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Dr. Fred A. Schmer
Mr. Robert E. Isakson
Mr. Jeff C. Eidenshink

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57006

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16. Abstract

LANDSAT and aircraft remotely sensed data has been evaluated by participating South Dakota government agencies. A synopsis of the final results of the investigations are reported. The most successful analysis techniques are discussed. The cost effectiveness of LANDSAT data as a tool for resource management is provided.

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PREFACE

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

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INTRODUCTION

This report is of a LANDSAT Follow-On Project, NASA Contract NAS5-20982. The contents of the report are a synopsis of the final report. The report contains the findings of the three South Dakota governmental agencies involved: the Department of Natural Resource Development, the Game, Fish and Parks Department, and the State Planning Bureau. Remote sensing data and associated techniques have been studied. Emphasis has been placed on procedures which can be easily initiated using present state government financial and personnel restraints. The study site is the Belle Fourche River Basin in Western South Dakota. Results and conclusions reported herein include all aspects of the project.

PROBLEMS

Within the investigation of mapping aspen using digital LANDSAT data, an undetermined problem occurred in the classification. The problem was detected when two different size areas were rectified using DIRS and classified using K-Class, a software package used to classify the data. It so happened that a small area was common to both rectified areas. A comparison was made and it was noticed that the classification in the common area was different in each case. This was very distressing especially when one considers one of the major advantages of digital classification is the fact that supposedly a classification scheme can be used in an area of a scene other than the area in which it was developed, assuming the areas are spectrally similar. In this case it couldn't even be used in the same area. There is some information which possibly links the problem to the resampling procedure used within DIRS.

It is thought that when DIRS resamples, the radiance values of the pixels are changed. So the radiance value of a pixel depends on the location of the starting point of the rectification. It should be noted that the problem didn't occur in large homogeneous areas of aspen but rather in narrow strips of aspen. The resampling and changing of radiance values seemed to eliminate these areas in some instances and exaggerate them in others. However, it could not be completely determined whether the problem was DIRS or K-Class. The problem did prohibit a complete evaluation of DIRS and of the ability of LANDSAT data for use in aspen mapping.

One of the distinct advantages of LANDSAT data in comparison to more conventional data sources is its timeliness. For many studies, like aspen and general land use mapping, data delivery within six months to one year of collection could be considered "new" enough. However, for the more dynamic hydrologic basin conditions such as surface water fluctuations, the timing becomes critical and should be reduced to less than a week from date of imaging to date of delivery to users. A record was kept on the EROS Data Center standing LANDSAT orders. For 35 delivered orders, the average delivery date was eight weeks from the date of data collection. For current water resources monitoring in an operational situation, this would be an unacceptable turn-around time.

The NASA high altitude imagery was delivered approximately three months after data collection, again too late for operational water monitoring situations. Such a turn-around time is also unacceptable for many other resources management situations. However, it should be pointed out that contractual agreements with commercial firms would allow for collection and delivery of aerial photography as specified by the user.

ACCOMPLISHMENTS

Final Report

During this period each participating agency completed a report discussing their results. The reports are being combined into the draft final report. A complete preliminary draft report is now being evaluated by the agencies, with further comment and refinement being requested. It is anticipated that the draft of the final report will be sent to NASA by the end of March 1977.

Land Use

GF&P and DNRD are under a legislative mandate to provide resource inventories of each of the state's 16 river basins every four years. Detailed information regarding land, its use, and the spatial distribution of the various uses, is a significant input for these surveys. In addition, a state land use data base for use by all resource management agencies in South Dakota is being prepared by SPB. Therefore, land use was of primary interest to all project participants.

Historically, land use information has been obtained from a variety of sources including the Conservation Needs Inventory and the Crop and Livestock Reporting Service Reports. Usually such tabular data are subdivided into political subdivisions, such as counties, rather than hydrologic areal divisions, such as river basins. This results in estimating errors as the data are manipulated into a river basin or other status and does not provide important spatial information.

To assist in selecting an optimum LANDSAT data source for Level 1 land use mapping, available LANDSAT imagery was reviewed. A ten-township (83,279 hectare) area was selected for a concentrated study. Two dates of high altitude coverage and LANDSAT data for each of the months, May through November, were available. The June high altitude aircraft interpretations were used in interpretive comparisons with LANDSAT data.

Initial LANDSAT interpretations were conducted using the Bausch and Lomb Zoom Transfer Scope (ZTS) and a 27 July 1975 LANDSAT color composite transparency. Base map scales of 1:250,000 and 1:125,000 were used. The ZTS interpretations were time consuming, primarily because of the problems relating to the registration of the image to the base map. Another difficulty encountered using LANDSAT data interpreted from the ZTS system was spatial accuracy. As interpretations approached the edges of the field of view and then were re-registered to the next interpretive area, adjoining interpretation lines did not consistently align with one another. This specific problem was reduced somewhat at the larger 1:125,000 scale, but field of view was reduced fourfold. Consequently, the problem of registering to the base maps was increased at 1:125,000. For certain sections of western South Dakota, there are areas where no map-related landmarks are visible in a LANDSAT image for the ZTS field of view. These areas make accurate registration of a single township difficult and time-consuming. Based on these experiences, use of the ZTS-LANDSAT transparency combination is not recommended as a sole LANDSAT interpretive device for use by South Dakota state agency personnel in interpreting Western South Dakota for land use.

Interpretation of 1:125,000 and 1:250,000 print enlargements of the same transparency used in the ZTS evaluation were investigated. The results indicate increased accuracy to be available by interpreting at a scale of 1:125,000 versus 1:250,000. Aggregation of rangeland into agricultural land appeared to be alleviated by interpreting the 1:125,000 scale prints.

