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PRELIMINARY EVALUATION OF ERTS-1 FOR DETERMINING NUMBERS AND DISTRIBUTION OF PRAIRIE PONDS AND LAKES

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ABSTRACT

ERTS-1 and aircraft multispectral data collected over a North Dakota test site during July 1972, are compared to evaluate the capability of the satellite sensors to detect numbers and distribution of prairie ponds and lakes. Recognition maps using ERTS-1, MSS 7 data are generated using a level slicing technique. Surface water areas larger than two acres are recognized, but ponds in the one-to two-acre range are detected only at random. The proportion estimation technique will improve the accuracy of area determination and small pond detection.

1. INTRODUCTION

Management of migratory waterfowl is a responsibility of the Bureau of Sport Fisheries and Wildlife (BSF&W). In North America, the primary breeding areas of waterfowl are the prairies and parklands of the northern states and the prairie provinces, and extend into northern Canada and Alaska. Numbers and distributions of wetlands (natural ponds and lakes) in these regions are one of the principal criteria used in developing an index of annual waterfowl production. The BSF&W, the Canadian Wildlife Service, and various states and provinces have made annual systematic breeding-ground surveys since 1947 (1). Aerial surveys, conducted in May and July, are used with air-ground correction factors to provide indices for breeding populations, habitat conditions, and waterfowl production. Additional regional wetland surveys are made periodically to assess the long-term ecological changes due to natural and economic causes.

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Canadian and U. S. wildlife biologists have suggested that a reliable production index could be derived, independent of the size of the breeding population, from an estimate of the number of ponds remaining in mid-July (2). The degree of wetness, especially changes in number of ponds, during the May-July period is now determined from established aerial transects. Biologists have speculated that these indices could be obtained more rapidly and accurately using airborne or spaceborne sensors and associated automatic data processing techniques.

To investigate the potential of remote sensing techniques, in 1968 and 1970 the Environmental Research Institute of Michigan (ERIM, prior to 1 January 1973, the Willow Run Laboratories of The University of Michigan) conducted a series of airborne multispectral scanner (MSS) data utilization and processing experiments to determine capabilities for measuring seasonal changes in waterfowl habitat. These studies were conducted 30 miles northwest of Jamestown, North Dakota at the Woodworth Station, a 6-square-mile research area operated by the BSF&W, Northern Prairie Wildlife Research Center, Jamestown. Biological interpretation and site coordination were provided by the BSF&W.

The BSF&W and ERIM are presently involved in the processing and analysis of data obtained by ERTS-1. Earlier work demonstrated the reliability of water recognition from processed aircraft multispectral scanner data (3, 4 and 5). Similar techniques are now being applied to satellite scanner data. Primary objectives of the current work are to map and generate statistics on water bodies down to the smallest size ponds detectable and to determine changes in wetness between spring and summer using ERTS-1, MSS 7 (0.8-1.1 um) data. Coincident aircraft scanner and photographic data are being used to interpret and correlate spacecraft results. The initial ERTS-1 pass over the Woodworth test site occurred in late July, which delayed until 1973 the evaluation of satellite data for detecting seasonal change in wetlands. We anticipate that a sequence of May-July coordinated data sets will be obtained in 1973 which will permit us to continue investigations of change in seasonal wetness.

The 1972 ERTS and aircraft data have been processed to evaluate ERTS MSS data for determining numbers and distribution of prairie ponds and lakes. We have demonstrated the feasibility of pond and lake mapping using concurrent aircraft and spacecraft data and processing techniques derived from the previous aircraft program.

2. RECOGNITION TECHNIQUES

Previous investigations have tested several techniques for mapping water bodies. These include; (1) pattern recognition using multispectral data channels in the visible range, (2) thermal contrast between water and a terrain background, and (3) signal level slicing of radiation received in a single reflective infrared band. Signal level slicing is the simplest method to implement because the reflectance of water is uniform and lower than most other scene objects. The method requires determining a signal level which separates low radiance water bodies from the other higher radiance objects in the scene. Investigators have evaluated this technique in near infrared regions (0.8-2.5 μm) and have obtained good success in all except the 2.0-2.5 μm atmospheric window, where lesser amounts of solar energy are available for scene illumination.

