7.8-10053
CR-155514
SDSU-RSI-77-17

APPLICATION OF REMOTE SENSING TECHNOLOGY IN SOUTH DAKOTA TO ASSESS WILDLIFE HABITAT CHANGE, DESCRIBE MEANDERING LAKES, IMPROVE AGRICULTURAL CENSUSING, MAP ASPEN, AND QUANTIFY CELL SELECTION CRITERIA FOR SPATIAL DATA

(E78-10053) APPLICATION OF REMOTE SENSING TECHNOLOGY IN SOUTH DAKOTA TO ASSESS WILDLIFE HABITAT CHANGE, DESCRIBE MEANDERING LAKES, IMPROVE AGRICULTURAL CENSUSING, MAP ASPEN, AND QUANTIFY CELL (South Dakota State G3/43 N78-15542 HC A05/MF A01 Unclas 00053

For

National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C.
July 1, 1977 - December 31, 1977

Semi-Annual Progress Report
Grant No. NGL 42-003-007

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57007

SDSU-RSI-77-17

APPLICATION OF REMOTE SENSING TECHNOLOGY IN SOUTH DAKOTA TO ASSESS WILDLIFE HABITAT CHANGE, DESCRIBE MEANDERING LAKES, IMPROVE AGRICULTURAL CENSUSING, MAP ASPEN, AND QUANTIFY CELL SELECTION CRITERIA FOR SPATIAL DATA

Principal Investigator
Victor I. Myers

Original photography may be purchased from:
EROS Data Center
Sioux Falls, SD

Authors

R. G. Best
K. J. Dalsted
J. C. Eidenshink
F. A. Schmer
M. E. Wehde

For

National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C.
July 1, 1977 - December 31, 1977

Grant No. NGL 42-003-007

Abstract

The application of remote sensing techniques is being utilized in projects of current interest in South Dakota. Each application will be abstracted in the following paragraphs.

The loss of deer wintering habitat due to change of vegetation structure is an important concern to resource managers in the Black Hills. Temporal changes in the areal extent of open meadow-like in the Black Hills was accomplished using black and white (1961) and color infrared (1976) aerial photography. A reduction of nearly 1100 hectares of open area (1961 vs 1976) was determined by photo-interpretive procedures. Additional temporal changes in roads and power line corridors are in the process of being quantified. Color infrared imagery was also applied successfully in habitat evaluation procedures required in wildlife management.

Applications of both Landsat and aircraft imagery in the management of meandered lakes are presented. Water regime, encroachment of farming within the meander line, uncontrolled burning, and municipal use of meandered lakes can be monitored on a monthly or yearly basis on enlargement prints of Landsat imagery. Manual and automated interpretation techniques for classification of hydrophytes from color infrared imagery are evaluated and illustrated. Partitioning of reflectance effects by use of photographic color separation and ratios of separations to improve classification of hydrophytes are discussed.

Soils of southeast South Dakota are being evaluated to determine their influence on crop signatures derived from Landsat digital data. Procedures to develop background reflectance strata for improved classification accuracy will be tested. Training data (major crop was corn) were collected on 18 major soil associations. Digital analysis of data from two Landsat tapes (June 5 and July 29) will determine stratification zones based on the soils, crops, and the time of season. Preliminary results obtained from digital analysis (June 5 tape) of four soil associations in Lincoln County indicate that soil association data may not be an adequate baseline stratifying tool early in the growing season. Digital evaluation of all the data will be completed during FY 1978.

An aspen inventory has been developed for the Black Hills of South Dakota utilizing digital analysis of Landsat CCT's. Indications are that the inventory generated from digital analysis is more accurate than either manual interpretation of high altitude photography or the existing U.S. Forest Service type maps. A major concern is the development of an effective and economical method for producing thematic maps of the inventory results. Several methods are investigated and the results are discussed.

A cellular referenced, resource data processing system is being studied. The objectives are (1) to analyze the relationships between cell size, resource tabulation (inventory) accuracy, theme mapping accuracy and data processing costs, and (2) to define a map sampling procedure for assistance in all size selection, given accuracy and cost constraints. The approach and progress, primarily with objective one, are reviewed.

TABLE OF CONTENTS

Table of Contents Continued

LIST OF FIGURES

List of Figures Continued

LIST OF TABLES

ACKNOWLEDGEMENTS

Appreciation is extended to the State of South Dakota and National Aeronautics and Space Administration (NASA Grant No. NGL 42-003-007) for their funding role in maintenance of these active technology transfer programs. Special thanks to Mr. Joe Vitale, NASA Technical Officer, for his continued support of these ongoing projects.

Remote Sensing Applications to Wildlife Habitat Change, Description of Meandering Lakes, Agricultural Censusing, Aspen Mapping in South Dakota, and the Development of Cell Selections Criteria for Spatial Data

This report will outline the status of current applications-oriented work in South Dakota. Technology developed through past NASA support is being applied in current programs of importance in South Dakota. This report will also list the items that are scheduled to be completed in Fiscal Year 1978.

The on-going programs are being undertaken with the following goals or objectives: 1) assessing wildlife habitat change in the Black Hills (1961-1976); 2) classifying meandering lakes in eastern South Dakota; 3) improving classification of agricultural crops in southeast South Dakota; 4) mapping aspen in the Black Hills by classification of Landsat tapes; and 5) determining cell size criteria to ensure pre-determined accuracy limits and/or cost constraints.

The progress reports will be presented in sequence as separate sections. Each section will address the progress-to-date and the results scheduled for completion by the end of the fiscal year.

WILDLIFE HABITAT CHANGE

Habitat change is a contingency of great importance in wildlife conservation plans. In recent years Game, Fish & Parks (GF&P) personnel have become increasingly concerned about an areal change of habitat in the Black Hills. The increasing encroachment of the forest has been historically documented (1874 to 1972) in a pictorial manner (Progulske, 1974). These drastic changes in forest structure are due mainly to man's control of fire. Other factors are also important in decreasing habitat quality in the Black Hills; the dissection of the forest by roads and trails and increased recreational development are two such potentially detrimental forces.

Of major concern to the habitat manager are the open meadow-like areas within the forest. These areas provide edge which is an important factor in providing vegetative diversity for wildlife, especially deer (McCaffery and Creed, 1969). Edge is a transitional zone (ecotone) between two vegetative types, i.e. forest and meadow. The additional penetration of sunlight along the edge allows increased growth of herbaceous and shrubby vegetation. This type of growth is of great importance for deer winter habitat. However, forest stands have become too thick ("dog-hair") in many areas preventing the needed penetration of sunlight to maintain vegetative diversity. The areal extent of existing open areas is also being infringed upon by the spread of pine growth.

A quantitative description of this habitat change is needed in order to make the necessary provisions to maintain the areal extent of the open meadow-like areas. Quantitative data is also needed to assess the impact of recent additions of roads, trails, and recreational areas. For proper management guidelines to be established, data of the previous types are needed. Mitigation alternatives are needed to maintain these important habitat types. These alternatives include but are not restricted to clear cutting, prescribed burning, and thinning. Important factors involved in determining where mitigation occurs include desirable seed sources, landscape positions (including elevation), aspects, and locations with respect to wildlife utilization. The maintenance of these openings is important to ensure a sufficient source of food and shelter for many wildlife species.

Conventional means of quantifying the changes of forest openings and the addition of new roads involve intensive ground and road surveys. Remote sensing technology can circumvent the time and expense needed to locate these critical areas. The Black Hills, which cover over a million acres, provide a study area which can utilize remote sensing procedures to monitor and evaluate the aforementioned forest changes in a timely fashion. The use of RB-57 color infrared photography (CIRP) also provides an excellent interpretive medium for forest classification, forest disease detection, and habitat evaluation (Anson, 1971). Data derived from RB-57 and older conventional aerial photography can provide baseline data for monitoring changes in the forest structure.

Remote sensing technology can further assist the habitat analyst by providing an interpretive base for eliminating unnecessary and costly ground evaluations. Often the habitat evaluation of a particular area must include ground observations of the entire area. With a suitable scale (1:24,000) and photo interpretation key, the analyst can use RB-57 data to evaluate a particular area of forest first in the office, thus delimiting only the ground observation points which are of particular interest. For example, when an area of forest is scheduled for a timber sale a wildlife specialist can first evaluate the CIRP in the office, delineating and ranking the critical habitat areas, wildlife access routes, and areas with the least habitat value. The specialist can then visit these critical areas to confirm the initial evaluation; in this manner the field inspection can be narrowed to only those areas of special concern. The specialist also gains an added perspective of the habitat composition and value by using CIRP integrated with field investigations.

Remote sensing technology is being applied to assist GF&P personnel in the Black Hills by providing the following data: 1) quantitative assessment of open area and road changes from 1961-1976; and 2) habitat evaluation using CIRP procedures. Remote sensing techniques can provide an added dimension to resource evaluation in wildlife habitat management and planning.

METHODS AND MATERIALS

Black and white 1961 panchromatic photography (USDA Forest Service 9/14/61) in the form of photo index sheets at 1:63,360 was photo-interpreted for open meadow-like areas, roads, and power line corridors in the Black Hills. Mylar and translucent drafting paper overlays were used to record the data. Spatial Data Equipment was used to measure the areal extent of open meadows; the average of two measurements gave the final figure. Road types were recorded as paved, all weather, dirt, or primitive; a Forest Visitor's Map (U.S. Forest Service, compiled in 1961 and partly revised in 1972) was used to aid in identifying and locating the road types. However, only the roads which were visible on the imagery were recorded. Linear determinations of edge and roads were determined from the average of two measurements using an automatic planimeter (Numonics Model 1224).

RB-57 color infrared imagery was photo-interpreted to provide the 1976 data. Data derived from the 1976 imagery (which was flown in 9/9/76) was extracted and recorded in the same manner as the 1961 data. A slightly smaller scale (approximately 1:100,000) of the CIRP was used; the cost factor involved in enlarging the original color transparencies to 1:63,360 was prohibitive. It is felt that the superior quality of the CIRP more than offset the scale differential. However, to ensure that scale difference did not bias the results, the 1961 open area data was systematically checked against the 1976 open area data to make sure that all corresponding open areas were accounted for. Field investigations were undertaken to confirm many of the 1976 delineations and to investigate any questionable areas. The 1976 roads delineations is partially completed and is scheduled for completion in FY 1978.

The field investigations also served to familiarize GF&P personnel with the CIRP representations of Black Hills' phenomena. Data collected during these field examinations will be used to develop a photo-interpretive key for GF&P personnel. The key at a 1:24,000 scale will include identification of the following classes: 1) ponderosa pine (a minor component may be Black Hills spruce) and three divisions of crown or canopy density; 2) aspen and other deciduous trees; 3) open meadows and differentiae based on moisture regimes; 4) pine infestation by beetles; 5) geologic formations which are apparent e.g. taconite deposits; and 6) any further classes as may be indicated by GF&P personnel.

The overlays and photo-interpretive key will be made available to GF&P personnel for review and accuracy checks, and for office use. The data supplied will be used in field evaluations and management plans (see Appendix A).

RESULTS AND DISCUSSION

The basic premise of this study was to incorporate remote sensing technology into habitat management programs in the Black Hills. This progress report will be directed toward the implementation of three specific applications; these applications are as follows: 1) quantify changes in the meadow-like openings and roads from 1961 to 1976; 2) provide a photo-interpretive key for the 1976 CIRP to be used by GF&P cooperators; and 3) identify applications of CIRP in habitat assessment especially to aid in prescribing management alternatives in timber sale areas.

An example of the rough interpretive product derived to quantify open areas, roads, and power line corridors is shown in Fig. 1. The 1976 roads and power line interpretations are only partially complete at this time, they will be finished by the end of FY 1978. The relatively non-orthographic nature of the two photo base maps prevented a compositing of interpretive overlays to measure change. Instead each overlay product will be or has been measured (i.e. areally or linearly).

