SGT
E7.9-10.170
CR-158166

SDSU-RSI-78-26

REMOTE SENSING APPLICATIONS TO

RESOURCE PROBLEMS IN SOUTH DAKOTA

(E79-10170) REMOTE SENSING APPLICATIONS TO RESOURCE PROBLEMS IN SOUTH DAKOTA Semiannual Progress Report, 1 Jul. - 31 Dec. 1978 (South Dakota State Univ.) 91 p HC A05/MF A01 CSCL 08F G3/43 N79-20441 Unclas 00170

For

National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C.

July 1, 1978 - December 31, 1978

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

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

7.9-10.170
CR-158166

SDSU-RSI-78-26

REMOTE SENSING APPLICATIONS TO RESOURCE PROBLEMS IN SOUTH DAKOTA

Principal Investigator
Victor I. Myers

Contributors

R.G. Best
K.J. Dalsted
M.E. DeVries
J.C. Eidenshink
J.L. Heilman
S. Sather-Blair
F.A. Schmer
B.K. Worcester

For

National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C.

July 1, 1978 - December 31, 1978
Grant No. NGL 42-003-007

ORIGINAL CONTAINS COLOR ILLUSTRATIONS

Original photography may be purchased from:
EROS Data Center
Sioux Falls, SD 57198

Abstract

Utilization of remote technology is currently being applied to resource problems in South Dakota. Six separate projects are underway in FY 1979. Each ensuing paragraph will present an abstract of accomplishments to date and expected directions in the remaining months of FY 1979.

Application of soils data in Landsat CCT classification is being evaluated in Spink County. Six soils strata representing a variety of topographies, textures, and parent materials are being used to investigate soil-multicrop spectral signatures. Two Landsat CCT's (14 May 1978 and 28 June 1978) are on order and extraction procedures under the auspices of the ESCS will begin in early February. Analysis of CCT classification will include an evaluation of the influence of soil properties on crop signatures, temporal effects, and possibly some digital transformations.

Aircraft data were collected over Six-Mile Creek Watershed at four times during the diurnal temperature cycle on September 5 and 6, 1978 to provide data for a geohydrologic and an environmental evaluation of the Watershed. Data are being used to develop a drilling plan for an investigation of the proposed dam and recreation site, evaluate water table elevations and soil moisture, and provide information for assessing erosion potential in the Watershed. The resource information will be used by SCS to prepare a final Working Plan and the Environmental Impact Statement for the Watershed.

Procedures for the interpretation of available winter habitat on Landsat imagery are presented and illustrated. Six classes of winter habitat were interpreted with an overall classification accuracy of 76.6% in a test of the procedures. The use of Landsat imagery for seasonal monitoring and spatial distribution of habitat is illustrated.

Aerial data (1370 m AGL) were collected over Wind Cave National Park on 26 July 1978. Prairie dog town characterization, including vegetation sampling and ground level photographs, was accomplished during the week preceding the overflight. A color infrared mosaic (1:15840) of the entire park is near completion. The mosaic will be used with ground data and supplementary information to determine the extent of the prairie dog towns as well as provide insight to prairie dog expansion areas, new vs. old town spectral signatures, vegetative indicators of expansion, and other vegetative indices.

The Lake Herman Watershed in southeastern South Dakota has been selected as one of seven watersheds in the United States for involvement in the National Model Implementation Program (MIP). Remote Sensing Institute is cooperating with numerous other state and local agencies to provide baseline watershed data. Color infrared photography of the watershed was collected July 1978. This data, which was a base for land cover delineation, along with detailed soil information has been digitized and entered into a computerized geographical information system. These data will provide quantitative information on soils-land use relationships and it is hoped this information will provide some of the necessary variables in the Universal Soil Loss Equation. The end results will provide a comprehensive picture of the watershed before ameliorative procedures are put into action.

Reflectance measurements of ten different species of hydrophytes were made with an Exotech radiometer during flower/early seed and senescent growth stages. Procedures were used to estimate the percent of vegetative cover and to ratio out effects of background reflectance. Reflectance means and standard deviations were calculated. A duncan's multiple range test will be used in future analysis to determine if reflectance means are significantly different. Spectral curves for each of the 10 species during the senescent stage were plotted from reflectance measurements made in the laboratory with an Isco scanning spectroradiometer.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The National Aeronautics and Space Administration (NASA) and the State of South Dakota have provided the major funding for these application projects. Contributions of funding by the SCS and U.S. Park Service is acknowledged with appreciation. The contributions of Mr. Joe Vitale, NASA Technical Officer, to overall support of this grant are appreciated.

REMOTE SENSING APPLICATIONS TO RESOURCE PROBLEMS IN SOUTH DAKOTA

Application of remote sensing technology to various important resource topics is currently being implemented in South Dakota by Remote Sensing Institute in cooperation with various local, state, and federal agencies. These cooperative projects are supported by National Aeronautics and Space Administration (NASA) and the State of South Dakota with additional funds supplied by several of the cooperating agencies. This report will provide an up-to-date assessment of current progress in each of six individual projects. A separate section contains a synopsis of each current project and a listing of all previous NASA and NASA related project titles. In addition, follow-up reports of past NASA related activities are included.

A brief description of each project is listed as follows: 1) assessment of soils information as it influences the accuracy of a Landsat multicrop classification; 2) use of thermal imagery and low level aerial photography in watershed planning; 3) application of remote sensing to provide habitat data in the state-wide Pheasant Restoration Act; 4) utilization of remote sensing technology in the National Model Implementation Program, Lake Herman Watershed; 5) use of low level aerial photography in the development of prairie dog management techniques; 6) classification of hydrophytes (wetland vegetation) from remotely sensed data.

APPLICATION OF SOILS DATA TO A MULTICROP INVENTORY IN SPINK COUNTY

INTRODUCTION

Application of remote sensing technology to the identification of agricultural crops is important to agencies and individuals whose interest lies in local, national, and international estimates of crop acreage and subsequent production. Landsat computer compatible tapes (CCT) have provided researchers with a tool capable of providing spectral data of large regions on a repetitive cycle. Much research has been centered on crop identification from Landsat data (Sigman et al., 1977; Bizzel et al., 1975). Prominent in this aspect of remote sensing activity is the Economics, Statistics, and Cooperatives Service (ESCS) of the USDA with local support from the Crop Reporting Districts (CRD).

The ESCS procedures used in investigating Landsat CCT and crop identification are based on a sound statistical approach toward area-wide sampling (Wigton and Bormann, 1978) however, stratification in this procedure is based largely on homogeneity of land use. Variability within crop spectral signatures especially that caused by the influence of soils are accounted for only in a general manner in that land use strata may be roughly akin to some soil units.

Soil influence on spectral signatures of crops has been noted by numerous researchers (Lemme, 1975; Tucker and Miller, 1977;

Wiegand et al., 1977). A recent NASA funded project in southeast South Dakota applied soil association data as an aid in explaining corn spectral variability (Myers et al., 1978). The results of this study showed statistical evidence for the support of stratification by soil association to reduce corn spectral variability. The soil characteristic of importance in this study was parent material (loess and glacial till).

The present study involves a cooperative endeavor between ESCS and RSI to evaluate soil influence on spectral signatures (Landsat-derived) in Spink County. This project will investigate the influence of parent materials, topographies, and surface soil textures on the agricultural crops grown in Spink County. This study will attempt to establish relationships between soils and crop spectral signatures. The establishment of cogent correlations will set the stage for further crop acreage estimations and the subsequent yield estimations. Agencies which should benfit from optimal results are the State Agriculture Department, Crop Reporting Districts, and other agencies whose interests will be served by more acreage estimates.

MATERIALS AND METHODS

The study area (Fig. 1) is located in region of diverse topography and soils. Soil groups as depicted in Fig. 1 are synonomous with soil associations with exception of soil group one, two, and

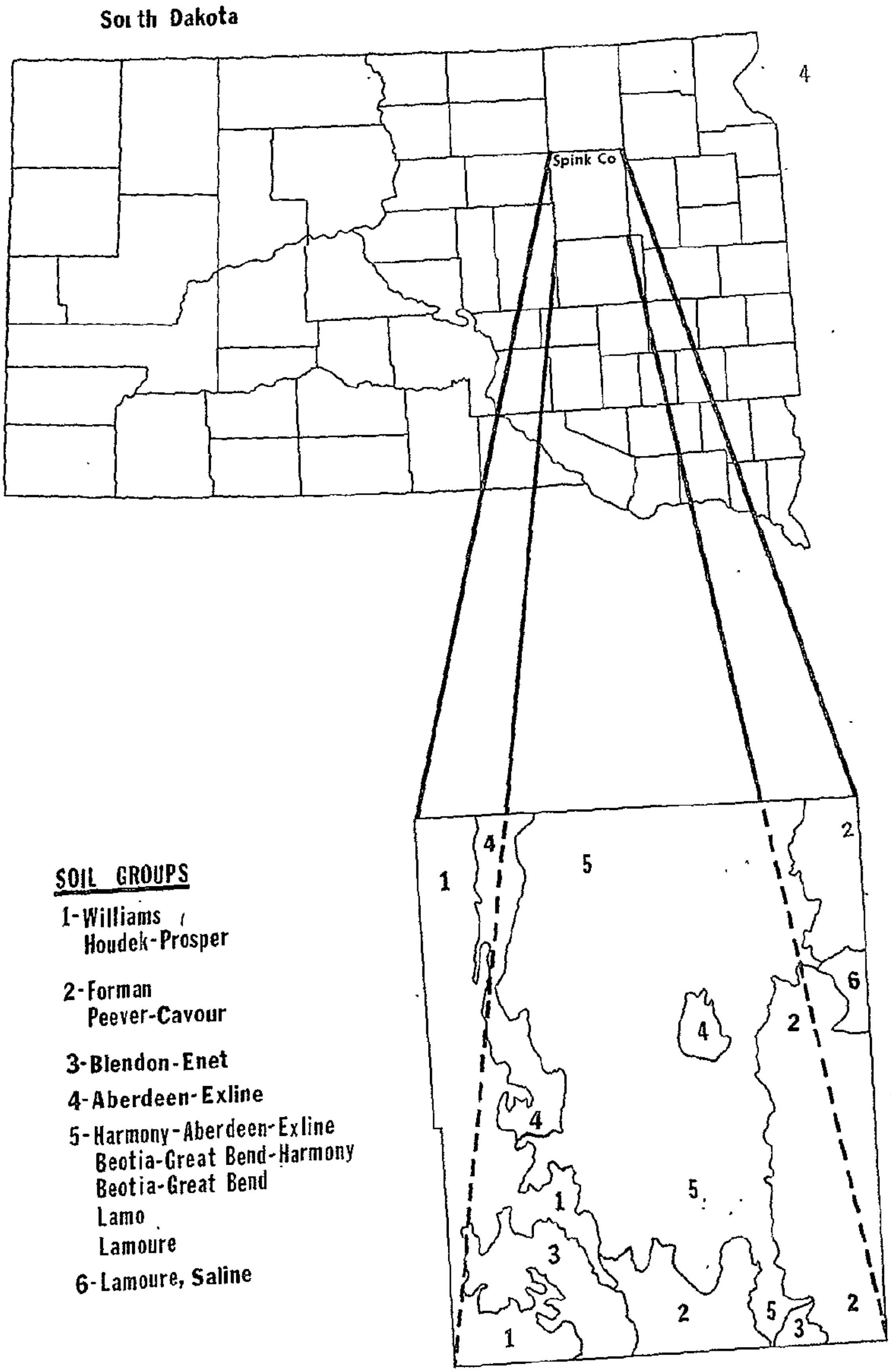

Fig. 1. Location of study area and its derived soil group. .

five; these units (one, two and five) contain associations that either are too difficult to separate into discrete units or are of similar characteristics. A brief description (Westin et al., 1954) of each soil group is listed in Table 1. The dominant feature of Spink County is Glacial Lake Dakota (soil groups 4 and 5). The remaining landscapes are influenced by other glacio-fluvial processes.

Table 1. General soil characteristics of the derived soil groups of Spink County.

Soil Group‡	Slope (%)	Landscape	Texture
1	3-15	Upland	Medium to fine
2	0-5	Upland	Moderately fine
3	0-6	Outwash plain	Sandy
4	0-3	Lake bed	Medium to fine (contain claypan)
5	0-3	Lake bed	Medium to fine
6	0-6	Upland	Moderately fine (saline varient)

‡See Fig. 1 for component soil associations.

Spink County has a climate characterized by hot summers and cold winters. Precipitation occurs predominantly in the spring and early summer months. Table 2 shows the 1978 rainfall distribution from April through July.

The ground sampling scheme was established by the ESCS using their techniques (Van Steen and Wigton, 1976). This procedure used

Table 2. Precipitation records at four stations in Spink County, April through July, 1978.

SPINK COUNTY DAILY PRECIPITATION (IN INCHES)

DAYS

MONTH	T	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
APRIL																																
Redfield	2.08		0.37	T‡	0.03		T		0.04	T	T		0.04					T	0.88	0.11				0.27	0.28				0.03	0.03		
Mellette	2.98		0.19	0.07	0.12		0.03	T		0.36	0.01		0.15				0.01	T	1.12	0.18	T	T		0.23	0.34	0.02			T	0.14	0.01	
Conde	1.74		0.16	T	0.03			T		0.07			0.22					T	0.76	0 02	T			0.15	0.32	0.01					T	
Ashton	2.84				0.35						0.13		0.22						1.0	0.25					0.69					0.20		
MAY																																
Redfield	5.42							0.39	0.87	0.40		T	0.04	0.08						0.03						0.46		1.15	0.23	2.07		T
Mellette	6.04							0.32	1.19	0.06		T	0.09	0.27						0.20		0.25		T		1.42	T	0.27	0.03	1.62	T	0.32
Conde	4.21						0.24	0.71	0.10				0.38							0.25						1.05		0.34		0.91		0.23
Ashton	4.35								1.39				0.10	0.14						0.09						0.79		0.29			1.41	0.15
JUNE																																
Redfield	2.42			0.17				0.10		T			T		0.29		T				0.11		0.15		0.04	T	0.07				1.49	
Mellette	3.79	0.02	T	0.18	T			0.10	0.01	T			0.08		T		T			0 05			0.02	T	0.10		T			2.50	0.73	
Conde	2.46	0.05		0.03				0.10					0.22		0.03		0.51				0.01				0.02	0.09	0 30				1.10	
Ashton	2.57			0.09				0.14							0.04									0.31			0.50				1.49	
JULY																																
Redfield	1.85	0.13						0.33	0.38				0.45							0.07		0.27	0.22									
Mellette	1.81	T					0.27		0.72			0.04						0.06	0.01	T	0.36	0.33	0.01		0.01							
Conde	2.81	1.03			0.05			0.52	0.38	0.01			0.30						0.03	0.02		0.24	0.22						0.01			
Ashton	2.37	1.32						0.09			0.42		0.15							0.02		0.23	0.14									

‡ T - Trace, too small to measure

ORIGINAL PAGE IS OF POOR QUALITY

the six predetermined soil strata (Fig. 1) to locate quarter section regions (segments) within each stratum. Segment totals per soil group are listed as follows: 1-^{20}, 2-^{20}, 3-^{15}, 4-^{15}, 5-^{24}, and 60-^{10}. The segments were located and outlined on 1:15,840 color infrared 1975 RB-57 prints. Within each segment, field boundaries, cover or crop types, and pertinent field notes were recorded on mylar transparencies during the course of the ground data collection. Table 3 lists the crop or cover types per soil group.

Two computer compatible tapes (CCT) were used, 14 May 1978 and 28 June 1978 scenes. Data extraction procedures are now being implemented by ESCS personnel. Procedures developed by ESCS (Cook, 1977) will be used to locate and extract segment data from the CCT's. Once segment data are extracted and filed, classification and analysis will take place.

REPORT OF PROJECT STATUS

As was pointed out in the Methods section, this project is in an early stage of completion. No results have yet been generated. Completed thus far are the ground data collection, characterization, i.e. field boundary location, crop cover codes, and pertinent field notes, and filing on computer tape. These data along with topographic and highway maps have been forwarded to ESCS personnel for use in the data extraction phase of the study.

Table 3. Crop types summation recorded with each soil group.

Crop Inventory Tally

Crop or Land Use	Soil Group 1	2	3	4	5	6
Corn	10	7	13	5	10	2
Winter wheat	1	7	3		1	1
Spring wheat	10	10	3	5	16	5
(durum)		2			2	
Oats	2	1	3	1	2	
Sunflower					7	2
Flax		2				1
Barley			1	1	2	
Summerfallow	1	8	3	2	5	5
Grain sorghum				1		
Tame grass	11	10	11	5	14	3
Alfalfa	7		2	1	7	2
Range	9	9	10	3	8	6
Farmstead	2	1	1		4	1
Trees		2	2		1	1
Water	1			2	2	
Wasteland		2	2	1	2	

Cooperation with the ESCS will continue as each aspect of this study is bridged. In sequence, the following steps (time dependent on arrival of CCT's) are anticipated in arriving at results and interpretations: 1) ESCS procedures to register ground data to CCT's; 2) data extraction from CCT's and error checking of field boundaries; 3) establishment of training data and necessary statistics preliminary to scene classification; 4) scene classification on the ILIAC system; 5) analysis of scene classifications and examination of the relationship of soil groups to classification results; and 6) other statistical procedures, as needed, to define temporal and soil-effect relationships. Anticipated arrival of the CCT's is late January at which time step 1 will commence.

