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PINTAILS AND PIXELS: A POTENTIAL APPLICATION OF LANDSAT TECHNOLOGY TO WATERFOWL HABITAT INVENTORY

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I. ABSTRACT

An integrated resource inventory program involving Ducks Unlimited (Canada), Purdue University (LARS), Interdisciplinary Systems Limited (Canada) and the Canada Centre for Remote Sensing is described. The objective is to test the feasibility and operational capability of applying over a wide area, Landsat data classification techniques in order to identify, map and measure the areal extent and relative quality of waterfowl breeding habitat, primarily in the Prairie Pothole Region of Canada.

Ducks Unlimited (Canada) is a private, non-profit conservation organization dedicated to preservation of wetlands in Canada. The Prairie Pothole Region of the southern prairie provinces is the focus of our efforts. Because of its abundance of wetlands, its well documented importance to breeding waterfowl, and because habitat there is endangered by outright loss or at least significant degradation. An up to date and comprehensive inventory of wetlands is required to assist DU in the planning and budgeting phase of our reconnaissance and development programs.

The program is designed to provide maps at scales of 1:250,000 and 1:50,000 on which all wetlands over 25 ac (10 ha) in size are located. Maps are to be registered to and capable of directly overlaying existing NTS mapsheets. Tabular output will include a table of wetland statistics which will locate individual wetlands (UTM reference), and provide an area estimate. For wetlands 25 ac or greater in size, acreages of various wetland zones will be indicated as well as an estimate of shoreline distance. Summary statistics will be provided for each mapsheet which provide a breakdown of wetlands according to size classes, providing number in each class, total acreage and acreages of the various zones.

II. INTRODUCTION

The purpose of this paper as a lead-off to this session on wetlands is threefold. It will describe as the title suggests, a potential application of Landsat data and computer assisted processing to the special requirements of a private company. It will outline the nature of those needs and will explain why Ducks Unlimited (Canada) is involved in this exciting field. Lastly, it will describe the uses to which DU plans to put the results initially as well as possible future applications.

The study is an integrated resource inventory program involving the participation and expertise of Ducks Unlimited (Canada) biologists, staff of Purdue University's Laboratory for the Application of Remote Sensing, Interdisciplinary Systems Limited (Canada), and the Canada Centre for Remote Sensing. The objective of the program is to test the feasibility and operational capability of applying over a wide area, Landsat data classification techniques in order to identify, map and measure the areal extent and relative quality of waterfowl breeding habitat, primarily in the "Prairie Pothole Region" of Canada.

A. THE AREA

The "Prairie Pothole Region," otherwise known as the northern prairies or Great Plains, extends from South Dakota north to the Boreal forests of Saskatchewan and Alberta. It covers an area of approximately 240,000 square miles in its narrowest definition including mixed grass prairies and the parklands.[1] In a vegetative sense, the region should also include tall grass and short grass prairie associations and would therefore include portions of Minnesota, Nebraska, and Montana and cover some 460,000 square miles.[2] We are concerned with the mixed prairie (grassland) – aspen parkland portion of the Prairie Pothole Region of Canada plus portions of the mixed woods transition between aspen parklands and coniferous or boreal forest.[3] These generally correspond to recently elaborated Mid-Boreal Wetland Region (Transitional Mid-Boreal Wetland District), and Prairie Wetland Region (Aspen Parkland and Grassland Wetland Districts) as proposed by the National Wetlands Working Group.[4]

This area, particularly the pothole region of Canada is extremely important to waterfowl in that approximately 50% of all breeding ducks in North America attempt to breed there each year despite the fact it comprises perhaps only 10% of the breeding range.[2,5,6] The primary reasons for this importance are its general fertility and glacial history which produced numerous depressions on the landscape, perhaps as many as 10 million.[7] These depressions are variable in size, distribution and depth and a variable number hold water depending on the year or season. Anywhere from six million to about 1.5 million hold water each May but this number shrinks to between five million and 561 thousand by July, the actual number of which depends on precipitation in any given year.[8] This loss of water areas is more pronounced in grassland associations than in the aspen parklands.[2]

There is a strong correlation between waterfowl production from the region and total waterfowl production on a continental basis (see above). As well, 60% of the variability in annual fall population estimates for mallards can be attributed to the number of mallard young produced in grassland associations of the Prairie Pothole Region.[2] Further, there have been shown strong correlations between mallard production in the region and the factors, number of May ponds, number of breeding pairs and number of July Ponds.[8] It is likely the same general relationship holds for other duck species as well.

