

RANGELAND INVENTORY & MONITORING



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Selected Bibliography of Remote Sensing Applications

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

RANGELAND INVENTORY AND MONITORING

SELECTED BIBLIOGRAPHY OF REMOTE SENSING APPLICATIONS

PREPARED BY
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AND
BRANCH OF BIOLOGICAL RESOURCES
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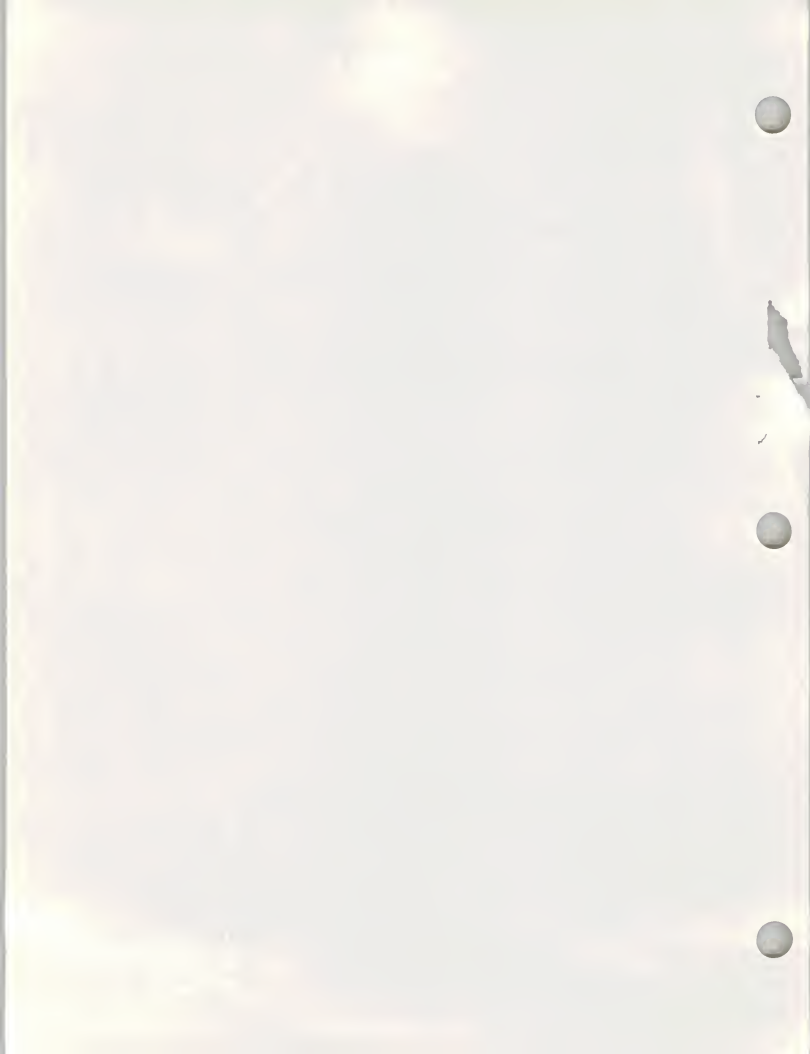
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TABLE OF CONTENTS

	Page
Introduction (or guidelines for using bibliography).	1
Table 1 - Papers Which Discuss the Analysis of Remote Sensing Data for use in Rangeland Management Activities	2
Selected Bibliography	3
Table 2 - Demonstrated Capability of Various Remote Sensing Methodologies to Provide Vegetation Data Necessary for Rangeland Management Decisions	54
Glossary of Terms	57
Acronyms and Abbreviations.	59

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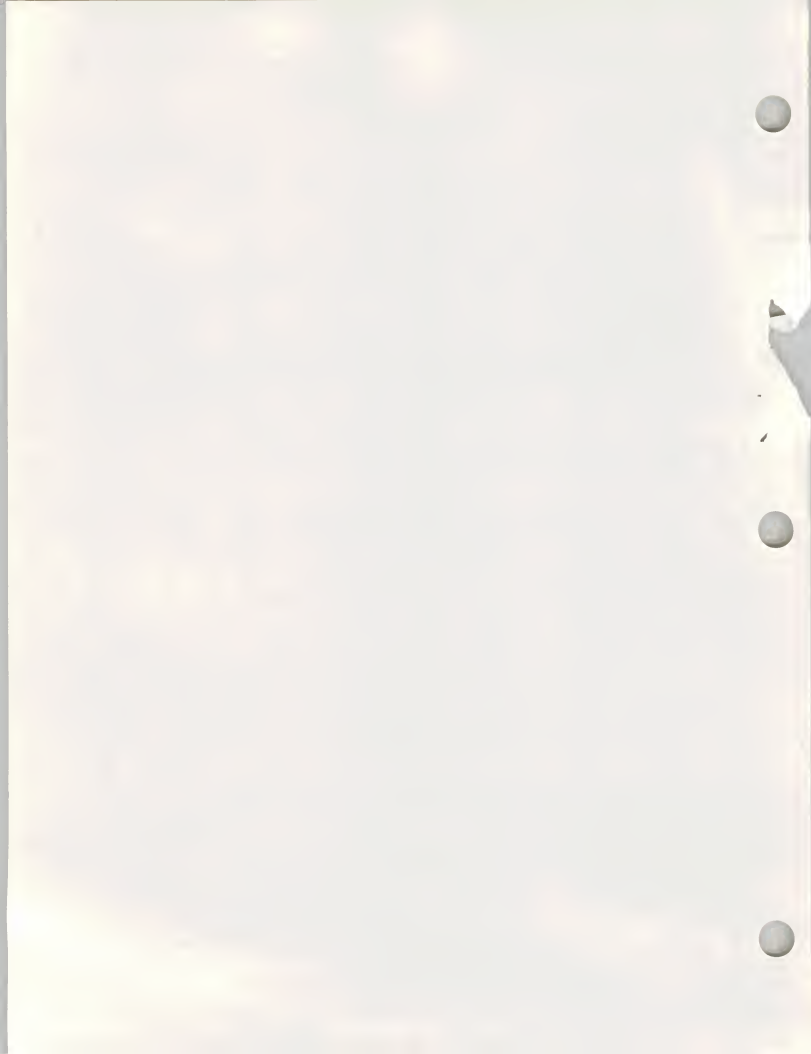
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INTRODUCTION

Because of worker shortages and dollar constraints, the Bureau of Land Management (BLM) needs more economical and efficient methods for inventorying and monitoring rangeland activities.

Remote sensing, which is the observation or measurement of an object without coming into physical contact with it, has been used for rangeland inventory and monitoring since the 1930s. The primary remote sensor was, and still is, the aerial camera. Other sensors include multispectral scanners, thermal radiometers, and radar that can be mounted on aircraft or satellite platforms. These early studies demonstrated that vegetation could be mapped more efficiently and accurately using aerial photographs rather than ground methods (Clouston 1950, Driscoll 1969, Carnegie and Reppert 1969).

In 1983, a Rangeland Remote Sensing Task Force was formed to investigate the possibilities of using remote sensing in the BLM's rangeland management activities. Based on a Task Force recommendation, this selected bibliography, has been prepared by the Branches of Remote Sensing and Biological Resources, Denver Service Center, for the purpose of providing BLM personnel with a listing of pertinent rangeland remote sensing information.

This selected bibliography provides a list of the significant papers written from 1950 to 1985 on the use of remote sensing for inventorying and monitoring rangeland. Papers that did not seem to be pertinent or that duplicated other (more major) studies were not listed (identified). Also, some papers could not be located in time for possible inclusion in this bibliography. These may be incorporated as the bibliography is updated or revised.

Papers are listed numerically and alphabetically by author(s), followed by the year, title, and source of the paper. If possible, the author's abstract has been included, although some abstracts have been abbreviated. In many cases, no abstract could be obtained, so the author's summary or introduction was substituted. In a few cases, the reviewers had to summarize the major ideas of the author's paper. (Abstracts, summaries, introductions, and reviewer's notes have all been identified accordingly in the bibliography.) Some papers include both abstract, etc., and reviewer's notes if the reviewer thought the abstract was not complete or that relevant information should be brought to the reader's attention. (If a reviewer's note was not included, the abstract, etc., was considered to be satisfactory.)

Table 1 lists a number of papers that discuss the analysis of remote sensing data for use in rangeland management activities such as inventory, monitoring, etc. For example, papers 3, 17, and 25, etc., discuss manual interpretation of remote sensing data related to rangeland inventory.

Table 2 summarizes the demonstrated capability of various remote sensing methodologies to provide data concerning vegetation attributes such as cover, production, frequency, density, composition, structure, reproduction, and species identification that are needed to make rangeland management decisions.

The column headed "Related References" refers by numbers to those papers dealing with specific vegetation attributes. For example, those papers that deal with "cover" are indicated by numbers 2, 3, 5, 8, etc.

Copies of all papers listed in this bibliography can be obtained from the Bureau of Land Management, Denver Service Center, Library (D-553A), Denver Federal Center, Building 50, P.O. Box 25047, Denver, Colorado 80225-0047, phone FTS 776-6434.

TABLE 1
PAPERS WHICH DISCUSS THE ANALYSIS OF REMOTE SENSING
DATA FOR USE IN RANGELAND MANAGEMENT ACTIVITIES

RANGELAND MANAGEMENT ACTIVITIES	DATA ANALYSIS METHOD			
	Manual Inter- pretation (paper number)	Digital Processing (paper number)	Manual & Digital (paper number)	Other (paper number)
Rangeland Inventory	3, 17, 25, 28, 37, 43, 57, 63, 74, 82, 91	8, 32, 38, 48, 49, 54, 62, 65, 67, 90, 97	31, 35, 42, 60, 66, 70*, 77, 89	7, 33**
Rangeland Monitoring	1, 9, 16, 24, 59, 61, 68, 69, 72, 73, 75, 85, 94, 95, 96	44, 47, 71, 78, 87***	10, 45, 46	93***
Rangeland Monitoring and Rangeland Inventory	2, 12, 14, 20, 26, 29, 30, 39, 53, 55, 56, 88 40***	6, 15*, 18, 21, 22, 34, 41, 50, 76, 80, 81, 83, 86	11, 13, 23, 27, 36, 51, 52, 84	
Other: Planning Soils Premapping	5, 92	64 58	79	

* Planning

** Microdensitometer

*** Radiometer

SELECTED BIBLIOGRAPHY

1. Ahern, F.J., R.J. Brown, K.P.B. Thomson, C.M. Pearce, G. Fedosejevs, and K. Staenz. 1981. Optical characteristics of Alberta rangeland as related to remote sensing. pp. 159-173. Presented at the Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba.

AUTHOR ABSTRACT: In 1980 the Canada Centre for Remote Sensing carried out a project to improve the state of remote sensing applied to the Mixed Grass and Rough Fescue rangelands of Western Canada. That project had a demonstration component (reported elsewhere) and a research and development component.

The research and development component involved a detailed study of the optical characteristic of rangeland vegetation in an attempt to provide improved qualitative and quantitative information of use to range managers. Areas investigated included interband correlations; the role of grass, forbs, shrubs, litter, carryover, and soil in determining the spectral reflectance of both rangeland types; and the optical manifestation of soil moisture and plant moisture. A study of simulated thematic mapper imagery was also carried out.

This investigation produced a greater understanding of the optical behavior of individual rangeland vegetation components throughout the growing season, leading to an interpretation guide for qualitative assessment of range conditions using Landsat images. These images are contrast enhanced using a special process developed in this project. An operational system for qualitative range condition estimates in the Mixed Grass Prairie using this form of imagery is supported on a sound scientific basis.

This study indicated that a qualitative assessment of range conditions is difficult in the Rough Fescue Prairie with green-red-infrared composite color imagery but is promising with imagery which includes the mid-infrared region to be provided with the thematic mapper, particularly toward the end of the growing season. We recommend against further work toward a quantitative biomass estimation system for the Canadian Mixed Grass and Fescue Prairie until thematic mapper data becomes routinely available.

REVIEWER'S NOTE: A good paper discussing the problems of using satellite imagery for range production and monitoring.

2. Aldrich, R.C. 1981. Limits of aerial photography for multiresource inventories. pp. 221-229. Proceedings, Arid Land Resource Inventories: Developing Cost Efficient Methods. USDA, Forest Service General Technical Report WO-28.

AUTHOR ABSTRACT: This paper reviews the qualities of aerial photographs in terms of resource information needs and makes recommendations for their use in arid land resource inventories. Photographic scales, films, formats, quality, and distortions are discussed in relation to recommended applications.

3. Aldrich, R.C. 1976. Evaluation of Skylab (EREP) data for forest and rangeland surveys. USDA, Forest Service Research Paper PSW 113. 83 pages.

AUTHOR ABSTRACT: Range Inventory--Classification of range plant communities was attempted at two levels of the ECOCLASS system--three Region and eight Series classes. Skylab photographs from the S190A multiband camera and the S190B terrain mapping camera (June and August 1973), high altitude aircraft photographs (June and August 1973), and Forest Service-acquired large-scale photography were used in the tests. Both visual and microdensitometer techniques were tested.

Procedures were developed for sampling plant communities for use in photointerpretation training and tests. Procedures were also developed to map cultural features from Skylab photographs. In a separate study, foliar cover estimates made on large-scale color photographs were compared with measurements made on ground transects.

Interpreters classified Grassland and Conifer Region classes with a mean accuracy of 98 percent or greater on both Skylab and support aircraft photography, regardless of date or film type. For the Deciduous (Aspen) class, accuracy was 80 percent or greater on the August CIR aircraft photographs, but was not acceptable on Skylab photographs. Coniferous Series class accuracies were dependent on date and film type, but inconsistently so. Accuracies were greater at small scales, probably because mixed tree species formed homogeneous units with a dominant species signature and a lower resolution. Within the grassland Series, Shortgrass was classified with an accuracy of 95 percent or greater on both Skylab and aircraft photographs, regardless of date or film type. For Wet Meadow, accuracy was greater than 90 percent on both June and August aircraft photographs, regardless of film type or scale, and was also acceptable on both color and CIR Skylab photographs taken in August. Mountain Bunchgrass was not accurately classified on Skylab photographs, but on the August aircraft photographs the classification was acceptable regardless of film type or scale. Topographic slope and aspect, mountain shadows, ecotones, season, and class-mixing affected classification of plant communities.

In microdensitometer point-sampling, significant differences in mean optical densities at the 95 percent probability level were a measure of separability. At the Region level, Conifer, Deciduous (Aspen), and Grassland classes were separable. However, the Deciduous class could be separated from the other classes with significant differences only on color film. Ponderosa Pine was the only coniferous Series class that was separable from the other three conifers, regardless of

date or film type. Spruce/Fir and Lodgepole Pine were not separable at any date or on any scale or film type. Douglas-fir was separable from the other three conifers on both the June CIR and August color S190A Skylab photographs. Grassland classifications at the Series level varied in acceptability. However, Shortgrass, Mountain Bunchgrass, and Wet Meadow were separable on August S190A color photographs. Optical density was more dependent on community mixing than on the growth stage of the plants at the time (season).

Both Skylab and aircraft photographs were useful to map the areal extent of Conifer and Grassland, but the Deciduous (Aspen) class could not be mapped with acceptable accuracy. Except for Wet Meadow, Series level classes could be mapped with acceptable accuracy only if class-complexes were formed: Ponderosa Pine/ Douglas-fir, Lodgepole Pine/Spruce/Fir, and Shortgrass/Mountain Bunchgrass.

Paved and gravel roads, utility corridors constructed within the last 10 years, larger mining excavations, and clusters of buildings could be mapped on Skylab photograph enlargements. On the other hand, 1:100,000 scale aircraft photographs were needed to map dirt roads, minor earth excavations, utility corridors older than 10 years, and individual buildings. Foliar cover and plant litter measured on large-scale CIR photographs of nondiverse grasslands were related to ground measurements with a correlation coefficient of 0.75. This is considered acceptable for range surveys. The relationship for foliar cover of shrubs was acceptable only on diverse grasslands.