Soil characteristics peculiar to Spink County will be evaluated in the analysis and interpretation phase of this project. The success of this portion of the project is tied to establishment of sound relationships between soil information and crop spectral variabilities.

REFERENCES

Bizzel, 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. 10th Int. Sympos. on Remote Sens. of Environ., Ann Arbor, Mich.

Cook, P.N. 1977. Texas '74 remote sensing project. Statistical Reporting Service, USDA, Washington, D.C.

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

Myers, V.I., et al. 1978. Remote sensing applications to resource problems in South Dakota. SDSU-RSI-78-14. Remote Sensing Institute, South Dakota State Univ., Brookings.

Sigman, R., C.P. Gleasen, G.A. Hanuschak, and R.R. Starbuck. 1977. Stratified acreage estimates in the Illinois crop-acreage experiment. Machine Processing of Remotely Sensed Data Sympos. Purdue Univ., West Lafayette, Ind.

Tucker, C.J., and L.D. Miller. 1977. Soil spectra contributions to grass canopy spectral reflectance. Photogram. Eng. and Remote Sens. Vol. 43(6):721-726.

Westin, F.C., G.J. Buntley, W.C. Moldenauer, and F.E. Shubeck. 1954. Soil Survey of Spink County, South Dakota. Ag. Exp. Sta. Bull. 439, South Dak. State Univ., Brookings.

Wiegand, C.L., H.W. Gausman, R.W. Leamer, A.J. Richardson, J.H. Everitte, and A.H. Gerbermann. 1977. Soil, water, and vegetation conditions in south Texas. Type III Final Report for Goddard Space Flight Center, Greenbelt, MD

Wigton, W.H., and P. Bormann. 1978. A guide to area sampling frame construction utilizing satellite imagery. ESCS, USDA, Washington, D.C.

Von Steen, D.H., and W.H. Wigton. 1976. Crop identification and acreage measurement utilizing Landsat imagery. Statistical Reporting Service, USDA, Washington, D.C.

GEOHYDROLOGIC AND ENVIRONMENTAL ASSESSMENT OF SIX-MILE CREEK WATERSHED

INTRODUCTION

Serious land and water resource problems (flooding, erosion and sedimentation, drainage) periodically affect Six-Mile Creek Watershed (Fig. 2) located in portions of Brookings and Deuel Counties near the eastern border of South Dakota. Flooding, caused by either snowmelt or summer storms, occurs primarily in the lower portion of the 76-square mile watershed where approximately 3,500 acres of farmland are affected. Approximately 45 percent of this area is cropland; the remainder is pasture, permanent hayland, or urban.

Urban flood damage generally occurs in the northwest part of Brookings. Most of the 15,000 population of the watershed is urban (the Town of White, the City of Brookings, and South Dakota State University are within its borders).

Erosion and sedimentation are contributing to the flooding by reducing channel capacity. Areas of gently rolling land in the upper reaches of the watershed are vulnerable to sheet erosion. Although much of the erosion is within tolerable limits, the cummulative effect of down stream deposition of sediment is serious.

Poor surface and subsurface drainage has reduced crop production is some areas of the flood plain. There are about 3,600 acres of

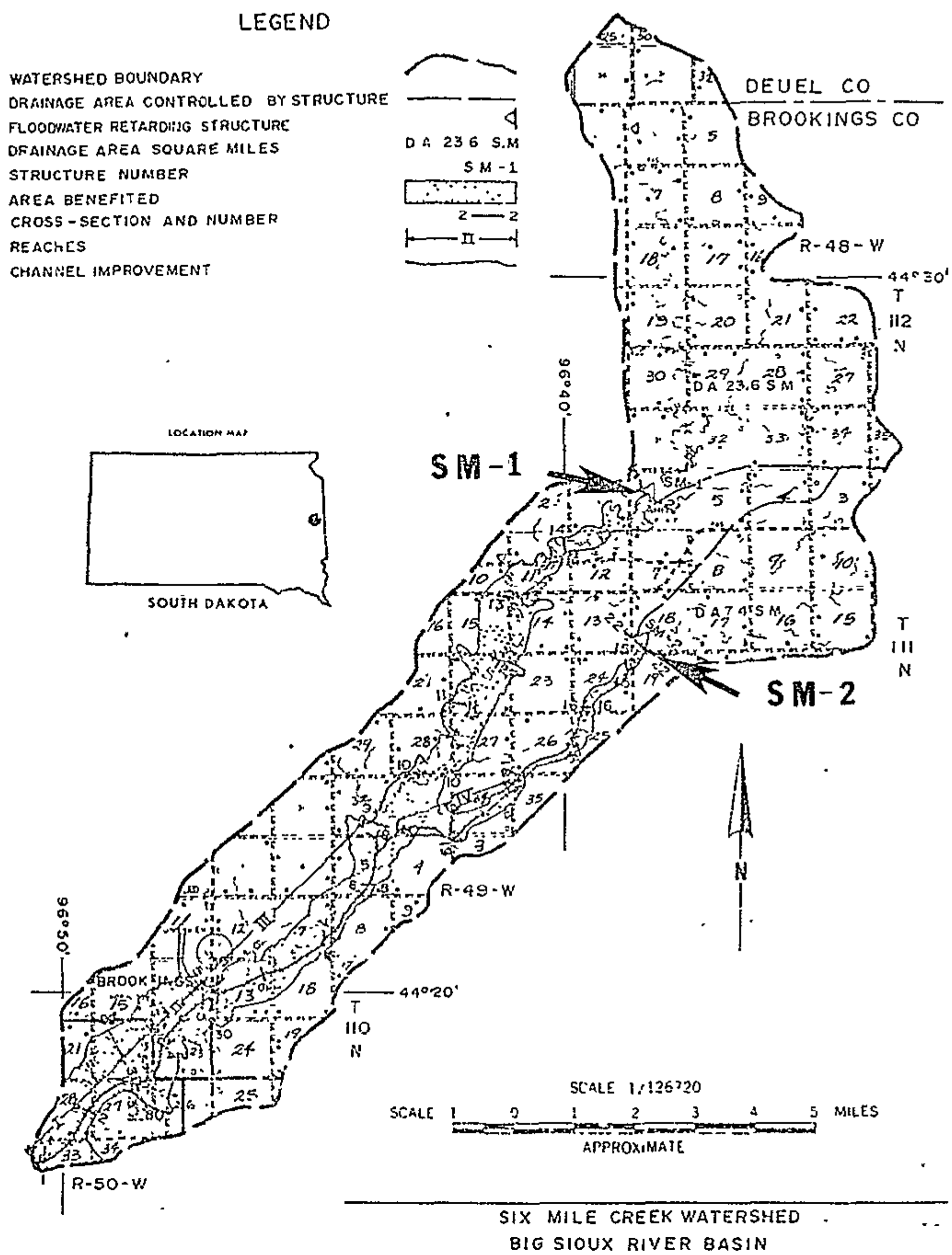

Fig. 2. Location and description of Six-Mile Creek Watershed

poorly drained land, of which approximately 55 percent is cropland which would become more productive with improved drainage.

The need for a project to solve land and water resource problems in the Six-Mile Creek Watershed was established in 1969 as a result of the Big Sioux River Basin Study. A field examination report from the South Dakota Conservation Commission, completed in October, 1970, laid the groundwork for the organization of the Six-Mile Creek Watershed District on July 6, 1971. Public meetings, at which interested people expressed their concern regarding problems affecting the watershed, have been held annually since the watershed's organization.

Summarized below are proposed solutions and probable impacts discussed at those meetings.

* Installation of single or multipurpose floodwater retarding structures, combined with land treatment, would reduce peak flows below the structure. Multipurpose structures could also be used for recreation as well as sediment traps..
* Channel modification along with land treatment and a combination of single or multipurpose structures would reduce flooding, improve.drainage, and provide opportunities for recreation.
* Runoff and erosion would be significantly reduced by the application of land treatment measures (crop rotation, terraces, grassed waterways, etc.)

* Without any action, flooding, erosion, uncontrolled sedimentation, and agricultural water management problems would still exist. Economic losses would increase in the future as a result of intensified flooding caused by sediment buildup.

Leadership for public involvement in proposed solutions to the problems has been provided by Brookings County Conservation District, Deuel County Conservation District, East Dakota Conservancy Sub-District, and Six-Mile Creek Watershed District. These sponsors have the support of the Brookings County Commissioners, the City of Brookings, and the Town of White.

The Six-Mile Creek Watershed District and the South Dakota Conservation Commission requested assistance from the Soil Conservation Service (SCS) under the authority of Public Law 566 to develop a plan for solving the previously discussed problems affecting the watershed and for meeting the water-based recreational needs in the general area of the watershed. As a result of that request, a potential site for floodwater-retarding structures have been selected (SM-1 in Fig. 2), and a study plan for potential development of the watershed has been implemented.

The Six-Mile Creek Watershed Board of Managers, SCS, and interested sponsors requested the cooperation of the Remote Sensing Institute (RSI) in developing and applying remote sensing techniques in scheduled FY 78-79 geohydrologic and environmental evaluations of the watershed. Key aspects of those SCS investigations are summarized below.

* Geohydrology - Preliminary foundation investigations have been completed for the two proposed dam sites. Observation wells will be installed at the proposed recreation site to monitor water table elevations, and evaluate extent of sand and gravel deposits to determine potential seepage losses. The groundwater table will be studied in other parts of the watershed to predict effects of the proposed structure on drainage and municipal and rural water supplies. Soil moisture and associated surface and subsurface drainage will be evaluated.
* Environmental Assessment - Basic data describing the current situation in the watershed will be collected. Of particular interest are estimates of wind and water erosion potential for describing land-treatment needs and predicting sediment yield. Major factors contributing to erosion (crop and pasture production patterns, surface residue, biomass, etc.) will be evaluated. Current production patterns will be evaluated to assess the economic impact of improved drainage within the watershed.

Hyland and Andrawis (1977) used thermal imagery to evaluate seepage losses from the Pattie Creek Watershed Reservoir in southeastern South Dakota (the reservoir went completely dry in 1976). Extensive drilling operations and analyses of data from observation wells did not reveal the cause of the water loss. The thermal imagery revealed an unexplained thermal anomaly in a region of the reservoir. A test hole was drilled in the vicinity of the anomaly and a gravel stringer was found that was unlike any others in the reservoir in terms of permeability properties. The sands and gravels ranged in depth from 3 to 14-m below the soil surface. SCS engineers are currently analyzing the permeability data to determine if the presence of the sands and gravels could explain the water loss from the reservoir.

A similar analyses of thermal data of the potential dam site and recreation area on Six-Mile Creek Watershed will be conducted. This investigation represents the first time that remote sensing data will be used to establish a drilling program for evaluating the suitability of a particular area for retaining water. In addition, new procedures for using thermal data for evaluating water table depths and soil moisture will be developed as part of this investigation. If successful use of these techniques can be demonstrated on Six-Mile Creek, they can then be routinely used as a tool for optimizing data collection for impact analyses in future planning and development on other watersheds.

STATUS OF INVESTIGATION

The detailed SCS field investigation for the environmental assessment of the watershed, scheduled for the summer of 1978, was postponed. SCS was supposed to provide ground truth for the remote sensing portion of the environmental assessment. As a result, some of the original objectives of this investigation cannot be met at this time.

The SCS geohydrologic investigation of the watershed is proceeding on schedule. All scheduled test wells for 1978 have been drilled on the site of the proposed dam on Six-Mile Creek.

Thermal imagery were acquired over the entire watershed and two adjacent flight lines at four periods in the diurnal temperature cycle (midday, after sunset, midnight, and predawn) on September 5 and 6, 1978, at an altitude of 2700 m AGL. Thermal imagery of the proposed dam and recreation sites were acquired at midday and midnight at altitudes at 1220 and 2440 m AGL. Photographic coverage (color IR, black and white IR, black and white with red filter) of the entire watershed at an altitude of 2440 m AGL was obtained on September 5 and 7, 1978.

The two adjacent flight lines were selected because they contained 25 observational wells for monitoring water table depths. Soil temperatures at 50 cm below the surface, soil moisture in the 0 to 50 cm profile, depth to water table, and water table temperatures were collected at the observation well sites in support of aircraft data acquisition.

Thermal data are being used to develop and evaluate remote sensing techniques for estimating sub-surface soil temperatures, soil moisture, and depth to water table. SCS geologists are currently analyzing thermal and color IR imagery of the dam and recreation sites to select areas for drilling observation wells as part of their 1979 geohydrologic investigation. Personnel in the SCS district office are evaluating land use in the watershed using 1:20,000 and 1:48,000 black and white and color IR imagery.

PRELIMINARY RESULTS AND FUTURE PLANS

A major assumption of the geohydrologic investigation is that the occurrence of shallow aquifers produces a heat sink that influences subsurface and surface temperatures (Cartwright, 1968a). Cartwright (1968b) found that soil temperatures measured at a 50-cm depth over an aquifer were cooler in the summer than those over the surrounding landscape.

During daylight hours on September 5-7, 1978, a series of 50-cm temperatures were measured by copper-constantan thermocouples at locations where operational observation wells existed to verify the findings of Cartwright. The temperatures were measured for several soil types, cultural practices and land use categories. Results indicated a highly significant positive correlation ($r = 0.69^{**}$) between 50-cm soil temperatures and depth to water table up to three to four meters (Fig. 3). Significant correlations

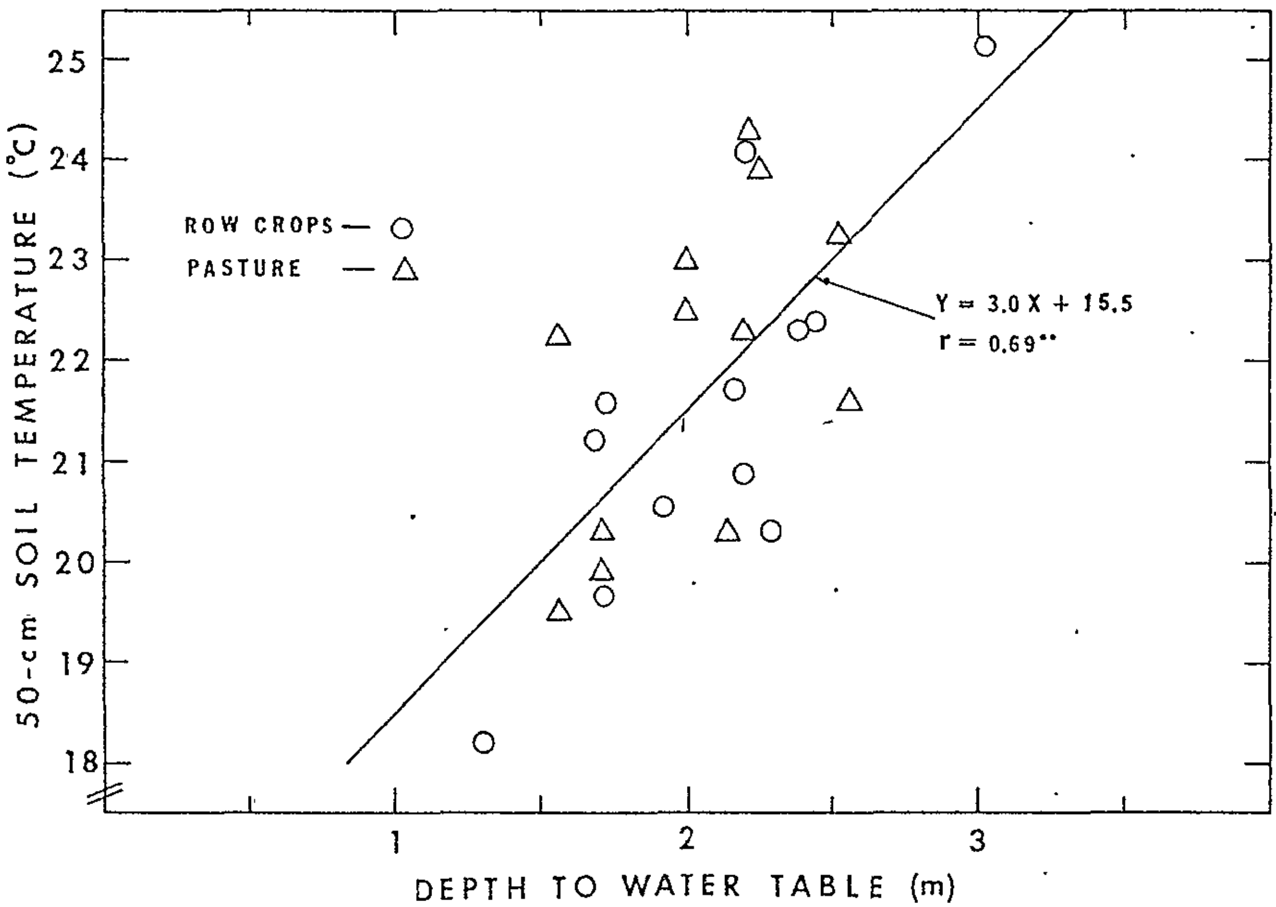

Fig. 3. Relationship of 50-cm soil temperatures to depth to water table for row crops and pasture (soil temperatures were measured during daylight hours on September 5-7. 1978).

were not obtained at depths greater than about four meters. The relationship was significant for row crops (corn, soybean, sunflower and sorghum) and pasture (improved and unimproved). Fields of bare soil and stubble in which soil temperatures were measured were too few to draw any conclusions for those two land use categories. The results shown in Fig. 3 appear to support the assumption that shallow water tables produce a heat sink effect. Aircraft data are being used to evaluate the effect of the heat sink on thermal emittance from the soil surface.