The minimum mapped open area was approximately 2.0 hectares (5 acres). Although open areas less than 2.0 ha are prime concern to habitat maintenance (McCaffery and Creed, 1969), the resolution and scale of the imagery precluded a consistent denoting of these areas. Open area estimations of discernable burn areas from 1961 to 1976 were virtually the same. The variable age of the burn areas (i.e. some are more recent than others) prevents a generalization that might indicate that new reforestation by ponderosa had occurred. However, 15 years of ponderosa growth (1961-1976) and the addition of new pine trees certainly would reduce the effective meadow-like area. This consideration

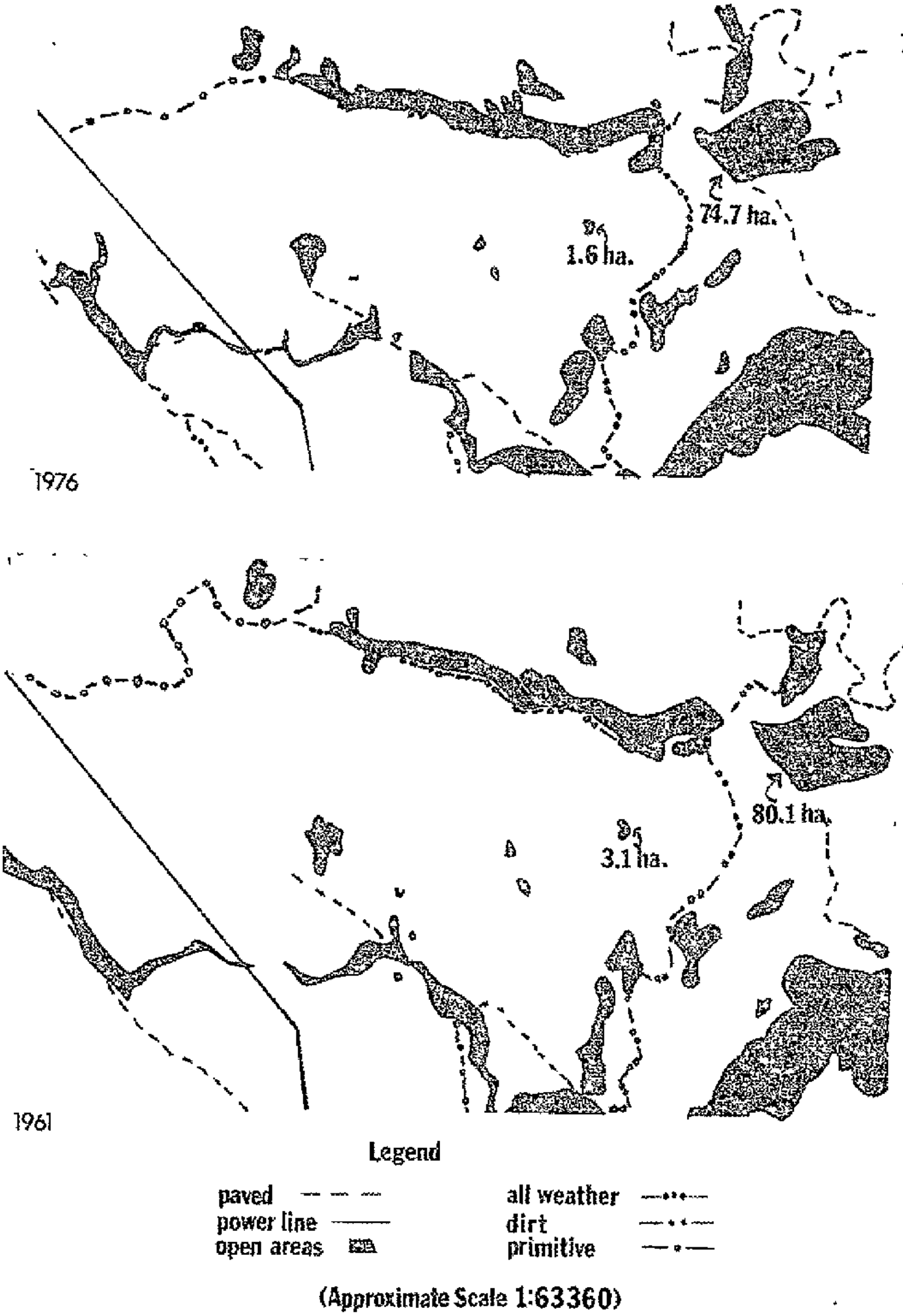


Figure 1. Display of interpretations derived from remote sensing imagery of the Black Hills. The 1976 data is slightly enlarged from the original overlay. Areal and linear measurements are made from these data products.

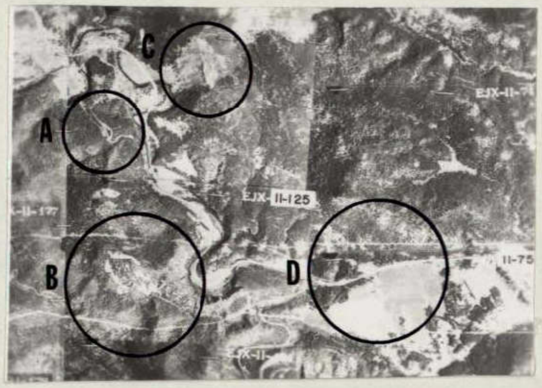
indicates the open area loss from 1961 to 1976 is somewhat conservative. Further investigation is needed to differentiate the signatures of immature ponderosa from deciduous components as recorded on CIRP.

The results of the open area and edge determinations are listed in Table 1. The data presented in Table 1 indicates an overall trend of open area loss between 1961 and 1976. However, statistical inferences which will indicate whether these two areal measures are significantly different are in the process of being determined. The edge and edge-unit area may indicate some temporal changes in the shape of some open areas (i.e. less area in the narrow and/long 1976 openings). Figures 2 and 3 show some of the changes that have occurred between 1961 and 1976. The variable exposure on the original 1961 photo-index sheets is apparent in Figures 2 and 3. The superior quality of CIRP is also apparent when comparing it to the black and white photography.

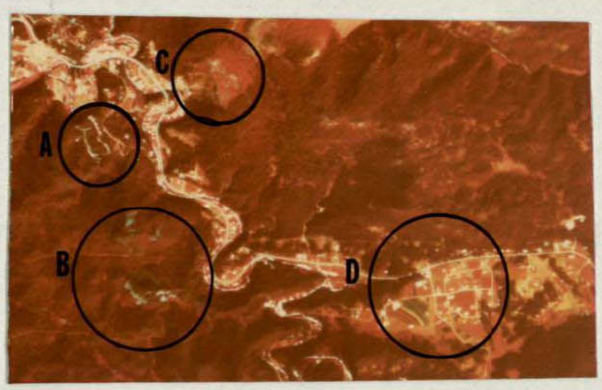
Table 1. Areal and edge measurements in the Black Hills. The 1961 data were derived from black and white photo index sheets (U.S. Forest Service) and the 1976 data were derived from color infrared RB-57 imagery.

	Open Meadow-like Area (hectares)	Edge of Open Area (kilometers)	Edge/Unit Area (km/ha)
1961	54,083	4,423	.082
1976	52,899	3,846	.073

The determination of data quantifying new roads and power corridors (1961 to 1976) will be used in habitat quality determinations. The effect of new roads is a variable factor determined by the time and intensity of use. For example, a potentially detrimental effect of a heavily used timber access road



1961

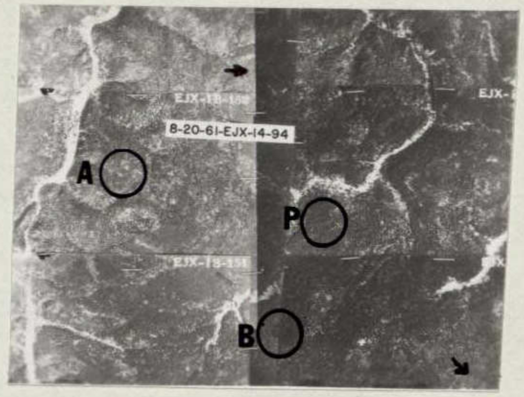


1976

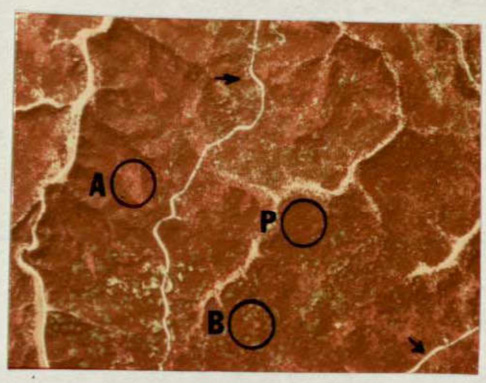
Scale: 1:63360

Figure 2. Example of temporal change in the Black Hills (1961-1976). A) The addition of a new road; B) canopy enclosure of ponderosa pine; C) enclosure of aspen - note advantages of CIRP for identifying vegetative communities; and D) new housing development area.

ORIGINAL PAGE IS
OF POOR QUALITY



1961



1976

Scale: 1: 63360

Figure 3. Example of new road additions from 1961 to 1976 (arrows). Also note the signatures of ponderosa pine (P), aspen (A), and pine beetle infestations (B).

and the concurrent timbering activity may be the diversion of deer away from prime habitat and movement to less desirable habitat. It appears that the Black Hills are becoming more and more crisscrossed by roads and trails.

A photo-interpretive key for effective use of RB-57 data will be put together for use by GF&P personnel. The key will aid in assessing habitat composition, aspect, and potential. It will also be of great value when selecting specific areas for field investigation. The added perspective gained from using CIRP is very beneficial to resource management personnel (see Appendix A).

SUMMARY AND CONCLUSIONS

Remote sensing data can be used to quantify certain forest changes and trends. Color infrared imagery (together with corresponding ground investigation) can be used to advantage by resource management personnel in assessing the habitat parameters needed for management planning. Reduction of field investigation as afforded by useage of CIRP allows a more timely compilation of the factors needed for effective habitat management planning.

DATA PRODUCTS COMPLETED AND SCHEDULED FOR COMPLETION

Completed

1) Open area determination in the Black Hills, 1961 to 1976
2) Roads and power line corridors from 1961 imagery
3) CIRP for GF&P field use

To be completed

1) Roads and power line corridors from 1976 imagery
2) Photo-interpretation key

References

Anson, A. 1971. Color aerial photography in the plant sciences and related fields. Amer. Soc. of Photogram., Falls Church, Va. 288 p.

McCaffery, K.R., and W.A. Creed. 1969. Significance of forest openings to deer in northern Wisconsin. Tech. Bull. No. 44, Depart. of Nat. Res., Madison, Wis.

Progulske, D.R. 1974. Yellow ore, yellow hair, yellow pine. Bull. 616, Ag. Exper. Sta., South Dak. State Univ., Brookings.

Appendix A

SOUTH Dakota

Department of Game, Fish and Parks

Pierre, South Dakota 57501 • Phone 224-3387

Division of Administration

3305 West South St.
Rapid City, SD 57701

July 29, 1977

Kevin Dalstad
Remote Sensing Institute
South Dakota State University
Brookings, SD 57006

Dear Kevin:

Infa-red photos of the Black Hills you have provided have been very useful in my work as a Resource Management Specialist for the South Dakota Game, Fish and Parks Department.

My responsibilities, in addition to providing liaison between the Department and Federal Agencies, is to provide wildlife habitat management recommendations to the USFS prior to and during timber harvest activities. Recommendations are submitted in order to preclude habitat degradation. In order to do this, on the ground reconnaisance and subsequent evaluations are made. Infa-red photos, properly ground truthed and interpreted, provide a record of past land use patterns and existing vegetation. With this source of information at hand, better management decisions on how habitat is to be manipulated in the future can be made. On the ground evaluations using existing maps are pretty limited in scope. Infa-red photos give better over-all perspective. I am sure that the more I work with these photos and the better acquainted I get with each area, I will be in better position to utilize the information contained in the photos. Vegetation identification is only a small portion of the information these photos contain.

Perhaps we can get together again soon and establish additional ground truth data. I will have another timber sale soon to recon near Spearfish. I have no photo coverage, and I have been wishfully thinking how nice it would be to have the coverage right now.

In the meantime, please accept my best regards.

Sincerely,

Nicholas Grkovic

Nicholas Grkovic
Resource Management Specialist

NG/i

SOUTH DAKOTA
GAME, FISH & PARKS

SOUTH Dakota
Department of Game, Fish and Parks
~~Pierre, South Dakota 57501 Phone 224-3387~~

Division of Administration
3305 West South Street
Rapid City, SD 57701
PHONE: 394-2391

December 12, 1977

Kevin Dalsted
Remote Sensing Institute
South Dakota State University
Brookings, SD 57006

Dear Kevin:

This letter will provide an update on the use and use potential of the infra-red photos of the Black Hills you have provided me.

As a result of liaison between this Department and a recent US Forest Service upgrade of wildlife and wildlife habitat priorities in the Black Hills, US Forest Service budgets for wildlife management have increased considerably over the last fiscal year and prior years. This will mean increased emphasis on the use of such photos throughout the hills as the annual wood fiber harvest will increase in the coming years. Since wildfire will not be used as a tool to remove overstory, canopy removal will have to be accomplished through wood fiber removal. These photos have provided good use in making management recommendations, since they show what is on the ground at the time. A drawback is a thorough understanding of the information that the photos provide. In this regard, if I can be of further help in providing ground truth data, do not hesitate to call on me.

Since my last report to you, I have provided a wildlife habitat recommendation input on six separate proposed timber sales. The photos have been helpful in providing an increased perspective and thus meaningful in providing the base for good management recommendations.

A complete photo coverage of the Black Hills will be necessary in the future.

Sincerely,

Nicholas Grkovic
Resource Management Specialist

NG/dmh

SOUTH DAKOTA
GAME, FISH & PARKS

Applications of Remote Sensing in the Management of Meandered Lakes

by
Robert G. Best

INTRODUCTION TO THE PROBLEM

In 1957 the South Dakota Game, Fish, and Parks Department (GFP) was given authority and responsibility by the State Legislature to administer meandered lake or trust lands (SDCL 41-2-18). Meandered lake lands are those areas that were omitted from the original government survey. The Federal Government issued no titles to these lakes and lake beds but dedicated them to the People of South Dakota. These areas range in size from 20 to over 7,850 acres and they vary from closed stands of hydrophytes to open water prairie lakes. These 250 meandered lakes represent a primary source of outdoor recreation for the people of South Dakota such as hunting, fishing, boating, etc.

Until recently, there has been only limited management of the meandered lakes. Game, Fish, and Parks personnel are now implementing a management program to utilize the optimum recreational potential for these areas. An inventory of these areas based on original survey plots has been completed (Dvorak, 1973) but descriptions in the original survey of the meander line are vague and often incomplete. Maps and inventories of vegetation, use of adjacent lands, etc. needed to formulate management plans are not available and would require considerable manpower to complete in a ground level survey program.

