniper
<i>Pinus ponderosa</i>	Ponderosa pine



APPENDIX FIGURE 2. FOUR PASTURE REST-ROTATION GRAZING SYSTEM FOR LAVELLE CREEK ALLOTMENT, 1969-80.

APPENDIX FIGURE 3. EXAMPLES OF THE FIVE TEXTURE CLASSES USED TO INTERPRET 1:31,680 COLOR INFRARED TRANSPARENCIES OF THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

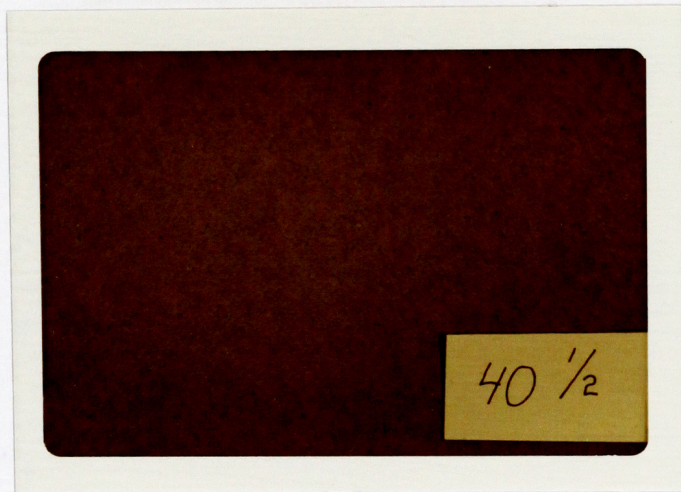


1 = Extra Fine Texture



2 = Fine Texture

APPENDIX FIGURE 3. (cont.)

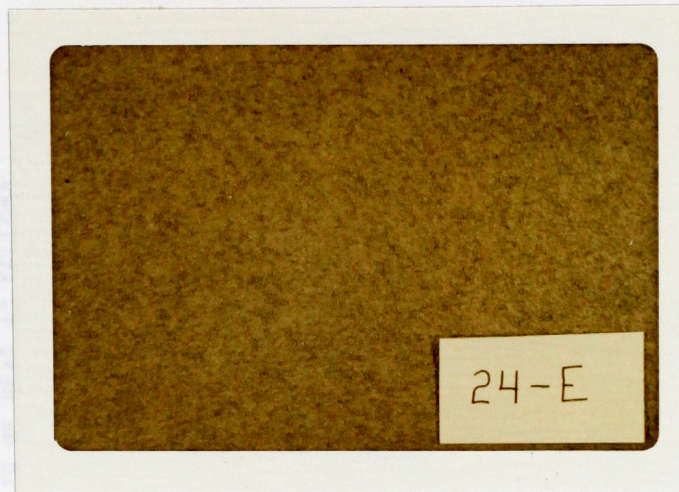


3 = Medium Texture



4 = Coarse Texture

NOTE: Numbers in the lower right hand portion of each photograph indicate the grit of each piece of sandpaper.

APPENDIX FIGURE 3. (cont.)

5 = Extra Coarse Texture

NOTE: Numbers in the lower right hand portion of each photograph indicate the grit of each piece of sandpaper.

SPSS FOR SPERRY UNIVAC 1100 EXEC 8, VERSION H, RELEASE 8.1-UW1.0, OCTOBER 1980

SPACE ALLOCATION 7875 WORDS ALLOWS FOR.. 37 TRANSFORMATIONS
 WORKSPACE 1125 WORDS 150 RECODE VALUES + LAG VARIABLES
 TRANSPACE 1125 WORDS 300 IF/COMPUTE OPERATIONS

```

1. FILE NAME      MIBSTUDY, MISSOURI BREAKS STUDY
2. VARIABLE LIST  RFILA, GFILA, TEXTU, REGRCO, RESHCO, REFOCO,
3.                    REGDCO, PERSHCO, ASPECT, GRCONF, RFILB, GFILB
4. INPUT FORMAT    FIXED (F2,0,1X,F2,0,1X,F1,0,1X,F1,0,1X,F1,0,
5.                    1X,F1,0,1X,F1,0,1X,F1,0,1X,F1,0,1X,
6.                    F2,0,1X,F2,0)
    
```

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS
RFILA	F2,0	1	1-2
GFILA	F2,0	1	4-5
TEXTU	F1,0	1	7-7
REGRCO	F1,0	1	9-9
RESHCO	F1,0	1	11-11
REFOCO	F1,0	1	13-13
REGDCO	F1,0	1	15-15
PERSHCO	F1,0	1	17-17
ASPECT	F1,0	1	19-19
GRCONF	F1,0	1	21-21
RFILB	F2,0	1	23-24
GFILB	F2,0	1	26-27