Soil moisture can significantly influence surface thermal emittance and affect interpretation of thermal data for locating shallow aquifers. A finite different heat flow model (Meyer et al., 1975) was used to simulate the effect of soil moisture profiles on the surface temperature. Results indicate that surface temperatures at about 1400 and 0600 hours are dependent on soil moisture. The results also suggest that temperatures at 0800 and 2100 hours are relatively insensitive to soil moisture.

Summarized below are future plans and anticipated products of the investigation.

<u>Geohydrology</u>:

* Site selection for drilling observation wells - SCS analyses of thermal and color IR data of the dam and recreation sites for selecting potential drilling locations for their 1979 investigation will continue. It is

anticipated that a drilling program partially based on analyses of remote sensing data will be established.

* Depth to water table - Information on water table fluctuations is important since high water tables can carry salts into the root zone of crops, and leaching of pollutants into shallow aquifers can affect municipal and rural water supplies. Water table information will be used by SCS to evaluate the potential impact of the dam on the groundwater regime within the watershed. Presently, there is little water-table information available for most of the watershed. Thermal data of the two flight lines adjacent to the watershed, and the heat flow model will be used to assess the potential for evaluating depth to water tables using remote measurements of surface temperature. Documentation of results and developed algorithms will be provided. If results appear promising, similar analyses of the watershed itself could be conducted in the future.
* Soil moisture - Thermal data of the two adjacent flight lines will be used to evaluate the potential for evaluating relative surface soil moisture differences under various conditions of land cover. Soil moisture information will be used by SCS to evaluate runoff potential and sedimentation in the recreation site and the main channel of Six-Mile Creek.

Environmental Assessment:

* Erosion potential - SCS analyses of land use in the watershed will continue. Land use will be encoded into a geographic data base and merged with soil type information which has previously been encoded at 1.1 acre (0.45 ha) cell sizes. The data base will provide base line information for SCS to evaluate erosion potential in the watershed at some future date. Erosion data will be used by SCS to evaluate potential deposition of sediments into the recreation area and the stream channel.

Information related to soil moisture, water table elevation and erosion potential will be used by SCS in preparing the final Working Plan and the Environmental Impact Statement for Six-Mile Creek Watershed.

REFERENCES

Cartwright, K. 1968a. Thermal prospecting for groundwater. Water Resources. Res. 4:395-401.

Cartwright, K. 1968b. Temperature prospecting for shallow glacial and alluvial aquifers in Illinois. Illinois State Geological Survey Circular 433, Urbana, Illinois.

Hyland, J. and A.S. Andrawis. 1977. Hydrologic investigation of the Newton Hills State Park region of the Alcester quad. Preliminary Report SDSU-RSI-77-09 to SCS, Huron, South Dakota.

Meyer, C.R., J.A. Tunheim, and D.G. Moore. 1975. Heat flow-temperature model for remotely mapping near-surface water tables by thermography. South Dakota Academy of Sciences. Vol. 54.

APPLICATION OF REMOTE SENSING IN THE PHEASANT RESTORATION PLAN FOR SOUTH DAKOTA

INTRODUCTION

The State of South Dakota can no longer claim the reputation of being the "Pheasant Capital of the World." Pheasant populations have declined to a very low level. Wildlife biologists, land owners and hunters are now involved in a project to develop and maintain a high pheasant population. Governor Richard Kneip authorized the South Dakota Pheasant Congress in November 1975. The Pheasant Congress has the "responsibility to identify alternatives to restore pheasants in South Dakota, and thus improve pheasant hunting and the associated recreational and economic benefits."

Declines in pheasant numbers have been associated with losses of available habitat though increased agricultural production and improvement in farming technology. The Pheasant Restoration Act, senate bill 142, was approved by the 52nd session of the South Dakota Legislature. Monies generated by a hunter pheasant restoration stamp and funds allocated by the legislature will be used by the South Dakota Department of Game, Fish and Park (GFP) "for the purpose of restoring the state pheasant population." The GFP has formulated a Pheasant restoration plan utilizing recommendations from the Pheasant Congress and funds from the Pheasant Restoration Act.

The goal of the plan is to develop 6500 acres of pheasant nesting cover and 500 acres of renovated shelterbelts each year. The nesting cover will be developed by retiring small acreages of croplands which will be seeded to a grass-legume cover type. These tracts of nesting cover will be developed in areas where adequate winter cover is available. Shelterbelt renovation will be used to improve winter cover in areas where none is available. When areas are selected for habitat development a Pheasant Restoration Cooperative Agreement will be filed for those parties involved. The Pheasant Restoration Plan also includes predator control and restocking efforts. Cooperators in the plan are provided with technical assistance on predator control and the raising and releasing of pheasant chicks.

The objective of this study is to demonstrate the application of remote sensing in an operational pheasant restoration program in South Dakota. The use of snow-covered Landsat imagery for locating and monitoring available winter cover is documented and illustrated in the attached report entitled "The Interpretation of Winter Wildlife Habitat in Eastern South Dakota on Landsat Imagery", which was presented at the Pecora IV Symposium, on Application of Remote Sensing Data to Wildlife Management.

The Pheasant in South Dakota

Ring-necked pheasants were first successfully introduced in South Dakota in 1908. An estimated 200 pheasants were killed during the first one day legal hunting season, October 30, 1919.

The South Dakota pheasant population increased annually to a total in excess of 10 million birds by 1937. Severe winter weather reduced their numbers to about 5 million from 1938-1940. The population increased again to over 10 million birds between 1940 and 1949 because numerous areas couldn't be farmed as a result of extremely wet conditions and a lack of manpower, fuel and machinery due to WW II. By 1950 farms had returned to normal production and pheasant number declined to a low of approximately 3.2 million birds. The population increased slightly to 5-10 million birds by 1959. A third period of population in excess of 10 million occurred between 1958 and 1963, which corresponds with the "soil bank year", when up to 10 percent of the state's cropland was idled as a result of the Federal program. Since 1963 the pheasant populations have again declined and remained at a very low level between 2 and 5 million associated with efficient cleanland farming.

The pheasant not only is the number one game bird in South Dakota but it also has a sizeable economic impact for the South Dakota businessman. It is very difficult to estimate a dollar value for a pheasant, however, five states in the midwest have reported that resident hunters spend an average of over $15.00 to bag a pheasant (Labisky, 1973). The GFP estimate only an average expenditure of $10.00 by South Dakota residents because of generally better hunting available. The average expenditure for non-residents was reported to be $22.50 for every bird in the bag. It is obvious from these figures that resident and non-resident pheasant harvests can have a sizeable impact on the state's economy. Both the number of resident and non-resident hunters and total bag of pheasants has been drastically reduced because of low pheasant numbers. The information in this section is a brief summary of data presented to the South Dakota Pheasant Congress at its first meeting December 6, 1975. The data was prepared by South Dakota Department of Game, Fish and Parks and published as "The Pheasant in South Dakota."

Anticipated Results

A search for winter Landsat imagery of eastern South Dakota has been completed. Mosaics will be prepared for different years and different snow cover depths. Interpretations of available winter cover will be made using the procedures developed by Best and Sather (1978). These data in conjunction with existing pheasant census and production data will be used to select critical areas for restoration sites. Existing high and low altitude color and color infrared imagery will be reviewed for use in monitoring of established nesting plots. These data will also be used to verify Landsat interpretations.

Literature Cited

Best, R.G. and S. Sather-Blair, 1978, The Interpretation of Winter Wildlife Habitat in Eastern South Dakota on Landsat Imagery, SDSU-RSI-J-78-13 Pecora IV Symposium, on Application of Remote Sensing Data to Wildlife Management (In Press).

Fowler, R., C. Trautman, A. Carter, L. Rice and J. Kranz. 1975. The Pheasant in South Dakota. South Dakota Dept. of Game, Fish and Parks, Pierre, SD. 34 pp.

Labisky, R.E., Chairman, Agricultural Program Committee. 1973. Midwest Council Report. Association of Midwest Fish and Wildlife Commissioners.

THE INTERPRETATION OF WINTER WILDLIFE HABITAT IN EASTERN SOUTH DAKOTA ON LANDSAT IMAGERY

Robert G. Best and Signe Sather-Blair

Abstract.--A technique to interpret the quantity and quality of available winter wildlife habitat on Landsat imagery is presented. Six classes of winter habitat were interpreted with an overall classification accuracy of 76.6% in a test of the procedures. The use of Landsat imagery for seasonal monitoring and spatial distribution of habitat is illustrated.

INTRODUCTION

Availability of protective cover for wildlife during the winter is an important survival factor in the midwestern region of the United States (Green 1938, Hammerstrom and Blake 1939, Grondahl 1953, Lyon 1954, Gates 1971, Ozaga and Gysel 1972). Not only can direct mortality losses due to winter weather severely reduce a wildlife population (Green 1938, Kimball 1948, Lyon 1959) but lower reproduction success the following spring has also been associated with winter weather severity (Gates 1971, Verme 1977). Clearly, in the past wildlife biologists have not placed enough importance on availability and quality of winter cover.

Land use practices in eastern South Dakota have limited winter habitat for wildlife to primarily wetlands, shelterbelts, riparian areas, and farmsteads. Agricultural fields also provide protective shelter and food periodically.

Little quantitative research has been done on the use of the above mentioned habitat areas by wildlife during the winter. Most of what has been done has concerned pheasants. Green (1938) and Grondahl (1953), working in Iowa both observed heavy pheasant use of wetlands in early winter. Since the wetlands on their study area were relatively small (3.2 ha) these filled with snow as the winter progressed and thus lost their value as protective cover. In northern Illinois wetlands constitute the most important winter cover for pheasants (Robertson 1958). Gates (1974) concluded that population density tended to be roughly adjusted to the amount and distribution of wetland cover availability, and that as wetland habitat progressively disappeared pheasant numbers dropped accordingly in Wisconsin. He found 78-88% of the wintering pheasant population on his study areas associated with wetland cover.

Several investigators have found shelterbelts to be of value to wintering pheasant populations (Green 1938, Bue 1949, Grondahl 1953, Lyon 1959). Several shelterbelt characteristics however appear to determine their level of use. Grondahl (1953) found that the smallest shelterbelt (0.5 ha) was not used on his study area even though food was available only 122 m from it. The larger shelterbelts were regularly used for roosting. Besides size, the age of a shelterbelt as well as its juxtaposition to other cover and food source seems to strongly influence its use by pheasants (Green 1938, Bue 1949, Grondahl 1953, Lyon 1959).

Depending on cover availability and density along riparian areas it can potentially be excellent protective habitat for wildlife. Lyon (1954) speaking of pheasant winter cover preferences in eastern Colorado states "Where the river bottom was not grazed or burned, it offered a variety of food and cover unsurpassed by any other type." He found, however, that due to land use practices the quantity of this quality habitat was minimal. Human disturbance also appears to significantly affect pheasant use of farmsteads although limited use has been noted especially during adverse weather conditions (Green 1938, Grondahl 1953).

[1]Paper presented at the Pecora IV Symposium, on Application of Remote Sensing Data to Wildlife Management, Sioux Falls, South Dakota, Oct. 10-12, 1978. SDSU-RSI-J-78-13.

[2]Associate Wildlife Specialist and Graduate Research Assistant, respectively, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57007.

Because of fall plowing and/or short stubble height during most years, agricultural fields offer little cover (Westin 1954, Gates 1974). During years where fields are left unharvested or tall stubble (>.3 m) is present this cover type can provide cover as well as food provided snow depth is limited (Bue 1948, Westin 1954).

Suitable habitat for winter protection is being destroyed and/or reduced in quality by such practices as fall plowing, wetland drainage, removal of shelterbelts and overgrazing. In view of these land use practices assessment and inventory of available winter habitat should be of prime concern to wildlife management agencies. A method to achieve this goal that is both time and cost efficient would be a valuable aid. Remote sensing technology has been demonstrated to be useful in these regards (Varney et al., 1973, Frentress and Frye 1975, Gilmer et al. 1975, Scheierl and Meyer 1976, Best and Moore 1977). Landsat imagery has been found to be particularly suited for photo-interpretation of winter wildlife habitat due to the contrast between the highly reflective snow cover and relatively lower reflectance of vegetation emerging through the snow (Best and Sather 1978).

The objective of this study was to analyze winter Landsat imagery to provide information concerning the availability of winter wildlife habitat.

CHARACTERISTICS OF LANDSAT

The Landsat program began in June 1972 with the launch of Landsat 1. The program was expanded to include Landsat 2 and 3, launched 5 January 1975 and 5 March 1978, respectively. The satellites orbit the earth in circular, sun-synchronous, near-polar orbits at an altitude of approximately 915 km. Each satellite orbits the earth approximately 14 times per day and views the same scene on earth every 18 days. Until 6 January 1978, when Landsat 1 malfunctioned and was shut down, Landsat's 1 and 2 were providing repetitive coverage on a 12/6 day schedule. The orbit of Landsat 3 has been adjusted to provide 9 day repetitive coverage in conjunction with Landsat 2.

The Data Collection System (DCS) on Landsat 1 and 2 is comprised of a 4 band Multispectral Scanner (MSS) and a 3 channel Return Beam Vidicon (RBV) camera. The DCS on Landsat 3 has a 5 band MSS and single channel double resolution RBV. Table 1 is a summary of the spectral sensitivity of the sensors in the Landsat DCS.

Table 1.--Spectral sensitivity of sensors in Landsat DCS.

	Sensor	IPF Band Code[1]	Wave-length(μm)	Color Rendition
Landsat 1 and 2	RBV	1	0.475-0.575	green
		2	0.580-0.680	red
		3	0.690-0.830	near-infrared
	MSS	4	0.5-0.6	green
		5	0.6-0.7	red
		6	0.7-0.8	near-infrared
		7	0.8-1.1	near-infrared
Landsat 3	RBV		0.505-0.750	green-red
	MSS	4	0.5-0.6	green
		5	0.6-0.7	red
		6	0.7-0.8	near-infrared
		7	0.8-1.1	near-infrared
		8	10.4-12.6	thermal infrared

[1] Image Processing Facility

The data are transmitted from the satellites to the NASA Image Processing Facility. The data can be purchased from the EROS Data Center in the form of photographic 24 by 24 cm or 70 by 70 millimeter transparencies, contact or enlargement prints and/or computer compatible tapes (CCT's) in a digital format. Each image provides a near-orthographic view of a scene having dimensions of 185 x 185 km. The minimum resolution of the MSS is approximately 0.45 hectares. The 915 km altitude of the satellites and the narrow field of view of the sensors provide the capability to image this broad scene without the frame by frame characteristics of low altitude aircraft imagery.

PROCEDURES

The interpretation procedures reported herein are designed for use with Landsat transparencies or positive prints at any scale. The authors suggest the use of enlargement prints at scales from 1:125,000 to 1:60,000.

The criteria for interpretation of image features are tone, texture and shape. Photographic tone is the lightness or darkness on the imagery and corresponds to the reflectivity of the scene feature. Texture, the impression of smoothness or roughness on an image, is formed by tonal variations in groups of objects which are too small to be discerned as individual objects. The shape of an image feature at a given scale can be identified by the regularity and placements of tones and textures. Size and orientation of features are also used as interpretation aids. The following is a photo interpretation key designed to facilitate the interpretation of available winter habitat.