REVIEWER'S NOTE: The study was made in central Colorado and the Skylab photo scales were 1:1,000,000 and 1:2,800,000. The aircraft photo scales were 1:50,000, 1:100,000, and 1:400,000. The results of this study could be projected to the potentials of the space shuttle's large format camera.

4. Anderson, W.H., and F.X. Wallner. 1978. A selected bibliography: small format aerial photography. National Technical Information Service No. PB279849. 6 pages.

AUTHOR ABSTRACT: There are many examples of the usefulness of aerial photographs in natural resource investigations. Unfortunately, suitable aerial photographs are not always available, and contracting for new aerial photographs to be flown by a commercial aerial survey firm can be expensive, especially for relatively small areas such as a single farm, a 100-acre wetland tract, or a city park. Do-it-yourself aerial photography using small format cameras (typically 35 mm) has been shown to be a viable alternative in many instances, providing valuable aerial photographs on a cost-effective basis.

REVIEWER'S NOTE: This paper is an annotated bibliography.

5. Befort, W.A., R.C. Heller, and J.J. Ulliman. 1977. Idaho land-use mapping from Landsat transparencies. Idaho Forest, Wildlife, and Range Experiment Station, Station Note 28. 4 pages.

AUTHOR ABSTRACT: Visual interpretation of Landsat false-color composite imagery enabled the senior author to map land uses for the entire state of Idaho in two months' time during the summer of 1975. The mapping was part of the initial stage of the Pacific Northwest Regional Commission's Land Resources Inventory Demonstration Project; results are now published in the form of black-line overlays at scales of 1:250,000, 1:500,000 and 1:1,000,000.

6. Bentley, Jr., R.G., B.C. Salmon-Drexler, W.J. Bonner, and R.K. Vincent. 1976. A Landsat study of ephemeral and perennial rangeland vegetation and soils. Report BLM/YA/300-1700-1012. Denver, Colorado. 234 pages.

AUTHOR ABSTRACT: Several methods of computer processing were applied to Landsat data for the purpose of mapping vegetation characteristics of perennial rangeland in Montana and ephemeral rangeland in Arizona. The choice of optimal processing technique is dependent on the prescribed mapping task and site condition. Single channel level slicing and ratioing of channels were used for simple enhancement. Predictive models for mapping percent vegetation cover based on data from field spectra and Landsat data were generated by multiple linear regression of the six unique Landsat spectral ratios. Ratio gating logic and maximum likelihood classification were applied successfully to recognize plant communities in Montana. Maximum likelihood classification did little to improve recognition of terrain features when compared to a single channel density slice in sparsely vegetated Arizona. Our studies indicate that Landsat is more sensitive to differences between plant communities based on percentages of vigorous vegetation than to actual physical or spectral differences among plant species. Recommendations for development of an operational system for the Bureau of Land Management are included.

7. Boutton, T.W., and L.L. Tieszen, 1983. Estimation of plant biomass by spectral reflectance in an East African grassland. Journal of Range Management, 36(2):213-216.

AUTHOR ABSTRACT: Canopy spectral reflectance measurements at 0.800 and 0.675 μm were made in a grassland in Masai Mara Game Reserve, Kenya. The reflectance ratio (0.800/0.675 μm) was shown to be a reliable predictor of green biomass accounting for 70% of the variance in green biomass values. Significant error in the biomass estimates was shown to be due to plots which contained less than 30% of the total vegetation in the live condition. Estimation error tended to increase when time of sampling departed from the interval

of 1000 to 1400 hours, although this trend was not statistically significant. We conclude that the spectral reflectance technique can provide reliable estimates of plant biomass in grassland ecosystems where the proportion of live:total vegetation exceeds 30%.

8. Campbell, N.A., F.R. Honey, I.J. Tapley, D.G. Burnside, and W.F. Holman. 1982. Discrimination between rangeland pasture communities in the North-West of Australia using Landsat data. pp. 343-353. Proceedings, 16th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan.

AUTHOR ABSTRACT: The management of the rangelands of Western Australia requires both range inventory and trend estimation. This paper reports the progress of an investigation into the use of Landsat digital data for these purposes. The overall aim of the study is to examine the relationships between Landsat digital data and the vegetative characteristics of some rangeland types from different communities in varying range condition.

The area under investigation is located in the semi-arid north-west region of Western Australia, amidst tussock grassland and tall shrubland communities in a variety of condition classes.

The vegetation characteristics of sites located in five pasture communities in varying range condition were sampled at regular intervals during 1980 and 1981.

The aspects of the study reported here examine the relationship between measured vegetative characteristics of the pasture communities and the Landsat data, and the discrimination between the pasture communities using Landsat data.

There is one strong canonical correlation between the Landsat bands and the vegetative characteristics, with the canonical vector for the Landsat bands reflecting a contrast between band 5 (B5) and either band 6 (B6) or band 7 (B7), and that for the vegetative characteristics being dominated by the proportion of green biomass (PG). The relationship between the difference B6-B5 and the vegetative characteristics explains virtually all of the relationship between the two sets of variables.

Canonical variate analysis is used to discriminate between the pasture communities. Bands 5 and 7 give the best discrimination.

Excellent allocation of individual pixels is achieved. Atypical pixels are identified and discussed.

REVIEWER'S NOTE: Discussions tend to be dominated by statistical evaluations. Primary result seems to be demonstration of ability of Landsat MSS to determine greenness. Study sites are very small and questions of proper registration are appropriate.

9. Carneggie, D.M. 1972. Large-scale 70 mm aerial photographs for evaluating ecological conditions, vegetational changes and range site potential. Ph.D. Thesis. University of California, Berkeley. 180 pages.

AUTHOR ABSTRACT: Very large-scale color and color-infrared aerial photographs of rangeland in northeastern California were interpreted to determine their usefulness for evaluating ecological condition, vegetational changes, and range site potential. Detailed interpretation and measurement of these photographs, taken on three dates in 1967, and on one date in 1969, have demonstrated their value as a sampling tool for range resource analyses. Interpretation tests indicate that photographs are best for differentiating between the greatest number of plant species when the plants are at or near peak foliage development. Color-infrared photographs were only slightly better than conventional color photographs for plant species identification, but were much better for differentiating plant vigor, and for detecting the presence of healthy plant material. The absolute number of plants at a site cannot be detected at any given date by means of photo analysis. However, analysis of photos taken at two different dates can account for changes in plant composition, numbers and size. A comparison of photo measurements with known ground measurements of linear intercept and area of targets and shrubs demonstrates the usefulness of large-scale aerial photographs for estimating shrub parameters such as foliage cover and linear intercept.

REVIEWER'S NOTE: Excellent analysis of large-scale aerial photo capabilities and applications in shrub-grass ranges. Accuracies of various analysis techniques are presented. Report is well organized and data is clearly presented. Highly recommended reading if interested in large-scale aerial photo applications for rangeland monitoring.

10. Carneggie, D.M., and S.D. DeGloria. 1974. Determining range condition and forage production potential in California from ERTS-1 imagery. pp. 1051-1059. Proceedings, Ninth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Seasonal phenological development of annual grasslands in California were monitored with Landsat (ERTS) digital data and imagery. Although no quantitative data were presented, the authors report good results between Landsat and ground data for determining time of germination, cessation of plant growth, plant drying; and length of the greenfeed period, as correlated with the relative amount of forage in an area. In addition, Landsat data can be used for a permanent record of range condition and the effects of favorable and unfavorable climatic conditions on a rangeland site. Range condition as used in this paper is not the same as the BLM definition.

11. Carneggie, D.M., S.D. DeGloria, and R.N. Colwell. 1975. Usefulness of Landsat data for monitoring plant development and range conditions in California's annual grassland. pp. 19-41. Proceedings, First NASA Earth Resources Survey Symposium, Houston, Texas.

AUTHOR ABSTRACT (abbreviated): The investigators established a network of sampling sites throughout the annual grassland region to correlate plant growth stages and forage production to climatic and other environmental factors. Plant growth and range conditions were further related to geographic location and seasonal variations.

A sequence of Landsat data was obtained covering critical periods in the growth cycle. This data was then analyzed by both photointerpretation and computer aided techniques. Image characteristics and spectral reflectance data were then related to forage production, range condition, range site and changing growth conditions.

As a result of this study, it was determined that repeat sequences with Landsat color composite images do provide a means for monitoring changes in range condition. Landsat spectral radiance data obtained from magnetic tape can be used to determine quantitatively the critical stages in the forage growth cycle. In addition, a computer ratioing technique provided a sensitive indicator of changes in growth stages and an indication of the relative differences in forage production between range sites.

The anticipated benefits from Landsat monitoring of annual range vegetation include: (1) more accurate determination of germination and drying periods for planning movement of grazing animals to or from annual grassland ranges; (2) predictions of the remaining length of the green feed period made early enough to plan more efficiently for alternative sources of livestock feed; (3) comparison of conditions and relative forage production between grazing areas within a season, and comparison of condition and productivity for a given area between seasons; (4) determination of time when dry forage creates a fire hazard in order to better allocate men and equipment for fire suppression; and (5) assess extent and location of grazing areas influenced by abnormal climatic conditions, be it drought or abundance of forage.

REVIEWER'S NOTE: Anticipated benefits claimed by authors relate to use on annual grasslands only. Authors' use of term "range condition" relates to greenness or dryness of plants. Operational use of this technique has not been verified and would certainly depend on how rapidly information could be given to managers.

12. Carneggie, D.M., and J.N. Reppert. 1969. Large-scale 70 mm aerial color photography. Photogrammetric Engineering and Remote Sensing, 35:249-257.

AUTHOR ABSTRACT: Large-scale 70 mm color and color infrared aerial photographs of northeastern California grasslands and shrublands were evaluated to determine their interpretability for improving range resource inventories. Detailed interpretation of these photographs, taken at three dates, indicates many potential applications in the inventory and management of range resources. By virtue of the high resolution obtainable, and the color dimensions of hue, value, and chroma, trained interpreters can use large-scale photography for: (1) detecting and identifying range plants; (2) identifying soil surface features (rockiness, surface erosion, disturbance by grazing animals, rodent burrows and trails, animal droppings, and dead plant material); and (3) quantifying plant and soil surface features such as foliage cover, plant density, surface rockiness, and amount of soil disturbance.

13. Carneggie, D.M., B.J. Schrupf, and D.A. Mouat. 1983. Rangeland applications. pp. 2325-2384. Manual of Remote Sensing; Vol. II: Second Edition. R.N. Colwell, Editor in Chief. American Society of Photogrammetry, Falls Church, Virginia.

AUTHOR ABSTRACT: None supplied.

GENERAL CONTENTS: Basic remote sensing considerations for rangeland resource assessment: define resource problem; determine remote sensing data required; ensure staff qualification and training; correlate ground conditions with remotely sensed data; develop classification scheme and legend; define interpretation procedure and equipment; accomplish field verification and data collection; rectify and produce resource map; perform accuracy assessment. Rangeland resource inventory: objectives, costs and design; mapping and sampling; rangeland inventory using panchromatic aerial photographs; land cover and soil surveys using color and color infrared photographs; inventory applications using Landsat imagery; rangeland mapping using Landsat MSS digital data; sampling applications using remote sensing data. Rangeland resource monitoring: monitoring ecological range conditions; monitoring seasonal range conditions. Wildlife habitat assessment: habitat assessment with aerial photography; habitat assessment with satellite imagery. Animal census: aerial visual observations; aerial photographs for animal census; aerial thermal infrared scanning for animal census; radio telemetry for studying animal populations. Desertification of rangelands. Future outlook and conclusion. References.

REVIEWER'S NOTE: A good overview of state-of-the-art use of remote sensing in rangeland inventory and monitoring.

14. Carnegie, D.M., D.G. Wilcox, and R.B. Hacker. 1971. The use of large-scale aerial photographs in the evaluation of Western Australian rangelands. Technical Bulletin 10. Department of Agriculture, Western Australia, South Perth. 37 pages.

AUTHOR ABSTRACT: This report discusses the steps taken in conducting a photographic investigation to determine the feasibility of using large-scale aerial photographs to evaluate and monitor range condition in Western Australian rangeland. The use of color and color-infrared photographs obtained at various scales and at two different dates are compared.

The conclusions are that large-scale photo interpretation and measurement is a valuable tool when combined with a limited field survey, for obtaining information regarding the rangeland resource base.

The results of qualitative and quantitative interpretations demonstrate that large-scale photographs are an ideal base for mapping and recording individual plant species in a variety of plant communities. In some instances the color photographs were sufficient to identify certain plant species, but, with most plant species, and with surface litter and soil conditions, color-infrared was superior. The largest scale photographs (1/600 to 1/800) allowed the identification of small plant species such as perennial grasses, and the making of acceptable estimates of plant cover.

It was found that the photographs had to be taken 4 to 6 weeks after effective rain to be most interpretable.

REVIEWER'S NOTE: A good paper discussing how to incorporate large-scale color aerial photographs into a range survey and monitoring. Accuracy figures are included and the methods discussed could be used on BLM rangelands.

15. Cihlar, J., F.J. Ahern, M. Bernier, K.P.B. Thomson. 1985. Thematic mapper evaluation for agriculture and forestry in Canada: initial results. pp. 902-911. Proceedings, American Congress of Survey and Mapping, American Society of Photogrammetry and Remote Sensing, Fall Convention, Indianapolis, Indiana.

AUTHOR ABSTRACT: This paper describes initial results of the evaluation of the Thematic Mapper data potential for providing useful information for the management of Canada's agricultural and forestry resources. In selecting application areas, emphasis has been placed on those information requirements which could not be satisfied with MSS data. Results to date suggest that TM data can provide sufficiently accurate crop area estimates in areas with small or narrow fields, detailed spatial information for rangeland

monitoring, and forest type and condition (including harvest and some regeneration information). The studies also highlighted the strong need for digital image analysis systems and algorithms capable of handling significant amounts of TM data. Until such systems are available, enhanced TM image products will be the principal data format for practical (as opposed to research) use.

16. Claveran, A.R. 1966. Two modifications to the vegetation photographic charting methods. *Journal of Range Management*, 19(6):371-373.

AUTHOR ABSTRACT (Highlight): Two modifications to the vegetation photographic charting method are suggested: The use of Polaroid film to identify species and density in the field and the use of stereoscopic pairs to facilitate detailed analysis of vegetation and site characteristics in the laboratory.

17. Clouston, J.G. 1950. The use of aerial photographs in range inventory work in the National Forests. *Photogrammetric Engineering and Remote Sensing*, 16:629-631.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: The author describes photo preparation, photo interpretation, and map compilation for 1:20,000 black-and-white prints used during range inventory. Accuracy figures are not given but per-acre costs are.

18. Coiner, J.C. 1980. Using Landsat to monitor changes in vegetation cover induced by desertification processes. pp. 1341-1351. *Proceedings, 14th International Symposium on Remote Sensing of Environment*, Ann Arbor, Michigan.

AUTHOR ABSTRACT (abbreviated): States which occupy largely arid or semi-arid regions are concerned with the loss by desertification of potentially productive land. Therefore, an inexpensive and timely method to monitor some indicator of desertification would be of great assistance to those countries. To meet this need, a study was undertaken to develop Landsat-derived indicators of vegetation change associated with desertification.

The study area chosen is on the eastern edge of the Niger River delta in Mali, West Africa. Within the study area, four test sites were selected. Each site depicts a different combination of environmental factors typical of the region, where differing agricultural activities take place. These sites were selected to represent the diversity of environments within an area encompassed by one Landsat frame (25,600 km²/10,000 mi²).

Initial tests of three spectral indicators on 45 cells (2 km x 2 km) demonstrated that all three indicators were sensitive to vegetation changes. Because these indicators proved to be highly correlated, only correlation coefficient (r) for MSS band 2 versus MSS band 4 was used to extend the analysis.

At present, there is no independent way to validate the results of this experiment. Comparison of the Landsat derived vegetation maps with image analysis of the same area shows that the new procedure tends to overstate change. This may be due to a lack of ground developed class boundaries which would be essential to fine tune the product. It may also be that the vegetation indicator is more sensitive to slight changes in vegetation cover than the human interpreter, or is more consistent. Given the present collateral information, it is impossible to state the precise reliability levels of the vegetation status and change maps which are the product. Before the reliability of the monitoring procedures can be assessed with any degree of accuracy, more of this type mapping with Landsat data must be conducted. Inclusion of additional Landsat frames from the same area is also essential to validate the procedures for other years and to determine the size of the vegetation window at the end of the rainy period.