B. DUCKS UNLIMITED'S INTEREST IN THE AREA

As a private, non-profit conservation organization Ducks Unlimited (Canada) is dedicated to the preservation and improvement of wetlands, primarily because of their obvious importance to the waterfowl resource. As a result of reductions in waterfowl habitat and populations during the 1930's, Ducks Unlimited Incorporated, a U.S. Company, and Ducks Unlimited (Canada), a Canadian sister organization, were formed. Ducks Unlimited Inc., through contributions from sportsmen and other conservation minded individuals and organizations, raises funds with which to finance the securing and preserving of wetlands, primarily in Canada. Ducks Unlimited (Canada), operating independently but using funds provided primarily by DU Inc., has over the past forty-three years placed under agreement or easement approximately 2.6 million acres of Canadian wetlands. It is primarily because of this dedication to wetland preservation and of the fact the Prairie Pothole Region is the key to waterfowl production on the continent, that DU (Canada) concentrates work in the prairie and parkland regions of Canada.

Although there are differences of opinion regarding the relative importance of factors which are responsible for the steady decline in waterfowl populations, one major factor has been outright loss of breeding habitat coupled with alteration and degradation of what remains. The Prairie Pothole Region once produced 15 million

ducks annually but now produces less than one-third of that.[1] The main reason for the decline is said to be drainage of wetlands followed by destruction of upland cover by intensive cultivation of lands adjacent to potholes. Loss of wetlands from pristine times in the U.S. has been well documented with only about 50% of an original 127 million acres remaining. Those remaining are said to be vanishing at a rate of 200-300,000 acres annually.[1,9,10] Documentation of the rate of wetland loss in Canada is lacking but has been less. A minimum of about 13.6% of the original acreage and 6.4% of the number of wetlands had been lost by 1970.[1,11] Recent years have seen an acceleration in this, particularly in the recent dry years. For instance, in 1979, over 80% of all basins in a study area in Saskatchewan encompassing 126 quarter sections spread over four waterfowl strata were impacted by cultivation, drainage, filling and or breaking.[12] Much of this was temporary but all can and often do lead to eventual permanent loss.

As an organization attempting to preserve and/or stimulate the preservation of Canadian Wetlands, there is an urgency about getting on with the job and focusing on the prairie region. If we are to play any part in reversing the trend and in ensuring that Canadian Wetlands don't go the way of many of those in the U.S., a great deal must be done in a short time.

C. THE NEED FOR LANDSAT AND COMPUTER ASSISTED INVENTORY

Landsat data provide broad areal coverage and are amendable to machine processing and storage. The volume of data required to inventory the overall area of interest precludes any other method of comprehensive data acquisition and analysis.

Landsat data providing complete coverage of the entire area over a span of weeks are potentially available from as short a time ago as 1980. This is particularly important because current information is required. The greater the rate of change in a resource base, the greater are the problems in monitoring and planning management of the resource.[13] As noted above, wetlands are highly variable on annual and seasonal bases and are also being modified and/or destroyed at an unknown rate. An up to date, broad scale, repeatable data base is required and can only be provided by Landsat.

The costs associated with an inventory using Landsat data are potentially much less on a unit area basis than the use of conventional aerial photography. The results using Landsat should be available sooner even in view of the present lag between acquisition and production. However, once the system is operational it should be easily and quickly repeatable using other data sets.

III. THE PROCESS

Data being used for this program are Digital Image Correction System (DICS) subscenes acquired from The Canada Centre for Remote Sensing (CCRS) in Ottawa. These are geometrically corrected and registered to NTS base maps with lines of image data parallel to the easting direction. Each DICS has a dimension of 56 km by approximately 85 km and corresponds to one quarter of a 1:250,000 scale NTS mapsheet.

The selection of specific scenes and subscenes is based on three main factors: date of imagery, a general evaluation of habitat conditions, and data quality. Data from late June to early August in the years 1979, 1978, 1976 and 1974 (in that order of preference) were analyzed for the degree to which they offered cloud free conditions (less than 10% cover) and freedom from scanner related distortion. Scenes meeting these general requirements are selected first from 1979, then from earlier years, if necessary.

Once data are received at LARS, DICS are converted to appropriate LARSYS format and the four DICS tapes comprising a particular NTS mapsheet are copied to one 9-track 1600 bpi tape and filed.

It is not the purpose of this project to type wetlands, but the enumeration and mapping requires that wetlands be differentiated from other features or vegetation associations in the environment. As well, indications of wetland quality (with regard to utility for waterfowl use) and wetland permanence can be inferred from the number and nature of zones within the wetland. Thus, rather than simply concentrating on water areas, we are attempting to differentiate and classify major wetland zones including wetmeadow, shallow marsh, deep marsh and open water. There are well established ecologically significant zones which are indicators of size, permanence and recent water regimes in wetlands.[14,15] Classification of features in the uplands is also necessary to eliminate confusion of wetland zones with vegetation associations in the uplands.