Key to Photo Interpretation of Winter Habitat In Eastern South Dakota on Landsat Imagery

1a Predominant image feature, light tone, smooth texture........snow covered landscape

1b Dark tones, variable size and texture regular and irregular shapes.............. 2

2a Image features with irregular shapes, usually with mottled texture, may have light tones, smooth textured areas interspersed, size variable........wetlands with persistent emergent vegetation or municipalities[1]

2b Image features with regular shapes, may be linear, rectangular or circular.............................. 3

3a Linear features, length 5x greater than width, tone and texture variable depending on species composition and density.......................... 4

4a Straight linear features, length less than one mile, smooth or mottled texture, usually oriented E-W or N-S.................shelterbelt

4b An irregular linear feature, usually evident for several miles, meanders in any direction...............riparian

3b Non linear, regular shaped features......................... 5

5a Square or rectangular features, tone and texture variable........unharvested crops

5b Circular features............ 6

6a Large circular features (≳160 acres).....unharvested crops under center pivot irrigation

6b Small circular features "dots"............farmsteads

An example interpretation of a snow covered Landsat scene is presented in figure 1.

Two township sized areas were photo-interpreted by five interpreters each with varying degrees of experience. Interpretation accuracies were calculated using a modification of procedures as described by Kalensky and Sherk (1975).

RESULTS AND DISCUSSION

Vegetation emerging through snow cover is readily apparent on the imagery because of the reflectance contrasts between the highly reflective snow and the relatively lower reflectance of the vegetation. Only those sites which are not covered with snow and have sufficient vegetative density to be apparent on the imagery are considered by the authors to provide winter habitat. Some suitable areas may be smaller than the resolution of the sensor. Table 2 is a confusion matrix presenting the results of five interpreters who

Table 2.--Confusion matrix illustrating the classification accuracy winter habitat by 5 different interpreters.

CLASS		INTERPRETATION							OMISSIONS		
		A	B	C	D	E	F	TOTAL	No.	%	H_I%
Wetlands (A)		60	2	2	24	0	0	88	28	32	50
Shelterbelts (B)		1	63	4	7	0	0	75	12	16	73
Crops (C)		11	3	22	0	0	0	36	14	39	49
Farmsteads (D)		19	4	3	191	0	0	217	26	12	72
Municipalities (E)		0	0	0	0	5	0	5	0	0	100
Other (F)		3	2	0	16	.0	0	21			
TOTAL		94	74	31	238	5		442			
Commissions	No	34	11	9	47	0					
	%	36	17	29	20	0					
Overall Classification Accuracy K%		76.6									

[1]Confusion between wetlands and municipalities can be prevented by locating the municipalities with the aid of available road maps.

28D

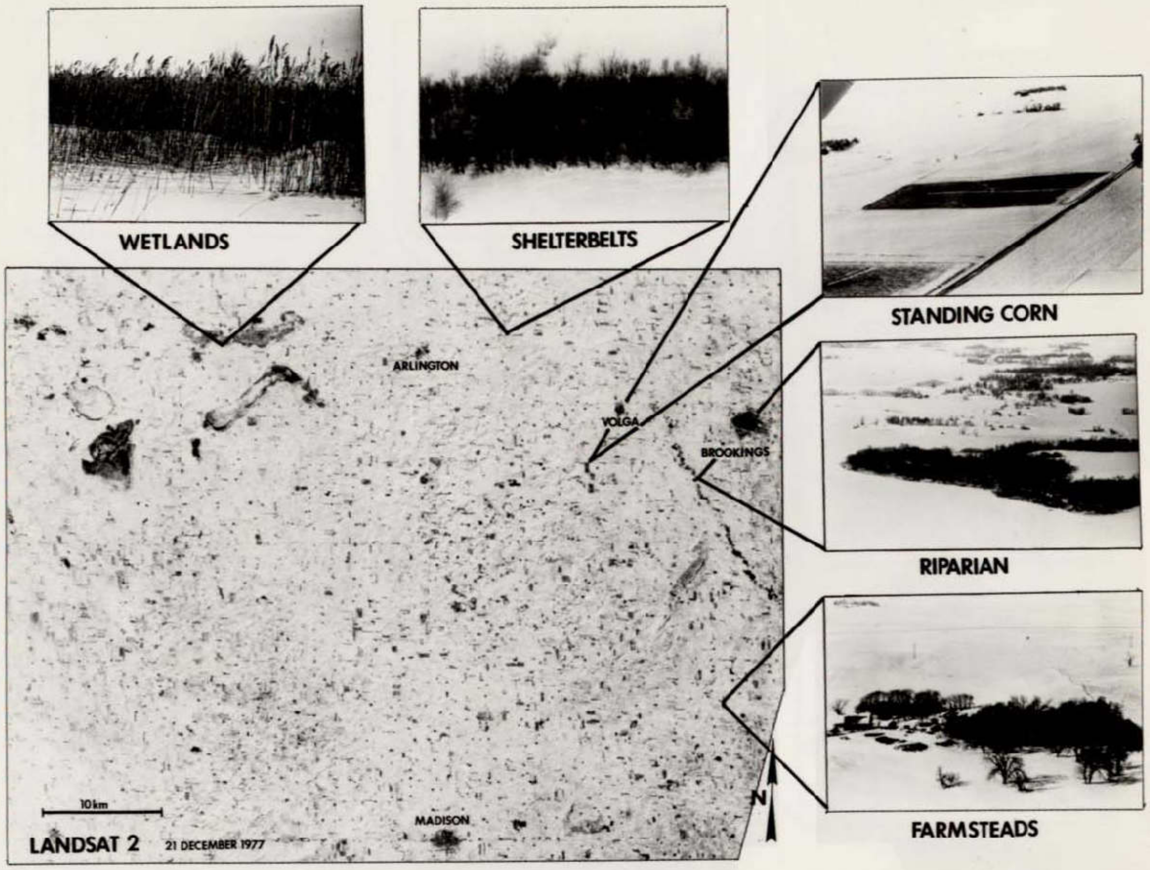

Figure 1.--Illustration of interpretation of winter habitat on Landsat imagery.

interpreted a two township size area on a 1:125,000 scale enlargement print. The overall classification accuracy was 76.6%. The largest source of confusion exists between the classes of wetlands and farmsteads. In almost every case there was no misclassification of large wetlands but the confusion occurred in distinguishing very small wetlands from farmsteads. The confusion between crops and wetlands can be attributed to the irregular shapes of some fields of crops because of greater snow depth in some portions of the fields due to the prevailing winds.

The reflectance of the vegetation emerging through the snow cover and resulting tone on the imagery, is a function of vegetative density and depth of snow cover. Assuming the density of vegetative cover is the criteria for determining the quality of habitat, than darker tones on the imagery indicate the best winter habitat. The dark toned "T" shaped feature at "A" (fig. 1) is a shelterbelt composed primarily of a dense stand of conifers. This can be contrasted with the shelterbelt composed primarily of deciduous trees at "B". Furthermore only wetlands with stands of persistent emergent vegetation are obvious on the imagery. Those wetlands with the most dense vegetative cover have the darkest tones and least mottled texture.

The repetitive coverage characteristics of Landsat allow seasonal or yearly monitoring of wildlife habitat. As the winter season progresses and snow depths increase more winter habitat becomes covered causing additional stress for wildlife populations. Figure 2 illustrates the loss of available winter habitat from 21 December 1977 to 3 March 1978. Numerous shelterbelts, wetlands and crops are available for cover and food in December and winter habitat is probably not a limiting factor. Heavy snowfall during January and February has limited the amount of available habitat by March.

21 Dec 1977 | 3 March 1978

Figure 2.--Mosaics of winter Landsat imagery (MSS7) illustrating regional differences and seasonal monitoring of available winter habitat in eastern South Dakota.

28F.

During normal winters agricultural fields have little or no value as winter wildlife habitat because residual vegetation is knocked down during harvesting and is easily covered by snow. When weather prevents harvesting of crops they may represent a significant proportion of available habitat and also provide a source of food. Numerous unharvested corn fields can be interpreted on the 1977 imagery.

Photomosaics of several snow covered scenes can be used as a regional map of the spatial distribution of winter habitat. Generalized differences in the quantity of available habitat are obvious (fig. 2). The Lake Dakota Plain (between Aberdeen and Redfield) in northeastern South Dakota is extensively farmed. The only available winter habitat is shelterbelts and the reparian habitat associated with the James River. The numerous wetlands in the Prairie Coteau provide abundant winter cover except in years of heavy snowfall.

The areal extent or the linear extent in the case f shelterbelts and riparian habitat can be measured on enlargement prints at scales of 1:60,000. The distance between areas of cover can also be measured. The spatial density of available winter habitat can be estimated from these measurements.

SUMMARY AND CONCLUSIONS

Wildlife losses resulting either directly or indirectly from winter exposure are important limiting factors in wildlife populations. Seasonal and yearly monitoring of available winter habitat in conjunction with ambient temperature data could provide data useful for predicting the severity of winter on wildlife populations. Wildlife management plans, in the Northern Plains States, should include winter habitat availability as one of the major components.

Winter habitat can be photo interpreted on Landsat imagery. Wetlands with persistent emergent vegetation can be identified by their irregular shape and mottled texture. Shelterbelts appear as dark toned straight linear features. The tone and texture may vary depending on the width, density and species composition of the trees present. Unharvested agricultural crops, which provide both escape cover and food for wildlife can be interpreted by dark tones and regular rectangular, square or circular shape. Riparian habitat, primarily shrubs and trees in the immediate flood plain of the rivers and waterways, can be interpreted by the presence of a meandering linear pattern. Farmsteads appear as small black dots resulting from the low reflectance of buildings and surrounding windbreaks. Urban areas can be confused with wetlands and should be interpreted with the aid of a supplemental map. Highway maps can be superimposed during printing to aid in spatially locating specific habitat.

LITERATURE CITED

Best, R.G. and D.G. Moore. 1977. Inventory of wetland habitat using remote sensing for the land proposed for irrigation in the Oahe Unit in eastern South Dakota, SDSU-RSI-77-03, Brookings, S.D., 38 p.

Best, R.G. and S. Sather. 1978. The interpretation of available winter wildlife habitat from Landsat imagery. S.D. Acad. of Sci., in press.

Bue, I.G. 1949. Winter behavior and mortality of pheasant in relationship to various types of cover, food and predation. S.D. Dept. Game, Fish and Parks, Spec. Rep. for Projects 19-D-2 and 17-R-3, 38 p.

Frentress, C.D. and R.G. Frye. 1975. Widlife management by habitat units--a preliminary plan of action. Proc. NASA Earth Resources Survey Symposium. Houston, Texas. 1A: 2450255.

Gates, J.M. 1971. The ecology of a Wisconsin pheasant population. Ph.D. Thesis, Univ. of Wisconsin, Madison. 912 p.

Gates, J.M. 1974. Seasonal movement, winter habitat use, and population distribution of an east central Wisconsin pheasant population. Dept. of Nat. Resources, Tech. Bull. No. 76, 55 p.

Gilmer, D.S., A.T. Klett, and E.A. Work. 1975. Evaluation of Landsat-1 system for monitoring waterfowl habitat in North Dakota. Workshop on Remote Sensing of Wildlife. Quebec City, Quebec. p. 77-98. Final Report, USDA-Forest Service.

Green, W.E. 1938. The food and cover relationship in the winter survival of the ring-necked pheasant, Phasianus colchicus torquatus Gmelin, in northern Iowa. Iowa St. Coll. J. Sci. 12: 285-314.

Grondahl, C.R. 1953. Winter behavior of the ring-necked pheasant, Phasianus colchicus, as related to winter cover in Winnebago County, Iowa. Iowa St. Coll. J. Sci. 27(4):447-465.

Hammerstrom, F.N., Jr. and J. Blake. 1939. Winter movements and winter foods of white-tailed deer in central Wisconsin. J. Mammal. 20(2):206-215.

Kalensky, Z. and L.R. Scherk. 1975. Accuracy of forest mapping from Landsat computer compatible tapes in Proceedings of the 10th International Symposium on Remote Sensing of the Environment. ERIM Ann Arbor, Michigan. p. 1159-1167.

Kimball, J.W. 1948. Pheasant population characteristics and trends in the Dakotas. Trans. N. Am. Wildl. Conf. 13:291-314.

Lyon, L.J. 1954. Pheasant winter roosting cover preference in northcentral Colorado. J. Wildl. Manage. 18(2):179-184.

__________. 1959. An evaluation of woody cover planting as pheasant winter cover. Trans. N. Am. Wildl. Conf. 24:277-289.

Ozoga, J.J. and L.W. Gysel. 1972. Response of white-tailed deer to winter weather. J. Wildl. Manage. 36(3):892-896.

Robertson, W.B., Jr. 1958. Investigation of ring-necked pheasant in Illinois. Ill. Dept. Conserv., Tech. Bull. No. 1. 137 p.

Scheierl, R. and M. Meyer. 1976. Evaluation and inventory of waterfowl habitats of the Copper River Delta. Alaska, by remote sensing Pac. N.W. For. and Range. Expt. Sta., Portland, Oregon, lAFHE RSL Research Report 76-3. 46 p.

Varney, J.R., J.J. Craighead, and J.S. Sumner. 1973., An evaluation of the use of ERTS-1 satellite imagery for grizzly bear habitat analysis. Proc. Third Earth Resources Tech. Satellite-1 Symposium. Washington, D.C. 1:1653-1670.

Verme, L.J. 1977. Assessment of natal mortality in upper Michigan deer. J. Wildl. Manage. 41(4):700-708.

Westin, H.G., Jr. 1954. The winter-spring movements of the ring-necked pheasant in northern Iowa. Iowa State Coll. J. Sci. 29(1):39-60.

NATIONAL MODEL IMPLEMENTATION PROGRAM
LAKE HERMAN WATERSHED

INTRODUCTION

The Lake Herman Watershed in southeastern South Dakota has been selected as one of seven water resources systems in the United States for involvement in the National Model Implementation Program (MIP). MIP is a pilot program initiated to illustrate the effectiveness of existing water resources quality improvement programs. It is anticipated that MIP will result in the establishment of guidelines and procedures to be used for nationwide water resources quality improvement.

MIP is administered through various federal groups within the United States Department of Agriculture and United States Environmental Protection Agency. South Dakota groups cooperating in the project include: South Dakota Department of Wildlife, Parks, and Forestry; South Dakota Department of Environmental Protection; East Dakota Conservancy Sub-District; First Planning and Development District; Lake Herman Development Association; Soil Conservation Service; Agricultural Stabilization and Conservation Service; Forest Service; Science and Education Administration; Economic, Statistical and Cooperative Service; Farmers Home Administration; the Cooperative Extension Service; and the Remote Sensing Institute.

The primary objective of the water quality improvement programs applied to the Lake Herman Watershed is to limit the influx of sediment and nutrients into the lake. In a survey by the State Lakes Preservation Committee it was determined that Lake Herman, because of high sediment and nutrient loading, had the poorest trophic State Index of all the lakes surveyed. In order to assess the effectiveness of water quality improvement practices it is necessary to establish baseline information about the watershed. This activity, which is cooperatively funded by SCS, has the objective to incorporate remote sensed and other resource data into a computerized geographical information system for the Lake Herman Watershed. The primary components of the information system are detailed soils information provided by SCS and land cover information obtained using remote sensing techniques.

The information system will facilitate the update of the information for evaluation and comparison and allow timely and current statistical information and thematic maps to be prepared at any scale for management decisions. The information system will be used: 1) to establish the current "base line" condition of the watershed, 2) to assist in the identification of areas in need of land treatment, 3) to assist in the evaluation and make recommendations on best management practices for the watershed, 4) to assist in the evaluation of water quality improvement treatments and structures, 5) to provide documentation of the accomplishments of MIP, 6) to locate bank stabilization problems and monitor the effects of stabilization, 7) to establish the current surface drainage network and monitor any changes which result from MIP, 8) to assist in identifying point and non-point pollution hazards, and 9) to monitor general water quality.

STUDY AREA

Lake Herman Watershed is approximately 18,225 hectares (45,000 acres) in size. The lake covers approximately 545 hectares (1350 acres) in area with an average depth of 1.7 meters (5.5 feet) and a maximum depth of 2.4 meters (8.0 feet). There are three major tributaries flowing into Lake Herman. Groundwater recharge to the lake is moderate. The predominant land use in the watershed is agriculture including several feedlots. The area is morainic and is characterized by drumlins and intervening lowlying marshes. Figure 4 is a map of the watershed.

METHODS AND MATERIALS

Detailed soils information for the Lake Herman Watershed were obtained from the SCS "Soil Survey of Lake County, South Dakota". The watershed is completely within Lake County.