19. Colwell, R.N. 1984. Remote sensing for natural resources: policy and management considerations. *Renewable Resources Journal*, 2(5):7-11.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Over-enthusiasm with modern remote sensing technology has resulted in a lack of attention for specific resource policy and management considerations. Some information needs have been ignored. Remote sensing has often been used indiscriminately to derive every kind of information possible, much of which is completely useless to the resource manager. Remote sensing scientists must know what policy decisions have been made regarding an area's natural resources, what specific resource management objectives have been met, and what resource management measures have been or will be adopted to achieve the objectives.

20. Dalsted, K.J., S. Sather-Blair, B.K. Worcester, and R. Klukas. 1981. Application of remote sensing to prairie dog management. *Journal of Range Management*, 34(3):218-223.

AUTHOR ABSTRACT: The areal extent of prairie dog towns in Wind Cave National Park (WCNP) has increased at an alarming rate in the past 20 years. An inventory method was needed to replace the time and labor intensive ground survey method, i.e., rod and transit. Color infrared (CIR) aerial photography (1,370 m above ground) provided a useful product for rapidly and accurately delineating prairie dog towns. Extent was determined by measurements on the CIR film to be 608 ha or 5.3% of the total WCNP area. Ground measurements, taken

near the time of the aircraft overflight, included general vegetation description of each prairie dog town and a vegetation sampling from 0.25 m² plot on a stratified, random basis. The ground data helped explain and identify the variations recorded on the CIR film. Soil and topographic information were used with the CIR film to determine likely expansion potential and probable direction of growth of the 11 major prairie dog towns in WCNP. The prairie dog town inventory and expansion potential of each town has probable usefulness in the development of management plans.

21. Deering, D.W., and R.H. Haas. 1980. Using Landsat digital data for estimating green biomass. Report No. NASA-TM-80727. 25 pages.

AUTHOR ABSTRACT: Relationships between the quantity of mixed prairie rangeland vegetation and Landsat MSS response were studied during four growing seasons at test sites throughout the United States Great Plains region. A Landsat derived parameter, the Normalized Difference (ND) was developed from theoretical considerations for statistical estimation of the amount and seasonal condition of rangeland vegetation. The ND parameter was tested for application to local assessment of green forage biomass and regional monitoring of range feed conditions and drought. These investigations have shown that for grasslands in the Great Plains with near continuous vegetative cover and free of heavy brush and forbs, (1) the Landsat digital data can provide a useful estimate of the quantity of green forage biomass (i.e., within 250 kg/ha), and (2) at least five levels of pasture and range feed conditions can be adequately mapped for extended regions.

REVIEWER'S NOTE: ND and its relationship to green biomass are explored by using Landsat images. Authors refer to determining production, which is a general term, not specific pounds of forage per acre by species.

22. Deering, D.W., J.W. Rouse, Jr., R.H. Haas, R.I. Welch, J.C. Harlan, and P.R. Whitney. 1977. Applied regional monitoring of the vernal advancement and retrogradation (green wave effect) of natural vegetation in the Great Plains Corridor. Final Report, Contract No. NAS5-20796, Texas A&M University, Remote Sensing Center, College Station, Texas. 165 pages.

AUTHOR ABSTRACT: The Landsat-2 follow-on investigation has shown that Landsat digital data products can be effectively employed on a regional basis to monitor changes in vegetation conditions. TVI6 (the normalized difference of Bands 5 and 6) was successfully applied to an extended test site and the Great Plains Corridor in tests of the ability to assess green forage biomass on rangelands as an index to vegetation condition. A strategy for using TVI6 on a regional basis was developed and tested.

The Great Plains Corridor investigations have shown that 1) for rangelands with good vegetative cover, such as most of those in the Great Plains, and which are not heavily infested with brush or undesirable weed species, the Landsat digital data can provide a good estimate (within 250 kg/ha) of the quantity of green forage biomass, and 2) at least five levels of pasture and range feed conditions can be adequately mapped for extended regions.

23. Driscoll, R.S. 1974. Use of remote sensing in range and forest management. pp. 111-133. Proceedings, Great Plains Agriculture Council. Sioux Falls, South Dakota, July 25-26, 1974.

AUTHOR ABSTRACT: None supplied.

SUMMARY: Aerial photography of all kinds is and will continue to be the primary remote sensing tool for the natural vegetation resource manager, at least for the next few years. New and improved film types and camera optics are producing high quality aerial photographs from very large scale to very small scale. Quality control of film and processing is improving rapidly. Applications of multistage and multiseasonal photography are becoming more apparent as we match film/optics resolution to specific target surfaces, such as individual plant species, and as improvements are made in multistage sampling requirements.

Optical-mechanical scanners are the most promising sensor systems available to the natural resources manager. The data, in the form of electrical signals on magnetic tapes, are directly computer compatible. The hazards of potential data loss due to film exposure and processing are lower than with aerial photography. Problems on data processing are being solved.

The full usefulness of satellite imagery for natural resources is uncertain. Many results are based on a priori knowledge of a specific situation, and the spatial extension of results has been minimally investigated. Low resolution in relation to the resource managers' needs, and data management including data processing, are the primary limitations. Spectral and spatial resolution of satellite sensors are constantly being improved and data management problems are being solved.

Human input will always be necessary in the analysis and interpretation of any kind of remotely sensed data. We must establish improved analysis procedures, and develop logical statements about the results of analysis of remotely sensed data. We must be careful to not oversell the machine nor undersell the human.

24. Driscoll, R.S. 1973. 70 mm aerial photographs for range vegetation analysis. p. 13. Abstracts of Annual Society of Range Management Meeting, Boise, Idaho.

AUTHOR ABSTRACT: Seventy millimeter aerial camera systems in concert with a variety of black-and-white and color aerial films provide the range resource analyst an invaluable tool to assist with the analysis and surveillance of range vegetation. These cameras are small, light weight, have very rapid shutter speeds (up to 1/7200 of a second), and fast film advance mechanisms (up to 7-12 frames per second). These attributes are exploited to secure very large-scale (up to 1:600 or larger) aerial photographs with minimum edge distortion and motion-free images for stereoscopic interpretation of low stature vegetation.

This camera/film system has greatest application to range vegetation analysis as a sampling mechanism whereby 70 mm photographs are used to sample strips of landscape photographed at small scale or low resolution or both on conventional format film from aircraft or space platforms. Sampling can be done to: (1) determine the areal extent of intricate plant community systems, the patterns of which do not permit accurate measurement on normal scale photographs; (2) detect and identify individual shrubby and herbaceous species to estimate density (numbers), cover, and distribution; (3) estimate relative amounts of plant cover and bare soil; (4) estimate herbaceous standing crop; and (5) estimate population dynamics of some small mammals in relation to habitat change.

Color infrared (CIR) photographs provide the most accurate information about individual species identification and measurement. Normal color and CIR provide about equal information regarding bare soil. Vegetation mapping with color and CIR is easier than with black-and-white once the interpreter is familiar with the imagery.

25. Driscoll, R.S. 1971. Color aerial photography-a new view for range management. USDA, Forest Service Resource Paper RM-67: Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 11 pages.

AUTHOR ABSTRACT: Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountainmahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large-scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of

the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

REVIEWER'S NOTE: No accuracy or cost figures given.

26. Driscoll, R.S. 1970. Identification and measurement of shrub type vegetation on large-scale aerial photographs. Section 32:1-15. Third Annual Earth Resources Program Review, Vol. II, Agriculture, Forestry, and Sensor Studies. Manned Spacecraft Center, Houston, Texas.

AUTHOR ABSTRACT: Important range-shrub species were identified at acceptable levels of accuracy on large-scale (1:600 to 1:1,500) 70 mm color and color infrared aerial photographs (positive transparencies). Identification of individual shrubs was significantly higher, however, on color infrared. Eight of 11 species were identified correctly more than 80 percent of the time on color infrared and two species were correctly identified 100 percent of the time. Six species were identified more than 80 percent correctly on color photographs but none were identified 100 percent correctly. Photoscales smaller than 1:2,400 had limited value except for mature individuals of relatively tall species, and then only if crown margins did not overlap and sharp contrast was evident between the species and background. Larger scale photos (1:800 or less) were required for low-growing species in dense stands. The crown cover for individual species was estimated from the aerial photos either with a measuring magnifier or a projected-scale micrometer. Photo measurements were significantly correlated with ground measurements. These crown cover measurements provide techniques for earth-resource analyses when used in conjunction with space and high-altitude remotely procured photos.

27. Driscoll, R.S. 1969. Aerial color and color infrared photography--some applications and problems for grazing resource inventories. In: Aerial Color Photography in the Plant Sciences. pp. 140-149. Proceedings, Aerial Color Photography Workshop, University of Florida, Gainesville.

AUTHOR ABSTRACT: None supplied.

INTRODUCTION (abbreviated): While inventories have been conducted by ground sampling for decades, only a small fraction of the range has been covered, and this very sketchily due to its extent and remoteness. On the other hand, aerial photographs, coupled with ground techniques, provide the opportunity to circumvent some of the sampling problems. The photographs contain much detailed information about the vegetation, can be obtained rather quickly, and may provide some detailed study that would not be possible by

ground search alone. Color aerial photographs offer greater possibilities to enhance grazing resource inventory techniques than do conventional black-and-white photographs. The three color dimensions--hue, value, and chroma--provide more photo-interpretive characteristics than do mere shades of gray.

28. Driscoll, R.S. 1969. The identification and quantification of herbland and shrubland vegetation resources from aerial and space photography. Second Annual Progress Report, Earth Resources Survey Program, OSSA/NASA, Houston, Texas. 75 pages.

AUTHOR ABSTRACT: This is the second annual progress report of a study to assess the merits of large-scale color and infrared color aerial photography for detecting and identifying herbaceous and shrubby plant species and communities at four test locations in Colorado. Added emphasis was placed on multistaged sampling techniques to quantify earth resources photography from space using Apollo 9 color infrared photographs of an area around Roswell, New Mexico, for base data.

Space photographs of the earth's resource areas similar to those obtained by the Apollo 9 mission of the Roswell, New Mexico area, provide the instantaneous synoptic base for classifying and pre-stratifying groups of associated plant communities. These data provide knowledge on location and areal extent of generalized vegetation types and are useful for broad land use planning and management decisions. However, as more detailed quantitative information is required of the plant community types included in the generalized stratifications, multiscaled aerial photographs are required to provide sampling bases of these units.

A multiple sampling technique involving subsampling is described whereby color infrared aerial photos at scales of 1:80,000, 1:20,000, and 1:2,400 are used to estimate the areal extent of the specific plant communities and to estimate specific plant species density. The 1:80,000 scale photos, sampling the Apollo 9 photo base, are satisfactory for determining the area of ecosystems with image boundary characteristics markedly different from adjacent units. Photoscales of 1:20,000 are required for those units with subtle image differences between units. The 1:2,400 scale photos provide the data base needed to estimate plant density and dispersion in shrub environments where individual species are widely spaced.

A photo interpretation key for shrubs was developed to compare film type and photoscale for identification of individual shrubs. Image characteristics used were class categories of crown shape, crown margin, foliage texture, foliage pattern, plant size, shadow, and color. Large-scale (1:800) color infrared photos obtained in early

summer have a slight advantage over color photos for this purpose. The degree of identification accuracy achieved by photo interpreters varied according to photo interpretation experience and knowledge of the area photographed. The least experienced interpreter identified 6 of 11 species with accuracies greater than 90 percent using color infrared photos. Reducing photoscale to 1:2,400 lessened the usefulness of the image characters except for shrub stands where individual plants were spaced greater than three feet apart.

The need for multiseasonal photography obtained both from earth orbiting satellites and from aircraft for herbland and shrubland inventory is discussed.

REVIEWER'S NOTE: Good reference for continued use of aerial photographs for range inventory studies.

29. Driscoll, R.S., and M.D. Coleman. 1974. Color for shrubs. Photogrammetric Engineering and Remote Sensing, 40:451-459.

AUTHOR ABSTRACT: Identification of individual shrubs was significantly better on large-scale (1:800-1:1,500) 70 mm color infrared aerial photographs than on normal color. Seven of 11 species were identified correctly more than 80 percent of the time on color infrared; two were correctly identified 100 percent of the time. Six species were identified more than 80 percent correctly on color photographs, but none were identified 100 percent correctly. Photoscales smaller than 1:2,400 had limited value except for mature individuals of relatively tall species and then only if crown margins did not overlap and sharp contrast was evident between the species and background. Larger-scale photos (1:800 or larger) were required for low-growing species in dense stands.

30. Driscoll, R.S., P.O. Currie, and M.J. Morris. 1972. Estimates of herbaceous standing crop by microdensitometry. pp. 358-364. Proceedings, 38th Annual Meeting, American Society of Photogrammetry, Falls Church, Virginia.

AUTHOR ABSTRACT: Green standing herbage of seeded big bluegrass (*Poa ampla*) and corresponding dry weight were each regressed as dependent variables (Y) on color infrared photo image density (X) obtained from two photoscales: 1:563 and 1:3855. Standing crop biomass expressed by the linear equation: $Y = a + b(X)$ was from the 1:563 photoscale. The coefficient of determination ($r^2 = 0.752$) between image density and harvested dry weight was highly significant ($P = 0.01$). The same regression using the smaller photoscale (1:3855), although significant ($P = 0.05$), was not as good ($r^2 = 0.639$). Mean image density of six simulated productivity levels was significantly different ($P = 0.05$) among most levels of production represented in both photo scales.

31. Driscoll, R.S., and R.E. Francis. 1975. Range inventory. Classification of plant communities. pp. 26-43. Evaluation of ERTS-1 Data for Forest and Rangeland Surveys. R. C. Heller, Technical Coordinator, USDA, Forest Service Research Paper PSW-112. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

AUTHOR ABSTRACT: None supplied.

INTRODUCTION: The primary objective of this test was to determine at what level in an accepted hierarchy of plant community classification ERTS-1 imagery could be successfully used in a central Colorado mountainous area. A further objective was to determine the kind of aircraft support photography that would be needed to extend the classifications to the degree of detail required in range resource inventory.

REVIEWER'S NOTE: Mapping of coniferous forest, deciduous forest, water, and wet meadow. The paper compares accuracy of satellite imagery to aerial photography. Satellite imagery is useful in detecting major changes in land use or in detecting major change in vegetation and is useful in stratifying for multistage sampling. Aerial photo scales of 1:20,000 are required for detailed mapping to the series level. Photo scales of 1:2,000 or larger are required to evaluate habitat types for plant cover.

32. Driscoll, R.S. and R.E. Francis. 1970. Multistage, multiband, and sequential imagery to identify and quantify non-forest vegetation resources. Third Annual Progress Report for Earth Resources Survey Program, OSSA/NASA, Rocky Mountain Forest and Range Experiment Station. 70 pages.

AUTHOR ABSTRACT: This is the third annual progress report of a study to assess the merits of space and supporting aircraft photography for the interpretation and analyses of non-forest (shrubby and herbaceous) native vegetation. The research includes the development of a multiple sampling technique to assign quantitative area values of specific plant community types included within an assigned space photograph map unit. Also, investigations of aerial film type, scale, and season of photography for identification and quantity measures of shrubby and herbaceous vegetation have been conducted. Some work has been done to develop automated interpretation techniques with film image density measurement devices.

The aerial photoscales to use for subsampling space photographs for area of plant community types depends on the complexity of the vegetation within a space photo mapping unit. For a pinyon-juniper forest mapping unit near Roswell, New Mexico, included in Apollo exposure 3806, 1:20,000 scale photos were required to determine the

areal extent of three specific plant community types verified by ground examination. Photoscales at 1:80,000 were of limited value because two of the community types could not be separated due to similar image characteristics. The best dot-grid system for estimating plant community area, considering cost and sampling error, is 36 dots per inch² using 50 percent of the subsampling units within a primary sampling unit. At least 2:1 ratio of secondary to primary sampling units is required to provide acceptable information about plant community area.