The spatial accuracy of 1:125,000 color composite print interpretations (as compared to June high altitude aircraft data) were calculated. Table 1 contains the accuracy information for seven months of growing season data. For each month listed, a variety of interpretations were conducted by RSI and agency personnel. The interpretations for each month's data were evaluated and that interpretation having the highest percentage of agricultural land interpreted as agricultural land, was selected to represent each of the respective months. Rangeland is interpreted as rangeland approximately 90 percent of the time; irrespective of time of season. Agricultural land interpretations are much more seasonally dependent. It appears, from the data in Table 1, that a prime date for interpreting agricultural land from LANDSAT for Western South Dakota is in the mid-June to July growing season and that the interpretations will provide adequate base data for resource management.

The interest in land use by SPB was focused on producing a Level I partial Level II land use inventory using LANDSAT CCT data. Analysis was attempted in the Butte County in which the northern part of the basin lies. The results were unsuccessful due to spectral confusion caused by the background soil radiance of the fingerlike extensions of claypan soils in the area (see Figure 1).

Level 1 land use is the most "course" form of land use information. Quite often more detailed data are required. An area called the "strip area," and located along Interstate 90 between Rapid City and Sturgis, was selected for a more detailed analysis. The strip is in a valley between the foothills of the Black Hills and the geologic formation called the Dakota Hogback. Because of the adjacent Hills area and easy access

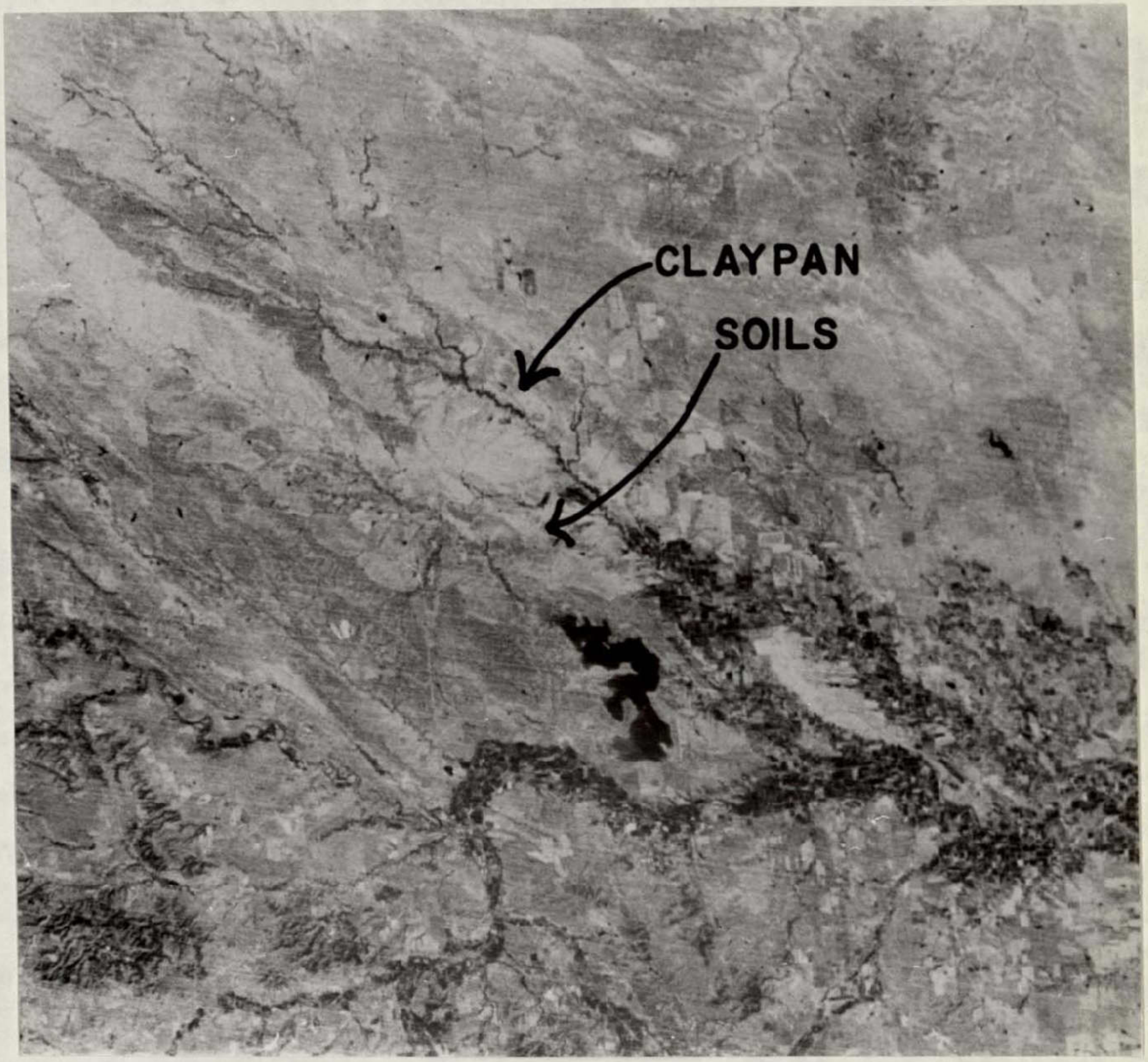

Figure 1. Portion of Butte County showing claypan soils which inhibit digital analysis.

TABLE 1. LANDSAT LAND USE INTERPRETATION BREAKDOWN (as compared to RB-57 ground truth) FOR BEST DATA IN EVERY MONTH.