It has been demonstrated in previous NASA contracts (Best et al., 1976) and elsewhere that remote sensing techniques can be adapted for interpreting the parameters required in this project.

Present plans call for management of the area bounded by the normal high water line which, in most cases, differs from the meander line because of natural lake succession and changes in peripheral land use. The normal high water line is defined as the limit of hydrophytes. Certain of the parameters required to formulate management plans include: normal high water line, species of hydrophytes present, area of open water, and land use within and adjacent to the high water line. GFP personnel will develop "cooperative management agreements" with those who own land adjacent to the meandered areas. These agreements will include planting of food plots to benefit wildlife, opening of closed stands of emergent vegetation by controlled grazing and prescribed haying and burning, fencing, and providing public access areas. The overall objective of the cooperative management agreements is to enhance the watershed and associated wildlife while increasing their recreational use by the public and allow legal agrarian uses of these trust lands by the farming community.

This project is a joint effort between the Remote Sensing Institute and South Dakota Department of Game, Fish and Parks to utilize remotely sensed imagery to aid in the formulation of cooperative management agreements regarding meandered lake lands. Remotely sensed data provides a perspective of the meandered lakes that is not available in ground-level observations. Interpretations of satellite and aircraft imagery provide the data required for management planning in a timely fashion and without the large manpower requirements of ground-based data collection. Preliminary studies indicate a potential for an operational use of remote-sensing techniques to be developed.

The techniques that are developed in this project will be documented and presented to GFP personnel. Conservation officers and regional supervisors will be involved directly in the interpretation and ground verification of a subsample of meandered lake to provide experience in the interpretation techniques.

METHODS

Kingsbury County in east-central South Dakota was selected by the Land Management Specialist from GFP as the test site for the preliminary analysis of remotely sensed data. The area has 17 meandered lakes with a wide variety of characteristics which provide a major source of outdoor recreation.

Numerous cloud-free, high quality Landsat scenes were available for the county. High-altitude color and color-infrared RB-57 imagery were available for portions of the county. Low-altitude color infrared imagery of all the meandered lakes was collected with the RSI aircraft on 8/10/77 and 8/17/77.

Landsat Monitoring of Meandered Lakes

The advantages of temporal analyses were illustrated by selecting cloud-free Landsat scenes at approximately one-month intervals from May 1976 to November 1976. Scenes from October 1974-1976 were chosen to illustrate yearly Landsat monitoring of meandered lakes. A scene from January 1974 was also selected to illustrate the advantages of snow cover for vegetation analysis. Black and white enlargement prints of MSS 5 and MSS 7 were used for interpretation. A county road map was superimposed onto each during printing to aid in location of areas of interest. Changes in water regime, vegetation, encroachment of farming, municipal use and in one case uncontrolled burning from date to date were recorded.

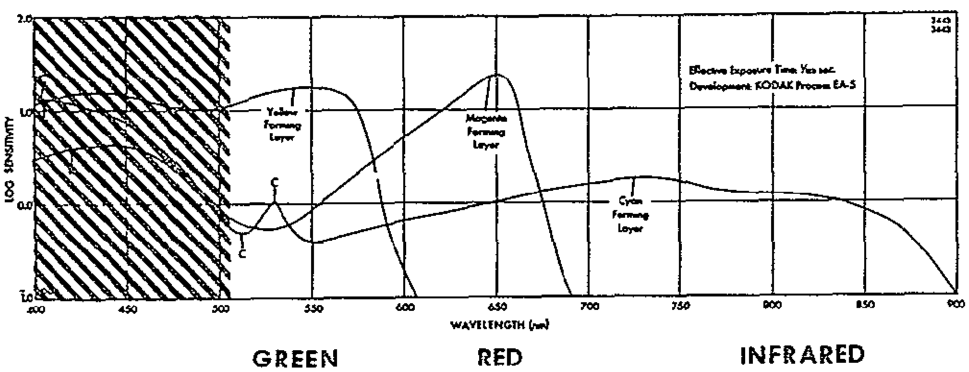
Classification of Hydrophytes

The areal extent of hydrophyte growth was the criteria selected for determining the extent of a meandered lake to be managed. Furthermore, accurate classification of hydrophytes can improve the accuracy of wetland classifications from aircraft photography. An area of a large hydrophyte filled meandered lake within Kingsbury County was selected to develop and test interpretation techniques. Low altitude (10,000 ft. AGL) color-infrared (KODAK 2443) imagery of the area was collected on 8/17/77.

Color Separation of IR Film

Black and white panchromatic separations were made of the 3 film layers in order to partition the effects of the different wavelength that the film was sensitive to. When the film was exposed through a Wratten 89b filter, the confusing effects of exposures by wavelengths less than 510 nm are eliminated. The yellow, magenta and cyan film layers are sensitive to green, red and near infrared wavelengths, respectively (see figure 4).

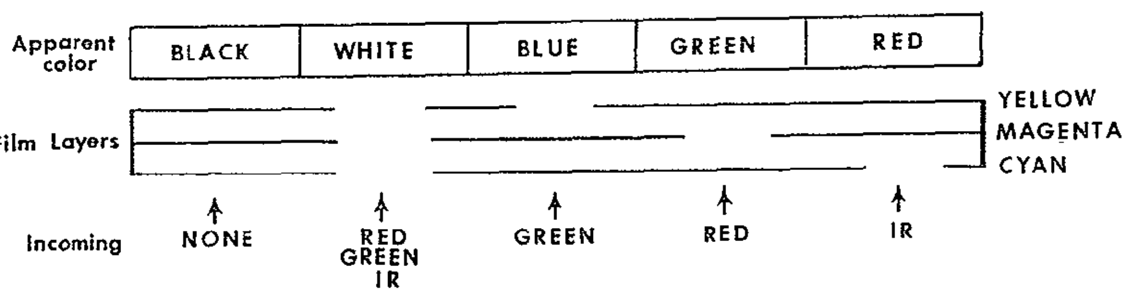
Figure 4. Spectral sensitivity* curves for Kodak Aerochrome Infrared Film 2443 (after Kodak, 1971).



* Sensitivity is defined as the reciprocal of the exposure (ergs/cm^2) required to produce a density of one above D min.

Infrared radiation produces red tones on the imagery by exposing away the cyan layer allowing the magenta and yellow to add subtractively. All other colors and hues are formed by different combinations of exposures by different wavelengths (see figure 5).

Figure 5. Production of colors by subtractive process for color infrared film.



It is this principle that allows one to partition reflectance effects by making color separations. Red (wratten 25), green (wratten 74) and blue (wratten 98) filters were used to partition the reflectance effects of infrared, red and green from the original CIR film. Separations were made on panchromatic film which was equally sensitive to all 3 wavelengths and processed to $\gamma = 1$ to maintain the relative reflectance effects of the original film. Pin registering combinations of positive and negative separations was used to produce a ratioing effect (Lockwood, 1975). Table 2 shows the combinations used and the resulting spectral ratios. All other ratios would be similar to one of these but with inverse functions.

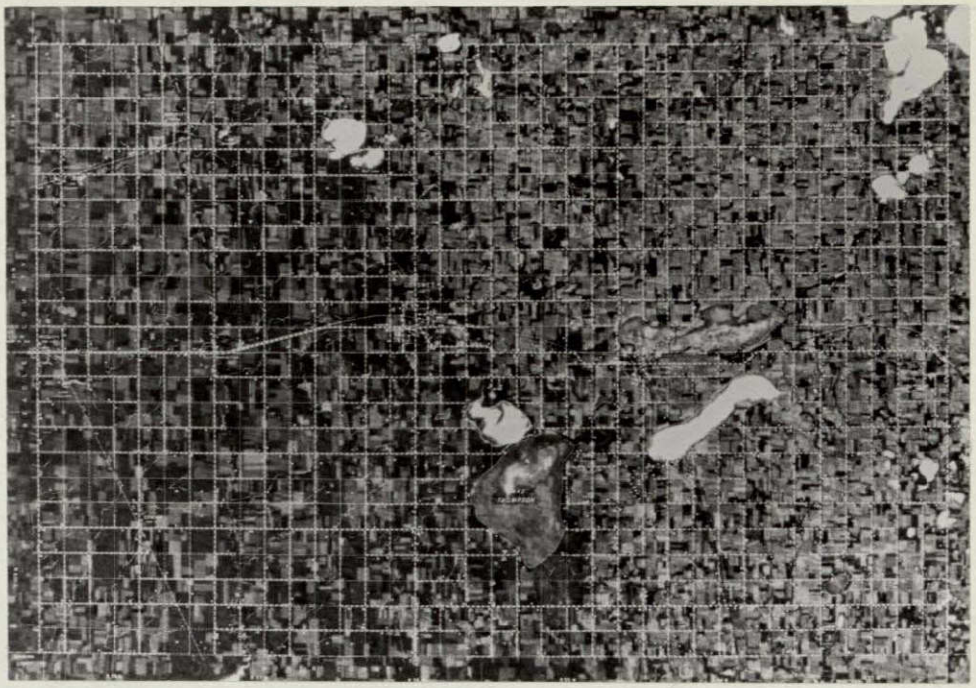
Table 2. Table of separation combinations and resulting spectral ratios.

SEPARATIONS		SEPARATION RATIO	SPECTRAL RATIO
RED+	BLUE-	RED.........BLUE	IR.......GREEN
RED+	GREEN-	RED........GREEN	IR.........RED
BLUE+	GREEN-	BLUE.......GREEN	GREEN......RED

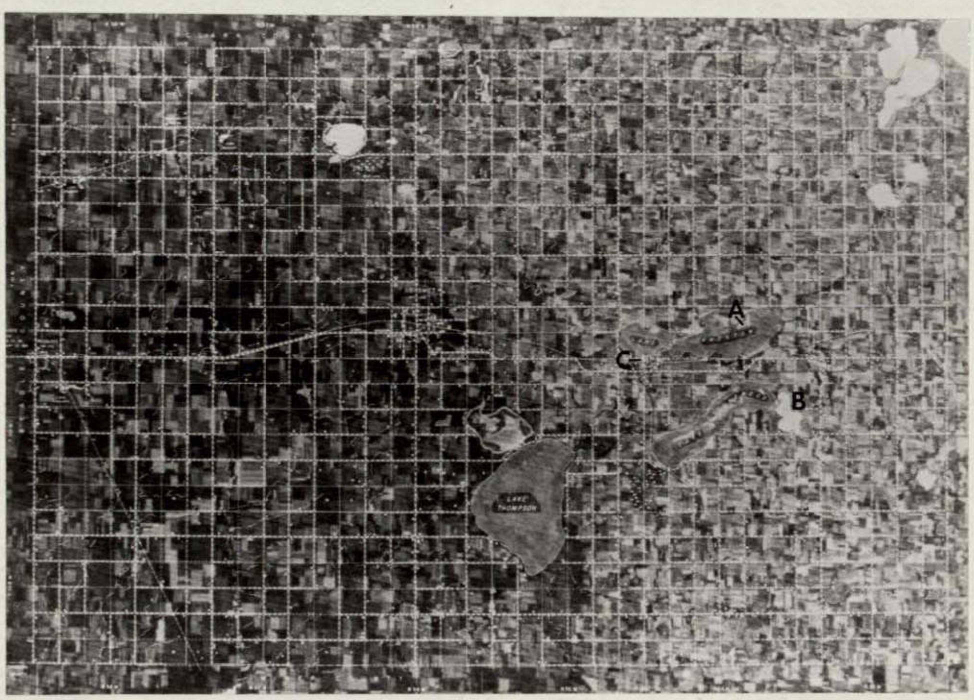
Manual and automated density slicing techniques were used in the interpretation of original imagery and color separations. Color and black and white enlargement prints were interpreted manually and verified in the field. Interpretations were based on tone, texture and patterns and required both interpretation and field experience. In order to simplify the procedure the imagery and separations were analyzed on Spatial Data Model 703 density slicer. Each image was "sliced" into 4 equal density increments and color encoded on CRT monitor. Enlargement prints were made from 35-mm slides taken of the monitor. A classification of the hydrophytes will be made by identifying the relative density of each class in each separation.