Identification of individual shrubs is significantly greater on large-scale color infrared aerial photos exposed in July as compared to normal color aerial photos. Considering all species, 82 percent of 456 test specimens were correctly identified on color infrared; 76 percent were correctly identified on normal color. Mature plants of tall species are readily identified on photoscales up to 1:2,400. Photoscales of 1:800 or less are required for low-growing species in complex plant communities. Color infrared photos (1:600-1:800 scale) exposed in June provides the greatest amount of information for identifying herbaceous species.

Film image density, measured by microdensitometry, of different classes of standing crop on seeded rangeland are significantly different. Image density of grass stands representing 20 percent increments of crop year production was significantly less than the image density representing total production.

Optical-mechanical scanner data collected by the University of Michigan aircraft and the NASA RB57F in July 1970 have not yet been analyzed.

33. Driscoll, R.S., J.N. Reppert, and R.C. Heller. 1974. Microdensitometry to identify plant communities and components on color infrared aerial photos. *Journal of Range Management*, 27(1):66-70.

AUTHOR ABSTRACT (Highlight): Image density differences in color infrared aerial photos can be used to discriminate individual shrub and tree species of a pinyon pine-juniper plant community. In addition, image density was used successfully to identify six general plant communities: ponderosa pine, spruce-fir, aspen, big sagebrush, native grasslands, and seeded grasslands. However, different sites and cultural treatments within native grasslands and ponderosa pine forest could not be so easily discriminated, even though visual differences were apparent in the photos.

REVIEWER'S NOTE: The procedure described is not operational and more research is needed. No accuracy figures were given.

34. Driscoll, R.S., and M.M. Spencer. 1972. Multispectral scanner imagery for plant community classification. pp. 1259-1278. Proceedings, International Symposium on Remote Sensing of the Environment, Ann Arbor, Michigan.

AUTHOR ABSTRACT: Optimum channel selection among 12 channels of multispectral scanner imagery identified six as providing the best information for computerized classification of 11 plant communities and two nonvegetation classes. Intensive preprocessing of the spectral data was required to eliminate bidirectional reflectance effects of the spectral imagery caused by scanner view angle and varying geometry of the plant canopy. Generalized plant community types--forest, grassland, and hydrophytic systems--were acceptably classified based on ecological analysis. Serious, but soluble, errors occurred with attempts to classify specific community types within the grassland system. However, special clustering analyses provided for improved classification of specific grassland communities.

REVIEWER'S NOTE: Article discusses the use of a multispectral scanner at a flight altitude of 3000 feet aboveground.

35. Ellis, S.L. 1978. Shrubland classification in the Central Rocky Mountains and Colorado Plateau. U.S. Rocky Mountain Forest and Range Experiment Station. USDA, Forest Service General Technical Report. RM 55:199-203.

AUTHOR ABSTRACT: Selection of appropriate vegetation categories is essential for efficient and accurate supervised Landsat multispectral computer classifications. Shrubland Communities of the western United States present a classification challenge because of their heterogeneity. A systematic separation of spectral classes found in the ground truth data (large-scale CIR aerial photography) and stratification of training fields by soil, vegetation density, and slope and aspect was found to be a useful procedure in separating heterogeneous shrubland communities.

36. Everitt, J.H. and P.R. Nixon. 1985. Using color aerial photography to detect camphorweed infestations on south Texas rangelands. pp. 431-439. Proceedings, American Congress of Survey and Mapping-American Society of Photogrammetry and Remote Sensing, Fall Convention, Indianapolis, Indiana.

AUTHOR ABSTRACT: Camphorweed (*Heterotheca subaxillaris*) is a troublesome weed that is increasing in abundance in sandy soils on south Texas rangelands. During late September to late October, it produces a profusion of bright yellow flowers and becomes very conspicuous. Field spectroradiometric plant canopy measurements showed that camphorweed had significantly higher ($p \geq 0.05$) visible

(0.45- to 0.75-um waveband) reflectance than did five other associated species and mixtures of species. Its visible reflectance did not differ from that of broom groundsel (Senecio spartioides), a weed species toxic to livestock that also produces bright yellow flowers at the same time as camphorweed and occasionally occurs with camphorweed on rangelands. However, broom groundsel usually occurs in small stands and is not considered a major problem on south Texas rangelands. The conspicuous yellow flowers of both species made them distinguishable from other plant species on conventional color (0.40- to 0.70-um waveband) aerial photos of rangeland areas. Microdensitometric film measurements showed that camphorweed could be distinguished quantitatively from other rangeland vegetation. Thus, conventional color aerial photography may be useful to distinguish camphorweed infestations and monitor its spread on south Texas rangelands.

REVIEWER'S NOTE: The principles applied in this study may be applicable to situations occurring on the public lands.

37. Everitt, J.H. and P.R. Nixon. 1985. False color video imagery: a potential remote sensing tool for range management. Photogrammetric Engineering and Remote Sensing, 51(6):675-679.

AUTHOR ABSTRACT: False color video imagery was evaluated as a potential remote sensing tool to assist in assessing rangeland resources. Aerial video and CIR photographic imagery were obtained simultaneously of three different rangeland areas in south Texas: (1) a range infested with huisache and mesquite trees, (2) a fertilized bermudagrass range, and (3) a native range comprised of mesquite and live oak trees. Video imagery was obtained with three black-and-white video cameras -- two of them visible and one visible/near-infrared sensitive -- each equipped with narrowband filters. The narrowband video images of each scene were combined on an image processor to produce false color video composite images. The color responses of the video composite images to the rangeland species were similar to those of the CIR photographic imagery. These results showed that a false color video camera would have considerable potential as a tool to assist in rangeland evaluation and other applications that necessitate "real time" analysis.

REVIEWER'S NOTE: Video imagery has potential for "real time" analysis of rangeland fires and flooding but the resolution is not as good as color infrared aerial photography.

38. Everitt, J.H., A.J. Richardson, and A.H. Gerbermann. 1985. Identification of rangeland sites on small scale (1:120,000) color-infrared aerial photos. Photogrammetric Engineering and Remote Sensing, 51(1):89-93.

AUTHOR ABSTRACT: Microdensitometry was tested on small-scale (1:120,000) color infrared (CIR) aerial photos to distinguish among ten rangeland sites (two brushland, six grassland, two barren land)

in southern Texas. Aerial photos were taken in May 1981 when the vegetation was in its peak foliage development. Optical density readings were made on CIR film with white, red, green, and blue light. Optical density readings made with either white or blue light were better for distinguishing higher order classification of three range types (brushland, grassland, and barren land), but readings made with red light distinguished more of the ten range sites. Discriminant analysis using all four optical density light readings differentiated among the ten sites with 100 percent classification accuracy. By these results, we showed that automated photo-interpretation could be used to identify a variety of rangeland sites on small-scale CIR photos.

39. Everitt, J.H., A.J. Richardson, A.H. Gerbermann, C.L. Wiegand, and M.A. Alaniz. 1977. Utilization of satellite data for inventorying rangelands in South Texas. p. 136. Proceedings, Annual Meeting American Society of Photogrammetry, Washington, D.C.

AUTHOR ABSTRACT: Blackbrush (*Acacia rigidula*) is a native shrub found on a variety of soil types in south Texas and northern Mexico. It often becomes a serious management problem on rangelands, especially where associated species have been removed. During late February to late March it produces small cream to light yellow flowers that encompass the entire plant giving it a conspicuous appearance. Field spectroradiometric plant canopy measurements showed that blackbrush in flower had significantly higher ($p=0.05$) visible light (0.45- to 75- μ m waveband [WB] reflectance than did 6 other associated plant species or mixtures of species. The conspicuous light yellow color of blackbrush in flower made it distinguishable from other plant species on both conventional color (0.40- to 0.70- μ m WB) and color infrared (CIR) (0.50- to 0.90- μ m WB) aerial photos. However, conventional color photography was superior to CIR photography because blackbrush had a more distinct image on color photography and it could also be identified on smaller scale photos. Microdensitometric measurements made on conventional color film showed that blackbrush had significantly lower optical counts than those of associated species. These results show that aerial photography may be a useful tool to distinguish blackbrush from other plant species in late winter or early spring to locate its endemic areas, monitor its spread, and delineate areas needing control.

REVIEWER'S NOTE: Shrub species may be detected and identified using conventional color and color infrared photography, if a species exhibits a contrasting color during a specific phenological stage, such as peak flowering.

40. Gausman, H.W., J.H. Everitt, A.H. Gerbermann, and R.L. Bowen. 1977. Canopy reflectance and film image relations among three South Texas rangeland plants. *Journal of Range Management*, 30(6):449-450.

AUTHOR ABSTRACT (Highlight): Field spectroradiometric measurements for canopy reflectances of three dominant south Texas woody plants (cenizo, honey mesquite, live oak) were used successfully to predict their color infrared film images and distinguishability: cenizo, whitish; honey mesquite, relatively light magenta; and live oak, darker magenta.

41. Girard, C.M. 1982. Estimation of phenological stages and physiological states of grasslands from remote sensing data. *Vegetation*, 48(3):219-226.

AUTHOR ABSTRACT: Two radiometers measuring reflectance factors have been used at a height of 1.50 m above some grasslands in C. France. The results show that both spectral data are sensitive to the photosynthetic activity of the grassland. Measurements made in April, May, June, and July show that grasslands have quite different spectral behaviour according to soil conditions or to grazing level. Grasslands on dry or wet soils may be separated from those of normal soils for which overgrazing and trampling affecting the growth of species, are shown by the different spectral values. Such 'on the ground' remote sensing measurements may then be proposed for evaluating the range of growth and development of different grasslands.

42. Gordon, R.C. 1974. Usefulness of Skylab color photography and ERTS-1 multispectral imagery for mapping range vegetation types in Southwestern Wyoming. University of Wyoming, Laramie. Report No. NASA-CR-141293. 56 pages.

AUTHOR ABSTRACT: This project used aerial photography scales 1:43,400 and 1:104,500 to evaluate the usefulness of Skylab color photography (scales 1:477,979 and 1:712,917) and ERTS-1 multispectral imagery (scale 1:1,000,000) for mapping range vegetation types. The project was successful in producing a range vegetation map on the 63,000 acres salt desert shrub type southwestern Wyoming.

Techniques for estimation of above-ground green biomass have not yet been confirmed due to the mechanical failure of the photometer used in obtaining relative reflectance measurement. However, graphs of log transmittance versus above-ground green biomass indicate that production estimates may be made for some vegetation types from ERTS imagery. Other vegetation types not suitable for direct ERTS estimation of green biomass may possibly be related to those vegetation types whose production has been estimated from the multispectral imagery.

REVIEWER'S NOTE: Range mapping using Skylab photos and Landsat images.

43. Graetz, R.D., D.M. Carneggie, R. Hacker, C. Lendon, and D.G. Wilcox. 1976. A qualitative evaluation of Landsat imagery of Australian rangelands. Australian Rangeland Journal, 1(1):53-59.

AUTHOR ABSTRACT: The capability of multirate, multispectral ERTS-1 imagery of three different rangeland areas within Australia was evaluated for its usefulness in preparing inventories of rangeland types, assessing on a broad scale range condition within these rangeland types, and assessing the response of rangelands to rainfall events over large areas.

For the three divergent rangeland test areas, centered on Broken Hill, Alice Springs, and Kalgoorlie, detailed interpretation of the imagery only partially satisfied the information requirements set. It was most useful in the Broken Hill area where fenceline contrasts in range condition were readily visible. At this and the other sites an overstory of trees made interpretation difficult.

Whilst the low resolution characteristics and the lack of stereoscopic coverage hindered interpretation it was felt that this type of imagery with its vast coverage, present low cost and potential for repeated sampling is a useful addition to conventional aerial photography for all rangeland types.

REVIEWER'S NOTE: No accuracy figures are given but it is a good paper describing the capabilities and limitations of manually interpreting Landsat single bands and false color composites. Range condition as discussed in this paper is not the same as used by the BLM.

44. Graetz, R.D., M.R. Gentle, R.P. Pech, and J.F. O'Callaghan. 1982. The Development of a land image-based resource information system (LIBRIS) and its application to the assessment and monitoring of Australian arid rangelands. pp. 257-275. Proceedings, International Symposium on Remote Sensing of Environment, First Thematic Conference, Remote Sensing of Arid and Semi-Arid Lands, Cairo, Egypt.

AUTHOR ABSTRACT: A land image-based geographic information system (LIBRIS) has been developed to support rangeland resource management.

The study area is centered on the mining town of Broken Hill (Lat. 32°S, Long. 141°30'E) which lies within the semi-arid rangelands of southern Australia.

The information system was developed to integrate Landsat spectral data with other relevant spatial data sets, tenure rangeland type, elevation and slope which was required to improve the interpretation of Landsat imagery and to permit modeling and report generation.

LIBRIS uses a simple vegetation/Landsat response model. The model, based on field reflectance data, has two indices (or axes) representing the proportions of 'cover' and 'greenness' (vigor) of the rangeland vegetation.

Classifications of plant cover condition are integrated with land tenure boundaries to provide reports of land cover condition classes and changes in these classes over time (1972-1980) for each property (ranch).

Finally the land cover information has been incorporated with slope to derive a map and report of susceptibility to erosion; an index which is of fundamental importance to arid land management.

REVIEWER'S NOTE: The term "range condition" is different from BLM's definition.

45. Graetz, R.D., and R.P. Pech. 1982. The utility of Landsat for monitoring the ephemeral water and herbage resources of arid lands: an example of rangeland management in the Channel Country of Australia. pp. 1031-1046. Proceedings, International Symposium on Remote Sensing of Environment. First Thematic Conference, Remote Sensing of Arid and Semi-Arid Lands, Ann Arbor, Michigan.

AUTHOR ABSTRACT: The conception and development of a cost-effective, Landsat-based resource information system for a unique part of Australian rangelands is described.

The study area, termed the Channel Country, is in the centre of the continent's arid rangelands and includes the floodplains of three large ephemeral inland rivers that flow from areas of high rainfall into the desert.

Though remote and sparsely settled, this country carries appreciable herds of cattle. As improved land management and financial profitability of grazing operations would flow from a better synchrony of grazing use with forage production, there is a requirement for information on the size, extent and duration of floods. With this information carrying capacity of any area of land can then be forecast by pastoral managers.

Two methods for predicting carrying capacity were assessed. The first is a model of the rainfall/run-off relationship of the catchments. The second, more successful method, used Landsat data to monitor the area of flooding and subsequent ephemeral forage growth.

Consequently a Landsat-based monitoring system for the water and forage resources of the Channel Country has been developed and is under test. The authors believe that such a system is widely applicable but that sociological rather than technological factors will limit its introduction in many countries.

REVIEWER'S NOTE: A discussion of large area, ephemeral range monitoring with Landsat. Cover and greenness indexes are discussed. A narrative report with little quantitative analysis and no accuracy evaluations.

46. Griffiths, G.H., and W.G. Collins. 1982. The development of a method using Landsat satellite imagery for detecting and monitoring desert encroachment into areas of semi-arid vegetation in northern Kenya. pp. 1217-1218. Proceedings, International Symposium on Remote Sensing of Environment, First Thematic Conference, Remote Sensing of Arid and Semi-Arid Lands. Ann Arbor, Michigan.

AUTHOR ABSTRACT: None supplied.

INTRODUCTION: The primary objective of the project is to determine whether multispectral Landsat imagery can be used to detect and map desert encroachment into the sparse vegetation surrounding the nomadic settlement of Kargi in Northern Kenya.

Fieldwork to collect ground-truth data during a pilot project in 1979, combined with a study of available aerial photographs for 1952 and 1972 has shown that there has been both a loss of vegetation cover and a change in the botanical composition of common plant species. The provision of a permanent supply of water, recurrent drought, notably the Sahel-Sudan drought of 1968-73, and pressure upon resources from an expanding population, has led to desert encroachment up to a radius of 10 km from Kargi.