Computerization of the soils information was achieved by gridding the soil survey map sheets. To facilitate data handling

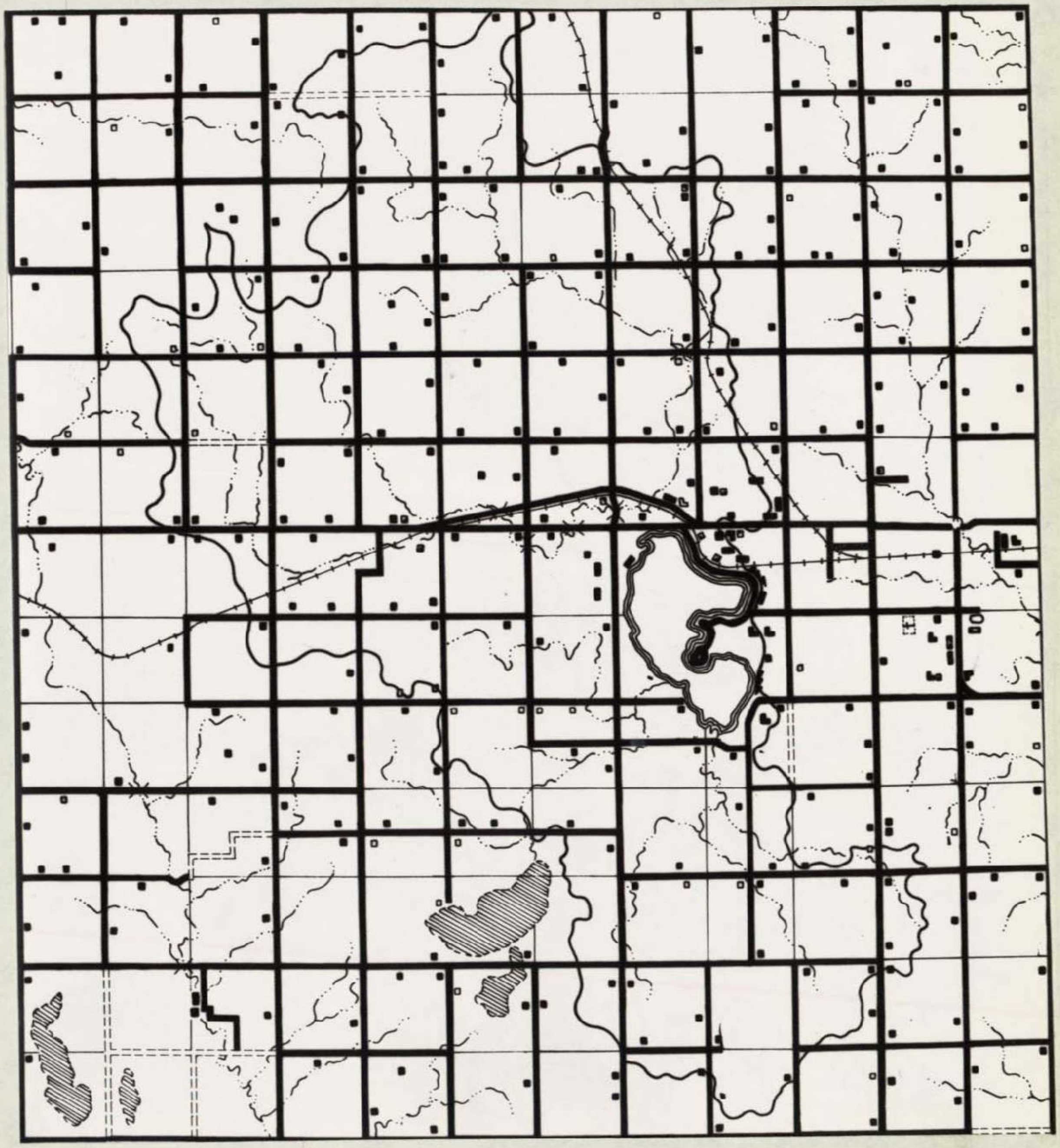

Fig. 4. Map of Lake Herman Watershed.

each square mile was gridded separately treating each square mile or section as a subset of the watershed. The grid cell size selected was .25 hectares (0.625 acres). This cell size was chosen because the agencies involved expressed a desire to work with a cell resolution approximating .405 hectares (1 acre). The .25 hectares (.625 acres) is also a multiple of 640 acres which is the common unit of measurement for a section of land under the United States Rectangular Survey System (township and range). There are a total of 59 soil classifications within the watershed. Each cell was assigned to the classification which was dominant within the cell.

The cellular soils information was entered into the computer and processed for coding errors. In addition, each section was machine plotted on mylar and overlayed onto the soil survey map sheet to verify that the cellular data conformed closely to the polygonal data of the soil survey. Figure 5 is a line plot of one section overlayed onto the soil survey map section. After the verification each of the subsets was merged together for the entire watershed.

The land cover information for the watershed was interpreted from 1:8000 scale 9 inch color and 70 mm color infrared aerial photography collected by RSI in July, 1978.

Prior to the interpretation of the photography, ground truth data were collected for the watershed. The ground truth data were obtained by recording the land cover type that occurred in each quadrant of almost every road intersection within the watershed.

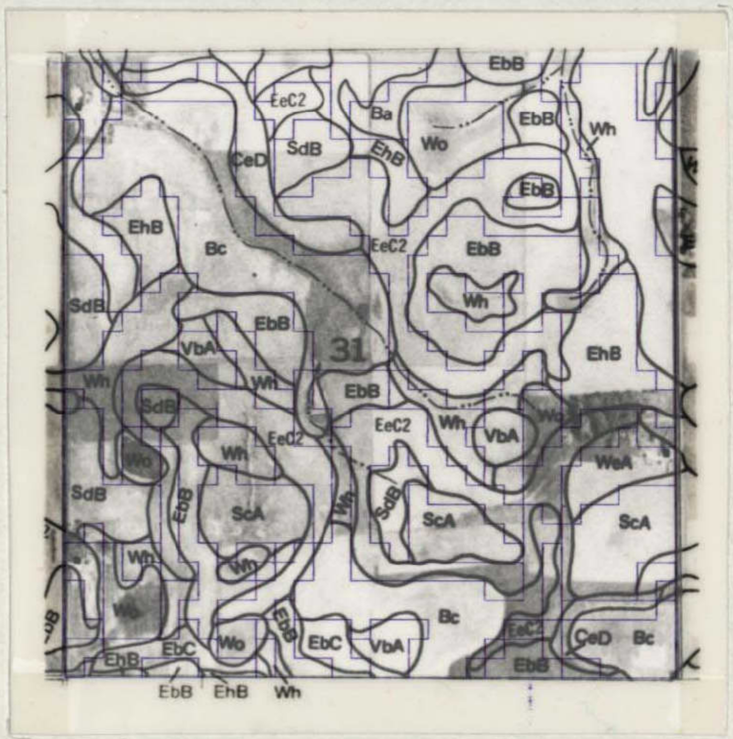

Fig. 5. Soil survey map sheet overlayed with line plot of digitized soil information.

This information was used to train the interpreters and verify interpretation results.

Eleven land cover categories were selected and approved by SCS. They are: water, wetland, row crops, small grains, hay, pasture, idle land, fallow, farmsteads, trees, and urban buildup.

The land cover data was interpreted and digitized on a section basis like the soils data. The cell size for the land cover data was also .25 hectares (.625 acres). Each cell was assigned to the class which was dominant within the cell.

Each section was machine plotted and overlayed onto the photography to ensure all category boundaries were digitized correctly. Figure 6 is a line plot of the digitized land cover data overlayed onto a color print of the corresponding area. The land cover subsets were merged for the entire watershed.

RESULTS AND DISCUSSION

Computerization of the land cover and soils data has been completed. The data will be used to produce statistical and map information. Statistical information on acreages of land cover type, soil type, and acres of a land cover type on a specific soil type are some examples.

Map information will be produced to meet cooperating agency needs specifically those of the Soil Conservation Service. It is

ORIGINAL PAGE IS
OF POOR QUALITY

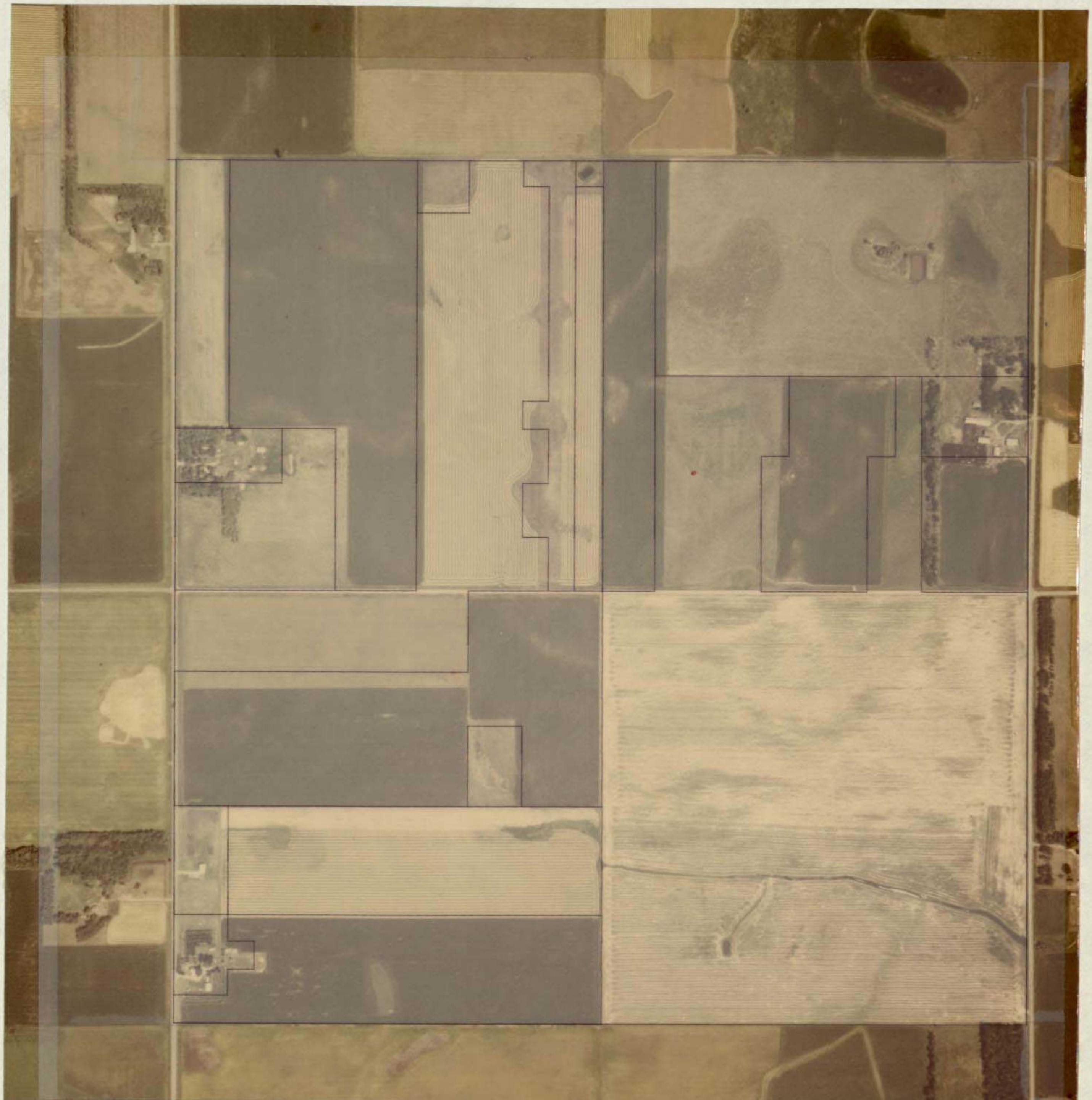

Fig. 6. 1:8000 color print overlay with line plot of interpreted land cover data.

anticipated that primary analysis will involve the Universal Soil Loss Equation (USLE). USLE is widely used as a tool in prediction of long term erosion on agricultural land (Wischmeier and Smith, 1965). Input variables for USLE analysis will be obtained from the soil survey and the land cover data. Typical output maps from the USLE will include soil loss potential, erosion hazards and critical erosion areas.

CONCLUSION

It is anticipated that the computerized geographical information system will be a helpful tool in developing a management plan for the Lake Herman Watershed. Future analysis will be directed towards identifying and quantifying water quality management problems.

REFERENCES

State Lakes Preservation Committee. A plan for the classification, preservation and restoration of lakes in northeastern South Dakota. 1977.

Wischmeier, W.H. and D.D. Smith. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agricultural Handbook No. 282. May 1965.

PRAIRIE DOG MANAGEMENT

INTRODUCTION

Black-tailed prairie dog management efforts on public lands center around the control of the size and the number of prairie dog towns. Prior to 1972, toxicants such as sodium fluoroacetate (1080) and strychnine were used on public lands to efficiently control prairie dog population increases (Lovaas 1973, Robinson 1973). President Nixon banned the use of these chemical toxicants on public land effective 1972. As a result many public land areas in South Dakota have experienced a substantial increase in prairie dog town acreage (U.S.F.S. Environ. Statement 1977, Lovaas 1973).

For example, the acreage of prairie day towns in the Conata Basin in Pennington County, South Dakota was 608 percent greater than in 1968. Lovaas (1973) noted that prairie dog towns in Wind Cave National Park doubled in size from 1967 to 1971. This dramatic increase in prairie dog town acreage in western South Dakota is of economic concern since many investigators have shown that prairie dogs are highly competitive with livestock for range forage (Kelso 1939, Stoddard and Smith 1955, Valentine 1971).

Prairie dog town expansion and colonization is an important concern of the National Park Service personnel at Wind Cave National Park. Management of prairie dog town size is necessary to insure that the quality of the range is not reduced. Quality of range is directly related to the carrying capacity of the park for its resident big game species. Another concern is that the rapid population expansion will result in immigration into public use areas within the park and onto bordering private lands.

Future management control programs within the park are dependent on acquisition of an accurate and current inventory. Remote sensing technology has proved to be a useful tool in this regard for various wildlife species management programs (Frentress and Frye 1975, Heyland (ed.) 1975, Cheatham 1973). Increases in prairie dog town size and numbers make conventional field surveys costly and time consuming (McClanahan pers. comm.). The use of remote sensing technology offers a great potential for future prairie dog management decisions.

Materials and Methods

Since the study was designed to evaluate both current and historical data, the initial project work involved compiling previous Park Service survey data (Table 4). This data will be integrated into the interpretative analysis (i.e. town growth rate and direction potentials) along with resource information upon the completion of the 1978 mosaic.

Ground data collection took place from 9 July to 15 July 1978. The emphasis in designing this phase of the study was to provide quantitive data to characterize the vegetation in the dog towns,

Table 4. Survey of historical prairie dog acreages as compiled by National Park Service, 1961-1977.

PRAIRIE DOG TOWN	ACREAGE	DATE
Bison Flats	154	1961
Bison Flats	206.6	1963
Bison Flats	245.3	1967
Bison Flats	409	1971
Bison Flats	556.1	1977
Norbeck	93.96	1966
Norbeck	127	1971
Norbeck Dam	68	1961
Norbeck Dam	84	1963
Pringle	53.4	1975
Pringle Cut-Off	40.3	1974
Rankin	9.77	1963
Rankin	11.3	1970
Research Reserve	63	1963
Research Reserve	159.46	
Sanctuary	122.7	1964
Sanctuary	150.89	1967
Sanctuary	176.1	1970
Shirttail Canyon	21.9	1963
Shirttail Canyon	22.0	
Shirttail Canyon	32.16	1970
Shirttail Canyon	28.5	1977
Southeast	57.6	1964
Southeast	65.5	1966
Southeast	123.282	1970
Northeast	38.99	1977

along expansion zones, and in the bordering non-disturbed vegetation. Data were collected at 11 dog towns. Vegetative parameters were measured at sampling stations which were picked in the field to be representative of each respective town and its surrounding area. These stations which were 0.25 were keyed to 1976 RB-57 color prints in order that the stations could be located later on the current imagery. The number of stations per town (Table 5) depended on the size of the town and the heterogenity of the town's vegetative community. Information collected at each station included estimation of vegetative species composition and height, taking a vertical color and color infrared slide from a 1 m height, and clipping the vegetation in the 0.25 m^2. Other general notes were taken peculiar to each dog town in order to aid in later identifying these features on the imagery.

Table 5. List of prairie dog towns sampled and number of sampling stations per town.

PRAIRIE DOG TOWN	NO. OF SAMPLING STATION
Bison Flats	5
Highland	3
Homestead	2
Norbeck	7
Northtown	1
Pringle	4
Rankin	2
Research Reserve	3
Sanctuary	5
Shirttail Canyon	6
Wind Cave Canyon	1
TOTAL	39

On 17 July 1978 data were collected from an altitude of 1371 m (4500 ft.). Color, color infrared (CIR) and black and white imagery were collected.

The process of assembling and compiling the ground data and aircraft imagery is now underway. After examining all the imagery, CIR was chosen as the best product to accomplish the project goal. A mosaic of the park is nearing completion.

Ground data has been tabulated. Clippings from each station have been dried and weighed; forbs and grasses were separated prior to weighing. Color prints (4 x 5 in.) were made of the 1 meter vertical slides of the stations. A random dot grid was overlaid on the prints and the following categories were noted: 1) live vegetation; 2) nonlive vegetation; and 3) soil. These data will be analyzed with the clippings data to give an indication of ground cover characteristics within towns and bordering the towns.