RESULTS

Numerous characteristics of meandered lakes can be interpreted on Landsat imagery. Repetitive coverage allows monthly or yearly monitoring when cloud-free scenes are available. A display with monthly scenes from May to November 1976 scenes for October 1974-1976 and an example snow-cover scene was presented to the South Dakota GF&P Commission at their September meeting. Figure 6 a,b, and c are examples of the products that were presented. A change in water regime is the most obvious characteristic and perhaps the most important. As the water level drops numerous changes, including vegetation structure, water quality and encroachment of agriculture within the meander line, occur in the lakes. During 1976 many lakes dried up because of drought conditions (see figure 6a and b). During extremely dry years these lake beds can be plowed and planted to small grains as seen at A in figure 6b. The amount of agricultural use within meander line must be monitored to prevent excessive damage to wetland habitat. The light toned area marked B in figure 6b is an area of uncontrolled burning which destroyed a large area of wetland vegetation which would otherwise provide valuable winter cover. The burn area is completely revegetated and snow melt and rainfall have

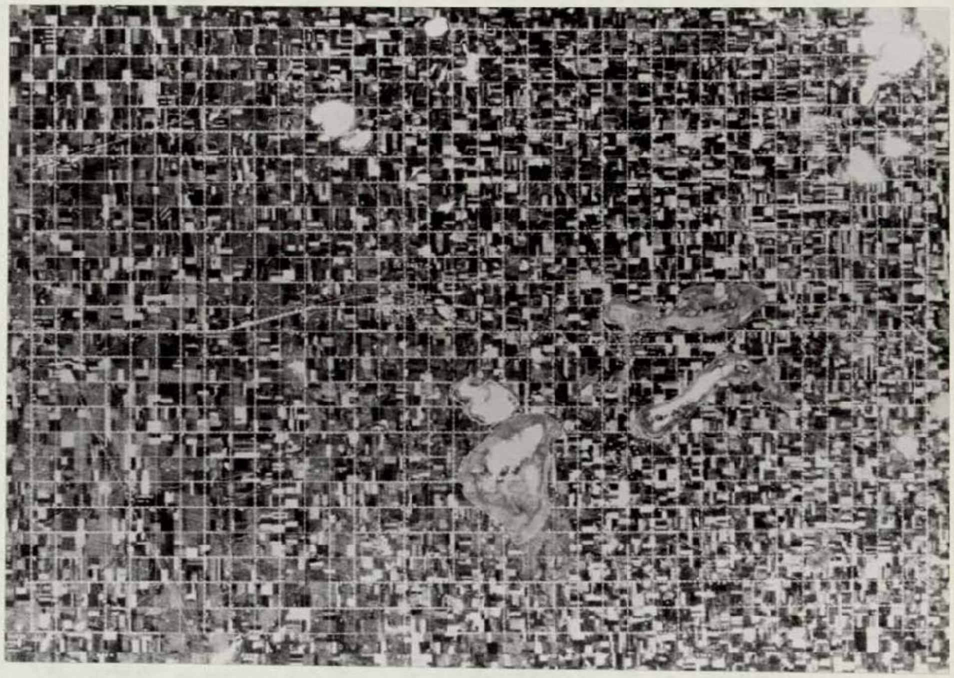


a. May 6, 1976 #2470-16324



b. November 20, 1976 #2668-16264
Note encroachment of agriculture at A, uncontrolled burn area at B and municipal sewage lagoon at C.

Figure 6. Landsat prints of Kingsbury County, with roads superimposed, to illustrate applications of Landsat imagery for monitoring meandered lakes.



c. June 6, 1977 #866-16175

Figure 6 continued.

partially filled the lake by June, 1977. Note also the presence of the municipal sewage lagoon in figure 6a, b, and c at C. Resolution and the length of time required to receive Landsat imagery are factors which limit the use of Landsat in an operational program. Cost benefits of temporal data may outweigh both limitations.

Vegetation classes can be interpreted by tonal and textural differences on both the original color-infrared and black and white reproductions of aircraft imagery (see figure 7). Six classes of hydrophytes could be interpreted from enlargement prints (see figure 7b). Two classes, Typha sp. and Scirpus sp. are genus' in which species could not be separated. Only two species of hydrophytes, Scholochloa festucacea and Phragmites communis could be consistently interpreted when they occurred in pure dense stands. The shallow marsh class is a mixed stand consisting of Scirpus sp., Eleocharis sp., Sparganum sp., Polygonum sp. and grasses. The wet meadow zone is a mixed stand of grasses and sedges and is a peripheral zone which delimits the extent of the basin. Manual interpretations of separations and separation ratios have not been completed. Considerable interpretation experience and knowledge of aquatic plant communities is required to make an accurate manual interpretation of the above classes.

The automated density slicing technique simplifies the interpretation because it requires no experience. Figure 8 is an example of color encoded density slice of the positive infrared separation. The density increases by equal increments in the following order: yellow, cyan, green, red. The best separation of the hydrophyte classes occurred

4a. CIR image of portion of meander lake.

4b. Interpretation of hydrophyte classes on black and white reproduction of CIR imagery.

Figure 7. Color infrared and black and white enlargements illustrating tonal and textural variation representing different classes of hydrophytes.

ORIGINAL PAGE IS
OF POOR QUALITY

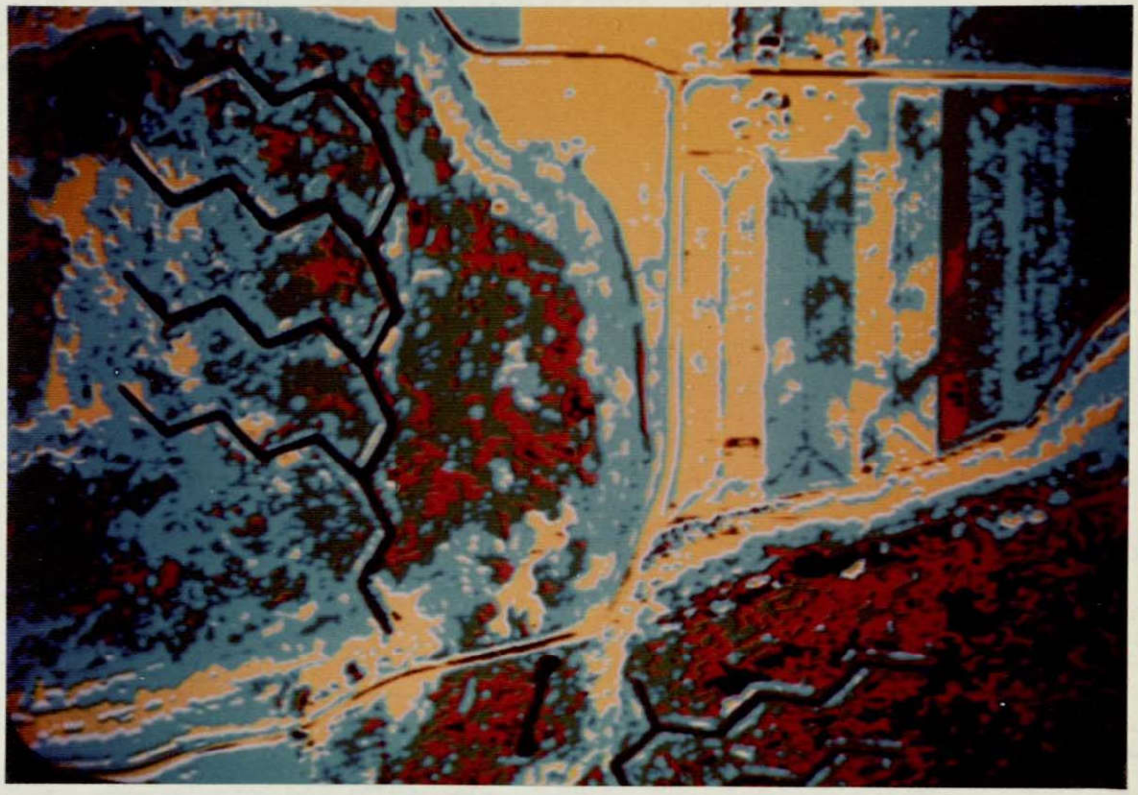


Figure 8. Color encoded density slice of positive infrared separation of CIR film.

in the infrared separation. Pure dense stands of Typha sp. had the lowest relative reflectance and are approximately delineated as the red increment. The green increment represents stands of Scirpus sp. and Scirpus sp., Typha sp. mixed stands. The cyan increment has thin stands of Scolochloa festucacea and also the wet meadow vegetation. Pure dense stands of Schochloa festucacea and shallow marsh vegetation have the highest relative infrared reflectance and appear in the yellow increment. It is possible to separate classes in the same density increment by considering their relative reflectance in the other separation and ratios of separations. Figure 9 is an example of the classification of hydrophytes from the density sliced separations and ratios. This process will be investigated further during the rest of the project. A digital analysis which employs unequal density increments will be pursued if time permits.

Techniques will be presented to GFP personnel in a seminar to be scheduled in the spring. Imagery will be made available for continued use in their region.

SUMMARY OF PROGRESS

The application of remote sensing for managing meandered lakes has progressed as follows:

1. Meetings were held with the land management specialist from South Dakota Game, Fish, and Parks. Meandered lakes in Kingsbury County were selected for preliminary analysis.

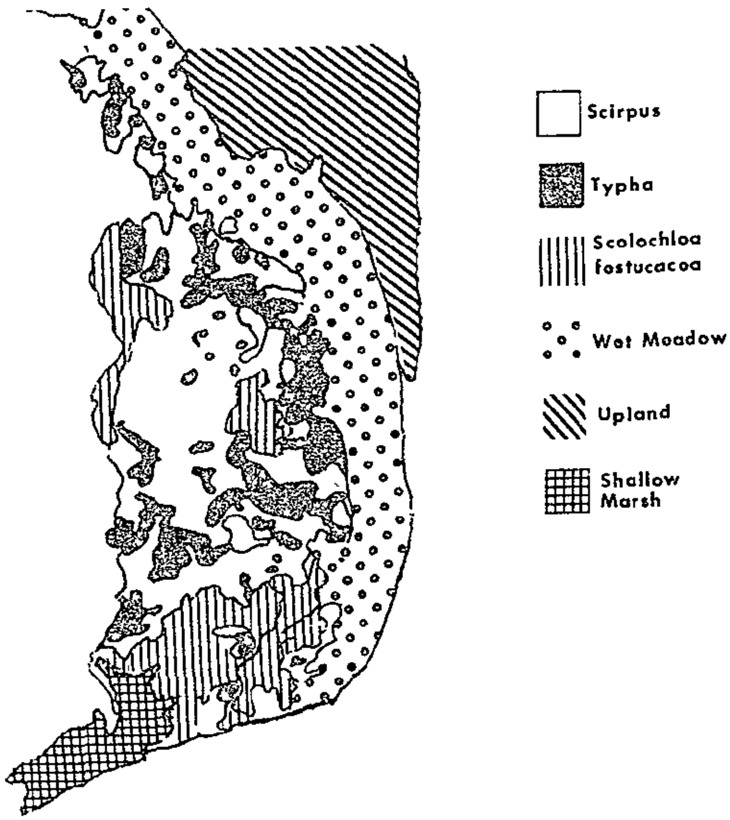


Figure 9. Classification of hydrophytes from density sliced separations and ratios.

2. Manual and automated density slicing techniques for interpreting hydrophyte classes from infrared imagery have been developed and documented.
3. The use of Landsat imagery for monitoring meander lakes was explored and results were presented to GFP commission.

LITERATURE CITED

Best, R.G., D.G. Moore, and W.G. Brewster. 1976. Color-infrared Aircraft Photography to Identify and Classify Wetlands in the Lake Dakota Plain of Eastern South Dakota. SDSU-RSI-76-03, Brookings, South Dakota. 16 pp.

Dvorak, D. 1973. Listing of Meandered Lakes. State of South Dakota Department of Game, Fish and Parks, Pierre, South Dakota. 9 pp.

Eastman Kodak Co. 1971. Kodak Data for Aerial Photography. Rochester, New York. 80 pp.

Lockwood, H.E. 1975. Photographic Image Enhancement and Processing. The Fifth Biennial Workshop on Color Aerial Photography in Plant Sciences and Related Fields. American Society of Photogrammetry, Falls Church, Virginia. pp. 29-44.

Transformations of Landsat digital tapes have successfully been used to describe soil background contributions to vegetative signatures throughout the growing season in relatively small, intensively sampled areas (Kauth and Thomas, 1976; Richardsen and Wiegand, 1977). In the above studies the contribution of soil reflectance to the overall vegetative signature was stratified into two and three levels of similarity, respectively. However, regional variability (e.g. parent materials) often precludes extrapolation of results to other areas. Therefore, the incorporation of soil stratification procedures into operational programs must be preceded by research projects which look at various physiographic regions. Research studies can then assess the impact of a wide range of soil and soil properties on vegetative signatures.

Statistical Reporting Service (SRS) has successfully used automatic classification of Landsat digital tapes to identify agricultural crops. Presently SRS uses a general land use stratification. This type of stratification may result in high accuracy levels under reasonably homogeneous conditions, but heterogeneous areas within a general land use area may cause decreased classification accuracy. SRS personnel have indicated an interest in stratification of sample frames by soil background reflectance zones. Favorable results may lead to further development of this study in conjunction with the SRS. Other interested agencies include State Agriculture Department and the Crop Reporting Service (CRS). The procedures and results of the study will be reported to the SRS, CRS, and State Agriculture Department for potential use in improving cropland estimates.

The major thrust of this study is to test the concept of improving crop inventory procedures by accounting for variable soil influences on Landsat-derived crop signatures in southeast South Dakota. Soil association data will be investigated as a starting point for the stratification procedure. An attempt will be made to quantify the soil features which impart a significant influence on crop (corn) signatures derived from Landsat data. This study is aimed at setting up an operational procedure whereby the variability, caused by soils, in crop signatures can be accounted for.

Methods and Materials

The procedures outlined in FY 1977 NASA Annual Progress Report have been used with a few alterations in the expansion of this project. Therefore, only a brief description of any repetitive procedures will be presented.