The area of interest is a part of a wider area now being studied by a UNESCO Integrated Project for Arid Lands (IPAL), which was established partly in response to the Nairobi Conference on Desertification in 1976. The project area occupies 2,500 sq km with the centre at Kargi (Long. 37°35'E, Lat. 2°30'N), approximately 100 km east of Lake Turkana. Vegetation consists of an open community of predominantly *Acacia* bush with grassland, with a typical cover density between 20-30% growing on basement-derived sediments. It is extensively grazed in areas of security from tribal raiding and within reasonable distance from water, by the herds of Rendille nomads.

REVIEWER'S NOTE: Sparse vegetation difficult to separate from surface materials.

47. Haas, R.H., D.W. Deering, J.W. Rouse, Jr., and J.A. Schell. 1975. Monitoring vegetation conditions from Landsat for use in range management. pp. 43-52. Proceedings, First NASA Earth Resources Survey Symposium, Houston, Texas.

AUTHOR ABSTRACT: A summary of the Landsat Great Plains Corridor projects and the principal results are presented. Emphasis is given to the use of satellite acquired phenological data for range management and agri-business activities. A convenient method of reducing Landsat MSS data to provide quantitative estimates of green biomass on rangelands in the Great Plains is explained. Suggestions for the use of this approach for evaluating range feed conditions are presented. A Landsat Follow-on project has been initiated which will employ the green biomass estimation method in a quasi-operational monitoring of range readiness and range feed conditions on a regional scale.

48. Haas, R.H., E.H. Horvath, and W.A. Miller. 1984. Using a digital data base for inventory and management of public rangelands. pp. 155-161. Natural Resources Foundation Symposium on the Applications of Remote Sensing to Resource Management, Seattle, Washington. American Society of Photogrammetry, Falls Church, Virginia.

AUTHOR ABSTRACT: Land resource inventories provide data used in planning and managing public rangeland administered by the Bureau of Land Management. A method was identified for stratifying the resource area into sites of similar production and management potential prior to field sampling. Three data sets were employed in the final strategy for mapping range capability classes. The data base included digitized soils boundaries, digitized administrative boundaries, and vegetation classes derived from Landsat spectral data. For mapping range capability classes, the plant community types were mapped within dominant range sites as indicators of successional status. The grid cell data were finally converted to polygons and mapped on a 7.5-minute quadrangle format (1:24,000 scale).

REVIEWER'S NOTE: Work performed in the Worland District of Wyoming, using Landsat to provide present vegetation data. Report does not include accuracy determinations. Project results require further evaluation by BLM. Report includes a cost analysis of the procedure.

49. Haas, R.H., E.H. Horvath, and W.A. Miller. 1982. Landsat applications for SVIM (LAS): Final Report, Geological Survey Contract # 14-08-0001-20129. EROS Data Center, Sioux Falls, South Dakota. 85 pages.

AUTHOR ABSTRACT: A cooperative project between the EROS Data Center (EDC) and BLM evaluated the feasibility of mapping present vegetation using Landsat Multispectral Scanner (MSS) data, and using this

vegetation data as input to mapping site writeup areas (SWA's). Landsat digital data acquired at two dates, digital terrain data, and digitized map information (soil series, allotments, and administrative units) were registered to a Universal Transverse Mercator (UTM) map projection with 50-meter grid cells. A hierarchical vegetation classification framework was developed to differentiate the ecologically significant plant community types. It was determined that spectral stratification is a useful aid for classifying and labeling natural vegetation types. Three data sets were employed in the final strategy for mapping SWA's: (1) the Landsat-derived present vegetation, (2) digitized soil series data, and (3) digitized boundaries of administrative allotments. Soil series were aggregated to form dominant range sites. Range site and administrative allotment files were merged to create pre-SWA's. Vegetation types were then mapped within range sites, using a set of decision rules which aggregated vegetation classes as indicators of ecological succession and trend for a given kind of rangeland. The procedure developed for mapping SWA's properly identified the significant soil/vegetation zones on the arid and semiarid rangelands in northwest Wyoming.

REVIEWER'S NOTE: The definition of SWA as used in this document varies slightly from the definition of SWA used by BLM. SWAs are often made up of several ecological sites each having a unique vegetation association. The procedure used in this study appears to have more potential to identify seral communities or community types than SWAs. No accuracy figures were given.

50. Haas, R.H., and D.C. Johnston. 1984. Monitoring range utilization on the Crow Creek Indian Reservation: Final Report, Geological Survey Contract # 14-08-0001-20129. EROS Data Center Library, Sioux Falls, South Dakota. 105 pages.

AUTHOR ABSTRACT: A cooperative project between the EROS Data Center (EDC) and Bureau of Indian Affairs (BIA) tested the feasibility of developing cost-effective procedures for monitoring grazing use and rangeland vegetation trends on Reservation lands. The objective of this two year effort was to use Landsat multispectral scanner (MSS) data within a spatial data base to produce and evaluate indexes of rangeland use and condition trends for the Crow Creek Reservation in central South Dakota. Orientation of the project was toward developing procedures specifically for BIA management needs.

Brightness and greenness transformations of Landsat data were used to measure spectral differences which were interpreted as degree of utilization at the end of the growing season. Brightness and greenness change, measured by comparing scenes in several growing seasons, provided an alternative approach for measuring changes that can be interpreted as vegetation condition trend.

The project has produced evidence that Landsat MSS data can be used to monitor herbaceous vegetation conditions on grasslands. Brightness and greenness transformation of spectral data are best used in context of a geographical information system.

51. Haas, R.H., and F.A. Waltz. 1983. Evaluation of thematic mapper data for natural resource assessment. pp. 122-133. Proceedings, Eighth William T. Pecora Symposium, Sioux Falls, South Dakota.

AUTHOR ABSTRACT: The U.S. Geological Survey EROS Data Center evaluated the utility of Landsat Thematic Mapper (TM) data for natural resource assessment, emphasizing manual interpretation and digital classification of the data for U.S. Department of the Interior applications. Substantially more information was derived from TM data than from Landsat Multispectral Scanner (MSS) data.

Greater resolution of TM data aided in locating roads, small stock ponds, and many other land features that could be used as landmarks. The improved spatial resolution of TM data also permitted more efficient visual interpretations of land use, better identification of resource types, and improved assessment of ecological status of natural vegetation. TM data also provided a new source of spectral information that was useful for natural resource assessment. New mid-infrared spectral bands, TM band 5 and band 7, aided in distinguishing water resources, wetland vegetation resources, and other important terrain features. The added information was useful for both manual interpretation and digital data classification of vegetation resources and land features.

Results from the analyses of both TM and TM Simulator (TMS) spectral data suggest that the coefficient of variation for major land cover types is generally less for TM data than for MSS data taken from the same area. This reduction in variance should contribute to an improved multispectral classification of land cover types. The TM bands 5 and 7 also add a new dimension to multispectral analysis, contributing new information about vegetation in natural ecosystems. Although the amount of new information in TM bands 5 and 7 is small, it is unique in that the same information cannot be derived from four-band Landsat MSS spectral data.

52. Hacker, R.B., 1980. Prospects for satellite applications in Australian rangelands. Tropical Grasslands, 14(3):288-295.

AUTHOR ABSTRACT: The Landsat satellite system and its data products are briefly described. Rangeland applications in the fields of resource inventory, monitoring of seasonal conditions and monitoring of ecological condition are discussed. Inventory applications are already operational and it is concluded that monitoring of seasonal conditions is potentially operational. The potential for monitoring of ecological condition is still largely unproven.

REVIEWER'S NOTE: A good review of past studies that used satellite data for range inventory and monitoring.

53. Hacker, R.B. 1978. Use of large-scale aerial photographs for ecological studies in a grazed arid ecosystem. pp. 1895-1908. Proceedings, 12th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan.

AUTHOR ABSTRACT: Color aerial photographs at a scale of approximately 1:250 were used to obtain plant inventories for six study sites in a multilayered arid zone community. Species were divided into size classes based on canopy area. Coordinates for each individual, read from the photographs, were transformed to ground coordinates and used to produce plant counts in contiguous quadrats. Multiple pattern analysis of these data revealed the major features of community variation and their corresponding scales of pattern. Within-site variation in grazing pressure was the major factor influencing community pattern in three sites. Responses of the major species to grazing were clearly defined. Aggregation of shrubs around the relics of older populations of trees or large shrubs, or under the canopies of living individuals, primarily determined (or at least influenced) vegetation pattern on the remaining sites. The presence of these relics is thought to impose a weak fundamental pattern on this community.

REVIEWER'S NOTE: Seventy millimeter aerial color photography in western Australia enlarged to 1:250-scale was used to make detailed inventories of plant species. The species and track (livestock) density data were rigorously analyzed with statistical techniques to determine vegetation response to grazing pressure. Accuracy figures for species identification are not given.

54. Harlan, J.C., W.E. Boyd, C. Clark, S. Clarke, and O.C. Jenkins. 1979. Rangeland resource evaluation from Landsat. Progress Report RSC 3715-2, Texas A&M University Remote Sensing Center, College Station, Texas. 92 pages.

AUTHOR ABSTRACT: None supplied.

SUMMARY: The final report discusses the strategy, procedures, data and analysis results for the project. In addition recommendations for future work are made and detailed ecological site descriptions and an annotated bibliography are provided. A brief implementation plan for the project is given in Appendix A.

The significant findings of the study are that the ability to achieve useful Landsat biomass estimates for low biomass, semi-arid sites has been demonstrated, that efforts to counteract adverse atmospheric conditions and their effect on the biomass estimates

must be undertaken, and that effective ground sampling instrumentation must be developed. Regression results showed that the Normalized Difference parameter ND6 explained 75 percent of the variation in green biomass for normal clear sky data acquisitions. The departure of the July data from the regression line show that certain cloud conditions apparently can cause the ND6 values to shift causing overestimation of biomass. Based on the results of the study, recommendations are given to test the biomass estimation technique in other semi-arid and arid ecosystems, and to study methods to counteract the adverse atmospheric effects. Ground data acquisition solely by clipping is labor intensive and too time-inefficient for general use on large areas in semi-arid and arid regions. Consequently, development of a biomass measuring device, such as the two channel radiometer (biometer) is required.

Before Landsat herbaceous biomass assessment on arid and semi-arid rangelands can be universal some problems await solution: accounting for woody species contamination of the spectral data; the high reflectance of some exposed soils, and, depending on the status of others' research, the effects of high relief terrain. The recommendations, then, are that research be mounted to solve the problems. In addition, the basic biomass estimation technique described can be tested on other semi-arid and arid ecosystems of the intermountain and western states on land not affected by the stated problems.

REVIEWER'S NOTE: The study was done in northeastern Colorado grasslands and may produce comparable results in similar rangelands. The methodology may have problems in areas of high contrast soils or dense brush canopies.

55. Harris, R.W. 1951. Use of aerial photographs and sub-sampling in range inventories. *Journal of Range Management*, 4(4):270-278.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Aerial photographs provided an efficient and simple method for randomizing sampling units within range types of irregular conformation. They were found to be effective for accurate delineation of range type boundaries. The intensity of sampling required to secure acceptable sampling errors for all of the individual species is beyond the financial and time limits usually prescribed for inventories of most large range areas. The intensity of sampling required to secure precise information for those species that provide the bulk of forage taken by livestock is within practical limits. The procedure has been tested and found satisfactory for range condition and trend surveys.

56. Heintz, T.W., J.K. Lewis, and S.S. Waller. 1979. Low-level aerial photography as a management and research tool for range inventory. *Journal of Range Management*, 32(4):247-249.

AUTHOR ABSTRACT: An inexpensive technique is reviewed for using low-level aerial photography as a management and research tool for range. Modifications of a previously documented camera mount are reported that allow greater flexibility in the use of aerial photography for range evaluation. This technique involves the use of color infrared film with a 135 mm telephoto lens double filtered with orange and magenta filters.

REVIEWER'S NOTE: Describes use of 35 mm motordrive cameras mounted on door of fixed wing aircraft to acquire near vertical stereo photography. Photography used primarily to aid research studies. Report concentrates more on hardware and acquisition procedures than on analysis techniques.

57. Hironaka, M., E.W. Tisdale, and M.A. Fosberg. 1976. Use of satellite imagery for classifying and monitoring rangelands in southern Idaho. Idaho Forest, Wildlife, and Range Experiment Station, Bulletin 9. 7 pages.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Work performed in the early 1970s. Manual (visual) interpretation from Landsat images was accomplished. Accuracy figures are not included.

58. Horvath, E.H., D.F. Post, W.M. Lucas, and R.A. Weismiller. 1980. Use of Landsat digital data to assist in mapping soils on Arizona rangelands. pp. 235-240. *Proceedings, Sixth Annual Machine Processing of Remotely Sensed Data*, Purdue University, West Lafayette, Indiana.

AUTHOR ABSTRACT: The outline and results of more than three years of field and laboratory studies are presented. The work was done in cooperation with the Soil Conservation Service, the Bureau of Land Management, and the Forest Service. Spectral maps generated from Landsat satellite data were used to aid in soil and vegetation surveys of five sites in southeastern Arizona. The sites are rangeland with varied physiography and relief, but generally sparse vegetation. It was found that spectral maps show a very positive correlation with grey tones or color patterns on photographs, and can be an excellent auxiliary tool for locating boundaries of mapping units. They can also aid in the location of representative sites for pedon descriptions, and could be used as an aid to quality control and map correlation studies in the field. The type and/or color of the geologic parent material was the dominant factor affecting the response recorded by the satellite.

REVIEWER'S NOTE: This article primarily describes the potential use of Landsat MSS-derived spectral maps to create a preliminary soils map.

59. Hughes, L.E. 1981. High altitude photography and range trend. Rangelands, 3(5):197-198.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Aerial photographs of range sites in northern Arizona were observed for tone changes and field conditions on the ground. Dark tones occurred in two aerial photographs taken at 10-year intervals. The better range condition was related to darker tones and the poor condition with lighter tones. An exception to this would be darker tones of reinvading brush and trees in rehabilitated range. The use of high altitude photography could be used to detect a significant shift in trend quality; species lost or gained would be determined from field sampling. This photo interpretation technique is similar to the Landsat Brightness and Greenness concept.

60. Langley, P.G. 1971. The benefits of multistage variable probability sampling using space and aircraft imagery. pp. 119-126. Proceedings, Applications of Remote Sensors in Forestry. International Union of Forest Research Organizations, Freiberg, Germany. Druckhouse Romback and Co.

AUTHOR ABSTRACT: A new efficient multistage technique devised for application to resource inventories combines remote sensing from several altitudes with ground measurements. The method takes advantage of the increasingly finer resolution of remote sensor imagery that may become available on a sampling basis to increase the efficiency of sample selection in each subsequent stage. The precision of the estimated totals depends solely on the relationship between predictions made by image interpretation and the value of measured characteristics of the sample units used to estimate population parameters. Hence, the efficiency of a resource survey using the method depends on the quality of the image interpretation. The method is easy to use, operationally efficient, and provides for a greater proportion of the work to be carried out in the areas of higher value. Furthermore, the method obviates the need to know the exact land area encompassed by sample plots, thus greatly simplifying the photogrammetric aspects of resource survey work.

61. Lorain, G.E. 1970. 70 mm large-scale aerial photography for range resource evaluation. Masters thesis, University of Nevada, Reno. 93 pages.

AUTHOR ABSTRACT: None supplied.

INTRODUCTION: The vastness of rangelands, coupled with their relative inaccessibility, poses a difficult problem for adequate inventory and analysis by ground sampling systems. As management

becomes increasingly more intensive and demand for land use increases, the need arises for a good monitoring system. No single solution will probably suffice, but 70 mm low-level, large-scale aerial photography appears to have some merit for quickly gathering considerable information over large land areas. It is not suggested that ground systems be completely replaced, but a combination of the two used with a minimum of field checking.

This study is an attempt to develop the necessary techniques for gathering information to monitor range landscapes within a reasonable economic framework. Photographs are permanent records of vegetation. Data can be rechecked at any time in the future, if required, to eliminate the problem of variability among observers. In addition, a photograph provides the range manager with positive visual evidence to show the range user whether his range is deteriorating, improving or remaining unchanged.