Date	Ag. Land as Ag. Land	Ag. Land as Range	Range as Range	Range as Ag.	Avg. Accuracy $\frac{[A/A+R/R]}{2}$
24 May	84	16	84	16	84
12 Jun	84	16	94	6	89
27 Jul	84	16	91	9	88
5 Aug	73	27	92	8	83
1 Sep	68	32	89	11	79
Nov	52	48	93	7	73
Oct	40	60	96	4	68

to Rapid City, the state's second largest city, there has been a steady growth into the strip area itself and into the canyons of the foothills. Some homes are being built on unstable land; sanitary sewerage and water supply problems are compounded due to development location, and fire hazards are substantially increased as depth into the Hills increases and accessibility diminishes. A detailed land use inventory of development is desirable.

Obviously LANDSAT could not produce the house-by-house survey of urban development. Both high and low altitude aerial photography were gathered during June 1975 and were employed in the inventory. The basic scale for interpretation was 1:24,000. High altitude data were enlarged, using a ZTS, to match existing USGS Quadrangle maps of the area. The interpretation was coded onto mylar overlays on the appropriate 7 1/2 minute quad. A narrow portion of the strip area was covered by low altitude photography. This imagery was viewed stereoscopically to verify questionable high altitude interpretations. It was discovered that the high altitude photography did not offer adequate detail, within forested areas, to enable the accurate interpretation of certain housing sites. Much more accurate interpreting of these canyon and forest homes can be accomplished using stereo low-altitude photography.

For the first time, a land use map of the strip area has been developed. The map is the result of the SPB interpretation of June 1975 imagery. Such a base map, if periodically updated, will provide planning and zoning officials of both state and local governments an unequalled development monitoring capability.

Surface Water

The prairie areas of South Dakota have numerous small ponds which vary in size from small dugouts of less than half an acre to surfaces of over 10 acres. Wildlife indigenous to the area utilize these, incidental to the primary purposes of livestock water for which they were constructed. Therefore, the frequency and distribution of these water bodies have a bearing on the wildlife potential of the area. The relative permanency as well as the sizes, numbers, and distribution are important in monitoring total watershed water balance in an overall management program.

Initial work centered on a physical accounting of the numbers of bodies of water. A basin-wide interpretation of surface water was conducted using LANDSAT MSS7 transparencies, a 1:250,000 USGS Quadrangle map, and the ZTS. As previously stated, use of the ZTS results in significant registration problems when large areas are of interest. Enlargement to 1:125,000 on the ZTS was attempted but registration to the base map proved so difficult, in areas where LANDSAT-visible features are not recognizable on the map, as to preclude further work in this method of LANDSAT interpretation.

Evaluation of LANDSAT enlargement prints at various scales was made. The June color infrared, high-altitude interpretation was used as a comparative base (i.e. ground truth). The inventory for all LANDSAT print interpretations was less than the June high altitude aircraft interpretations and in no case exceeded 75 percent. This result is in terms of total numbers and not total surface area.

It was assumed that the small water bodies were causing the relatively low LANDSAT interpretations. Therefore, a more detailed interpretation, categorizing surface water into those equal-to or less-than the basic LANDSAT cell area (1.1 acres) and those greater-than the basic cell, was accomplished. Base data for this detailed surface water study were interpreted from black and white, near infrared, prints as enlarged from high altitude 70 mm film. Ground surveys of selected sections within the study area convinced participating agency personnel that use of such imagery for base data is warranted.

The interpretation resulted in the detection of 146 individual water bodies within a small test site. Table 2 lists the inventory data for this smaller area. The registration difficulties previously referred to, regarding 1:250,000 interpretations from the ZTS, are reflected in the high percentage of water bodies interpreted as water but (over one-third of the interpreted water) not actually water.

TABLE 2 DETAILED SURFACE WATER ANALYSIS.

Data Source	Data Date	Scale	Total No. Water Bodies	Percent of Total Which Is Not Water	Percent of Base Data Interpreted	
					≤.45 ha (1.1 acre)	>.45 ha (1.1 acre)
					Base Data	
High Altitude Black and White Print	25 Jun 75	1: 24,000	146	0	100	100
High Altitude Color IR Transp.	25 Jun 75	1:114,506	113	8	49	98
LANDSAT MSS7; ZTS	12 Jun 75	1:250,000	90	36	5	82
LANDSAT MSS7; Print*	24 May 75	1:125,000	93	22	17	81
LANDSAT MSS7; Print*	12 Jun 75	1:250,000	59	13	4	75
LANDSAT MSS7; Print*	12 Jun 75	1:125,000	85	23	10	83
LANDSAT MSS7; Print	27 Jul 75	1:125,000	38	8	1	52
USGS Quadrangle Map	1953	1: 24,000	119	24	55	70
ASCS Mosaic; Print (Photo Index)	Jun/Jul 68	1: 65,985	100	23	31	77

* Average of three interpretations

Also, an evaluation of LANDSAT CCT data was made. The analysis was performed by SPB using software developed in house. The date of imagery used was July 27, 1975. The accuracy obtained was nearly identical to that obtained from visual interpretation of a 1:125,000 MSS7 print for the same date.

The effect of the time of year of data collection is again revealed in that the May and June "over .45 hectare" interpretations are in excess of 80 percent of base data, while late July data allows inventory of 52 percent of the same base data. Climatological data substantiate the resulting lower July interpretations. In other words, both year and time of year of data collection are very important in the interpretation of surface water inventories.