The study area (Fig. 10) is located primarily in a warm, moist prairie region (Udic Ustoll soils). The soils in this area have formed in an area of diverse topography, surface textures, and parent materials (Fig. 11); this is a dominant factor in causing varied surface soil reflectivities. Field data were collected on a soil association basis to establish the contribution of soil background reflection to row crop signatures. However, several soil associations in the study area were not represented in this study. The determination of the inclusive soil associations was based on areal extent within the study area, land use

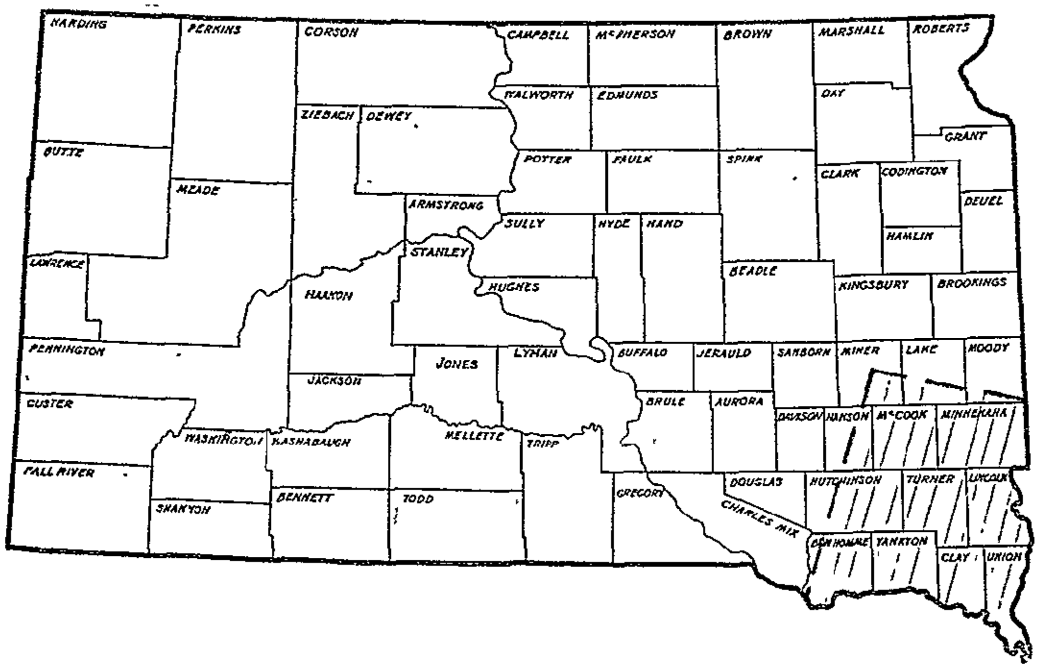


Fig. 10. Location of study area in agricultural inventory study.

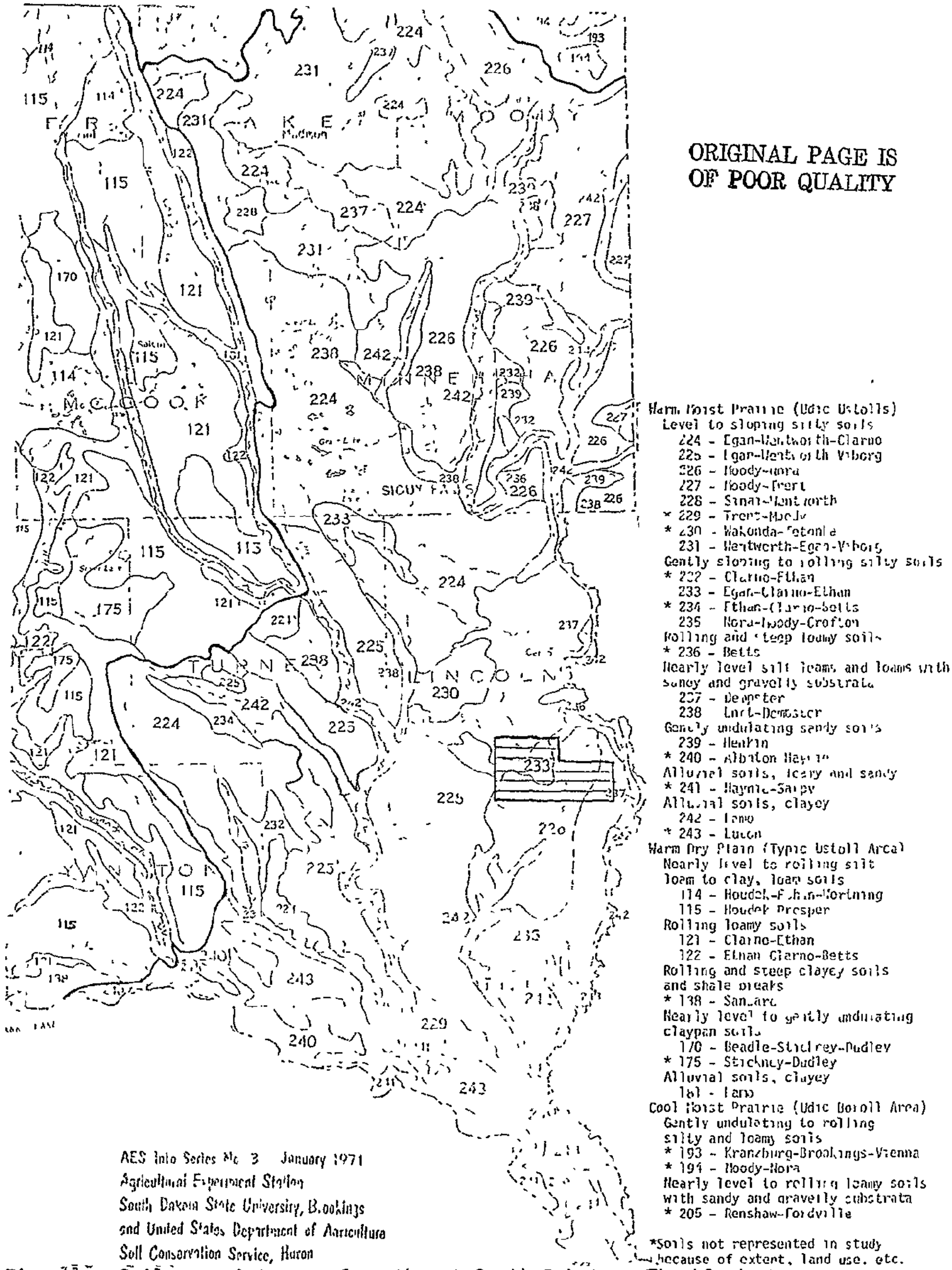


Fig. 11. Soil associations of southeast South Dakota. The blocked area is the location of the intensive study site. The dark line running through the length of the map differentiates the Warm, Moist Prairie from the Warm, Dry Prairie.

(i.e. cropped or not), and shape (e.g. narrow floodplain soils). In this manner only the major, cropped soil associations in the study area were sampled.

The collection of ground data was undertaken during the summer of 1977. The data collected included various crops but the major crop was corn. The collection of corn and other crops was dictated by the locations of major soil associations within the study area. Ground data were collected at road intersections and recorded on county highway maps (scale approx. 1:140,000). Prior to field work, soil association boundaries had been transferred to county highway maps via a reflecting projecter. Thus, a running tally could be kept to insure that sufficient ground data were collected within each major association (i.e. minimum 10 fields). The road intersections also provided an efficient means of registering or locating the field data on Landsat data. In addition, Skylab coverage of the study area provided a valuable means of recognizing and confirming the shape and configuration of the field data as it was notated on the highway map.

Two Landsat CCT (Computer Compatible Tapes) were obtained for data extraction, 5 June 1977 I.D. 2865-16123 and 29 July 1977 I.D. 2919-16095. Two methods of data extraction are being tested. The standard CCT printer maps with six overstrike levels and the Optronics P-1700 film recorder product (a component of ISI 270 System at the EROS Data Center) are shown in an area of intensive ground data (Fig. 12a and Fig. 12b respectively). Both methods employ manual location of field data as the initial step in the extracting procedure. The advantages and disadvantages of each method

Fig. 12a. Computer overstrike printout from CCT encompassing intensive study area. Reduction is approximately one-third. (Arrow indicates common registration point with Fig. 12b). Variable overstrike darkness was caused by the printer ribbon.

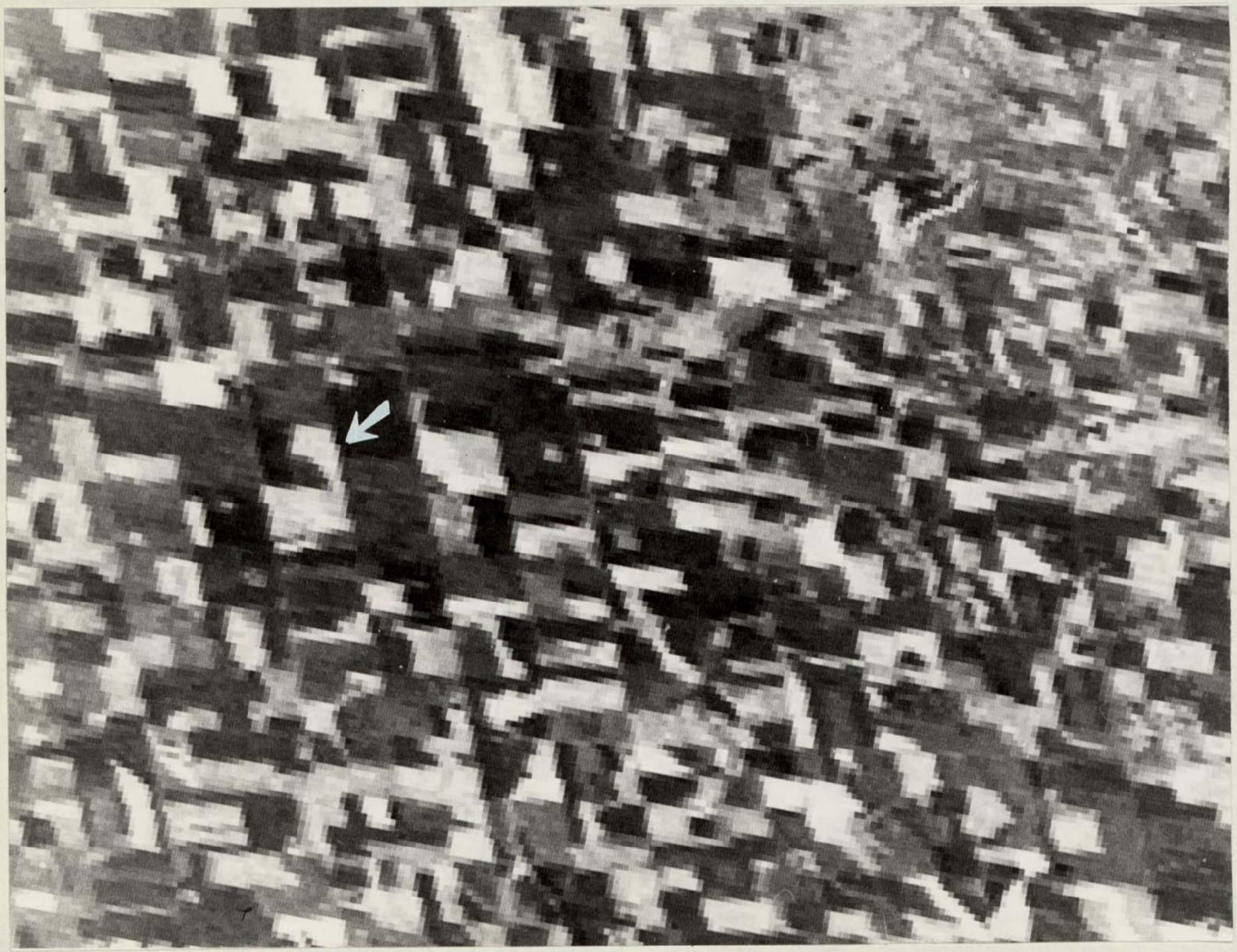


Fig. 12b. Optronics film recorder output. The row and column coordinates, which are registered on the edges of the data, are not shown. (Arrow indicates common registration point with Fig. 12a). This system (P-1700 ISI 270 System) has a 256 gray level capability; however, the film and the eye of the interpreter do not have this capability.

will be assessed; this will include ease of handling, time, accuracy, and cost.

Upon extraction of data, which is recorded by crop and soil association, statistical analyses will provide a basis for evaluation of the various radiometric signatures. The soil association signatures will be compared to each other to determine which contribute similar background reflectance. The sequence of statistical tests (after data extraction and error checking) is as follows: 1) means and variance; 2) analysis of variance; and 3) Duncan's multiple range test. Duncan's multiple range test determines the soil associations which have significantly different signatures. KCLASS and KTEST programs are then implemented to test classifier accuracy improvement when incorporation of soils strata is used as opposed to no stratification.

The extraction of the ground data has been completed for the June 5 Landsat overpass. Statistical analysis had been completed only for the intensively sampled area (Fig. 11, 12a, 12b). Automatic classification will next be used to test the strata; a single-class classifier will be investigated as a potential classifier. Various digital data transformations (Richardson and Wiegand, 1977; Kauth and Thomas, 1976) may also be investigated.

The ensuing results and discussion section, though not complete, will be limited to the intensively sampled area. Other ground data for the June 5 Landsat overpass have been extracted and are in the process of being analyzed.

Results and Discussion

The results to-date include only data from an intensively sampled area (Fig. 11). This area was sampled with more intensity than other soil association areas in the region because: 1) soil differences were readily perceivable on Landsat imagery; 2) topographic differences are pronounced in this area; 3) a detailed soil survey has been completed for this area; and 4) a region having the aforementioned factors was needed to test various concepts that will include data transformations, data extraction methods, and detailed soils data within soil associations.