THE INPUT FORMAT PROVIDES FOR 12 VARIABLES. 12 WILL BE READ
 IT PROVIDES FOR 1 RECORDS ('CARDS') PER CASE. A MAXIMUM OF 27 'COLUMNS' ARE USED ON A RECORD.

```

7. N OF CASES      UNKNOWN
8. INPUT MEDIUM    CARD
9. VAR LABELS      RFILA, RED FILTER WITH NCIC COLOR CHIPS/
10.                    GFILA, GREEN FILTER WITH NCIC COLOR CHIPS/
11.                    TEXTU, PHOTO TEXTURE/
12.                    REGRCO, RELATIVE GRASS COVER/
13.                    RESHCO, RELATIVE SHRUB COVER/
14.                    REFOCO, RELATIVE FORB COVER/
15.                    REGDCO, RELATIVE GROUND COVER/
16.                    PERSHCO, PER CENT SHRUB COVER/
17.                    ASPECT, GROUND ASPECT/
18.                    GRCONF, GROUND CONFIGURATION/
19.                    RFILB, RED FILTER WITH DUPONT CHIPS/
20.                    GFILB, GREEN FILTER WITH DUPONT CHIPS/
21. VALUE LABELS    REGRCO, REFOCO, REGDCO (1)0-10%
22.                    (2)11-20% (3)21-30% (4)31-40% (5)>40%/
23.                    RESHCO (1)0-5% (2)6-10% (3)11-15% (4)16-20%
24.                    (5)>20%/
25.                    PERSHCO (1)0-10% (2)11-15% (3)16-20% (4)21-30%
26.                    (5)>30%
27. DISCRIMINANT    GROUPS = PERSHCO(1,5)/
28.                    VARIABLES = RFILA,GFILA,TEXTU,ASPECT,GRCONF,RFILB,GFILB/
29.                    ANALYSIS = RFILA,GFILA,TEXTU,ASPECT,GRCONF/
    
```

APPENDIX FIGURE 4. A SAMPLE SPSS DISCRIMINANT ANALYSIS COMPUTER PRINTOUT OF DATA EVALUATION FOR THE MISSOURI BREAKS STUDY AREA, MONTANA, IN 1979.

30. METHOD = DIRECT
31. OPTIONS 2,5,6
32. STATISTICS 1,2

THIS DISCRIMINANT ANALYSIS REQUIRES 384 WORDS OF WORKSPACE.
33. READ INPUT DATA

AFTER READING 27 CASES FROM SUBFILE MIBSTUDY, END OF DATA WAS ENCOUNTERED ON LOGICAL UNIT # 5

----- DISCRIMINANT ANALYSIS -----
 ON GROUPS DEFINED BY PERSHCO PER CENT SHRUB COVER

27 (UNWEIGHTED) CASES WERE PROCESSED,
 13 OF THESE WERE EXCLUDED FROM THE ANALYSIS,
 13 HAD MISSING OR OUT-OF-RANGE GROUP CODES,
 14 (UNWEIGHTED) CASES WILL BE USED IN THE ANALYSIS.

NUMBER OF CASES BY GROUP

PERSHCO	UNWEIGHTED	NUMBER OF CASES WEIGHTED	LABEL
1	7	7.0	0-10%
2	3	3.0	11-15%
3	1	1.0	16-20%
4	2	2.0	21-30%
5	1	1.0	>30%
TOTAL	14	14.0	

GROUP MEANS

PERSHCO	RFILA	GFILA	TEXTU	ASPECT	GRCONF	RFILB	GFILB
1	13.57143	14.85714	2.42857	4.42857	3.85714	19.14286	19.14286
2	17.66667	17.00000	2.00000	5.66667	6.00000	18.66667	22.66667
3	17.00000	20.00000	3.00000	1.00000	1.00000	16.00000	31.00000
4	16.00000	15.50000	5.50000	4.50000	6.00000	20.00000	24.00000
5	10.00000	10.00000	5.00000	5.00000	8.00000	6.00000	18.00000
TOTAL	14.38714	15.42857	2.71429	4.50000	4.71429	18.00000	21.35714

GROUP STANDARD DEVIATIONS

PERSHCO	RFILA	GFILA	TEXTU	ASPECT	GRCONF	RFILB	GFILB
1	2.22539	2.60951	.78680	1.90238	3.02372	11.17182	5.42920
2	1.15470	2.00000	1.00000	2.08167	.00000	10.06645	.57735
3	INSUFFICIENT DATA FOR STANDARD DEVIATIONS						
4	2.82843	2.12132	2.12132	.70711	1.41421	16.97056	16.97056
5	INSUFFICIENT DATA FOR STANDARD DEVIATIONS						
TOTAL	2.49945	2.95386	1.20439	1.91150	2.70124	10.39970	6.92384