The actual classification procedure involves "training" of the classifier using ground truth information or reference data in the form of maps, air photos (usually small scale colour IR), cover maps and other habitat reports from selected areas representing different physiographic areas (eg. Minnedosa pothole country or Tiger Hills region in Manitoba).

Initially, training areas covering 100 or more square miles were selected, grayscale picture prints showing 10 signature classes produced and specific "cluster sites" selected from within the larger area. These cluster sites are centered around an area for which good ground truth data are available. "Clustering" proceeds in order to identify as many distinct and separate classes of vegetation-water associations as possible, and as

well provide a good match to ground truth data. All four MSS channels are used in this procedure in order to develop training or classification statistics from several cluster blocks or training sites.

LARS has developed a classification program or classifier called AUTOLEVELS to do this work. AUTOLEVELS works with training statistics by defining the class mean plus or minus three standard deviations in each channel. The program identifies channels in which classes exist with no overlapping data values. Each pixel is tested to meet the classifiers criteria for each of the classes identified during training and is assigned to one of them. Since AUTOLEVELS does not use complex statistical measures (such as maximum likelihood methods) to identify class membership, it is four to ten times quicker than other methods, and therefore, less expensive. It has the advantage of using data from all four MSS Channels, a feature which compensates somewhat for any deficiency in precision of assigning class membership.

IV. THE PRODUCTS

A. MAPS

Maps at scales of 1:250,000 and 1:50,000 to match and overlay existing NTS map sheets will be produced. All wetlands equal to or greater than 25 acres (10 ha) in size will be outlined and precisely located according to UTM coordinates. Classified maps are to be registered to standard NTS cronaflexes showing towns, highways, section lines and other land features to make orientation of the user relatively easy.

Maps at the 1:50,000 scale will be produced only for mapsheets on which wetlands are of such density as to make the 1:250,000 scale maps unwieldy for field use. The exact number is yet to be determined.

B. TABLES

For each mapsheet a table will be produced which lists each wetland classified, providing UTM coordinates and a size estimate (Table 1). In addition, for those wetlands greater than or equal to 25 ac. in size, acreages of open water, deep marsh and shallow marsh are to be indicated as is a perimeter and shoreline development index (irregularity of shoreline).

Summary statistics for each 1:50,000 scale mapsheet are to be provided as in Table 2 where wetlands are grouped according to size classes and total number of wetlands, total acreage, and acreages of the various marsh classes are provided as well as total miles of shoreline and mean shoreline index. These individual tables can be combined to summarize all statistics by size class for each 1:250,000 scale mapsheet.

Estimates of accuracy of classification are also to be provided. Such factors as accuracy of wetland capture, accuracy of cover type classification and area estimate precision will be measured for each mapsheet and for each size class of wetlands.

V. DISCUSSION

To date classification accuracy has been encouraging. Location, size, shape and definition of zones has matched well with ground truth data at least for wetlands in excess of about 10 acres. Actual statistical analysis of these parameters are not yet available.

That computer assisted analysis of Landsat MSS data is useable for enumeration and evaluation of wetlands over 0.4 ha (1 acre) in size has been established.[16,17] Classification procedures involving maximum likelihood methods and reflectance in one MSS channel (Ch. 7) were used to generate pond numbers, and area and perimeter estimates for each wetland identified in North Dakota.[17] Thematic water mapping with a level thresholding technique of a single MSS channel was the most practical and easily implemented means to inventory water areas over 1 acre in size. Because 70-80% of all water areas in the Prairie Pothole region are less than 1.0 acre, the majority are not detected using Landsat data. This could be considered a major drawback if the purpose of the inventory is to monitor all water bodies and to thus determine the status of waterfowl breeding habitat relative to breeding ground pair surveys. Several authors have also suggested that these small waterbodies are either the most important component of waterfowl habitat, or are at least as important as other components.[9,18,19] Their exclusion from an inventory might therefore be considered generally serious, if it was the sole information base.

Gilmer et al.[16] used classification categories similar to those we used and for the same reasons-they reflect natural vegetation zones as outlined by Millar[14] and Steward and Kantrud.[15] Using July Landsat data, a maximum likelihood criterion and statistical pattern recognition techniques (all four MSS channels) it was possible to map upland and wetland vegetation associations with 75% overall accuracy which could be improved with multitemporal terrain classification techniques.[16]

Although our project using AUTOLEVELS and all four MSS Channels is as yet untested operationally results to date are promising. The cost is estimated at approximately $0.30/km^2, including data acquisition, software and software modifications, manpower, etc. These are high costs associated with initial phases; costs should be considerably lower as we get into production.