The selection of CCT data was initially intended for middle June. However, the June 5 date was the only date when cloud coverage was minimal over ground data collection areas; the only data excluded because of haze was in Clay County. Although, the growing season was approximately three weeks ahead of schedule, the June 5 data had minimal vegetative coverage in areas. Field observation at this time estimated corn height at approximately 20 to 30 cm; Richardsen et al. (1977) indicated classification of crops was best when the plants were taller than 30 cm. Therefore the July 29 CCT was obtained. The advantage of the additional tape and its value to the development of the stratifying procedure will be assessed in the continuation of this study.

The soils and their corresponding properties in the intensive study site are listed in Table 3. Further detailed descriptions of the four soils are available in the county soil survey (Driessen et al., 1971) or official soil series description. The mean reflectance and Duncan's multiple range test for corn on these soils is listed in Table 4. The

Table 3. Soils of the intensive study site and some of their characterizing features (see Fig. 10) for extent.

	Soil Association*	Slope and Parent Material**
225	Egan† - Wentworth - Viborg	nearly level (0-3% slopes), formed in glacial drift
235	Nora† - Moody† - Crofton	gently sloping to strongly sloping (3-15% slopes), formed in loess
233	Egan - Clarno - Ethan	gently sloping to rolling (3-15% slopes), formed in glacial drift
226	Moody† - Nora†	nearly level to sloping (0-9%), formed in loess

* Listing is in order of high to low soil composition.
** All soils are silty.
† Appears in more than one soil association.

Table 4. Mean reflectance and Duncan's multiple range test for corn on four soils.

	Mean Digital Count (from Landsat CCT) and Duncan's			
Soils	Band 4	Band 5	Band 6	Band 7
235	25.79*	33.79*	41.35*	17.74*
226	24.00*	30.70**	38.99*	16.83*
225	22.27**	27.20***	34.77**	15.06**
233	21.94**	26.50***	33.21**	14.08**

Similar treatment means (derived from Duncan's) are noted by one, two or three *'s.

soils formed in loess (235,226) have a higher reflectance than those soils formed in glacial drift (225,233). It appears that slope influences the reflectance values of the loess soils, i.e. 235 is greater than 226. This is due to exposure of subsoil caused by erosion on the steeper slopes and the subsequent deleterious effect on plant growth. The soils formed in glacial drift had very similar reflectance values. Obviously, the same major drift-derived soil (Egan) in both associations would cause one to expect this. It is the minor soils and soil inclusions which would appear to cause the slight difference in reflectance values.

As noted in Table 4, the best separation of data occurred in band 5. The frequency distributions for soils 225 and 233 are shown in Figure 13. Although the treatment means for the soil reflectance values in Fig. 13 were significantly different (Table 4), there is considerable overlap. The various maxima of the curves may represent the component soils of the respective associations.

At this point, it appears that soil association data may not be the best differentiating tool for establishing soil background reflectance zones early in the growing season. However, the use of a detailed soil survey to differentiate component soils within the soil associations is needed. In this manner a more homogeneous soil composition will be tested for reflectance contributions to corn signatures. It must also be kept in mind that results completed so far are for an early date (June 5). The July 9 CCT will show: 1) whether the soil background reflectance strata (as established from June 5 CCT) have changed;

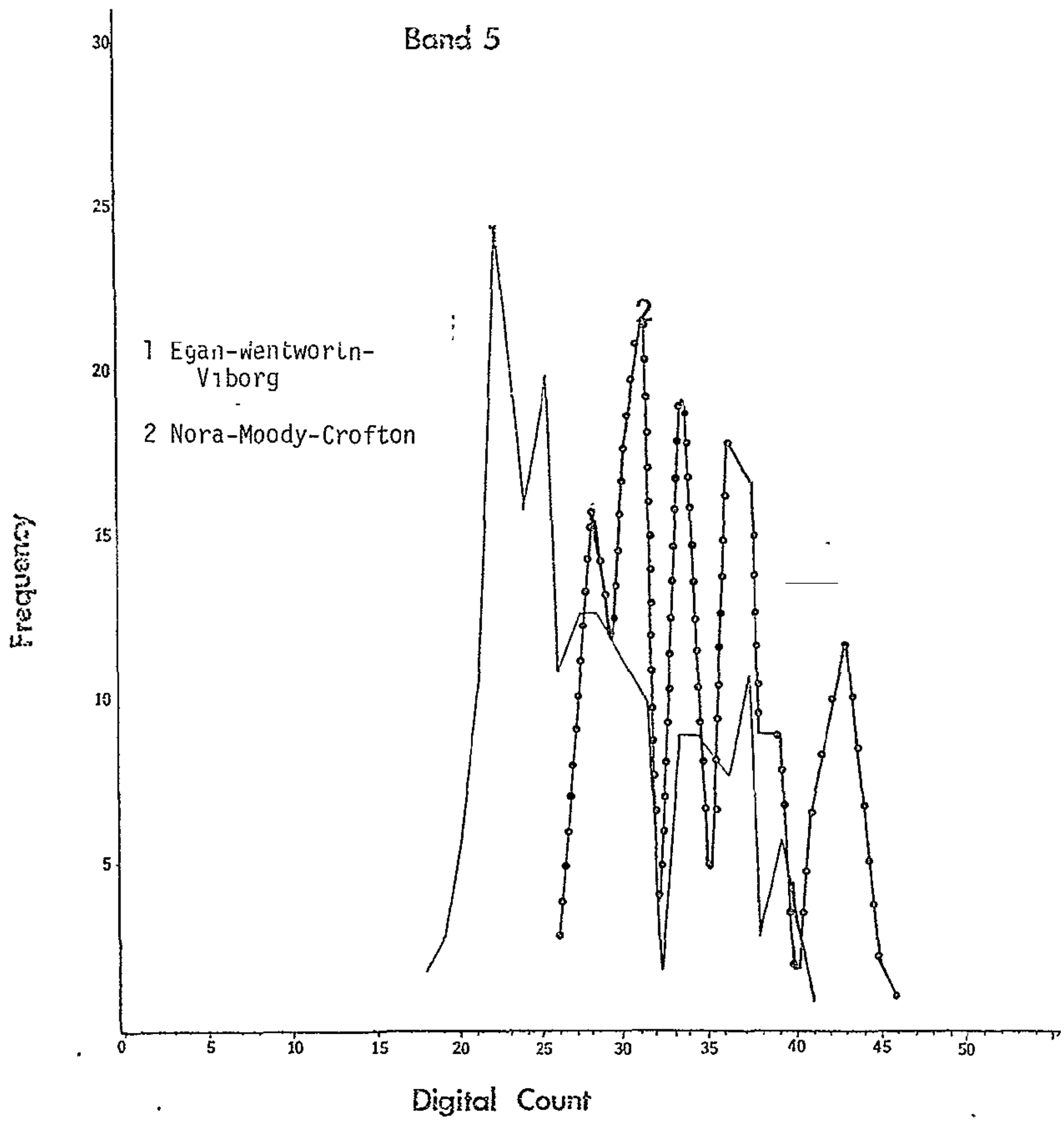


Fig. 13. Frequency distribution of band 5 digital data for corn on two dissimilar soil associations.

2) whether soil association data is an important stratifying tool for later seasonal dates; and 3) whether soil properties, which are important in determining reflectance zone, change as the crop canopy closes.

Completed

1) Data extracted and error checked for June 5 CCT
2) Statistical analysis for intensive study area

Scheduled for Completion

1) Data extraction for July 29 CCT
2) Statistical analysis for both CCT
3) Classifier testing of established strata
4) Use of detailed soil maps for refinement of causative factors in establishment of reflectance zones.

REFERENCES

Bizzell, R.M., F.G. Hall, A.H. Feiverson, M.E. Bauer, B.J. Davis, W.A. Malila, and D.P. Rice. 1975. Results from the Crop Identification Technology Assessment for Remote Sensing (CITARS) projects. Proc. Tenth International Symp. Remote Sens. Environ., Ann Arbor, Michigan (mimeo).

Driessen, J.L., G.E. Murphy, and W.D. Wiesner. 1971. Soil survey of Lincoln County, South Dakota. SCS-USDA and S. Dak. Ag. Exper. Sta., U.S. Gov. Print. Off., Washington, D.C.

Horton, M.L. and J.L. Heilman. 1973. Crop identification using ERTS imagery. Presented at NASA Symposium on Significant Results Obtained From ERTS-1 March 5-9, 1973.

Kauth, R.J., and G.S. Thomas. 1976. The tasselled cap - a graphic description of the spectral-temporal development of agricultural crops as seen by Landsat. Proc. Symp. Machine Proc. of Remote Sens. Data, 4B:41-51. LARS, Purdue University, West Lafayette.

Lemme, G.D. 1975. The influence of soils and vegetation on Landsat spectral signatures. M.S. Thesis. South Dakota State University.

Myers, V.I., F.C. Westin, M.L. Horton, and J.K. Lewis. 1974. Soil influences in crop identification. In Effective Use of ERTS Multispectral Data in Northern Great Plains. Remote Sensing Institute, South Dakota State University.

Richardson, A.J., and C.L. Wiegand. 1977. Distinguishing vegetation from soil background information. Photogram. Eng. and Remote Sensing, 43(12):1541-1552.

Stockton, John G., Marvin E. Bauer, Byron O. Blair, and Marion F. Baumgardner. 1975. The use of ERTS-1 multispectral imagery for crop identification in a semi-arid climate. LARS Information Note 040775. The Laboratory for Applications of Remote Sensing. Purdue University, West Lafayette.

Wiegand, C.L., H.W. Gausman, R.W. Leamer, A.J. Richardson, J.H. Everitt, and A.H. Gerkermann. 1977. Soil, water, and vegetation conditions in South Texas. Type III Final Report for Goddard Space Flight Center, Greenbelt, Md.

THE USE OF REMOTE SENSING TECHNOLOGY TO MAP ASPEN

INTRODUCTION

For the past three years the South Dakota Department of Game, Fish, and Parks has been involved in the study of the management potentials of aspen within the Black Hills. The main focus of the study is on the management of aspen for improved wildlife habitat, especially for ruffed grouse. Game, Fish, and Parks personnel have also been involved in a research study which evaluates aspen as a food source for livestock. Tests have shown that food rations containing processed aspen were superior to an alfalfa control ration in daily gain and feed required per pound of gain (Kamstra et al.).

Knowledge of the location of aspen stands is absolutely necessary for the improved management of wildlife habitat and potential industrial harvesting of aspen as a livestock food source. Aspen delineation studies conducted under NASA Contract NAS5-20982 and particularly NASA Grant #42-003-007 indicate that an aspen inventory generated from digital analysis of Landsat CCT's is more accurate than either manual interpretation of high altitude photography or the existing U.S. Forest Service type maps. The major limitation of the high altitude photography was interpreter fatigue. As interpretation time increased the criteria used for assigning the data into classes became more inconsistent resulting in low accuracy interpretations. The inconsistency is theoretically avoided by utilizing machine analysis because the decision making criteria are constant over time. The U.S. Forest Service type maps are basically outdated and generally have low spatial accuracy. Comparison of the digital classification and the ground truth was reported in the last annual report and indicates that a satisfactory classification has been developed. Present limitations exist in producing a user acceptable output product. The last six months have been devoted to evaluating several options in an attempt to produce an acceptable output product.

STUDY AREA

The Black Hills are located in western South Dakota and eastern Wyoming along the South Dakota-Wyoming border. The total area encompasses approximately 1.2 million hectares (3 million acres). The Black Hills are composed of deciduous and coniferous forest with intermingled grass meadows. The major conifer type is ponderosa pine and the major deciduous type is aspen.

Over the last 75 years the forest has become overstocked with pine. This is due primarily to the prevention of forest fires and the limited logging activity. The pine has overwhelmed many of the aspen stands and meadows. Consequently, there has been a severe loss of wildlife habitat.

GENERATION OF OUTPUT PRODUCTS

The manner in which spatial data is displayed plays a significant role in the acceptance and use of the data. Thematic maps which are generally used to display spatial data must be simple and understandable and yet detailed enough to serve the intended purpose. The maps must also be linked to some coordinate system to enable location of areas of interest. An important consideration in the generation of output products is the cost of producing in relationship to the intended use and benefit. Therefore, in this portion of the activity we have been concerned with an output product that the South Dakota Game, Fish and Parks Department would consider cost effective.

In addition to the cost of an output product, attention must be given to producing a product that is detailed, understandable and acceptable to the user. This can be a major problem because the people who will be using the maps have very little experience in remote sensing, especially in machine processing. The forester's experience and use of land cover information is in the analog or continuous form rather than discrete or cellular. Consequently, it is difficult to obtain acceptance of cellular output products produced by machine analysis.

The Department of Game, Fish, and Parks has expressed its desire to have the output products in a specific format that will facilitate their management efforts. The format consists of separate thematic maps, each of which corresponds to the precise area encompassed on a 7.5 minute quadrangle. It takes approximately eighty maps to cover the entire

Black Hills. The required scale of the maps is 1:31,680 which is equivalent to the U.S. Forest Service type maps. In addition, generalized maps at larger scales are desired.

At the outset of output product development it was decided to produce sample products for three quadrangles. The three areas were chosen for two reasons. First, to keep development costs low. Secondly, the three areas chosen represented varying degrees of complexity, the predominant land cover type was different, and they were from different portions of the Black Hills. The second reason had a two-fold purpose in that any production problems related to complexity would be detected and that the sample products because of their different locations within the Hills could be used for further field verification of the accuracy of the classification for the entire Hills area. The verification aspect required that the data be as detailed as possible. If the 0.45 hectare (1.1 acre) classification is not acceptable then any aggregation of the data will also be questionable.