FILE MIBSTUDY (CREATION DATE = 03/07/81) MISSOURI BREAKS STUDY

----- DISCRIMINANT ANALYSIS -----
 ON GROUPS DEFINED BY PERSHCO PER CENT SHRUB COVER

ANALYSIS NUMBER 1
 DIRECT METHOD: ALL VARIABLES PASSING THE TOLERANCE TEST ARE ENTERED.
 MINIMUM TOLERANCE LEVEL,..... .00100
 CANONICAL DISCRIMINANT FUNCTIONS
 MAXIMUM NUMBER OF FUNCTIONS OF VARIANCE: 4
 MINIMUM CUMULATIVE PERCENT OF VARIANCE: 100.00
 MAXIMUM SIGNIFICANCE OF WILKS' LAMBDA: 1.0000
 PRIOR PROBABILITY FOR EACH GROUP IS .20000

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
1*	3.79721	67.28	67.28	.8896885	0	.0566181	22.971	20	.2902
2*	1.30845	23.19	90.47	.7528671	1	.2716089	10.427	19	.5785
3*	.39244	6.95	97.42	.5308802	2	.6269954	3.7345	18	.7125
4*	.14541	2.58	100.00	.3562997	3	.8730505	1.0861	17	.5610

* MARKS THE 4 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS,

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3	FUNC 4
RFILA	.169967	-.46961	-.70028	-1.18121
GFILA	-.59160	-.79410	-.22823	-.48057
TEXTU	-1.36205	-.16172	-.42482	.23926
ASPECT	.46182	.56123	-.24541	.06816
GRCONF	.37838	.58673	.26402	.57522

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3	FUNC 4
1	-.27163	-.16619	-.40070	-.16760
2	.04125	.53986	.01871	.38813
3	-.71153	-2.87584	.63271	.35831
4	.48989	.52179	.98480	-.40257
5	-4.49109	1.37600	.25873	.45564

CASE	MIS VAL	SEL	ACTUAL GROUP	HIGHEST PROBABILITY GROUP	P(X/G)	P(G/X)	2ND HIGHEST GROUP	P(G/X)	DISCRIMINANT SCORES
M TUDY			1	1	.8671	.8143	4	.1201	.3237
M TUDY			1	1	.9855	.5858	4	.2416	.5622
M TUDY			1	1	.7533	.6218	4	.3333	.0836
M TUDY			1	1	.9033	.7290	4	.2293	.3344
M TUDY			1	1	.0000	.9873	4	.0000	.2320
M TUDY			1	1	.0000	.0000	4	.0000	.7115
M TUDY			1	1	.0000	.0000	4	.0000	.3760
M TUDY			1	1	.7774	.5716	4	.2869	.4934
M TUDY			1	1	.7988	.4181	4	.3306	.4104
M TUDY			1	1	.5555	.9224	4	.0059	.2508
M TUDY			1	1	.2585	.8704	4	.0044	.4558
M TUDY			1	1	.2585	.8185	4	.0044	.6332
M TUDY			1	1	.7908	.9161	4	.0522	.6332
M TUDY			1	1	.4000	.6049	4	.2566	.0182
M TUDY			1	1	.1780	.8986	4	.0066	.6782
M TUDY			1	1	.0511	.6682	4	.2000	.4611
M TUDY			1	1	.0633	.7965	4	.1644	.2955
M TUDY			1	1	.6988	.6587	4	.1721	.7409
M TUDY			1	1	.3177	.7932	4	.1197	.0278
M TUDY			1	1	.0299	.6750	4	.1725	.4079
M TUDY			1	1	.0000	.4888	4	.4188	.5370
M TUDY			1	1	.0000	.5365	4	.3374	.5370
M TUDY			1	1	.2900	.3878	4	.0288	.7949
M TUDY			1	1	.9556	.9711	4	.0288	.4007
M TUDY			1	1	.1579	.8887	4	.4220	.2788

CLASSIFICATION RESULTS -

ACTUAL GROUP	NO. OF CASES	PREDICTED GROUP MEMBERSHIP				
		1	2	3	4	5
GROUP 0-10%	7	71.4%	.0%	14.3%	14.3%	.0%
GROUP 11-15%	3	.0%	66.7%	.0%	33.3%	.0%
GROUP 16-20%	1	.0%	.0%	100.0%	.0%	.0%
GROUP 21-30%	2	.0%	.0%	.0%	100.0%	.0%
GROUP >30%	1	.0%	.0%	.0%	.0%	100.0%
UNGROUPED CASES	13	46.2%	23.1%	7.7%	15.4%	7.7%

APPENDIX FIGURE 4. (cont.)

SPSS BATCH SYSTEM

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PERCENT OF 'GROUPED' CASES CORRECTLY CLASSIFIED: 78.57%

CLASSIFICATION PROCESSING SUMMARY

27 CASES WERE PROCESSED,
27 CASES WERE USED FOR PRINTED OUTPUT.

APPENDIX FIGURE 4. (cont.)

SPSS BATCH SYSTEM

03/07/81

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PERCENT OF 'GROUPED' CASES CORRECTLY CLASSIFIED: 78.57%

CLASSIFICATION PROCESSING SUMMARY

27 CASES WERE PROCESSED
27 CASES WERE USED FOR PRINTED OUTPUT,

APPENDIX FIGURE 4. (cont.)