Future Work

Future work includes: 1) analysis of historical data and current data to determine rate of town growth and probable direction of growth; 2) provide interpretations of prairie dog town size from current data for present inventory needs; 3) interpret environmental factors associated with prairie dog towns (i.e. soils, vegetation, landscape, natural barriers) and map areas of potential prairie dog colonization; 4) develop a vegetation photo interpretation key and make a vegetation map of the park; 5) evaluate results and cost-benefit considerations of the methods for the study area.

REFERENCES

Cheatham, L.K. 1973. Censusing prairie dog colonies using aerial photographs. In Proc. Black-footed Ferret and Prairie Dog Workshop, p. 78-88.

Frentress, C.D. and R.G. Frye. 1975. Wildlife management by habitat units - a preliminary plan of action. In Vol. I, NASA Earth Resources Survey Sym. p. 245-255.

Heyland, J.D. (ed.). 1975. Workshop on remote sensing of wildlife. 191 p.

Kelso, L.H. 1939. Food habits of prairie dogs. USDA Circ. 529, 15 p.

Lovaas, A.L. 1973. Prairie dogs and black-footed ferrets in national parks. In Proc. Black-footed Ferret and Prairie Dog Workshop. p. 139-446.

McClanahan, L.F. 1978. Personal Communication.

Robinson, L.D. 1973. Black-footed ferret and prairie dog programs on Forest Service administered land. In Proc. Black-footed Ferret and Prairie Dog Workshop. p. 125-133.

Stoddard, L.A. and A.D. Smith. 1955. Range management. 2nd Edition. McGraw-Hill Book Co., New York, N.Y.

U.S. Forest Service. 1977. Prairie dog management. Draft Environment Publication. USDA-FS-R2-DES-AOM-FY 77-04. 91 p.

Valentine, J. 1971. Range development and improvements. Brigham Young Univ. Press. Provo, Utah. 516 p.

SPECTRAL REFLECTANCE OF HYDROPHYTES

INTRODUCTION

Identification of hydrophytes is of primary importance in the classification and subsequent management of wetland habitat. In operational wetland classification systems which utilize remotely sensed imagery as the primary data source, water regime parameters can be determined only by the presence of different indicator species of hydrophytes. The quality as well as quantity of wetland habitat can be estimated if hydrophytes can be accurately identified.

Investigators have reported varying degrees of success in classifying hydrophytes from remotely sensed data (Best, 1977; Cowardin and Myers, 1974; Anderson et al., 1973; Lukens, J.E., 1968; Shima, L., 1973; and numerous others). To date, very little work has been done to determine the optimal time for data collection or the spectral region which is best suited for differentiating classes of hydrophytes.

The objectives of this project are threefold. First, to determine if reflectance differences exist between different hydrophytes. Secondly, to determine the phenological growth stage at which maximum differences occur. Finally, to determine the spectral region in which maximum reflectance differences occur.

Measurement of reflected and incoming radiation were collected with an Exotech radiometer during different phenological growth stages for different species of hydrophytes. Additional reflectance data were collected with an ISCO scanning spectroradiometer and samples of each vegetation type. Reflectance data will be analyzed statistically to determine if there are significant reflectance differences between hydrophytes in each of four wave bands.

MATERIALS AND METHODS

Pure dense stands of 10 species of hydrophytes common to the wetlands of the area were selected for the project. The ten species were; Typha angustifolia (narrow-leaved cattail), Scirpus validus (soft-stem bulrush), Scirpus fluviatilis (river bulrush), Phragmites communus (common reed), Alisma plantago-aquatic (water plantain), Scolochloa festucacea (whitetop), Sparganium sp. (bur reed), Hordeum jubatum (wild barley), Polygonum amphibium (water smartweed), and Spartina pectinata (prairie cordgrass). These are all persistent emergents with the exception of whitetop which is a non-persistent. No species of rooted submergents were selected.

Ten sample sites were randomly selected within each stand by throwing a 3/4 m^2 hoop. Measurements of incoming and reflected radiation were made 1/2 m above the vegetation at each site with an Exotech radiometer. The radiometer is sensitive to four wavebands 0.5-0.6 μm, 0.6-0.7 μm, 0.7-0.8 μm, and 0.8-1.1 μm. The respective color renditions are green, red, near-infrared, respectively. Vertical 35 mm photographs were

---

Inclusion in this report of registered trade names or trademarks does not constitute an endorsement by the author or the Remote Sensing Institute.

exposed at each site to estimate the proportion of vegetative cover. When vegetative cover appeared to be less than 100%, vegetation was clipped off at the ground and litter removed or vegetation was pushed below the water surface and background reflectance measurements were made.

The percent reflectance was calculated as the ratio of reflected to incoming. Use of percent reflectance minimizes the variability due to differences in atmospheric conditions and sun angle. To further reduce sun angle effects measurements were made when sun angles were greater than 35° in the fall and 45° during the summer months. An attempt was made to partition out the effects of background radiation if vegetation density was less than 100% by using the following equation:

$$\rho = (A_v\rho_v + A_w\rho_w)$$

where: ρ = total % reflectance

A_v = % area of vegetative cover

ρ_v = % reflectance due to vegetation

A_w = % area of background

ρ_w = % reflectance of water

The percent area of vegetative cover and percent area of background were estimated with a random dot grid and enlargement prints of 35 mm vertical photographs of each site. Each estimate was an average of four counts of the dot grid which was rotated 90° and randomly dropped for each count.

Reflectance data have been collected during a two week period in August when the hydrophytes were in a flowering or early seed stage and during a two week period in October when the vegetation was in a senescent stage. A third data collection is scheduled for May in order to collect data prior to the vegetation reaching a flowering or seed stage.

Statistical means and standard deviations were calculated for each species of hydrophyte in each spectral band during the different phenological stages. A Duncan's multiple range test was used to test for statistically significant differences in the reflectance means. For the purpose of this study it will be assumed that species of hydrophytes with statistically different reflectance means should appear differently on remotely sensed imagery.

Laboratory Reflectance Measurements

Vegetation samples were collected and stored in plastic bags during the fall data collection. Reflectance measurements were made on these samples in the laboratory with an Isco scanning spectroradiometer. The system includes a specimen chamber with a constant light source which was constructed specifically for this purpose (Fig. 7). The specimen chamber was painted with a non-reflective black paint and the ring light source produced light in only the visible spectra (0.4-0.75 μm). The detector is shielded from direct radiation from the bulb by a non-reflective

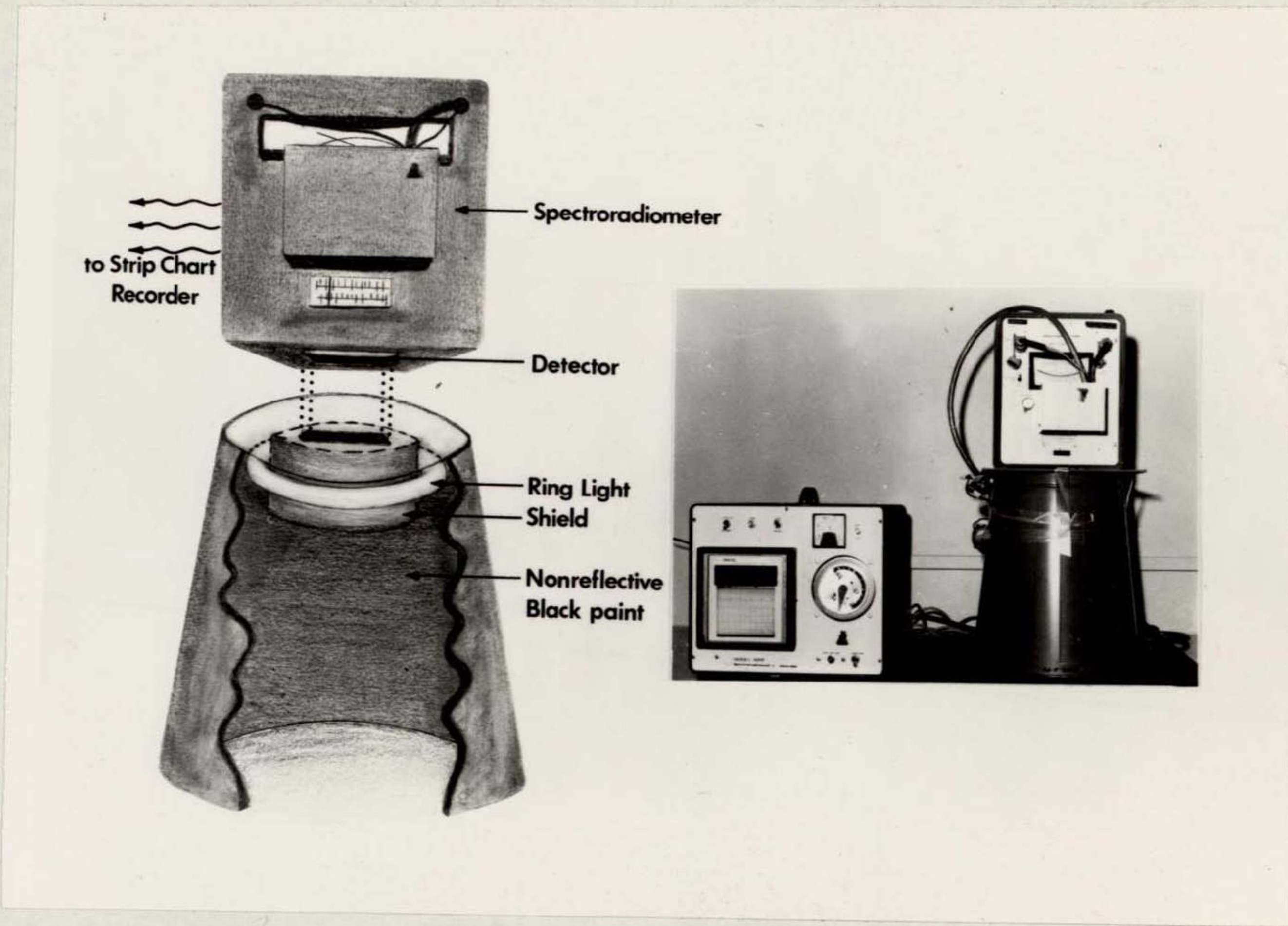

Fig. 7. Illustration of specimen chamber and ISCO scanning spectroradiometer used for laboratory reflectance measurements.

cylinder which also restricts the "look" angle of the detector. Vegetation samples were cut short enough to fit under the can and the entire look area was covered with vegetation. Duplicate traces were made for each sample. Percent reflectance curves were plotted from the scans. The objective of this method was not to simulate natural conditions, but to provide supportive data or data of narrow wavebands or in spectral regions for which the Exotech was not sensitive.

RESULTS AND DISCUSSION

For the purpose of this preliminary report the results and discussion presented herein will be limited to a presentation of reflectance means ($\overline{x}$) and standard deviations and an analysis of variance in those means. Results from the Duncan's multiple range analysis will be presented in a final report following the spring reflectance data collection.

Reflectance data for hydrophyte in the flower or early seed stage are presented in Table 6. These reflectance values have not been corrected for differences in stand density and background reflectance. However, only three species, Scirpus validus, Scolochloa festucacea and Sparganium sp., had less than 100% vegetative cover. If the vegetation in the stands is characteristic of each species these uncorrected values would be representative of a natural situation, whereas correction for background theoretically

Table 6. Spectral reflectance* data for selected hydrophyte in the flowering or early seed stage.

Vegetation Species	.5-.6 μm		.6-.7 μm		.7-.8 μm		.8-1.1 μm	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Alisma plantago-aquatic	5.1	0.4	5.8	0.3	18.4	2.2	24.9	1.5
Hordeum jubatum	7.9	0.5	10.1	0.5	20.5	1.1	22.1	7.3
Phragmites communus	3.9	0.4	3.3	0.6	19.4	2.2	28.0	3.2
Polygonum amphibium	5.9	0.4	6.3	0.3	22.5	2.2	34.3	3.1
Scirpus fluviatilis	4.3	0.4	3.9	0.4	24.7	3.1	39.2	7.4
Scirpus validus	3.3	0.3	4.3	0.7	16.6	1.4	24.9	1.7
Scolochloa festucacea	5.3	0.7	4.9	0.7	22.1	4.1	31.0	4.9
Sparganium sp.	4.6	0.3	4.0	0.4	25.6	5.1	34.0	5.7
Spartina pectinata	4.4	0.4	4.5	0.5	29.2	1.3	46.1	2.2
Typha angustifolia	4.8	0.5	5.3	0.5	34.7	6.1	56.7	3.3

*Reflectance data reported as a percentage of the incoming

provides reflectance due purely to vegetation. The statistical analysis of variance showed that both spectral region and vegetative species were highly significant in accounting for the variance in reflectance data.

Reflectance data for hydrophytes in the senescent stage are presented in Table 7. In general, reflectance values have increased from the early seed stage to the senescent stage. This is especially evident in the red waveband (.6-.7 μm). This is probably the result

Table 7. Spectral reflectance* data for selected hydrophytes in senescent growth stage.

Vegetation Species	.5-.6 μm		.6-.7 μm		.7-.8 μm		.8-1.1 μm	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Alisma plantago-aquatic	7.4	0.6	9.7	0.8	21.7	2.0	29.1	4.8
Hordeum jubatum	9.4	0.9	12.6	1.3	21.3	2.3	27.1	3.5
Phragmites communus	6.8	0.8	11.2	1.6	19.3	2.4	22.9	1.8
Polygonum amphibium	3.8	0.7	6.0	0.5	15.1	2.3	21.1	0.23
Scirpus fluviatilis	9.0	1.1	13.8	2.5	23.1	3.0	32.1	5.0
Scirpus validus	6.4	1.7	9.2	2.6	16.3	4.5	19.5	5.2
Scolochloa festucacea	21.1	5.7	30.7	7.1	62.0	15.8	69.6	11.8
Sparganium sp.	6.5	0.5	10.1	0.6	21.9	2.1	28.7	2.5
Spartina pectinata	13.8	2.1	23.7	3.2	43.8	3.7	59.6	4.5
Typha angustifolia	8.4	1.7	16.5	4.8	31.2	7.9	40.5	8.1

*Reflectance data reported as a percentage of the incoming

of the brown colors formed as the plants desicate. The analysis of variance showed that the variance in reflectance data during the senescent stage could also be accounted for by spectral region and vegetative species.

The reflectance curves that were plotted from the Isco scanning spectroradiometer data are presented in Figure 8. These graphs can not be directly correlated with field reflectance measurements. The laboratory

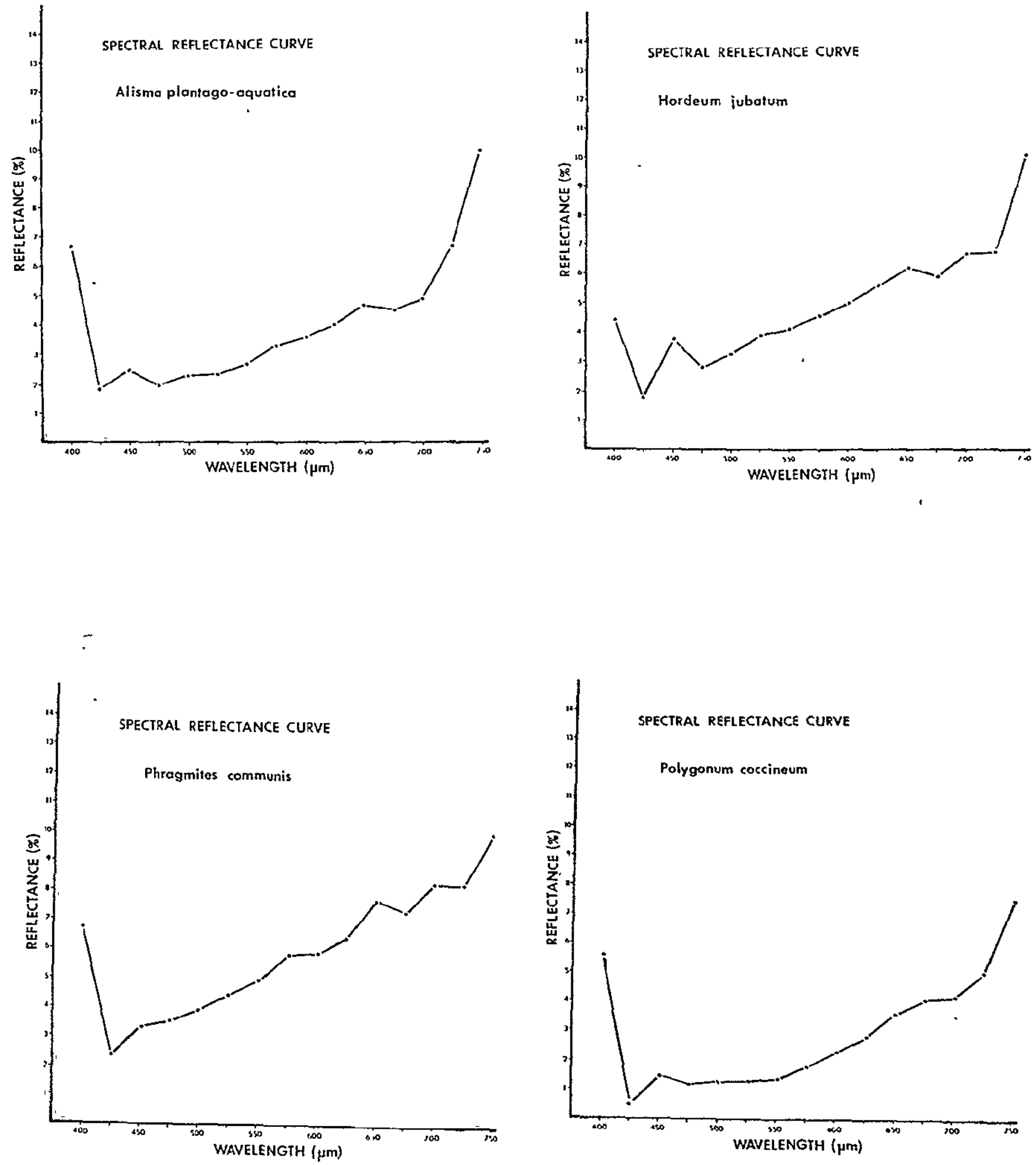

Fig. 8. Spectral reflectance curves plotted from ISCO spectroradiometer data.