The first method considered was intended to eliminate two problems associated with machine processing of high resolution (0.45 hectare [1.1 acre]) data. The first problem is the salt and pepper affect. Often times individual cells within a large relatively homogeneous area are classified differently than those of the large area. The difference in classification is usually due to a small variation in spectral reflectance which causes the cell to resemble some other land cover type or the cell in fact is a different land cover type. In either case, especially for the purposes of this inventory, the cell has very little significance and therefore should be grouped with the large homogeneous area. The second problem, which was previously discussed, is the cellular or blocky appearance of the data.

The salt and pepper problem can usually be solved by machine manipulation of the data. However, it is impossible at least within the scope of RSI's software development to remove the blockiness of the data. In order to remove the "blockiness" it was decided that the data should be manually generalized. Initially, the only map source of the data was greytone lineprinter maps. Utilization of the line-printer maps as a basis for the manual generalization can be done but there are some problems that must be dealt with. The principal problem is scaling. Because of the nature of lineprinters, maps produced on them have an awkward scale. The problem would only be minor in the beginning of the procedure, but towards the end when the scaled final maps were to be produced serious problems could arise. Consequently, it was decided to do the generalization on base maps of the data that were at the same scale needed for the final product (1:31,680). One of the three guadrangle areas was chosen and the data was plotted using a Calcomp drum plotter. The plots were generated using the original .45 hectare (1.1 acre) cellular data. All six themes were plotted on one map. The different categories were delineated by lines drawn at the boundaries where the categories changed. A number identifying which category each area belonged in was also plotted at the boundary lines. After the generalization was completed separate theme overlays were to be made and used in a photo lab for reproduction of color or black and white maps.

It took 2.5 hours to produce the line plot for the test area at a cost of $6. Just figuring plotting time alone it would take approximately 200 hours at a cost of about $480 to produce the eighty necessary maps. The generalization of the plots took nearly 2 man days each or about 160 man days for the entire area. It is estimated that it would have taken 1 man day to produce each one of the six separate theme overlays needed for reproduction or about 480 man days for the entire area. The combined cost of labor and plotting ruled out this method.

The second method tested was an offshoot of the first. It was felt that if plotting and generalization time could be significantly reduced the first method would be viable. In order to accomplish the time and cost reduction the data were aggregated to 4 hectare (10 acre) cells before plotting. A simple method of aggregation was used where a block of 9 cells was analyzed and a new larger cell was created. The cell was placed in a land cover class based on what the majority land cover was in the original block of 9 cells. Line plots of the aggregated data like those described in the first method were produced using a Calcomp drum plotter. There was a significant reduction in the complexity of data in comparison to the first method. Aggregation of the data also solved the salt and pepper problem previously discussed. Unfortunately, the manual generalization did not significantly reduce the blockiness of the data. The generalization process merely smoothed the corners of the existing cells. If a strong generalization had been performed it would have most likely introduced spatial inaccuracy into the data. Although the blockiness remained the method was further investigated because plotting and generalization cost had greatly decreased.

It took 30 minutes to produce the line plot for the test area at a cost of $1.55. Consequently, it would take about 40 hours and cost approximately $120 to plot the data for the entire area. The generalization of the plot took 3.5 hours. The plotting and generalization cost was about one-fourth as much as the first method and appeared feasible. However, the generalization of the 4 hectare (10 acre) cellular data was determined to be unnecessary because it did not remove the blockiness of the map.

The next task dealt with how to produce the necessary thematic maps. Since no manual generalization was performed the Calcomp plotter was used to produce scaled (1:31,680) thematic separations. Instead of producing line plots of all themes, the themes were plotted separately and each 4 hectare (10 acre) cell included in the theme was completely filled in. Figure 14 illustrates the plot for one theme. The plots could then be used as camera ready copy for production of color or black and white maps. Once again the cost of producing the plots raised some questions about product cost effectiveness.

It took 50 minutes to plot an average theme separation at a cost of $2.50. The theme that was plotted was of average complexity and was used to compute the estimated cost of the entire area. The total time needed to plot the theme separations was about 400 hours at a cost of about $1000. There was only minor labor costs because no generalization was done, and because no other obvious alternatives existed, the method was investigated further.

Figure 14. Cell plot of one theme.

Utilizing the Calcomp plotted theme separations, the first sample output product was produced using the Chromalin process. The procedure involves laminating a working surface, usually paper or mylar, with a film that is sensitive to ultra-violet light. The theme separation was overlayed onto the working surface and exposed to ultra-violet light. The exposed areas, the area where no darkened cell is present, are hardened and the unexposed areas become sticky. A colored powdered toner is applied to the working surface and sticks to the unexposed layers. The process is repeated over and over adding a different color for each new layer, thus producing a color thematic map. Figure 15 illustrates the Chromalin product with only three of the six themes.

Several problems were encountered using the Chromalin method. Two minor problems were related to the Calcomp plot data. The thematic cell plots were produced on paper which is somewhat unstable. Consequently it was extremely difficult to register each of the themes. Also, because the paper has a varying density over its surface, care had to be taken to avoid over exposing the sensitive film. If the film is overexposed the background of the paper is burned onto the film. Unfortunately, when the film is under exposed the toner does not stick evenly to the unexposed areas. Both of these problems could be avoided by plotting the data on a stable, clear base material such as mylar. Mylar is more expensive than paper so plotting cost would be somewhat higher.

The cost of producing the maps by the Chromalin was estimated at $60 per map for a total of $4,800 for the complete area. Therefore, the decision was made to investigate other methods to produce the final product which may result in a reduced cost.

Figure 15. Sample color thematic map produced using the Chromalin process. Map includes only three themes for a portion of one of the test areas.

The last method tested to date utilized a film recording device. Through a cooperative agreement access was obtained to the Optronics film recorder system at the EROS Data Center. Separate digital files for each of the three test areas were produced and recorded on magnetic tape. Within these files each category is assigned a different numeric value which determines the exposure of the film output of the film recorder. The degree of exposure creates grey levels which correspond to the categories. The film recorder output is used to produce black and white thematic maps. In addition, thematic separations were used to produce a color thematic map. Figure 16 illustrates a black and white thematic map for one test area and Figure 17 illustrates the color thematic map for the same test area.

One major problem was encountered utilizing the film recorder method. The negatives produced by the film recorder are very small scale and hence need to be enlarged approximately 18 times in order to attain the desired scale (1:31,680). When the data were enlarged a serious misregistration problem was encountered. The problem was apparently caused by incorrect mounting of the film in the recorder or some other system problem. An alternative is to utilize a film recorder which produces a color positive film directly. This option is to be tested in the next few weeks.

The film recorder output is the least expensive method attempted so far. It is estimated that black and white thematic maps for the entire Black Hills area could be produced for about $1600. That figure includes computer processing, film recorder processing, and

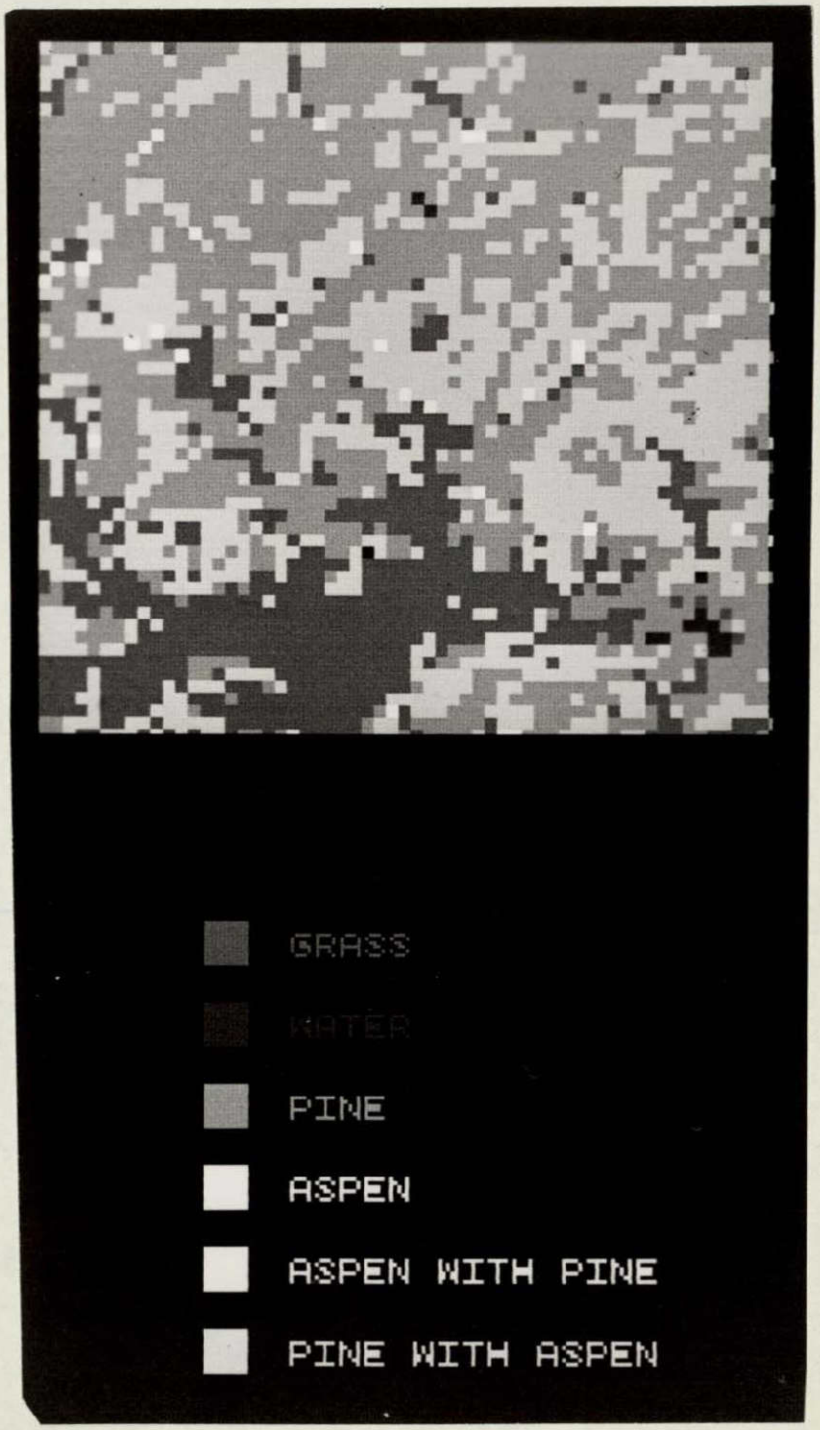


Figure 16. Sample black and white thematic map produced utilizing the Optronics film recorder system.

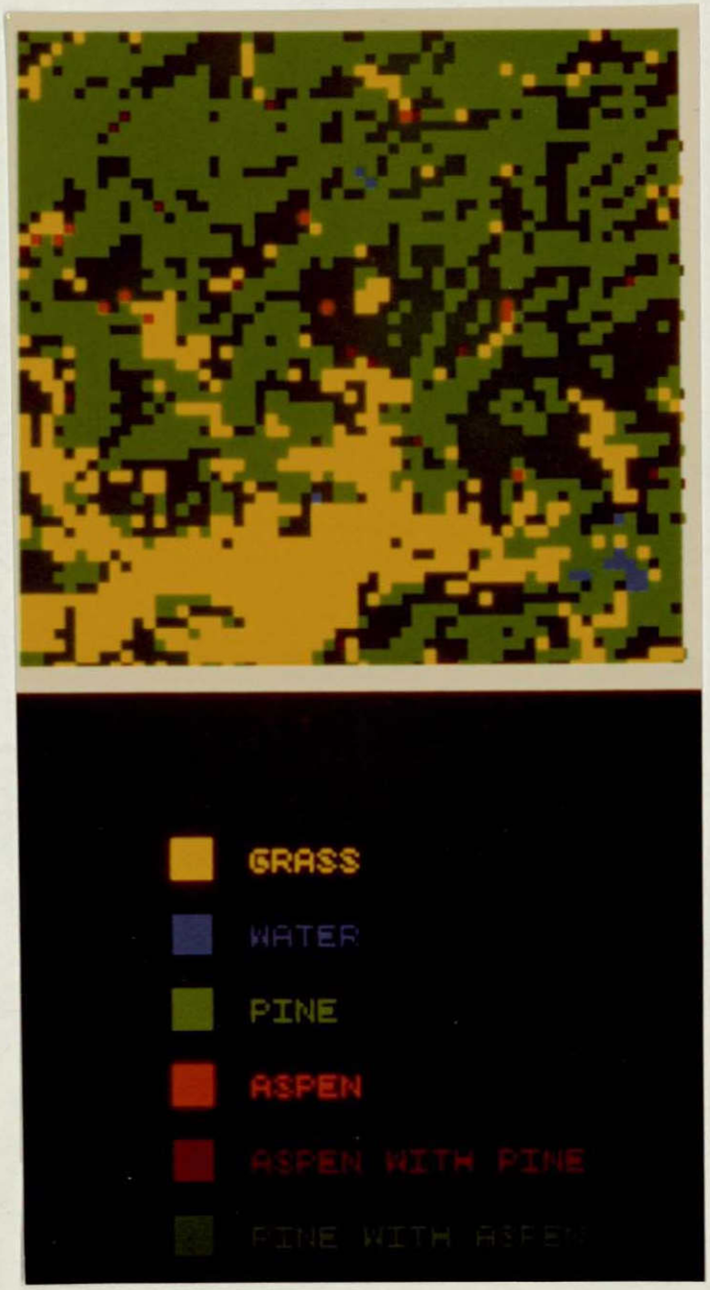


Figure 17. Sample color thematic map produced utilizing the Optronics film recorder system.

photo lab processing. Color products were much more expensive because more processing is necessary. Estimated cost of producing the eighty maps in color was $5200. The color product cost would be significantly reduced if the film recorder system that produces color film directly were used.