The primary objectives of this study are as follows:

1. To determine if the various species encountered could be identified on large-scale, color aerial photography;
2. To develop a plant identification key to aid subsequent observers to identify plant species;
3. To determine if vegetation parameters such as cover and density can be measured on photographs to record vegetation change over time;
4. To identify soil surface and erosional features and animal signs on photographs;
5. To compare the efficiency of aerial photographic techniques with conventional ground techniques for gathering data.

Plant species and other surface features were marked and measured in the field for later comparisons with the same data obtained from aerial photographs. In addition, cover and density were recorded in the field on all plant species for similar comparisons.

REVIEWER'S NOTE: Publication describes evaluation of 70 mm, large-scale photography for identification and measurement of range vegetation on six study sites in Nevada. Comparison of alternative quantification methodologies for determining cover are included. Time requirements for photo interpretation are discussed.

62. May, G.A., M.L. Holko, and J.E. Anderson. 1983. Classification and area estimation of land covers in Kansas using ground-gathered and Landsat digital data. NASA-TM 85518. 14 pages.

AUTHOR ABSTRACT: Ground-gathered data and Landsat multispectral scanner (MSS) digital data from 1981 were analyzed to produce a classification of Kansas land areas into specific types called land

covers. The land covers included rangeland, cropland, forest, residential, commercial/industrial, and various types of water. The analysis produced two outputs: acreage estimates with measures of precision, and map-type or photo products of the classification which can be overlaid on maps at specific scales. State-level acreage estimates were obtained and substate-level land cover classification overlays and estimates were generated for selected geographical areas. These products were found to be of potential use in managing land and water resources. This land cover information was obtained by utilizing an operational program within the U.S. Department of Agriculture. Statistical methodology is not discussed in detail, but is highly referenced for the interested reader.

63. McDaniel, K.C., D.H. Gates, R. Findley, and G. Miller. 1975. An inventory of rangeland brush control projects from ERTS-1 space imagery. *Journal of Range Management*, 28(6):499-500.

AUTHOR ABSTRACT (Highlight): Shrub-brush manipulation projects have had major ecological and economic impacts upon the 9,136 square miles of public and private rangeland in Malheur County, Oregon. Analysis of imagery from the Earth Resources Technology Satellite (ERTS-1) indicated that space-acquired data used in conjunction with field data, holds a potential for identifying, classifying, inventorying, and monitoring these changes occurring on rangeland areas.

64. McDaniel, K.C., and R.H. Haas. 1981. Classifying and characterizing natural vegetation on a regional basis with Landsat MSS data. pp. 197-203. *Proceedings, Arid Land Resource Inventories: Developing Cost Efficient Methods*, La Paz, Mexico. USDA, Forest Service, General Technical Report WO-28, Washington, D.C.

AUTHOR ABSTRACT: Landsat multispectral scanner imagery and digital data are suitable for classifying and quantifying natural vegetation conditions on a regional basis. Stratifying relatively uniform vegetation-soil systems on Landsat imagery is the first step in employing Landsat MSS data for regional vegetation survey programs. The second step is to establish the functional relationships of Landsat derived reflectance models to various vegetation parameters found in each stratified vegetation-soil system being inventoried.

65. McGraw, J.F., and P.T. Tueller. 1983. Landsat computer-aided analysis techniques for range vegetation mapping. *Journal of Range Management*, 36(5):627-631.

AUTHOR ABSTRACT: Landsat computer-aided analysis techniques were used to map the sagebrush-grass vegetation of northern Nevada. A final Landsat digital classification resulted in 14 spectral classes representing 8 range plant communities. Classification accuracy for

all sample plots was 86.4%, with individual class accuracies ranging from 77.8 to 95.4%. Classification methods included supervised, unsupervised, and guided clustering techniques using a maximum likelihood classifier.

REVIEWER'S NOTE: Vegetation mapping with Landsat MSS in the Saval Ranch area of Nevada. Accuracy figures are presented, although sites were not randomly selected.

66. McLeod, R.G., and H.B. Johnson. 1981. Resource inventory techniques used in the California Desert Conservation Area. pp. 260-272. Proceedings, Arid Land Resource Inventories: Developing Cost Efficient Methods, La Paz, Mexico. USDA, Forest Service General Technical Report WO-28, Washington, D.C.

AUTHOR ABSTRACT: A variety of conventional and remotely sensed data for the 25 million acre California Desert Conservation Area (CDCA) have been integrated and analyzed to estimate range carrying capacity. Multispectral classification was performed on a digital mosaic of ten Landsat frames. Multispectral classes were correlated with low level aerial photography, quantified and aggregated by grazing allotment, land ownership, and slope.

67. Merchant, J.W., and E.A. Roth. 1982. Inventory and evaluation of rangeland in the Cimarron National Grassland, Kansas. pp. 104-113. Proceedings, Seventh William T. Pecora Memorial Symposium, Sioux Falls, South Dakota.

AUTHOR ABSTRACT: The objective of this project is to identify and demonstrate the manner in which a range resource information system founded upon Landsat data may be employed by local level range managers. The study focuses on the Cimarron National Grassland (CNG) of southwestern Kansas. The 107,000 acre grassland is managed by the USDA, Forest Service for multiple uses, although grazing is particularly important. Landsat MSS data are computer classified to provide information regarding the distribution and condition of plant communities and the distribution of other cover types. A range resources data base designed to enhance local level range management is described. Ancillary data (e.g., soils, ownership, grazing records) will complete a comprehensive information system. Range managers who have evaluated initial project results believe that such information will facilitate decisions regarding future grazing management, allocation of resources and priorities for weed (e.g., sagebrush and yucca) control, reseeding efforts, and wildlife habitat improvement.

REVIEWER'S NOTE: Overall classification accuracy of 85% reported for nine land cover classes that include different cover percentages for grasses and sagebrush. Some qualitative work was done on vegetation indexes to determine biomass, but no definitive results were reported.

68. Meyer, M., F. Batson, and D. Whitmer. 1982. Helicopter-borne 35 mm aerial photography applications to range and riparian studies. Institute of Agriculture, Forestry, and Home Economics, Remote Sensing Laboratory. Resource Report 82-1, University of Minnesota, St. Paul. 80 pages.

AUTHOR ABSTRACT: With the objective of developing a system of range and riparian vegetation studies more cost-effective than current ground methods, a helicopter-borne 35 mm aerial photography system was designed and tested. Twenty-four locations (vegetation types) - six each on the Shoshone BLM District in Idaho, Elko BLM District in Nevada, Cedar City BLM District in Utah and the Montrose BLM District in Colorado - were flown in early summer, 1981, at a variety of altitudes with different film/filter combinations. The characteristics of the system, equipment, field results and recommendations are presented and discussed.

REVIEWER'S NOTE: Good discussion on procedural requirements.

69. Meyer, M., and P. Grumstrup. 1978. Operating manual for the Montana 35 mm aerial photography system - 2nd revision. Institute of Agriculture, Forestry, and Home Economics, Remote Sensing Laboratory. Resource Report 78-1, University of Minnesota, St. Paul. 62 pages.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Describes procedures for using 35 mm cameras, door-mounted on fixed-wing small aircraft, to acquire near-vertical aerial photographs of range study areas. Procedure was used during 1970s, primarily in Montana. Document describes acquisition procedures and generalized principles of analysis. Recommend that potential users discuss this technique with previous users before implementation.

70. Myers, V.I. 1973. Effective use of ERTS multisensor data in the Great Plains. Report No. NASA-CR-131238, South Dakota State University, Brookings. 20 pages.

AUTHOR ABSTRACT: ERTS imagery was used as a tool in the identification and refinement of soil association areas; to classify land use patterns between crop and fallow fields; to identify corn, soybeans and oats; and to identify broad generalized range ecosystems. Various data handling techniques were developed and applied to accomplish these tasks. A map outlining soil associations and relative land values was completed on a base mosaic of ERTS imagery and included as appendix B to this report. It was concluded that ERTS-1 imagery is useful for refining boundaries of major soil and vegetation types and for distinguishing cropland from rangeland, but greater resolution with more and narrower bands appears to be

necessary to provide information for use in range management; that May and late August ERTS-1 imagery is most useful for crop identification, however, development of less expensive machine data handling techniques is necessary for an operational crop identification system; that ERTS data can be effectively used to identify soil associations and can also be used as a base map upon which to publish soils information; and that differences in radiance values of different crops can, in part, be accounted for by soil differences.

71. Otterman, J., and R.J. Fraser. 1976. Earth atmosphere system and surface reflectivities in arid regions from Landsat MSS data. *Remote Sensing of Environment*, 5:247-266.

AUTHOR ABSTRACT: Previously developed programs for computing atmospheric transmission and scattering of the solar radiation are used to compute the ratios of the Earth-atmosphere system (space) directional reflectivities in the nadir direction to the surface Lambertian reflectivity, for the four bands of the Landsat multispectral scanner (MSS). These ratios are presented as graphs for two water vapor levels, as a function of the surface reflectivity, for various sun elevation angles. Space directional reflectivities in the vertical direction are reported for selected arid regions in Asia, Africa, and Central America from the spectral radiance levels measured by the Landsat MSS. From these space reflectivities, surface reflectivities are computed applying the pertinent graphs. These surface reflectivities are used to estimate the surface albedo for the entire solar spectrum. The estimated albedos are in the range 0.34-0.52, higher than the values reported by most previous researchers from space measurements, but are consistent with laboratory and in situ measurements.

REVIEWER'S NOTE: Introduces reader to albedo from the earth's surface. Differentiates overgrazed land from non-overgrazed land by albedo readings.

72. Owens, M.K., H.G. Gardener, and B.E. Norton. 1985. A photographic technique for repeated mapping of rangeland plant populations in permanent plots. *Journal of Range Management*, 38(3):231-232.

AUTHOR ABSTRACT: A lightweight aluminum photograph stand has been developed to record vegetation in permanent plots. At a camera height of 7 m, the plot size is 14 m² when using a 70 mm camera with an 80 mm lens. Minor errors were detected when testing the accuracy of the stand. This stand will be useful for obtaining a record of permanent plots for many different types of research studies.

REVIEWER'S NOTE: Ground photography using a non-stereo technique.

73. Pierce, W.R., and L.E. Eddleman. 1970. A field stereophotographic technique for range vegetation analysis. *Journal of Range Management*, 23(3):218-220.

AUTHOR ABSTRACT (Highlight): Color negative film used in a camera with a lens providing a good depth of field at short focal distances has produced stereo color prints that permit accurate identification and measurement of range vegetation with a pocket stereoscope. This system can overcome many of the problems of inventorying a range.

REVIEWER'S NOTE: Vegetation plots were photographed with a 70 mm camera suspended 5 feet aboveground. Species identification was 95% accurate, but small annual forbs were difficult to locate and identify. Another problem was photographing tall grasses on windy days.

74. Poulton, C.E., R.S. Driscoll, and B.J. Schrupf. 1969. Range resource inventory from space and supporting aircraft photography. pp. 20-1 to 20-28. *Second Annual Earth Resources Aircraft Program Status Review*. Vol. II, Agriculture, Forestry, and Sensor Studies. NASA/MSC, Houston, Texas.

AUTHOR ABSTRACT: None supplied.

SUMMARY AND CONCLUSIONS: As more detailed quantitative information is required about the ecosystems represented in the mapping units on space photography, multiscaled photos are required to provide the subsampling basis for obtaining the added detail. Photos at scales of 1:80,000 appear satisfactory for determining the areal extent of strongly contrasting ecosystems whose image characteristics are markedly different from adjacent units. However, as the differences between ecosystems become more subtle, so will their image characteristics; and the difficulty of interpretation increases as photo scale decreases. As the image differences become more subtle among phenologically different vegetations, the place of multiseasonal photography becomes more apparent. It appears from our work to date that multiseasonal photography may hold the best key to the correct identification of a maximum number of vegetational delineations on aerial or space photography. This is especially true where the seasonal development of the different vegetations is well known as a basis for interpretation.

Since resource management decisions require detailed information, scales of 1:20,000 or larger may be required to provide acceptable quantitative data for this information. Extremely large-scale photography will provide important additional information about the resource. Such things as range plant species density and dispersion can be measured by using photography of 1:2400 and larger scales. This kind of information is required for monitoring changes in

vegetation over time and for determining the actual makeup of the plant community. It is recognized that not all species in the ecosystem will be detectable and identifiable. However, measurement of the larger and perhaps most characteristic species of the community is possible. These often reflect the effects of man's use and manipulation.

As we continue to develop the capability of examining vegetational and related resources through space and aerial photography, it is important to keep in mind some of the interrelationships between the three major resource management functions, Policy and Broad Planning, Land-Use Decisions, and Resource Management, as well as the requirements of the separate activities within each of these functions. These are graphically portrayed in the chart of Figure 10 (refer to publication). It is very important to realize that present space imaging capability with which we have all been working is not well suited to the needs of day-to-day vegetational resource management. It best serves the needs of broad policy and planning. There are, however, many interrelationships between these various functions and activity levels. Depending on the specific nature of the problem, valid exception may be taken to this statement and to the generalities represented by the italicized indications of image applicability to the various jobs charted in Figure 10. Perhaps the greatest factor interacting with photo scale to determine usability is image resolution. Obviously, small-scale photography with exceptional resolution may be superior to low-resolution intermediate-scale photos when one considers enlargement capability. Based on the range of scales with which we have been working, Figure 10 presents our current assessment of the minimum requirements of each functional and activity level for imagery of natural resources to meet the varied needs of the resource user and management decision-maker. Depending on the function and level being monitored, the requirements for resource monitoring are also suggested by the italicized symbols in Figure 10.

75. Rains, A.B. 1970. The evaluation of African rangeland using aerial photographs. pp. 99-101. Proceedings, 11th International Grassland Congress.

AUTHOR ABSTRACT: None supplied.

SUMMARY: The use of aerial photography has become standard practice in natural resource surveys of extensive and frequently inaccessible areas; in Africa, such surveys of semi-arid areas are usually concerned with the evaluation of fodder resources.

Stereoscopic examination of air photographs allows physiognomic vegetation units such as woodland, savannah and grassland to be identified and delineated on the photographs; additional information can be inferred from the topography and burning patterns. Ground observation and measurements are essential to supplement this airphoto interpretation.

Types of film, scale and the methods and limitations of airphoto interpretation are discussed and rangeland surveys in Botswana are described.

REVIEWER'S NOTE: No accuracy figures were given, but according to the report, grassland could be recognized and the density of tall shrubs and trees could be determined from 1:60,000 black-and-white panchromatic prints. The density of woody plants in low shrub savannah were difficult to assess, but they could be inferred from the distribution and type of burning patterns.

76. Richardson, A.J., C.L. Wiegand, R.J. Torline, and M.R. Gautreaux. 1976. Land use survey comparison of Hidalgo County, Texas, for January 21 and May 27, 1973, Landsat-1 Overpasses. pp. 379-394. Proceedings, 42nd Annual Meeting, American Society of Photogrammetry, Washington, D.C.

AUTHOR ABSTRACT: Multispectral scanner (MSS) data collected by the first Earth Resources Technology Satellite (Landsat-1) on January 21 and May 27, 1973, were used for classification and acreage estimation studies of crop and soil categories in Hidalgo County, Texas. Classification results, based on approximately 1,400 fields, improved, using fields larger than 15 acres, with more than 25% plant cover, and with plants taller than 30 cm in both January and May 1973. Ground truth and computer acreage estimates for citrus, combined cotton and sorghum, and idle cropland categories were not significantly different for the respective dates of January, May, and January. The computer acreage estimates for citrus, combined cotton and sorghum, and winter vegetable categories differed from the Texas Crop and Livestock Reporting Service acreage estimates by 32, 8, and 47%, respectively. Thus, these results indicate a potential for an agricultural Landsat survey system for land use categories like citrus, combined cotton and sorghum, idle cropland, and vegetables.

77. Robinove, C.J. 1979. Integrated terrain mapping (of vegetation, soil, topography, and geomorphic features, to create a "land systems map" usable for grazing land management) with digital Landsat images in Queensland, Australia. Geological Survey. Professional paper. (1102), 39 pages.