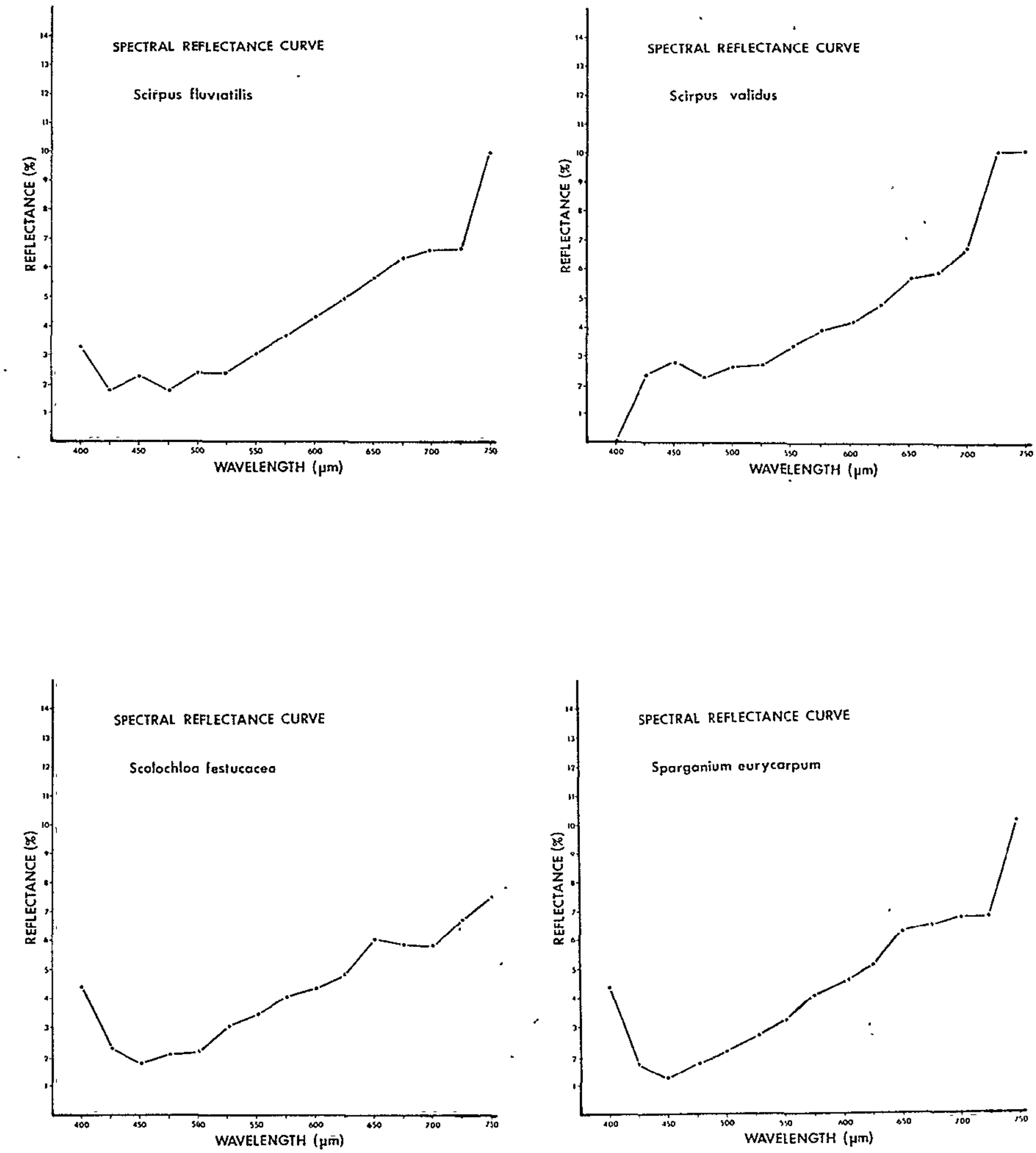

Fig. 8. Continued

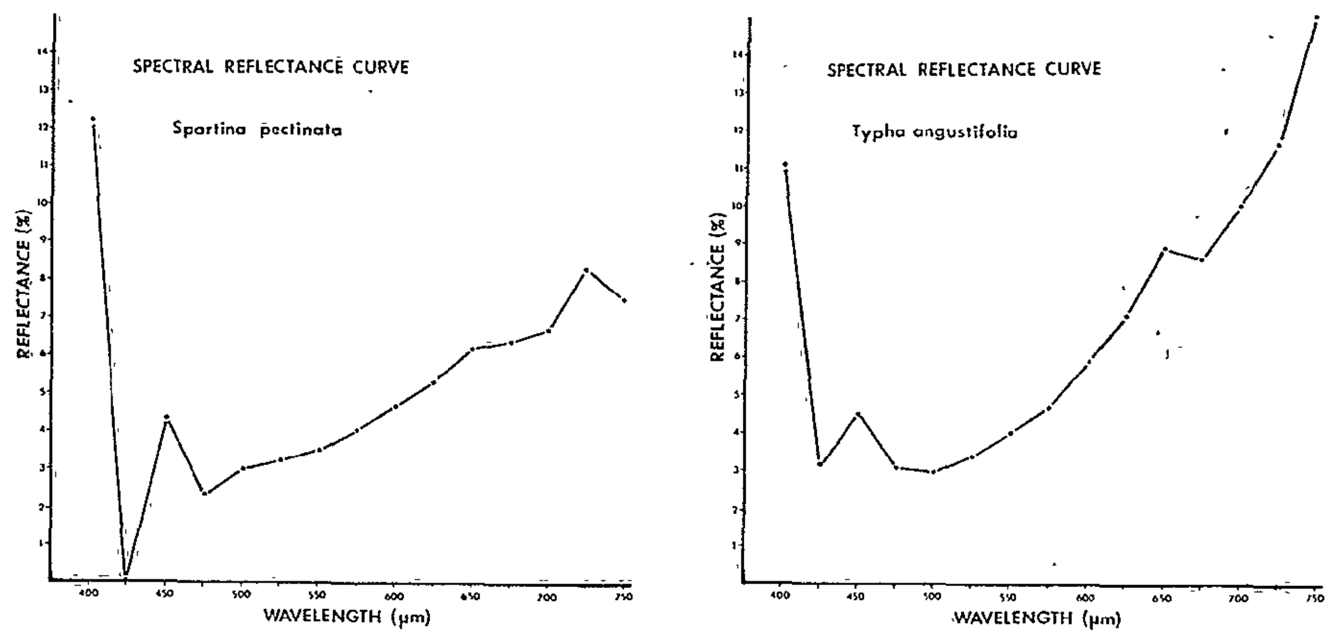

Fig. 8. Continued

technique is designed to provide supplemental information about hydrophyte reflectance under very stringent controls. The graphs can be used to make generalization about reflectance characteristics and provide data for specific wavelength rather than broad spectral bands. Several trends can be seen in the reflectance curves. In almost every case there is a peak in the blue wavelengths (.450 μm) and in the red wavelength (.650 - .675 μm). The reflectance in the yellow-green (.550 - .575 μm) portion of the spectrum is very similar for most species. Polygonum amphibium, which turns reddish brown during senescence, is a notable exception.

CONCLUSIONS

These preliminary results indicate that there are differences in spectral reflectance for different species of hydrophytes. Further analysis will indicate if these reflectance differences are significantly different. This analysis should also identify the waveband or bands and phenological growth stage in which maximum reflectance differences occur. This information should be valuable for selecting sensor sensitivity and data collection scheduling for the identification of hydrophytes or remotely sensed imagery.

LITERATURE CITED

Anderson, R.R., V. Carter and J. McGinness. 1973. ERTS-1 Investigation of Wetlands Ecology. Type II Report Nov. 1972-May 1973. American University, Washington, D.C. 35 pp.

Best, R.G., K.J. Dalsted, J.C. Eidenshink, M.E. Wedhe. 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. Semi-Annual Report to NASA, July 1, 1977 - December 31, 1977.

Cowardin, L.M. and V.I. Myers. 1974. Remote Sensing for Identification and Classification of Wetland Vegetation. J. Wildlife Management 38 (2) 308-314.

Lukens, J.E. 1968. Color Aerial Photography for Aquatic Vegetation Surveys. Proc. Symp. Remote Sensing of Environment, Univ. Mich., Ann Arbor 5:441-446.

Shima, L. 1973. Wetland Vegetation Mapping Using Aerial, Color-Infrared Photography. M.S. Thesis. The American Univ., Washington, D.C. 34 pp.

CELL SIZE STUDY

BACKGROUND

This addendum follows the results presented in the chapter entitled "Quantification of Cell Selection Criteria for Spatial Data" in the Annual NASA report (Myers et al., 1978). The foregoing report has outlined the basic tenets of this study, and as such only a cursory introduction will be included before presentation of additional results.

INTRODUCTION

The accuracy of information obtained from a cellular geographic information system is dependent on the cell size selected and the complexity of the map to be represented. It is obvious that utilizing smaller and smaller cell sizes will decrease mapping and inventory errors but the increasing number of cells will correspondingly increase costs. A scientific approach to selection of a cell size might utilize this cost-accuracy trade-off if it were possible to predict mapping-inventory error versus cell sizes for a particular map. The nature of this error-to-cell-size relationship is the subject of this study.

A detailed experimental study of the trend of increasing mapping and inventory error with increasing cell size was reported. Resolution number was defined as the grouping or aggregation factor used to join cells simultaneously in both X and Y dimensions to achieve a larger cell. Fig. 1 represents the mapping and inventory errors experimentally observed versus those resolution numbers which evenly divided the original data set dimensions.

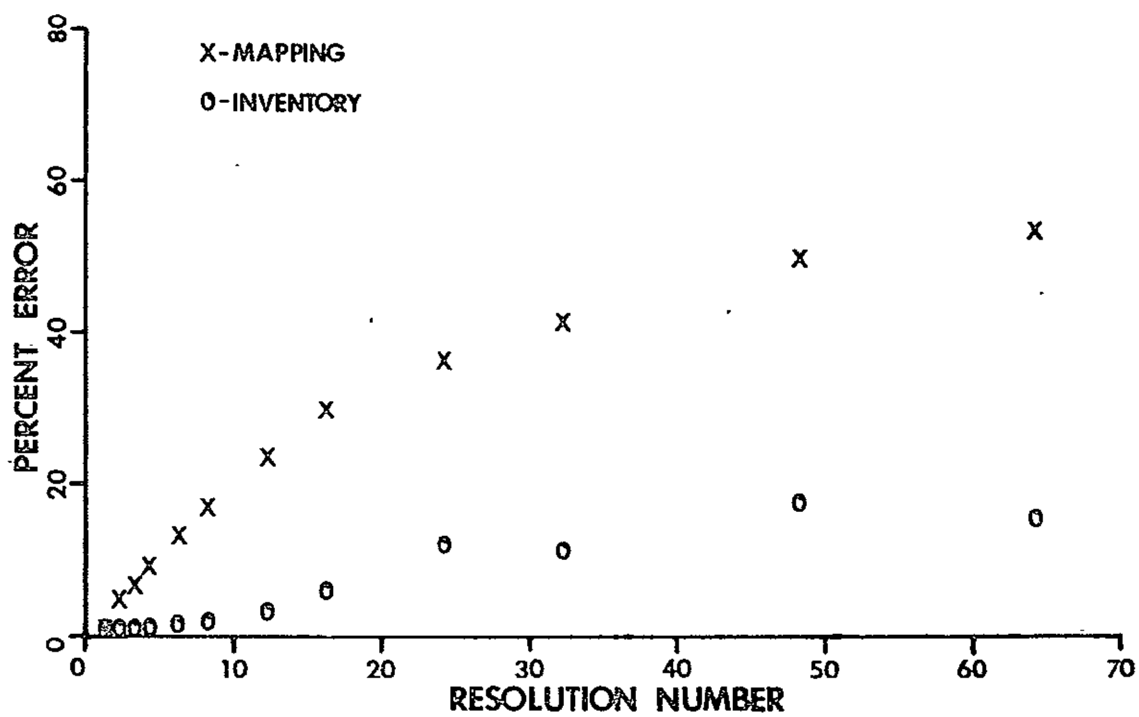

Fig. 1A. Mapping and inventory errors versus resolution number.

The span distribution (i.e. distribution of distances between boundaries) was investigated as a method of characterizing the map. Mean span and mean distance statistics were analyzed versus resolution number. The existence of a strong relationship of these statistics to resolution was considered encouraging evidence of the existence of a physical process. However, the statistics themselves were not considered useful in any universal sense because a "mean" value is not unique to a distribution.

During the course of the investigation of cellularization-error interaction, a distinct relationship between grid orientations and map regions was established: In a complex map the average error over all regions for one grid placement is conceptually equivalent to averaging all possible grid orientations over a single region. This latter case was investigated and found to exhibit well-behaved, grid-positional average error with increasing cell size. Hence the basis was established for the trends observed in Fig. 1.

Finally at the time of the NASA Annual Report, the observation was made that one half the cumulative span distribution related well to the mapping error. Continued experimentation has not proved or disproved the universal nature of such a relationship. Additional experimentation has, however, taken much more rigorous steps in the pursuit of a physical model of the relationship between span distribution and mapping errors for various cell sizes. This report will summarize continued developments in this area while leaving many technical details to a separate forthcoming report on the entire study.

THE MODEL

The usefulness of the span distribution itself as an input to a process model is appealing. This distribution is the "recipe" of boundary separations in any particular map; hence, a unique characterization of the map at hand and possibly of the class of maps in general.

The distribution represents the relative frequency of each of the unique boundary separations (n-units) in a map to be processed. For a particular cell size of m units there is a physical relationship of the cell with the span. This relationship is the source of mapping error. For a number of candidate cell sizes M a matrix can model the process of cell-to-span interaction to yield a prediction of mapping errors versus cell size. The model is diagrammed in Figure 2.

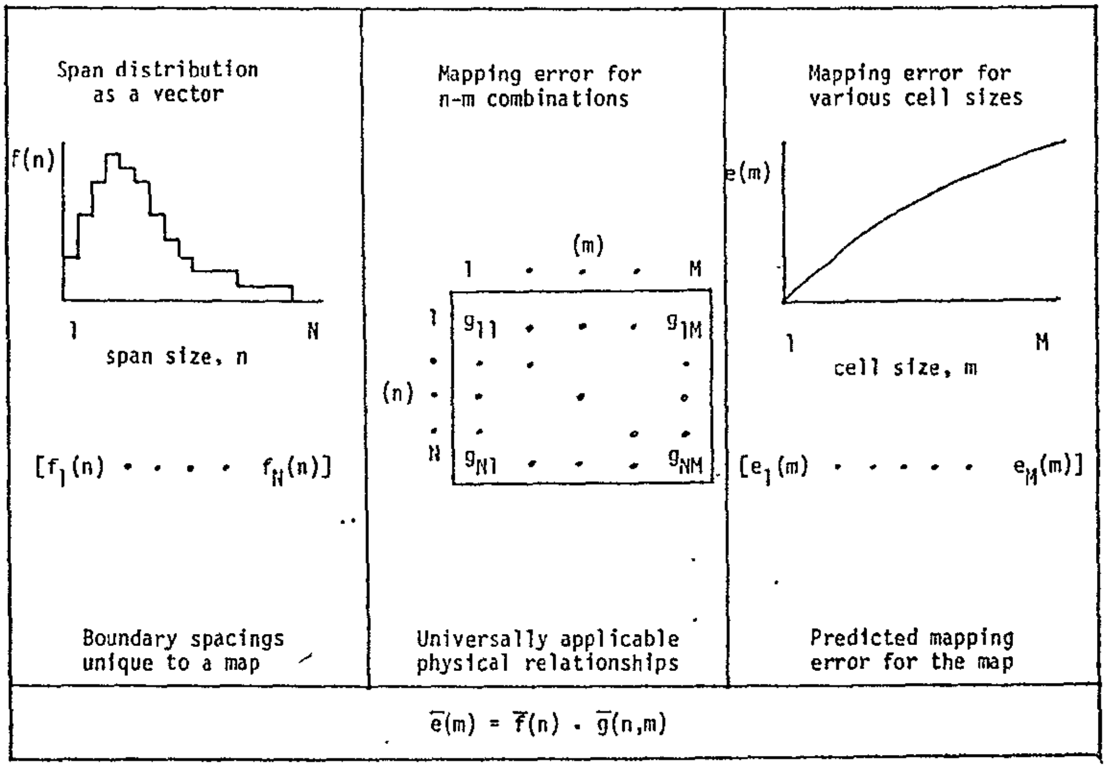

Fig. 2A. Components of the proposed mathematical relationship between span distribution and mapping error vectors.