Comparison of LANDSAT interpretations with 1:24,000 USGS Quadrangle maps reveals an important observation. In all but one LANDSAT interpretation (late July, for reasons discussed above) the larger water bodies were more accurately mapped using LANDSAT imagery than could be accomplished using existing USGS maps. Fully 73 percent of South Dakota is either unmapped at 1:24,000, or is mapped by 15-year old or older maps similar to those used in the above illustration.

Present agency procedure uses USDA ASCS photography for surface water inventories. Interpretation from the USDA ASCS photograph resulted in 77 percent identification of water bodies over .45 hectares. Interpretations of LANDSAT data produced "above 77 percent" figures in both the May and June 1:125,000 interpretations. The ASCS data were more accurate than LANDSAT for interpreting the less than .45 hectare water bodies. The apparent resolution of the imagery is offered as explanation.

The descrepancies between LANDSAT and ASCS interpretations of greater than .45 hectare water bodies might be the result of interpretive variabilities, the fact that the ASCS data are nearly ten years old, and the fact that part of the ASCS imagery was collected in July, a potentially dry period.

Drainage Systems

Of primary need in a basic hydrologic inventory of a river basin is development of accurate surface drainage information. Such data are important in watershed modeling, runoff predictions, and monitoring non-point pollution.

An accurate drainage map of the basin was not in existence, so an effort was put forth to develop and demonstrate a procedure to produce such a map. The basic premise was to work from available 1:24,000 USGS Quadrangle maps and upgrade this information using remote sensing. Where USGS maps were not available, all information had to be obtained from high altitude aerial photography and temporal (winter and summer) LANDSAT imagery.

For areas where no aerial photography or maps are available, drainage information was obtained from a combination interpretation of winter black and white and summer color composite LANDSAT prints. The winter scene accentuates certain drainage features via the combination effects of snow cover and sun angle. In very flat areas, the winter data are difficult to interpret. For these areas, the color composite provides drainage indicators such as vegetation along streams and soil erosion signatures. A combination of the two seasons allows for the generation of a LANDSAT-based drainage map in areas devoid of other data.

The interpreted drainage data from various sources were photographed and printed to the same scale for preparation of a controlled network mosaic. The mosaic was then re-drafted into the final drainage map. This was the first complete detailed drainage map available for the basin. This procedure is presently being used on an operational bases to develop surface drainage information for other basins in South Dakota.

Rangeland Use

Hundreds of thousands of acres of Missouri River bottomlands were inundated due to the construction of the Oahe and Big Bend Dams in South Dakota. The U.S. Army Corps of Engineers was to identify the best plan to mitigate wildlife habitat losses incurred through the submergence of these bottomlands. The South Dakota Department of Game, Fish and Parks was designated to provide wildlife management plans to the Corps of Engineers for the potential migitation lands. LANDSAT satellite imagery and aircraft imagery were used in the evaluation of one of these mitigation areas (see Figure 2).

Through a combined RSI and GF&P effort, remote sensing data were employed in a time-restricted (3 days) planning session. Primary data sources were LANDSAT and low altitude black and white (red filter) mosaics of the area. Data, visually interpreted, included surface water (multi-date analysis allowed for determining relative permanence) and land use within the proposed mitigation area and a surrounding 170 square mile area. From such data and soil association information previously obtained via LANDSAT interpretation, GF&P personnel developed a wildlife management plan. It is questionable whether any other source of data could have provided the extent of data interpreted from LANDSAT imagery.