AUTHOR ABSTRACT: Mapping with Landsat images usually is done by selecting single types of features, such as soils, vegetation, or rocks, and creating visually interpreted or digitally classified maps of each feature. Individual maps can then be overlaid on or combined with other maps to characterize the terrain. Integrated terrain mapping combines several terrain features into each map unit which, in many cases, is more directly related to uses of the land and to methods of land management than the single features alone. Terrain brightness, as measured by the multispectral scanners in

Landsat 1 and 2, represents an integration of reflectance from the terrain features within the scanner's instantaneous field of view and is therefore more correlatable with integrated terrain units than with differentiated ones, such as rocks, soils, and vegetation.

A test of the feasibility of the technique of mapping integrated terrain units was conducted in a part of southwestern Queensland, Australia, in cooperation with scientists of the Queensland Department of Primary Industries. The primary purpose was to test the use of digital classification techniques to create a "land systems map" usable for grazing land management. A recently published map of "land systems" in the area (made by aerial photograph interpretation and ground surveys) which are integrated terrain units composed of vegetation, soil, topography, and geomorphic features, was used as a basis for comparison with digitally classified Landsat multispectral images. The land systems, in turn, each have a specific grazing capacity for cattle (expressed in beasts per km²) which is estimated following analysis of both research results and property carrying capacities.

Landsat images, in computer-compatible tape form, were first contrast-stretched to increase their visual interpretability, and digitally classified by the parallelepiped method into distinct spectral classes to determine their correspondence to the land systems classes and to areally smaller, but readily recognizable "land units."

Many land systems appeared as distinct spectral classes or as acceptably homogeneous combinations of several spectral classes. The digitally classified map corresponded to the general geographic patterns of many of the land systems. Statistical correlation of the digitally classified map and the published map was not possible because the published map showed only land systems whereas the digitally classified map showed some land units as well as systems.

The general correspondence of spectral classes to the integrated terrain units means that the digital mapping of the units may precede fieldwork and act as a guide to field sampling and detailed terrain unit description as well as measuring of the location, area, and extent of each unit.

Extension of the Landsat mapping and classification technique to other arid and semi-arid regions of the world may be feasible.

REVIEWER'S NOTE: No accuracy figures were given and digital processing techniques are not state-of-the-art.

78. Robinove, C.J., P.S. Chavez, Jr., D. Gehring, and R. Holmgren. 1981. Arid land monitoring (in the Desert Experimental Range in southwestern Utah) using Landsat albedo differences images. Remote Sensing of Environment, 11(2):133-156.

AUTHOR ABSTRACT: The Landsat albedo or percentage of incoming radiation reflected from the ground in the wavelength range of 0.5 μm to 1.1 μm , is calculated from an equation using the Landsat digital brightness values and solar irradiance values, and correcting for atmospheric scattering, multispectral scanner calibration, and sun angle. The albedo calculated for each pixel is used to create an albedo image, whose grey scale is proportional to the albedo. Differencing sequential registered images and mapping selected values of the difference is used to create quantitative maps of increased or decreased albedo values of the terrain. All maps and other output products are in black and white rather than color, thus making the method quite economical. Decreases of albedo in arid regions may indicate improvement of land quality; increases may indicate degradation. Tests of the albedo difference mapping method in the Desert Experimental Range in southwestern Utah (a cold desert with little long-term terrain change) for a four-year period show that mapped changes can be correlated with erosion from flash floods, increased or decreased soil moisture, and increases or decreases in the density of desert vegetation, both perennial shrubs and annual plants. All terrain changes identified in this test were related to variations in precipitation. Although further tests of this method in hot deserts showing severe "desertification" are needed, the method is nevertheless recommended for experimental use in monitoring terrain change in other arid and semiarid regions of the world.

79. Schmer, F.A., R.E. Isakson, and J.C. Eidenshink. 1977. Investigation of remote sensing techniques as inputs to operational resource management. Report No. SDSI-RS1-77-12, Brookings, South Dakota. 173 pages.

AUTHOR ABSTRACT: The primary objective of the study is to assist participating state agencies to evaluate remote sensing (with emphasis on unmanned resource satellite data) as a cost effective data source in operational programs. Participating South Dakota agencies include: The Black Hills Conservancy Subdistrict, the State Planning Bureau, the Game, Fish and Parks Department, and the Department of Natural Resource Development. With the exception of the Sub-district, each agency has committed half a man-year to the project. With NASA high altitude aircraft imagery, low altitude aircraft data, and ground truth information, Landsat data are being evaluated as a data source for such programs as land use mapping, surface water inventories, aspen mapping, and crop identification. Both visual and computerized interpretations are being investigated. Also under investigation is a NASA-developed Digital Image Rectification (DIRS) which rectifies Landsat multispectral scanner digital data using Universal Transverse Mercator coordinates as a grid base. The DIRS package will be evaluated for the potential of improved digital data analysis. Resource data handling is being addressed via MAPCLASS, a program which provides a method of data

storage and handling with output via many different methods. Basic project results are discussed and recommendations are made on the operational use of Landsat data for South Dakota State Government.

REVIEWER'S NOTE: Land use mapping via remote sensing.

80. Seevers, P.M., J.V. Drew, and M.P. Carlson. 1975. Estimating vegetative biomass from Landsat-1 imagery for range management. pp. 1-8. Proceedings, First NASA Earth Resources Survey Symposium, Houston, Texas.

AUTHOR ABSTRACT: Evaluation of Landsat-1, band 5 data for use in estimation of vegetative biomass for range management decisions was carried out for five selected range sites in the Sandhills region of Nebraska. Analysis of sets of optical density-vegetative biomass data indicated that comparisons of biomass estimation could be made within one frame but not between frames without correction factors. There was high correlation among sites within sets of radiance value-vegetative biomass data and also between sets, indicating comparisons of biomass could be made within and between frames. Landsat-1 data are shown to be a viable alternative to currently used methods of determining vegetative biomass production and stocking rate recommendations for Sandhills rangeland.

REVIEWER'S NOTE: Article contains a good discussion about Landsat MSS capabilities for biomass estimation in the Sandhills of Nebraska. Cautionary statements offered by the authors should be noted.

81. Strong, L.L., R.W. Dana, and L.H. Carpenter. 1985. Estimating phytomass of sagebrush habitat types from microdensitometer data. Photogrammetric Engineering and Remote Sensing, 51(4):467-474.

AUTHOR ABSTRACT: Microdensitometry of large-scale color infrared photographs was investigated as an indirect technique to estimate phytomass production of three sagebrush steppe, *Artemisia tridentata*, habitat types on a mule deer winter range. Inverse relationships between phytomass production and reflectance varied between habitat types. Red reflectance explained 59 and 56 percent of the variation in phytomass production for two habitat types. Spectral variables were highly correlated, resulting in band ratios that were relatively constant with little predictive ability. An inverse curvi-linear relationship for data of two habitat types explained 76 percent of the variance in phytomass production with a standard error of 15 percent of the mean. In an evaluation of the regression models, phytomass production was underestimated due to incomplete representation in the models of large reflectance values from bare soil. Regressions using integral density and exposure had residual variances similar to those obtained using reflectance as the independent variable.

REVIEWER'S NOTE: Excellent reference for anyone contemplating a study of phytomass on rangelands with large-scale color infrared aerial photos.

82. Thomas, R.W., and S.D. DeGloria. 1979. Large-scale aerial photography as a sample stage in wildland resource inventories. pp. 15-33. Proceedings, Seventh Biennial Workshop on Color Aerial Photography in the Plant Sciences and Related Fields. American Society of Photogrammetry, Falls Church, Virginia.

AUTHOR ABSTRACT: The management of renewable natural resources requires accurate, timely, and efficient inventories. Sample methods which incorporate large-scale aerial photography enhance this inventory process by reducing the cost and sampling error of estimates. Many of the factors which must be evaluated when designing and conducting LSP-aided inventories are addressed. These include auxiliary variate definition, evaluation of appropriate sampling systems, construction of cost and sample size ratios between large-scale aerial photography and ground measurement, and discussion of inventory efficiency. Acquisition, measurement, and error sources associated with using large-scale aerial photography as a sampling medium are discussed. Recent applications which illustrate these inventory components are cited. Problem areas and improvements needed to increase the efficient utilization of LSP are also addressed.

83. Thompson, M.D., R.V. Dams, and G.M. Beaubier. 1983. Transfer of Landsat technology for operational PFRA range management programs in Southern Saskatchewan. pp. 793-804. Eighth Canadian Symposium on Remote Sensing, Montreal, Quebec.

AUTHOR ABSTRACT: The efficient use of western Canadian rangelands has been a concern of public officials and private ranchers since initial settlement, but has become more important in recent decades with increasing pressure on these lands. Following a technology transfer program in southern Alberta in 1980, the application of an enhanced Landsat image product to provide information on range use to managers was initiated in four southern Saskatchewan mixed prairie PFRA pastures. This study, carried out during the 1981 grazing season and continued in an operational mode in 1982, involved PFRA staff at various management levels, a consulting firm (Intera Environmental Consultants Ltd.) and the Canada Centre for Remote Sensing.

The 1981 pilot study showed that Landsat products provided valuable information to several levels of PFRA management, particularly with respect to relative range condition and use. Early season (May/June) and late season (September/October) images were found to be the most useful for evaluating changes in management practices on an annual and seasonal basis. In 1982, PFRA staff incorporated Landsat

products into their operational range management system for all 15 pastures within their jurisdictional area; the effects of management changes from 1981 were noted and further decisions were made following the 1982 grazing season based on Landsat products. The use of Landsat data has been successfully transferred into PFRA range management, and managers feel it promotes cost-effectiveness and efficiency of operation.

84. Thompson, M.D., R.V. Dams, and D.H. McCartney. 1983. The use of remote sensing to estimate productivity in a parkland seeded pasture. pp. 529-541. Eighth Canadian Symposium on Remote Sensing, Montreal, Quebec.

AUTHOR ABSTRACT: Recent progress has been made in the application of remote sensing to operational range management programs in the semiarid prairie regions of western Canada. However, the small seeded pastures in the parkland areas to the north present a much different problem in terms of the assessment of forage type and productivity during the grazing season.

With an eventual program objective of developing a forage evaluation system using remote sensing data, 23 cm and 35 mm aerial photographs were obtained over the Pathlow Pasture near the Agriculture Canada Melfort Research Station, Saskatchewan in 1979, 1981, and 1982. This pasture is seeded with a variety of introduced grasses and legumes typical of cattle forage in this parkland area. Intensive ground data collection at the times of the remote sensing overflights provided data for interpretation of forage type and productivity. Analysis of colour and texture, initially from 23 cm CIR prints and later from 35 mm CIR slides, separated biomass levels into 25 g/m² increments for six pasture types in 1981 and 20 g/m² increments for three pasture types in 1982. The results were repeatable from one year to the next using this simple analysis method; the change from 23 cm to 35 mm photography, a much more economical method of data acquisition, did not significantly alter the results. Seasonal analysis showed that data from June and July provided the most detailed and useful pasture management information. Digital analysis of productivity using Landsat data will be carried out in 1983.

85. Thomson, K.P.B., F.J. Ahern, R.J. Brown, C. Pearce, S. Hoyles, and G. Fedosejevs. 1983. New remote sensing techniques for monitoring the fescue grasslands of Alberta. pp. 543-558. Eighth Canadian Symposium on Remote Sensing, Montreal, Quebec.

AUTHOR ABSTRACT: The Canada Centre for Remote Sensing carried out a project in 1980 to develop the use of satellite imagery for range management in western Canada. The results of the project led to the development of an enhanced Landsat image product now being used operationally, for mixed grass prairie areas. The data collected

and analyzed over the rough fescue test sites of Stavely and Ross Lake in Alberta showed that the enhanced Landsat MSS images could not be used to unambiguously assess range condition or utilization in the fescue grasslands.

In the following year, work was concentrated on a detailed study of the relationships between grazing pressure and phenological development of the fescue areas. The optical characteristics of the fescue grasslands were also examined in more detail.

Airborne multispectral scanner data obtained in 1980, 1981, and 1982 have been used to simulate Thematic Mapper images. These Thematic Mapper images have been evaluated in relation to the detailed ground data collected in 1980, 1981, and 1982. The evaluation indicates that the Thematic Mapper data are a valuable source of information for range management in these rough fescue prairies.

The role of multitemporal Landsat MSS, TM, and SPOT/HRV composite images is also discussed. The multitemporal imagery is more clearly understood due to the knowledge of the phenological and optical development of the grasslands obtained during the detailed studies in 1980 and 1981.

86. Tucker, C.J. 1980. A critical review of remote sensing and other methods for nondestructive estimation of standing crop biomass. *Grass and Forage Science*, 35(3):177-182.

AUTHOR ABSTRACT: Several different techniques for the nondestructive estimation of pasture or range biomass are critically reviewed and compared to remote sensing methods. Similarities and differences between the visual estimation procedure, B-attenuation, capacitance meters, weighted disc, and spectral methods are discussed in terms of accuracy, time, ease of operation, operational constraints and calibration procedures. No one technique has been shown to be superior across the board to the other techniques reviewed for ground-based biomass estimation. A discussion of the strengths and weaknesses of each nondestructive method allows for the selection of the technique most suited to a particular application.

87. Tucker, C.J., C. Vanpraet, E. Boerwinkel, and A. Gaston. 1983. Satellite remote sensing of total dry matter production in the Senegalese Sahel. *Remote Sensing of Environment*, 13(6):461-474.

AUTHOR ABSTRACT: Nine predominately cloud-free NOAA 7 advanced very high resolution radiometer images were obtained during a 3-month period during the 1981 rainy season in the Sahel of Senegal. The 0.55-0.68 and 0.725-1.10 μm channels were used to form the normalized difference greenleaf density vegetation index and the 11.5-12.5- μm channel was used as a cloud mask for each of the nine images. Changes in the normalized difference values among the various dates were closely associated with precipitation events. Six of the

images spanning an 8-week period were used to generate a cumulative integrated index. Ground biomass samplings in the 30,000 km² study area were used to assign total dry biomass classes to the cumulative index.

REVIEWER'S NOTE: Total dry biomass estimated via satellite data analysis with ground sampling.

88. Tueller, P.T., G. Lorain, K. Kipping, and C. Wilkie. 1972. Methods for measuring vegetation changes on Nevada rangelands. Agricultural Experiment Station Technical Bulletin No. 16, University of Nevada, Reno. 55 pages.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Range condition and trend study was done on test sites in Nevada using oblique ground photography, vertical ground photography, and 70 mm large-scale aerial photography. The study was partially funded by the BLM and was designed to test frequency sampling done by conventional field methods compared to using ground and aerial photography. Cover and density were also measured on the photographs. Color and color infrared 70 mm aerial photography was flown at scales ranging from 1:160 to 1:1,960. Large-scale aerial photography can be used to identify all tree species, most shrubs, and some grasses and forbs. The authors did not say the optimum scale for species identification of shrubs, grasses and forbs. They did recommend 1:1200 scale as optimum for measurement of trees and large shrubs and 1:600 as the optimum scale for smaller species. Percent cover can be obtained from photographs more efficiently than ground methods if the species can be recognized. They were unable to determine density for most species. Also, plants under shrubs could not be detected and measured. They recommend a combination of vertical ground photography and 70 mm large-scale aerial photography for range condition and trend analysis to save time and reduce costs.

89. Tueller, P.T., and D.T. Booth. 1975. Photographic remote sensing techniques for erosion evaluations on wildlands. Final Report, BLM Contract 08550-CTS-2. University of Nevada, College of Agriculture, Reno. 97 pages.

AUTHOR ABSTRACT: Numerous film types, bands, scales and color techniques were evaluated for erosion features. Large scale (1:600) 70 mm vertical color aerial photography was found to be a practical method for taking inventory of erosion conditions on rangeland watersheds managed by the U.S. Department of the Interior, Bureau of Land Management. Photo evaluations on these large scale photographs were found to be as accurate and less costly than ground techniques. Small scale photographs (1:25,000 and smaller) are shown to be useful for mapping sites with similar erosion activity and potential, for

planning erosion sampling on watersheds and for inventorying and measuring large erosion features over considerable land areas. Procedures are described.