In addition to the production of the thematic maps techniques are being considered that would include the existing road network overlayed photographically on the thematic maps. The road network will be obtained from the 7.5 minute quadrangle series and reduced to fit the 1:31,680 scale maps of the corresponding area. The road network will aid in the location of areas of interest and increase the acceptability of the data. The cost of including the road network should not be excessive because the road network overlays already exist and the photographic procedure for including the overlays on the maps requires very little effort.

CONCLUSION

Preliminary indications are that the classification is accurate and the production of affective thematic maps will encourage Game, Fish and Parks personnel to utilize the data in the development of comprehensive wildlife habitat management plan for the Black Hills. Several methods for producing thematic maps for the entire Black Hills were tested. To date the use of a film recorder system appears to be the most feasible based on production costs and map quality. The sample products produced from the film recorder output are to be evaluated by Game, Fish and Parks personnel within a month. Investigation of alternative methods will continue. Documentation of the impact of the overall inventory project will be forthcoming in the FY 79 report.

REFERENCES

Kamstra, L.D., L.B. Embry, and M. Singh. 1975. Utilization of Aspen Tree Material as a Ruminant Feed Component. South Dakota State University Experiment Station. Brookings, South Dakota 57007.

CELL SIZE CRITERIA INVESTIGATION SUMMARY

INTRODUCTION

Digital hardware and software systems have evolved to an advanced state of processing power and capability with increased cost effectiveness. Hence, the storage, retrieval and analytical processing of geographically-oriented, spatial, resource data has become practical.

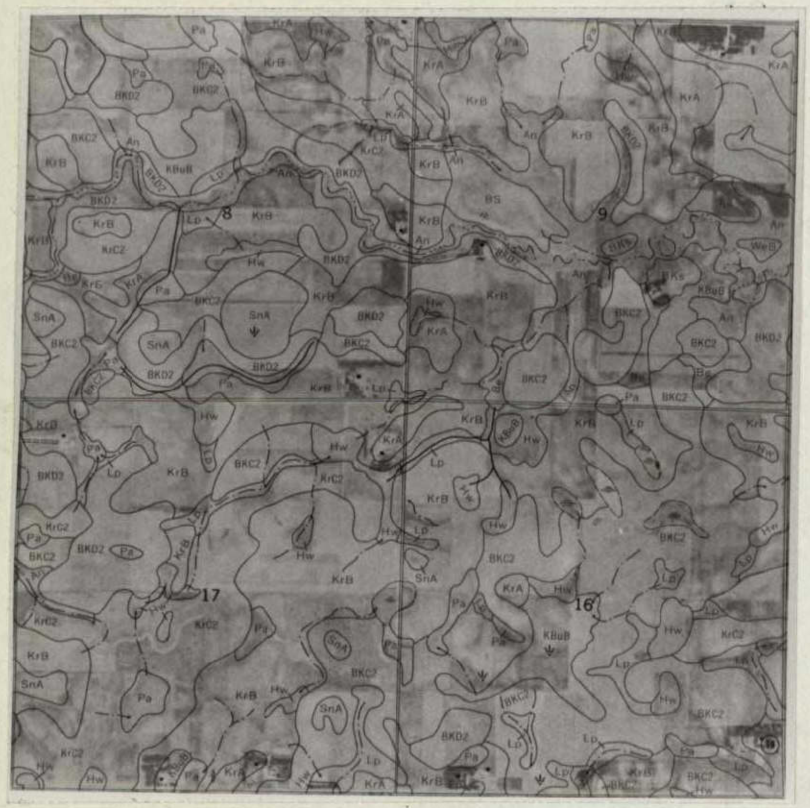
Of the two most widely accepted system approaches - polygon and cellular storage - the Remote Sensing Institute has chosen the latter as more naturally oriented toward remote sensing data forms such as scanner data or digitized photographic images.

In dealing with potential user agencies, the Institute has been able to provide assistance in applying the analysis techniques to specific resource management problems. Whether the user has chosen technology transfer or Institute assistance in system application, an intial decision on data set cell resolution is required.

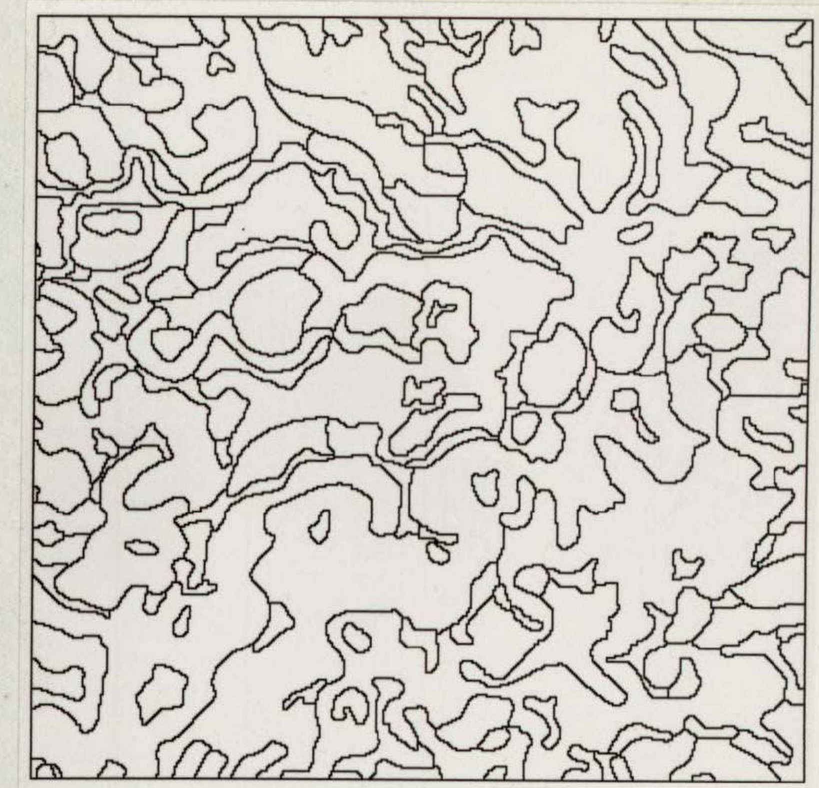
The impact of data set cell size selection is two-fold. The data set generated becomes permanently limited to that cell resolution or larger. The cost of processing and analysis is dependent on the data set sizes. The present investigation seeks to determine if it is possible to analyze or sample a parameter or parameters of an input resource map prior to actual digitization (cellularization) in order to determine the achievable accuracy in resource tabulation and mapping versus the cost of processing the corresponding data set. If successful, guidelines should result to assist users in obtaining the maximum utility from application of the computerized, cellular, spatial resource analysis system. All users would benefit from such a pre-digitization, performance-prediction technique since they could trade-off analytical performance obtainable against system operation costs before investing in data set generation at a particular cell size.

METHODS

To investigate the effect of cell size on system performance, a data set was created with a very small cell size. Four sections in Minnehaha County were digitized (Figure 18a). This relatively complex area was selected because of the irregularly shaped and sized soil delineations. The initial cell size of 8.38 meters (27.5 feet) on a side corresponds to a cell area of 70.258 m^2 (756.25 ft^2) or 0.007 ha (0.0174 acre). This data set of 384 by 384 cells at such a small cell size appears almost continuous (as opposed to quantized) when spatially mapped (plotted) and was assumed to represent the "true" or accurate map for further reference during the study (Figure 18b). An analysis sub-program of the data processing system allows aggregation of the cells by integer multiples and even divisors of the 384 cell base were utilized, i.e. aggregations of 2,3,4,6,8,12,16,24,32,48 and 64. The resulting data sets have effective cell sizes of 0.028, 0.063, 0.112, 0.252, 0.448, 1.008,



a) Source map



b) Computer generated map

Figure 18. Data set for resolution study. Part a) is original map segment. Part b) is plotted representation of the 0.028 hectare cell data set.

1.792, 4.032, 7.168, 16.128, and 28.672 ha (0.069, 0.156, 0.278, 0.625, 1.111, 2.500, 4.444, 10.000, 17.778, 40.000, and 71.111 acres, respectively). An additional reason for the selection of a 0.0174 acre cell as a base is that aggregations of 2.5, 10.0 and 40.0 acre cell sizes result which are typical selections of resource personnel who have no other technical guidelines for selection.

Having the twelve data sets prepared allowed resource tabulation of each set by soil categories, observing tabulation errors versus changing cell size. The aggregated data sets were composited (overlaid) on the base ('True') data set and areas of matching theme were considered accurate mapping. A mapping error versus cell size was then observed. Both types of performance are observable by soil category and by map as a unit.

Application of another data base processing algorithm in the package developed at R.S.I. allows generation of a display graph and tabulation of the inter-class-boundary distance distribution, which intuitively would seem to reveal map characteristics at the aggregation (cell size) used to generate the data set. Parameters of this distribution should relate to the mapping and tabulation performance of the data set. Furthermore the changes in the distribution with changing cell size should allow some predictive inference regarding performance of a given data set under differing cell sizes.

The observation of data processing application costs was possible during the application of the system to a three-theme compositing, mapping and tabulation analysis for a seven county region in western South Dakota. The cost data versus the data set parameters such as levels of themes, number of themes composited, number of change points processed etc., can be analyzed to get the necessary predictive relationships of data set versus cost.

RESULTS

Mapping and tabulation errors as a function of increasing cell size appear monotonic and bounded. The tabulation performance is subject to a slower rate of increase in error with increasing cell size than is the mapping performance. This is to be expected as tabulation can make use of offsetting errors of omission and commission whereas mapping cannot.

Preliminary analysis of the inter-boundary distance distributions indicate that the mean distance between boundaries relates nearly linearly to the aggregated cell size.

Initial inspection of cost tables on the various processing options indicate that cost prediction will be possible depending on anticipation of the analyses to be pursued once the data set(s) is (are) generated.

WORK REMAINING

All empirical components of the study will be complete when the cost functions of certain data set attributes are defined, when the data set characterizing boundary distribution parameter(s) are selected and functionally tied to performance, and when a resource-map sampling technique is defined to estimate the parameter(s) from the input map. Furthermore it is desired to pursue theoretical bases for the relationships found empirically.

Summary of Results and Expected Results For Each of
The Preceeding Applications-Orientated Projects

Wildlife Habitat Change
Summary
(1) Open area determination in the Black Hills, 1961 to 1976 were done
(2) Roads and power line corridors were taken from 1961 imagery
(3) Color Infrared Photography (CIR) supplied for Game, Fish, and Parks (GF&P) field use.

Expected Results
(1) Road and power line corridors from 1976 imagery to be interpreted.
(2) Have photo-interpretation key for CIR

Meandering Lakes
Summary
(1) Manual and automated density slicing techniques for interpreting hydrophyte classes from infrared imagery have been developed and documented.
(2) The use of Landsat imagery for monitoring Meander lakes was explored and results were presented to GF&P commission

Expected Results
(1) Short seminar with conservation officers and regional supervisors to familiarize them with the imagery that is available and to illustrate interpretations techniques
(2) Further develop hydrophyte classification techniques
(3) Provide data summaries for selected meandered lake for use in developing cooperative management agreements

Agricultural Censusing
Summary
(1) Data extracted and error checked for June 5 CCT
(2) Statistical analysis for an intensive study area

Expected Results
(1) Data extraction for July 29 CCT
(2) Statistical analysis for both CCT
(3) Classifier testing of established strata
(4) Use of detailed soil maps for refinement of causative factors in establishment of reflectance zones.

Map Aspen
Summary
(1) Several methods for producing thematic maps for the entire Black Hills were tested
(2) The film recorder output is being evaluated and results are expected within a month

Expected Results
(1) The development of a cost effective method for producing thematic maps of forest land cover types, primarily aspen
(2) Separate thematic maps that will correspond to the identical area represented by the individual 7.5 minute quandrangle series for the Black Hills area
(3) Statistical data such as acreages and percent cover by land cover type will be coded into a data base which will permit special data handling. The inventory will provide accurate assessment of the current status and location of aspen for forest and wildlife management purposes.

Quantify Cell Selection Criteria for Spatial Data

Summary

(1) A typical data set has been digitized and eleven additional cell sizes analyzed in both inventory and mapping performances.
(2) The spatial distribution of boundaries has been related to the accuracies achieved and a study is partially completed on selection of a distribution parameter to estimate for predictive purposes.
(3) Processing cost data from an applications contract has been gathered and organized for analysis in prediction of costs in relation to cell size.

Expected Results

(1) Formulation of a predictive relationship between cell size and the mapping and inventory accuracies of the data base
(2) Establishment of one or more spatial map parameters which also relate to application accuracies of the data base
(3) Definition of a map sampling procedure to estimate the spatial parameters which predict accuracies
(4) Establishment of cost predictive relationships for processing based on data set parameters
(5) Outline of cell selection criteria based on predicted accuracies and costs of processing