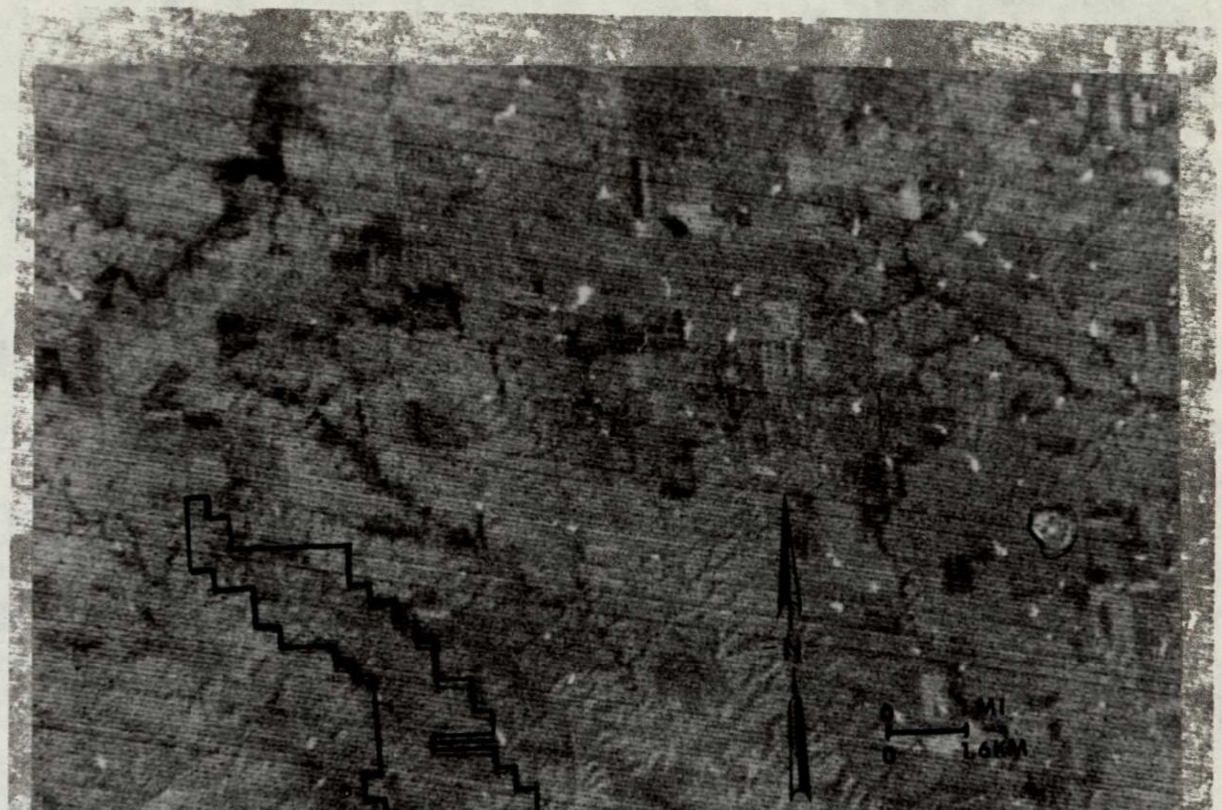

Figure 2. Proposed boundary of mitigation land as transferred to LANDSAT MSS7 of 26 Jul 75.

Floodplain Delineation

Floodplain analysis is of interest to water resource management and land development activities. Through the aide of data collected during this project, the SPB was able to evaluate the usefulness of remote sensing data in delineation of flood plains. The study site included the Belle Fourche River and Redwater Creek confluence near Belle Fourche, South Dakota. The site was selected because there is a city within the flood areas of these two river systems and USGS maps were available.

Visual interpretation of a high altitude 9" transparency was conducted using a ZTS in conjunction with a 1:24,000 USGS Quadrangle map. One interpreter mapped floodplain from the aerial photography registered to the map, and a second person interpreted floodplain boundaries using standard procedures from the contour map of the area.

In areas of steep slope, both interpretations were in agreement in the location of the floodplain. In areas of gentle slope, there were considerable differences in location. It was found that an interpretation of only contour lines resulted in difficulty when the contour interval was 10' or more and the distance between contour lines approached 1,320' (440 m). In such areas, high altitude imagery proved most useful. The interpreter is able to use various surface-related signatures such as soil types, vegetation differences, and the effects of previous floods. It is felt that optimum floodplain mapping can be obtained by using both data sources complementary (see Figure 3).

Water Quality

Considerable effort was expended in ground truth data collection for water quality studies. At sites located throughout the basin, DNRD and GF&P personnel coordinated ground measurements of pH, color, turbidity, transparency, and temperature.

Standard methods in existence provided very good data, however, they also incur considerable time and expense. The interest in applying remotely sensed data was not to replace existing standards but to identify the potential of its applicability.

It is important that water quality ground truth measurements be made as concurrent as possible with overflights. A major problem occurred in coordinating the NASA missions with ground truth. Several times when agencies were notified that the flight was to occur, the mission was cancelled due to weather conditions. With ground truth data collected, a period of three months passed before the high altitude data was received. In most water quality monitoring programs, such a delayed delivery would be unacceptable and it caused considerable apprehension by agency personnel in the potential use of the data.

The review of imagery indicated to participating agencies that water quality parameters are not easily interpreted from aerial photography. Certain types of data of interest to the various state agencies (pH, temperature, dissolved solids, BOD, COD, etc.) are not directly visible in water. Some studies have shown that, under certain conditions, these parameters can be statistically related to film densities. Such variances are most likely based on interwoven relationships between the "invisible parameters" and the visible (turbidity, suspended solids, algae growth) water quality constituents which can be recorded on film. Establishment of such relationships requires extensive ground truth data collection. Vignetting, sun angle effects, and extensive ground