90. Tueller, P.T., G. Lorain, R.M. Halvorson, J.M. Ratliff. 1975. Mapping vegetation in the Great Basin from ERTS-1 imagery. pp. 338-370. Proceedings, 41st Annual Meeting, American Society of Photogrammetry, Washington, D.C.

AUTHOR ABSTRACT: ERTS-1 resolution capabilities and repetitive coverage have allowed the mapping of the natural vegetation of Nevada by the following categories: southern desert shrub, salt desert shrub, northern desert shrub, pinyon/juniper woodland, mountain brush, aspen, meadows and marshlands, wheatgrass seedings, phreatophytes and cropland. Familiarity with landform, tone pattern, and other converging factors, along with multirate imagery, has been required. Color composites and winter scenes were particularly useful. A key to the vegetation on Nevada has been prepared for use with ERTS-1 color composites.

91. Van Zee, C.J., and K.G. Bonner. 1981. Estimating rangeland cover proportions with large-scale color-infrared aerial photographs. pp. 73-82. Proceedings, Eighth Biennial Workshop on Color Aerial Photography in the Plant Sciences and Related Fields, Luray, Virginia. American Society of Photogrammetry, Falls Church, Virginia.

AUTHOR ABSTRACT: Large-scale aerial photographs were utilized in a double sample with ground plots to estimate 12 rangeland cover types including percent cover by species, bare soil, litter and rock in a sagebrush-grass vegetation type in northeastern California. Nine-inch format color-infrared aerial photographs were acquired on August 3, 1980, at scales between 1:1,200 and 1:1,500 over the Harvey Valley, Lassen National Forest, project site. Prior to photograph acquisition, ground data were collected along line-point transects within 25 plots arranged systematically along four flight lines. Resolution of the photographs at these large scales was adequate for accurate identification of major shrub species. Nine-inch format photographs proved excellent for locating previously marked ground plots. A 92-percent correlation was found between photographs and ground measurements of cover when all 12 cover classes were considered simultaneously in multiple regression analysis. Ground plot costs were double photograph plot costs.

92. Warren, P.L. 1981. Sampling and description of vegetation for large-scale mapping at Organ Pipe Cactus National Monument. USDA, Forest Service General Technical Report, WO (28):352-358.

AUTHOR ABSTRACT: Desert vegetation of Organ Pipe Cactus National Monument, Arizona was mapped at 1:24,000 scale using natural color aerial photography in conjunction with detailed ground survey

methods. Field documentation included estimating prominence and cover of vegetation and recording terrain characteristics. Vegetation description emphasized floristic composition, physiognomy and the relationship of both to terrain features. The detailed descriptive legend not only identifies vegetation associations, but can also be used to extract more specific resource information. For example, distribution and abundance of columnar cacti were isolated for management purposes and distribution of jojoba was mapped to identify critical white-tail deer habitat.

REVIEWER'S NOTE: All vegetation is classified by photo interpretation and ground data collection.

93. Warren, P.L., and C.F. Hutchinson. 1983. Indicators of rangeland change and their potential for remote sensing environmental variables as symptoms of arid and semi-arid land degradation, ratio of shrub to grass cover. *Journal of Arid Environments*, 7(1):107-126.

AUTHOR ABSTRACT: Selected environmental variables were evaluated for their utility as indicators of rangeland change and their potential for remote sensing. Fifty-nine study sites were sampled in southern New Mexico. Total vegetation cover and the ratio of shrub cover to grass cover were related to disturbance. Increasing degrees of change were associated with a decrease in total vegetation cover, an increase in the ratio of shrub to grass cover and a decrease in organic soil cover (litter and algal crusts). Total vegetation cover and organic soil cover can be monitored from single-date satellite data, but total vegetation cover alone may provide ambiguous results. The ratio of shrub to grass cover, which is necessary to identify the direction of change can be determined by examining multirate satellite data that correspond to the times when grasses and shrubs exhibit their maximum green biomass.

REVIEWER'S NOTE: Satellite data were not analyzed but radiometric readings simulating Landsat channels were, as were 35 mm ground photo plots.

94. Wells, K.F. 1971. Measuring vegetation changes on fixed quadrants by vertical ground stereophotography. *Journal of Range Management*, 24(3):233-236.

AUTHOR ABSTRACT: A photographic technique for recording changes in vegetation on small fixed quadrats has been modified and improved. Two 35 mm cameras fired simultaneously are used instead of one to take stereophotographs. Transparencies are viewed directly by transmitted light under a zoom stereoscope and plant cover measured by point counts made on the photographs with the aid of a counter connected to an electrically operated stage. Assessment of species composition and herbage weight is also possible from the photographs which themselves form a permanent record of vegetation on the quadrats.

REVIEWER'S NOTE: Ground photography analysis techniques are discussed, building upon earlier work described by Wimbush, Barrow, and Costin (1967).

95. Wilcox, D.G. 1971. Range evaluation using aerial photography. *Journal of Agriculture Western Australia*, 12(6):141-143.

AUTHOR ABSTRACT: None supplied.

REVIEWER'S NOTE: Aerial photography can be used to monitor range condition, identify plant species, show trends in range condition, detect change in soil surface condition, and determine plant cover. Density of animal tracks can be a measure of pasture use. Film, photo scale, and film format are not discussed.

96. Wimbush, D.J., M.D. Barrow, and A.S. Costin. 1967. Color stereophotography for the measurement of vegetation. *Ecology*, 38:150-152.

AUTHOR ABSTRACT: The field equipment needed for a stereophotographic method of measurement of vegetation consists of a camera mounted on a rectangular frame on four legs, from which a stereo pair of photographs of the ground or vegetation surface can be taken. For color transparencies the stereo pair of images is projected upwards through two specially mounted projectors and prisms onto tracing paper on a glass table, from which the images are examined stereoscopically. Vegetation boundaries and other features are marked on the tracing paper, and the respective areas subsequently measured visually by superimposing a transparent plastic 100-compartment grid.

REVIEWER'S NOTE: Ground photography. A single 35 mm camera is used. Two stereo photos are acquired by physically sliding the camera to a new position on the frame. (See Wells (1971) article for description of a refinement of this technique.)

97. Work, E.A. and J.W. Foster. 1983. Maintaining a multistage inventory for resource management. pp. 452-455. *Proceedings, International Conference on Renewable Resource Inventories for Monitoring Changes and Trends*, Corvallis, Oregon.

AUTHOR ABSTRACT: The Bureau of Land Management, because of its responsibility for managing large and numerous tracts in the western United States, is utilizing several techniques for inventory and data base synthesis. Many of these techniques are automated. A two-stage sampling technique utilizing Landsat digital data and large-scale aerial photography is described. The assimilation of the resulting data into an information system in order to facilitate management decisions is illustrated for an area in northern New Mexico. This particular work emphasized applications dealing with range, woodland, and wildlife resources.

TABLE 2

DEMONSTRATED CAPABILITY OF VARIOUS REMOTE SENSING METHODOLOGIES TO PROVIDE
VEGETATION DATA NECESSARY FOR RANGELAND MANAGEMENT DECISIONS

Vegetation Attributes	Remote Sensing Methodology		Related References (Paper Numbers)
	Satellite (Landsat, NOAA)	Aerial Photography (large, medium, small scale)	
1. <u>Cover</u> : Determine amount of cover (basal, canopy, foliar, or ground) by species.	Cannot be determined. In some cases, shows cover type changes, e.g., from sagebrush to grass (ID)*. Cannot detect quantity change. Ground verification necessary.	Can detect some changes in shrub and grass species. Some quantification of species can be made using large-scale photographs. Discovered significant change in total cover using high-altitude photos (1:120,000), followed up with 1:15,000 aerial photographs and then ground truthing (AZ)*. Ground verification necessary.	2, 3, 5, 8, 9, 10, 12, 13, 14, 15, 16, 23, 24, 26, 28, 31, 33, 34, 35, 40, 43, 44, 45, 48, 51, 52, 56, 58, 61, 64, 66, 67, 68, 69, 70, 72, 73, 74, 77, 78, 87, 88, 91, 93, 94, 96
2. <u>Production</u> : Determine pounds of forage per acre by species.	Cannot be determined.	Cannot be determined.	1, 2, 7, 9, 11, 13, 21, 30, 32, 42, 45, 46, 52, 54, 55, 59, 70, 80, 81, 83, 85, 86, 87, 94, 95
3. <u>Frequency</u> : Determine presence or absence of species.	Cannot be determined.	Cannot be determined.	9, 12, 13, 27, 69, 72, 73, 88, 93, 94
4. <u>Density</u> : Determine the number of plants by species per acre.	Cannot be determined.	Can determine density for some species with large-scale photographs. Ground verification necessary.	9, 12, 13, 17, 23, 58, 61, 68, 69, 72, 73, 75, 88, 94

TABLE 2 (Continued)

Vegetation Attributes	Remote Sensing Methodology		Related References (Paper Numbers)
	Satellite (Landsat, NOAA)	Aerial Photography (large, medium, small scale)	
5. <u>Composition</u> : Determine species occurrence.	Cannot be determined.	Some shrub species can be detected using large-scale photographs (AZ and ID)*. Ground verification necessary.	9, 12, 13, 14, 17, 28, 34, 55, 61, 66, 72, 92, 93, 94, 96
6. <u>Structure</u> : Determine: - height by species - size by species - age class by species - form class by species	Cannot be determined.	Can make some height determination on shrubs (AZ and NM)*, using large-scale photographs. Ground verification necessary.	9, 13, 27, 53, 66
7. <u>Reproduction</u> : Determine by species	Cannot be determined.	Can determine tree encroachment into rangeland using large-scale photographs (MT)*.	9, 13, 53
8. <u>Species Identification</u> : Determine plant species.	Cannot be determined.	Can determine some shrub and tree species with large-scale photographs (AZ and ID)*. Can determine some tree species in riparian areas with medium-scale photographs (1:10,000-1:20,000) (MT)*.	3, 9, 12, 13, 14, 16, 25, 27, 28, 31, 32, 33, 34, 36, 37, 43, 52, 53, 55, 61, 66, 67, 69, 72, 75, 83, 94, 96

*Comments provided by States where techniques have been used.

GLOSSARY OF TERMS

albedo: The ratio of the amount of electromagnetic energy reflected by a body to the amount incident upon it, often expressed as a percentage.

bandwidth: That portion of the electromagnetic spectrum (expressed in μm) that a sensor band or channel can record. For example, Landsat MSS band 4 records bandwidth .5 to .6 μm .

canonical variate analysis: A statistical technique that increases the separability of categories defined within the data while minimizing the differences occurring within each category. An example of a category would be shrubland.

green-wave effect: Seasonal advancement of vegetation green-up.

ground-truth data (jargon): Term coined for data and information obtained on surface or subsurface features to aid in interpretation of remotely sensed data.

Lambertian reflectivity: Reflectance from an ideal, perfectly diffusing surface, which reflects energy equally in all directions.

Landsat imagery: Imagery or photo-like products produced from reflectance values recorded by a multispectral scanner.

microdensitometry: The relative measurement of light transmission through images on positive film transparencies. The measurement is termed optical density or simply density.

nadir: That point on the ground vertically beneath the perspective center of the camera lens.

Normalized Difference: Vegetation ratio technique derived by subtracting two channels and dividing by the sum of the same two channels. This technique enhances green biomass and normalizes the effect of different locations and times.

pixel (or picture element): A data element having both spatial and spectral aspects. The spatial variable defines the apparent size of the resolution cell; i.e., the area on the ground represented by the data values. The spectral variable defines the intensity of the spectral response for that cell in a particular channel.

real time: Time in which reporting on events or recording of events is simultaneous with the events.

species signature: The range of spectral reflectance values for a particular species in a given geographical area.

spectral reflectance: The reflectance of electromagnetic energy at specified wavelength intervals.

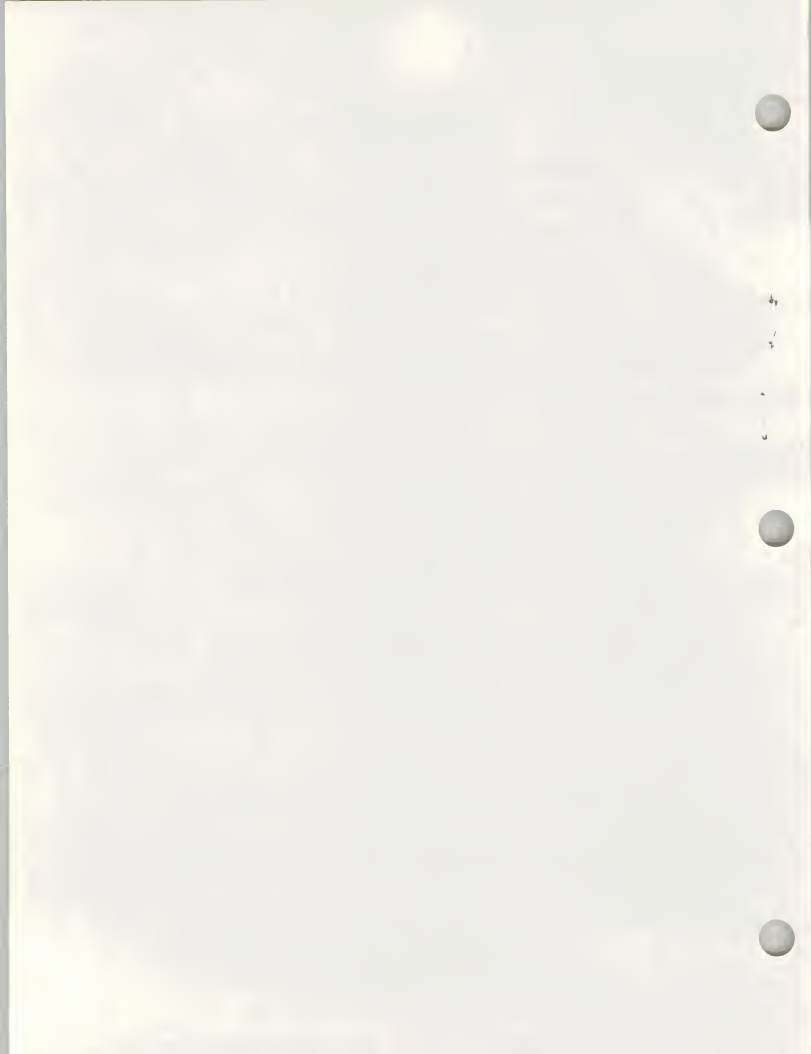
spectroradiometry: Using a radiometer to measure the radiation of an object as a function of wavelength.

SPOT: French remote sensing satellite launched in February 1986. The satellite has two High Resolution Visible instruments that use push-broom scanners to record reflectance values.

Thematic Mapper (TM) imagery: Imagery or photo-like products produced from reflectance values recorded by a thematic mapper sensor.

ACRONYMS AND ABBREVIATIONS

BIA - U.S. Department of the Interior, Bureau of Indian Affairs
BLM - U.S. Department of the Interior, Bureau of Land Management
CIR - Color infrared
DIRS - Digital Image Rectification System
EREP - Earth Resources Experimental Package
EROS - Earth Resources Observation System
ERTS - Earth Resources Technology Satellite, now called Landsat
IPAL - Integrated Project for Arid Lands
Landsat - Land satellite, formerly called ERTS
LIBRIS - Land, image-based, resource information system
LSP - Large-scale aerial photography
MSS - Multi-spectral scanner
ND - Normalized difference
NOAA - National Oceanic and Atmospheric Administration
PFRA - Prairie Farm Rehabilitation Administration
SPOT/HRV - Earth Observation Satellite/High Resolution Visible
SVIM (LAS) - Soil Vegetation Inventory Method (Landsat Applications for Soil/
Vegetation Inventory
SWA - Site write-up area
TM - Thematic Mapper
um - Micrometer
UNESCO - United Nations Educational, Scientific, and Cultural Organization
USDA - U.S. Department of Agriculture
UTM - Universal Transverse Mercator
WB - Waveband



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