The methodical pursuit of the error entries in the matrix was begun by consideration of one-dimensional effects only and a sequence of spans each of n-units isolated in an infinite spatial domain. The positional average of cellularizations was the first model attempted because of the experimental results reported earlier and the evidence of the existence of a map average principle. Defining rules were derived to allow generation of the matrix to any dimensions in a digital computer and the model was applied in accordance with the procedure outlined in Figure 2. (Only mapping error was modelled since this is a more critical measure of performance than inventory error.) The predicted mapping error is compared to the experimental in Figure 3. The model parallels the experimental but severely overestimates mapping error.

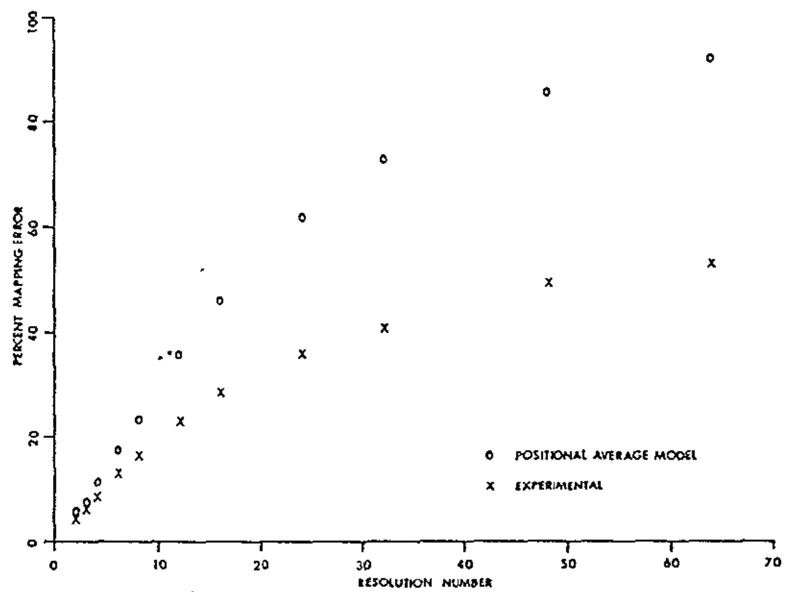

Fig. 3A. Predicted versus experimental mapping error. $\bar{g}(n,m)$ used was the positional average error fraction matrix.

The second generation model looked at corrective effects of non-isolation of the span of n-units. This step appeared logical in that any map is a finite continuum of adjacent spans rather than a sequence of isolated spans. The corrective entries for the matrix model are a function of the joint occurrence of one or more spans adjacent to the span under study. Thus the terms themselves are expressed as combinations, products, powers and cross-products of span distribution values. Since the maximum relative frequency of any span in the test data set was below 0.10 all cross-product, higher power terms were considered negligible and a first-order span adjacency model was pursued. Again it was possible to define a procedure for generating the correction matrix to any dimensions in a digital computer. The model was again applied as conceived in Figure 2. The result obtained from the second generation model is shown in Figure 4. The correction was appropriate in that it

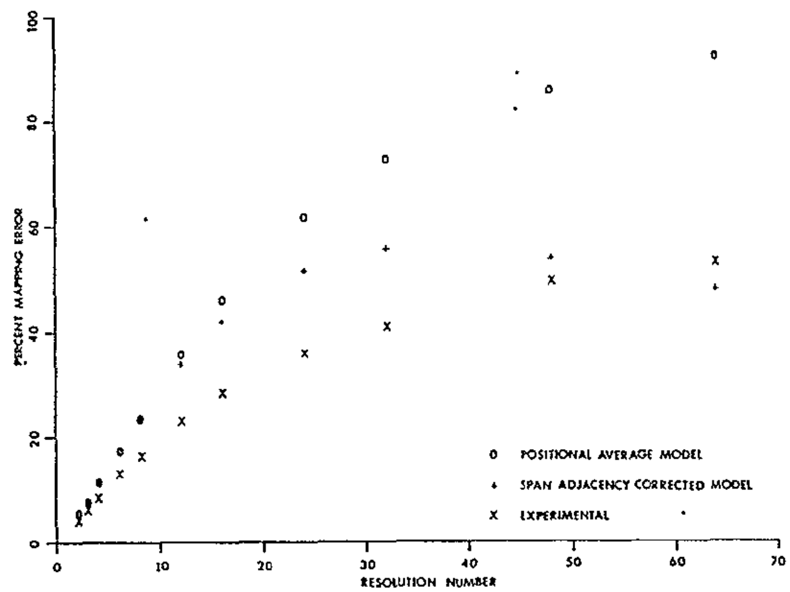

Fig. 4**A**. The experimentally observed mapping error compared to the positional-average model and the span-adjacency-corrected model.

everywhere reduced the magnitude of overestimation. The departure from "parallelism" between experimental and theoretical data may be accounted for by the dropping of higher power and cross product terms from the correction. Inclusion of these terms would further reduce the theoretical ordinates, making the model "better" at lower resolution numbers and further underestimative at higher resolution numbers.

A third generation model is now being re-designed to include two dimensional effects on a positional average basis.

INTERMEDIATE CONCLUSIONS

There appears to exist a universal physical process which can be modelled to allow the prediction of mapping error in a cellular information system given an estimate of the span distribution. Of equal importance is the potential application to decisions of cell size when converting from a polygon to a cellular information system.

Aerial Thermography Program

Remote Sensing Institute has published a brochure describing the program for using remote sensed thermal radiance information in energy conservation programs. RSI, in cooperation with the Minnesota Energy Agency, has prepared a comprehensive manual explaining the use of aerial infrared data in city and statewide energy conservation programs for the U.S. Department of Energy. In September, 1978, Dr. F.A. Schmer presented an invited paper at the "First National Conference on the Capabilities and Limitations of Thermal Infrared Sensing Technology in Energy Conservation Programs" sponsored by the American Society of Photogrammetry.

Program activities are continuing with contracts to survey several cities. Surveys of Missouri River mainstem power houses and other property of the Corps of Engineers is also continuing.

RESEARCH DEVELOPMENT AND APPLICATIONS PROJECTS
NASA OFFICE OF TECHNOLOGY TRANSFER DIVISION AND
OFFICE OF UNIVERSITY AFFAIRS
1970 - 1978

Funds in excess of one million dollars have been invested since 1970 in the Institute programs in South Dakota by the NASA Office of University Affairs for the purpose of technology transfer to state and local agencies and to encourage in-state groups to build their own remote sensing capability and encourage the state legislature to provide funds for these purposes. The following RSI projects, totally or partially funded by NASA Office of University Affairs (OUA), have been conducted over the past nine years. Cooperating agencies are shown in parenthesis.

Detection of Apparent Rooftop Temperatures by Thermography (U.S. Dept. of Energy, SD Dept. of Energy, numerous cities and towns in U.S.)

Use of Remote Sensing Techniques for Inventorying and Planning Utilization of Land Resources in South Dakota - Pennington County (Sixth District Planning Agency, Black Hills Conservancy Subdistrict, Pennington County Director of Assessment, Pennington County Commissioners)

Resource Inventory Through Remote Sensing for Land Use Planning in Meade County South Dakota (Sixth District Council of Local Governments, Cooperative Extension Service, Meade County Planning Commission. Meade County Planning and Zoning Administration Black Hills Conservancy Subdistrict, USDA SCS)

Land Evaluation Planning Utilization of Land Resources - Potter County (Potter County Commissioners, Potter County Director of Tax Assessment)

Remote Sensing Techniques for Making a Soil and Range Inventory (U.S. Bureau of Indian Affairs)

Hydrologic Investigations of the Newton Hills State Park Region of the Alcester Quadrangle (USDA SCS)

Location of Spoilage Areas Within Sugar Beet Piles for Optimum Harvest Scheduling (American Crystal Sugar Co., Moorhead, MN)

Use of Remote Sensing Technology to Monitor and Evaluate the Impact of Cultivation on Rangeland Ecosystems in Western South Dakota (SD Dept. of Wildlife, Parks, and Forestry)

Applications of Remote Sensing in the Management of Meandered Lakes (SD Dept. of Wildlife, Parks and Forestry)

Brookings County Map of Soil Textures and Land Forms on ERTS-1 Imagery (SDSU Plant Science Dept.)

Map of Soil Association Value Areas (SD Dept. of Revenue, USDA SCS, SDSU Plant Science Dept., Pennington County Director of Assessment)

Map of Soil Textures and Land Forms on ERTS-1 Imagery (SDSU Plant Science Dept.)

The Influence of Soils Upon Landsat Spectral Signatures (SDSU Plant Science Dept.)

Land Classification of the Lake Dakota Plain in South Dakota Using Remote Sensing Methods - Soil Limitations (U.S. SCS, U.S. Bureau of Reclamation, Oahe Conservancy Subdistrict)

Application of Remote Sensing to Improve Agricultural Censusing (SD Agricultural Dept; USDA Economics, Statistics, and Cooperative Service)

Use of Remote Sensing Technology to Map Aspen (SD Dept. of Wildlife, Parks and Forestry)

The Use of Remote Sensing Technology to Quantify Cell Selection Criteria for Spatial Data

Tornado Damage Assessment (SD Civil Defense Office)

Hail Damage Evaluation (SDSU Plant Science Department)

Monitoring Flood Damage with Satellite Imagery - Ferney Flood Study (USDA Crop Reporting Service)

Inventory of Wetlands Using Remote Sensing for the Proposed Oahe Irrigation Unit in Eastern South Dakota (U.S. Fish and Wildlife Service, Oahe Conservancy Subdistrict, U.S. Bureau of Reclamation)

Photographic Contrast Enhancement

Application of Remote Sensing to Detect Changes of Habitat in the Black Hills - 1961 to 1976 (South Dakota Dept. of Wildlife, Parks and Forestry)

National Model Implementation Program, Lake Herman Watershed (US SCS, Lake Herman Development Association, First Planning and Development District, East Dakota Conservancy Subdistrict, SD Dept. of Environmental Protection, SDSU Extension Service, USDA ASCS, US EPA)

Geohydrologic and Environmental Assessment of Six-Mile Creek Watershed (US SCS)

Pheasant Restoration Plan (SD Dept. of Wildlife, Parks and Forestry)

Prairie Dog Management (U.S. National Park Service)

Classification of Hydrophytes (SDSU Dept. of Wildlife and Fisheries)

A special report was prepared in September, 1978, for NASA, Office of Technology Transfer Division, Space and Terrestrial Applications, which included certain information on all NASA Office of University Affairs projects from 1970 through 1978. The information sheets on present projects and those with updated information are appended.

South Dakota State University

Remote Sensing Institute

TITLE: Application of Remote Sensing to Improve Agriculture Censusing

DESCRIPTION: Crop signatures are being extracted on a per soil association basis. An early and late season analysis revealed four significant statistical stratifications of crops by soil association groupings. Purpose is to improve crop acreage estimation and ultimately yield prediction. Concepts are being tested across diverse terrains of South Dakota.

FISCAL YEAR, REPORT NO: FY 1977, 1978, 1979; SDSU-RSI-77-08, SDSU-RSI-78-14

COOPERATING AGENCIES: South Dakota Secretary of Ag., Crop Reporting District, and USDA Economics, Statistics, and Cooperative Service

DATA SOURCE: Landsat

OTHER FUNDING FOR PROJECT: ESCS is providing in FY 1979: 2 CCT's, data extraction and scene classification on the ILIAC system.

COMMERCIAL SPIN-OFF: Investigation in progress.

SOUTH DAKOTA STATE UNIVERSITY
REMOTE SENSING INSTITUTE

TITLE: Geohydrologic and Environmental Assessment of Six-Mile Creek Watershed

DESCRIPTION: Geohydrology and environment of the watershed is being evaluated for implementation of solutions to control sedimentation and flooding. Remote sensing objectives include selecting sites for drilling observation wells; evaluating water table depths, surface and subsurface drainage, soil moisture, and cropping patterns

FISCAL YEAR, REPORT NO.: 1979

COOPERATING AGENCIES: U.S. Soil Conservation Service, Huron, SD

DATA SOURCE: Landsat, low altitude photography and thermal imagery

OTHER FUNDING FOR PROJECT:

COMMERCIAL SPIN-OFF: Investigation in progress

SOUTH DAKOTA STATE UNIVERSITY
REMOTE SENSING INSTITUTE

TITLE: Pheasant Restoration Plan

DESCRIPTION: Pheasant populations have declined to very low level in South Dakota. The Pheasant Restoration Act was approved by 52nd session of SD Legislature. The goal is to develop 6500 acres of nesting cover and 500 acres of renovated shelterbelts. Winter cover will be mapped on Landsat imagery to aid in selection of nest plot site. The site will also be monitored on existing high altitude CIR imagery

FISCAL YEAR, REPORT NO.: FY 1979

COOPERATING AGENCIES: SD Dept. of Wildlife, Parks and Forestry, Pierre, SD. Ken Soleman, WPF, Huron, SD

DATA SOURCE: Landsat and high and low altitude aircraft

OTHER FUNDING FOR PROJECT: Matching manpower from WPF

COMMERCIAL SPIN-OFF: In progress

SOUTH DAKOTA STATE UNIVERSITY
REMOTE SENSING INSTITUTE

TITLE: National Model Implementation Program, Lake Herman Watershed

DESCRIPTION: This is one of seven water resource systems in the U.S. in the National Model Implementation Program. The pilot program tests and evaluates various water resources quality improvement methods. RSI is utilizing Landsat and aircraft data to interpret basic resource information.

FISCAL YEAR, REPORT NO.: FY 1979

COOPERATING AGENCIES: Lake Herman Development Association, First Planning and Development District, East Dakota Conservancy District, S.D. Dept. of Environmental Protection, SDSU Extension Service, USDA, ASCS, USDA, SCS, USEPA.

DATA SOURCE: Landsat and low flying aircraft

OTHER FUNDING FOR PROJECT: SCS, $3,400 for flight and interpretation

COMMERCIAL SPIN-OFF: Project just started

SOUTH DAKOTA STATE UNIVERSITY
REMOTE SENSING INSTITUTE

TITLE: Prairie Dog Management

DESCRIPTION: Aerial color infrared photography is being interpreted to locate prairie dog towns and determine the rate of growth. The imagery will be photomosaicked and a vegetation type map prepared at a scale of 1:15,840. Data will be used to prepare an environmental impact statement for prairie dog management plans.

FISCAL YEAR, REPORT NO.: FY 1979

COOPERATING AGENCIES: U.S. Dept. of Interior, National Park Service

DATA SOURCE: RSI low level aerial photography

OTHER FUNDING FOR PROJECT: National Park Service, $3,400.00

COMMERCIAL SPIN-OFF: Potential spinoffs are twofold: 1) a national preservation of endangered species habitat is being considered; this would include all prairie dog towns as habitat for the black-footed feret; and 2) a BLM contract is being sought which would include mapping of prairie dog towns as part of a resource inventory in Montana.

SOUTH DAKOTA STATE UNIVERSITY
REMOTE SENSING INSTITUTE

TITLE: Classification of Hydrophytes

DESCRIPTION: This project is designed to measure the spectral reflectance of hydrophytes during different phenological stages. The objective is to determine if reflectance differences occur between different species and at which phenological stage does maximum separation occur. If reflectance difference occurs it will be concluded that different species will appear differently on aerial photography.

FISCAL YEAR, REPORT NO.: FY 1979

COOPERATING AGENCIES: SDSU Dept. of Wildlife and Fisheries

DATA SOURCE: Exotech Radiometer

OTHER FUNDING FOR PROJECT:

COMMERCIAL SPIN-OFF: In progress