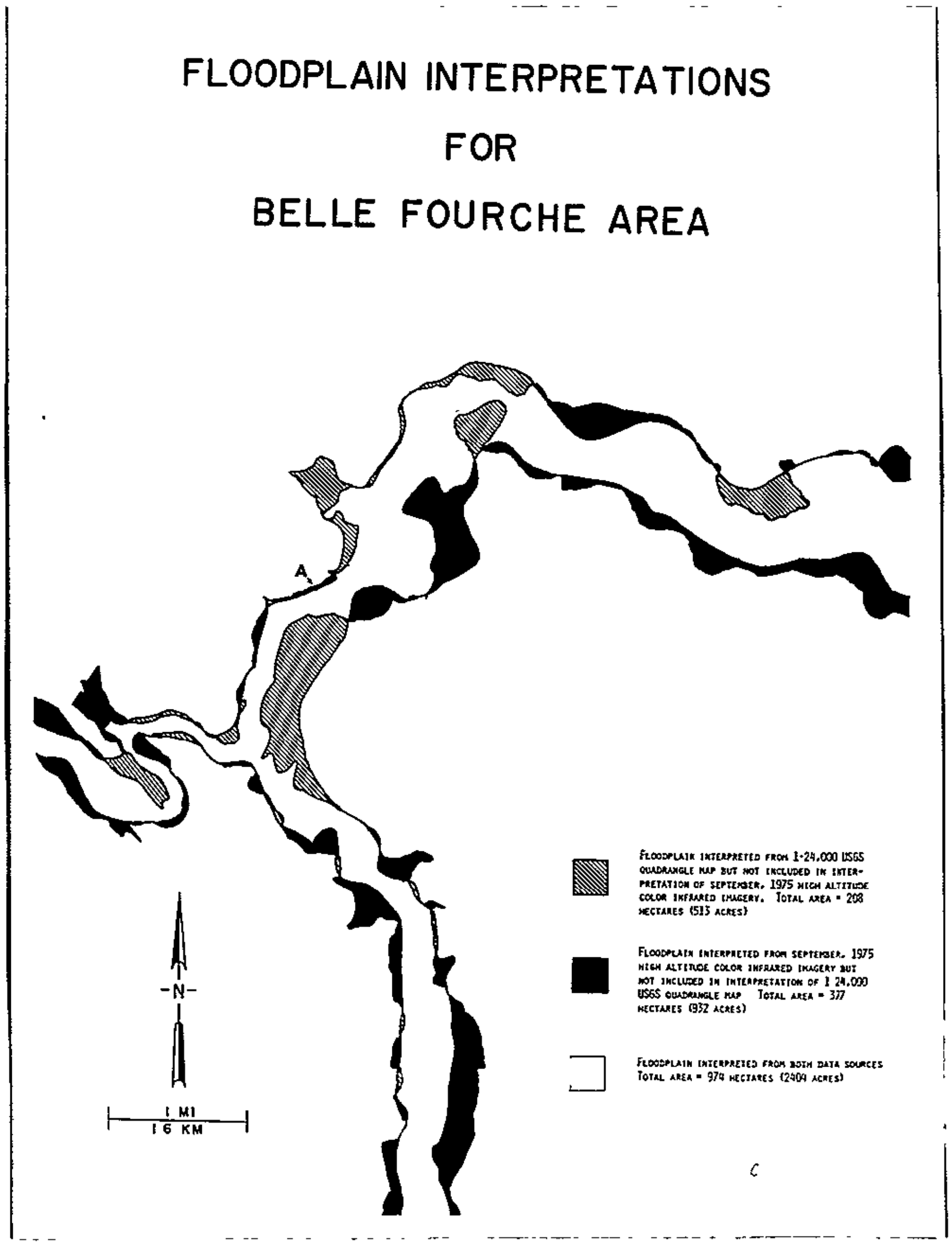

Figure 3. Flood plain interpretations for the Belle Fourche Area.

truth requirements, indicated that the operational use of such data collection methods was impractical for Western South Dakota at this time.

Canal Seepage

Remote sensing of water and wet/dry boundaries would appear to be an ideal method of detecting and monitoring canal leaks and/or breaks by utilizing a change in wetlands or vegetation cover adjacent to the waterways as indicators. This effort was designed to examine the potential for detecting leaks in a canal system via standard remote sensing techniques.

Neither high nor low altitude June imagery was of exceptional value as water was just beginning to enter the canal system. By September, the canals had been flowing full for about four months. Ground surveys located a seepage area. Standing water, approximately 15 cm deep, and cattails were present in this area. Ground level inspection of this and other seepage areas did not ensure that the wet areas were due to canal leaks, but verbal confirmation from a local irrigation district worker indicated a probability that the seeps were canal-fed.

In the seepage areas, wetlands-type vegetation predominated the standing water areas. A trained interpreter might be able to recognize such wetland areas on low altitude color infrared imagery, given enough basic research of the area to train himself. From a presently operational standpoint, it does not appear that simple photo analysis by relatively untrained interpreters can detect canal leaks from a color infrared film for this area. Possible greater attention to data timing and use of thermal data would allow for more easily interpreted data.

Crop Identification and Irrigation Delineation

Crop identification in an irrigation district is of particular interest to water resource planners to allow estimation of water requirements. The major cropping area within the Belle Fourche River Basin is that within the Belle Fourche Irrigation District. Initial efforts concentrated on obtaining ground truth data from which to base subsequent crop identification analysis. Ninety-one field areas within a low altitude flight line were inspected. The field patterns were easily identified on the June and September low altitude aircraft imagery, but visual identification of crops was not successful. Without the benefit of time-sequential data, crop distinction becomes very reliant upon the date of data collection. Apparent resolution of low altitude data might allow distinction of certain crops by observing cultivation patterns, etc. Even then, extrapolation of such interpreted data to basin-wide coverage would induce estimating errors similar to those already present in tabular data.

June, high-altitude data over this test area was cloud-covered, rendering it useless, and the September, high-altitude data is too late in the growing season to be of value as a single data source.

LANDSAT data were available over the test area for the months of May through October. Color composite print enlargements were visually interpreted to observe interpretable changes in reflectance patterns that might be indicative of crop types. It was obvious that differences exist as the growing season progressed but delineation of all but the larger fields was impossible.

Computerized data handling was then investigated. The ground truth areas were extracted and rectified. A histogram of LANDSAT CCT MSS data allowed selection of shade-print levels to maximize contrasts in line printer maps. More fields were identified on this form of LANDSAT data; however, of the 91 ground truth fields, only 18 were successfully located on the LANDSAT printouts of July and September. Doubts existed in the location of potential training fields and further analysis was not conducted. In theory, if sequential CCT data were used in conjunction with overlay capabilities, each field could be automatically monitored throughout the growing season for prediction of crop type. The procedures involved appeared to require considerable research and development. The system, therefore, was not considered as a presently operational method.

Before irrigated fields can be identified, it is necessary to identify crop cover and then compare dry-land and irrigated reflectance differences and this technology is certainly not an available operational procedure.

Aspen Delineation

The South Dakota GF&P Department is involved in studies of the management potentials of Black Hills Aspen. For the past two years, GF&P has addressed the potential for improving the habitat available for ruffed grouse through experimentally-prescribed cutting designed to remove decadent aspen stands and generate a new cycle of aspen growth. Department personnel have also been involved in a research study which is evaluating aspen as a livestock feed supplement. Preliminary conclusions indicate that aspen could serve as a major feed component. Knowledge of the location of harvestable aspen and monitoring of harvesting activities on a regular basis, would be required for proper management. Therefore, to commercially launch this or any other use determined as potentially feasible, a reliable inventory of the aspen resources is needed.