DU (Canada) will use the data and maps generated in order to plan, organize, cost and perform benefit/cost analyses of efforts aimed at wetland preservation in Canada. A knowledge of the distribution, abundance and quality of wetlands at least 0.4 ha in size or larger will enable us to plan manpower, equipment and funding needs required to develop wetlands in specific priority areas on the prairies. Our program traditionally has involved construction and/or management of individual basins (or groups of basins). It has also concentrated on wetlands larger than about 50 acres in size, an inventory of which is almost already complete. An inventory of smaller basins will provide the basic information for a reconnaissance and development program aimed at small wetlands. Those wetlands which are less than 0.4 ha in surface area, can hopefully be developed and preserved in conjunction with those in the 1.0 to 50 acre size range. Landsat IV will have greater resolving power and could provide for an inventory of basins less than 1 acre.

Further applications could be as simple as an update of the existing inventory in future years, in order to measure rates of change in habitat (wetland numbers). In addition, classification could be expanded to include upland habitat, particularly of native uplands associated with wetlands to provide more comprehensive information regarding wildlife habitat in general. Existing data bases available through Canada Land Data System could also be incorporated to provide rather precise, multi-faceted data for decision making by land use planners.

In any event, having an inventory is useful in itself only as a planning tool. Site specific data which can only be provided by resource managers in the field are required before goals such as those of DU (Canada) can be realized. This program should assist in planning and implementation of our programs quicker and with fewer unknowns than at present. The future appears bright for the use of remote sensing data and machine processing techniques in wildlife management.

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Table 1. Example wetland summary table which will accompany each 1:50,000 NTS wetland mapsheet.

UTM N/E		TOTAL ACRES	ACRES SMARCH	ACRES DMARCH	ACRES OPWAT	PERIMETER (MILES)	SHORELINE INDEX
5730823.	564453.	1.4					
5730746.	540565.	2.9					
5730594.	567124.	4.3					
5730746.	567887.	7.2					
5730746.	568574.	2.9					
5730670.	537054.	2.9					
5730518.	543159.	5.7					
5730518.	568651.	1.4					
5730442.	537283.	2.9					
5730442.	545525.	15.8					
5730442.	567277.	31.6	15.8	15.8	0.0	1.42	0.071
5730366.	562163.	1.4					
5730746.	564682.	48.8	24.4	24.4	0.0	3.31	0.134
5730366.	568040.	1.4					
5730213.	546899.	41.6	15.8	25.8	0.0	1.42	0.062
5730213.	566514.	27.3	27.3	0.0	0.0	1.04	0.056
5730137.	537664.	33.0	15.8	17.2	0.0	1.42	0.070
5730137.	568209.	1.4					
5730061.	538733.	1.4					
5730061.	539267.	40.2	27.3	12.9	0.0	1.89	0.084
5729985.	536901.	8.6					
5730061.	546670.	2.9					

Table 2. Example of summary statistics produced for each 1:50,000 scale NTS wetland mapsheet.

SUMMARY STATISTICS FOR 1:50,000 SCALE MAPSHEET 72P6

SIZE CLASS		NO. WETLANDS	TOTAL ACRES	AREA BY CLASS (ACRES) SMARSH	DMARSH	OPWAT	TOTAL PERIMETER (MILES)	SHORELINE INDEX
0-	5	467	1005.7	890.9	111.9	2.9	114.20	0.047
6-	25	113	1215.2	723.1	440.5	51.7	86.55	0.066
26-	50	12	387.4	155.0	215.2	17.2	19.70	0.082
51-	100	8	586.8	113.3	256.8	216.6	20.64	0.085
101-	200	5	682.9	103.3	385.9	193.7	18.94	0.094
201-	300	1	243.9	43.0	90.4	110.5	6.82	0.123
301-	400	2	691.5	206.6	373.0	111.9	18.56	0.141
401-	500	1	453.4	30.1	418.9	4.3	9.19	0.122
501-	600	0	0.0	0.0	0.0	0.0	0.0	0.0
601-	700	0	0.0	0.0	0.0	0.0	0.0	0.0
701-	800	1	766.2	180.8	502.2	83.2	13.45	0.137
801-	900	0	0.0	0.0	0.0	0.0	0.0	0.0
901-	1000	0	0.0	0.0	0.0	0.0	0.0	0.0
1001-	2500	0	0.0	0.0	0.0	0.0	0.0	0.0
2501-	5000	0	0.0	0.0	0.0	0.0	0.0	0.0
5001+		1	23004.8	452.1	1825.0	20687.7	139.30	0.259

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