Initial inventorying efforts centered on distinguishing between coniferous and deciduous trees. Visual interpretation of high altitude photography proved feasible but was very time consuming. Visual interpretation of 1:250,000 winter LANDSAT prints was more difficult. It was assumed that in a non-forested area the tree canopy would block reflectance of snow-covered, non-forested areas allowing for a visual interpretation of the forested areas. Negative prints were chosen for the interpretation as they are one step closer to the original, and interpreters usually prefer to map the white "highlighted" forested areas as opposed to the normally dark forested areas. With cross-referencing to high altitude aircraft imagery, the interpreter was able to distinguish forested, mixed, and non-forested areas. Distinction between coniferous and deciduous trees was expected from superimposing the winter interpretation on a summer LANDSAT color composite. However, the winter interpretation superimposed over the summer data revealed tonal differences indicative of forest density in addition to type and it was not possible to distinguish deciduous trees satisfactorily. In addition, visual distinction between known aspen areas and areas of thin pine with a thick grass undergrowth was extremely difficult.

Digital analysis of LANDSAT Computer Compatible Tapes (CCT's) of the 27 July data was then considered as a possible method of allowing distinction between the various reflectance signatures. A representative area was selected from high altitude aircraft imagery and the approximate

CCT pixel coordinates for the sample area were determined. Initially, data were removed from the tape and displayed via the line printer. Comparison of this "raw" data with aircraft imagery was conducted in an attempt to manually select CCT reflectance levels which would correspond to grass, pine, and aspen. A level was selected for each of the three classifications and a line-printer map was generated. Visual inspection of the level-sliced data revealed that excessive amounts of grass and thin pine were being misclassified as aspen.

An RSI classification program called "K-class" was then employed to determine if a statistical relationship could be developed using multiple MSS bands and selected training areas. Training areas of pine, thin pine, aspen, and grass were designated from high altitude aircraft imagery and selected ground truth. The area included sufficient samples to allow K-class to classify the data into the three basic categories of pine, aspen, and grass. The K-class processing of CCT data produced an apparently more reliable classification with less confusion between thin pine, grasslands, and aspen.

Mid-summer is not an optimum time for the collection of data to be used in aspen interpretation, as the differences between aspen and grasslands are relatively subtle. The July data were processed because of availability and to test procedures involved. Comparison of the June and September high altitude aircraft imagery shows that while aspen are interpretable from both, the distinction between aspen and grass is much more pronounced in the September data than in the June data. In September, the grasses have apparently dried and reflect considerably less than is the case in June. However, the aspen leaves are still as "green" in early September as in June. The distinction between grass and aspen is therefore, enhanced. A cloud-free September 1, 1975 LANDSAT scene (2222-16595) over the Black Hills provided an excellent opportunity to evaluate the later data.

Aspen, mixed aspen-pine, grass, and pine training areas were selected by reviewing high altitude imagery and selected ground truth information. With K-class trained, digital interpretations were conducted on three townships.

Visual interpretations of all three townships were conducted at 1:24,000 on the ZTS. To assist in evaluating the various data sources, all maps were reduced to the scale of U.S. Forest Service Type 1 Maps (1:32,000). Visual "analog" interpretations were manually converted to a cellular base of 1 acre cells for direct comparison with LANDSAT data. Comparisons were conducted using June high altitude aircraft imagery as the data base and are reported in Table 3.

TABLE 3. ASPEN CLASSIFICATION ACCURACIES AS COMPARED TO JUNE HIGH ALTITUDE AIRCRAFT VISUAL INTERPRETATIONS.

Source	Percent Aspen as Aspen	Percent Other as Other	Percent Average
T4NR2E:			
LANDSAT	49	92	70
USFS	34	97	65
T5NR2E:			
LANDSAT	62	84	73
USFS	--	--	--
T4NR5E:			
LANDSAT	45	97	71
USFS	41	95	68

There is a difficulty in measuring the accuracy of LANDSAT CCT interpretations (3). Because of the human factor in visual high altitude aircraft interpretation, areas of mixed aspen-pine are not easily interpreted with consistency. In areas of heavy pine, a mixed area might not be interpreted the same as if it were located in areas of solid aspen or grass. Comparisons between LANDSAT and high altitude aircraft interpretations would reveal these inconsistencies but it was felt that re-interpretation by the same interpreter would be too biased to be of any value. Selection of ground-studied, K-class training areas (with input from GF&P to allow accurate identification of training areas) and identification of the training areas by latitude and longitude would allow for further refinement of mapping procedures and would offer permanent "benchmark" areas on which to base subsequent aspen monitoring effects.

Information System

One of the major benefits of using remote sensing as a natural resource data source is the ability to extract data over large areas. Use of LANDSAT expands single-frame coverage to the immense areas of almost 3.5 million hectares (8.5 million acres). When the added dimension of temporal coverage is included, the potential amount of resource data can easily overwhelm conventional data storage/manipulation techniques.

Considerable effort was expended in the evaluation of entering remotely-sensed, and other resource information into a computer-based information system. MAPCLASS, as the program is called, allows for the manual coding of change-points into a data base rather than coding every cell in a grid system. The program also allows the computer to "overlay" and manipulate numerous data combinations entered into the data base. Output, via plotter, allows generation of maps at user-specified scales.

The grid input configuration can be based on any one of a variety of coordinate systems. South Dakota is subdivided into townships by a range/township ground survey. Because the nomenclature is widely used and understood, the decision was made to evaluate a data-base grid system using range and township lines as control. The basic cell size of 16.2 hectares (40 acres) was selected because it is small enough to obtain desired detail but large enough to keep digitizing times reasonable. A digitizing 40-acre grid system was generated using the CALCOMP plotter and associated software. Data coding consisted simply of obtaining desired data at a scale to match the digitizing grid, or generate a grid to match the data, and record the grid row and column number of change points in the data.

Cost Effectiveness

Certain basic assumptions were made to conduct a cost effectiveness study. High and low altitude aircraft flight altitudes were assumed as 60,000 feet and 10,000 feet respectively. Flight line side overlap was assumed to be 30 percent and stereo overlap as 60 percent. Labor estimates of $112 per day (including indirect costs) were used. Cost estimates for data collection, materials, equipment, and other variables were estimated, based on data gathered throughout this study. Another assumption basic to this analysis is that of single use of data. Proper coordination might permit a user to contract for a flight or purchase LANDSAT data and use the acquired data for more than one particular survey.

In addition to the various remote sensing data sources, ground surveys and present methods of data extraction were included in the analysis. In terms of visual interpretation, costs were calculated for: 1. transparency interpretation including new equipment costs (e.g. light table), 2. transparency interpretation without equipment costs, 3. print interpretation with a mosaic, and 4. print interpretation without a mosaic. A ground survey was not considered practical in the mountainous Black Hills area and was not included as an aspen data source. The present source of land use data is tabular data prepared by other governmental agencies requiring minimal processing for most applications. Surface water is presently mapped, using ASCS photo index sheet interpretations. U.S. Forest Service type maps are available for portions of the Black Hills at no cost.

For Level 1 land use, surface water inventories, and aspen mapping, costs were calculated for an interpretation at 1:125,000, encompassing an area like the Belle Fourche River Basin. The data were then reduced to a cost-per-township basis and are listed in Table 4. Cost analyses for the other application areas are being prepared but are not presently completed.

In terms of a strictly cost-per-township basis, present methods are the most "economical" for land use mapping. However, the added cost for a LANDSAT interpretation is deemed cost-effective in terms of the added information obtained. While LANDSAT surface water interpretations are less costly than present inventory methods, it is felt that the inability of LANDSAT to detect water bodies down to .5 acre in size prevent it as

TABLE 4. COMPARATIVE COSTS IN DOLLARS FOR VARIOUS SOURCES OF BASIC RESOURCE MANAGEMENT DATA.

Source	TRANSPARENCY		PRINT		Other
	With Equipment	Without Equipment	With Mosaic	Without Mosaic	
LANDUSE					
High Altitude Air. *	134	124	125	128	--
Low Altitude Air.	210	200	353	313	--
LANDSAT Color Comp.	33	3	4	6	--
LANDSAT CCT	--	--	--	--	31
Ground Survey	--	--	--	--	179
Present Method	--	--	--	--	1
SURFACE WATER					
High Altitude Air.	128	118	119	120	--
Low Altitude Air.	201	191	237	227	--
LANDSAT MSS7	32	2	1	3	--
LANDSAT CCT	--	--	--	--	5
Ground	--	--	--	--	179
ASCS (Photo Index)	--	--	4	4	--
ASCS (1:7,920)	--	--	46	80	--
ASPEN					
High Altitude Air.	196	190	150	206	--
Low Altitude Air.	296	283	368	383	--
LANDSAT CCT	--	--	--	--	55
Ground Survey	--	IMPRACTICAL APPROACH		--	--
U.S. Forest Service*	--	--	--	--	No Cost

* Limited Availability

being a viable tool. LANDSAT aspen mapping is a fairly expensive procedure (in comparison to land use and surface water mapping) because of the considerable computer analyses required. However, such costs remain one-third of those of the next viable alternative.

FUNDS EXPENDED

Total funds expended through November 31, 1976: $141,795.77. This does not include costs incurred by state agency participants as they invoice on a quarterly basis.

DATA USE (as of November 31, 1976):

Value of Data Allowed - $15,144.00

Value of Data Ordered - $11,316.00

Value of Data Received - $11,316.00

CONCLUSIONS

Successful operational applications of LANDSAT data were found for Level 1 land use mapping, drainage network delineation, and aspen mapping. Visual LANDSAT interpretation using 1:125,000 color composite imagery is the least expensive method of obtaining timely Level 1 land use data. With an average agricultural/rangeland interpretation accuracy in excess of 80 percent, such a data source is considered the most cost-effective of those sources available to state agencies. The costs do not compare favorably with those incurred using the present method of extracting land use data from historical tabular summaries. Participating agencies agree that the cost increase in advancing from the present procedure to a satellite-based data source is justified in terms of expanded data content. Use of visually interpreted temporal LANDSAT imagery can substantially improve the drainage knowledge of unmapped or poorly mapped areas of the state. Digital analysis of LANDSAT CCT data represents the most economical of the evaluated remote sensing aspen mapping procedures. Again, the presently available U.S. Forest Service typing maps are less expensive; however, in terms of providing the type of inventory/monitoring capability required by GF&P, such maps are considered as having very limited use. Surface water inventories are presently conducted by DNRD personnel visually interpreting ASCS photo index imagery. The cost of using LANDSAT data is one-third that of existing procedures, but LANDSAT data does not produce the required inventory detail (.5 acre minimum resolution desired) to allow incorporation as an operational inventory tool. At substantially increased costs, detailed surface water inventories can be accomplished using aircraft platforms. Irrigation canal leakage detection offers a potential application based on a proposed use of an airborne thermal scanner. MAPCLASS and its peripherals offer state agencies a powerful yet flexible method for storing and manipulating the varied resource data required for a complete inventory/monitor package.

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