Implementation of the level slicing technique is accomplished by first generating a digital gray map. From this pictorial representation samples of water bodies and other known areas which exhibit low reflectance values are selected. Histograms of the distribution of reflectance levels for each training category are constructed. These distributions tend to be Gaussian, and the histogram for water will be displaced from the reflectance distributions of other objects. It is then necessary to select a decision boundary which separates surface water from all other scene objects on the basis of their reflectances.

After determining the decision boundary (i.e., slicing level), computer software is then used which generates a printed map of surface water. This program is also capable of generating various statistical summaries. However, this latter feature is not discussed in this report.

3. RESULTS

Aircraft (ERIM C-47) and satellite data were collected on 28 and 31 July 1972 respectively. The Woodworth Station is located near the nadir of the ERTS frame selected for processing. Approximately ten percent of this frame, including the Woodworth site was processed for pond recognition. Within the processed area, two physiographic regions, the Missouri Coteau and the drift plains of east-central North Dakota, are represented. Occasional shallow ponds and lakes and a partly integrated drainage system are typical of the drift plains. Numerous but less shallow ponds and lakes and a non-integrated drainage are characteristic of the Coteau. Both regions contain some of the best waterfowl breeding areas in North America. Figure 1 is a computer generated water recognition map of about three percent of the selected ERTS frame. Aircraft MSS video (1.0-1.4 μm) showing a flight line which transects the Woodworth Station is indicated. Fish Lake is located near the center of the Station. Large prairie lakes clearly discernible from ERTS data include Round (approximately 0.8 mile in diameter), Barnes, and Chase Lakes. Generally, surface water areas larger than two acres are recognized. Each character (one digital sampling element) on this map represent 1.1 acres. If a one-acre pond were divided by two adjacent digital sampling elements, it may or may not be recognized as a water body. Figure 2 compares water recognition maps of ponds and smaller lakes generated from both satellite and aircraft data. Fish Lake has two elongated bays which are reproduced accurately in the ERTS imagery. However, some of the shoreline details of Big Lake are less accurately described. The elongated lake 1.2 miles east of Big Lake has areas of emergent vegetation and a chain of small open water areas which trail off to the southwest. These detailed features, although shown in the aircraft data are not apparent in the ERTS recognition map.

Histograms of reflectance values used to establish a decision boundary separating water and other features for the satellite and aircraft data are shown in Figures 3 and 4 respectively. In the spectral range under consideration (i.e, satellite 0.8-1.1 μm, aircraft 1.0-1.4 μm), both soils and water have low reflectance values. However, reflectance values for water are lower than those characteristic of soils, thus the two can be accurately separated (ERIM report in prep.). An examination of the satellite and aircraft recognition maps for false or omitted recognitions indicates that our decision boundaries provide accurate results. Histograms of several other scene objects are considered in the case of the aircraft data (Figure 4). During late July reflectance levels of some types of marsh vegetation are similar to soil. Shallow water which does not completely mask reflectance from bottom soil or submerged marsh vegetation may indicate reflectance values intermediate between marsh vegetation/soil and deep water. Shallow water and marsh vegetation histograms overlap because the shallow water training areas can be expected to contain some marsh vegetation and vice-versa. The location of the shallow water reflectance distribution between deep water and soil indicates the need to place a decision boundary for water recognition using ERTS data (Figure 3) nearer the soil distribution than the distribution for deep water. The ability to select shallow water training areas from satellite imagery is difficult because these areas tend to be small. Because of this the availability of aircraft imagery is important for our analysis of ERTS data.

Figure 5 is an enlarged portion of the ERTS recognition map. The dashes (omitted from the other recognition maps) represent boundary elements having reflectance values which fall within the range for soil and marsh vegetation. This condition (boundary effect) is especially prominent in the satellite recognition results. Some of these boundary elements may be attributed to marsh vegetation or bare soil margins surrounding the lakes. The boundary elements probably also contain some water. This causes the acreage of the lakes to be underestimated because the boundary elements are placed in the soil/marsh vegetation category.

4. DISCUSSION

Preliminary results demonstrate the degree to which surface water conditions can be determined using ERTS MSS data. Generally it appears that ponds larger than two acres are recognized, while water bodies in the one-to two-acre range are detected only at random. Techniques exist which can more reliably detect small ponds and improve the size estimates of larger ones. These improvements are felt to be essential for this analysis. The proportion estimation technique determines the proportion of objects present within a resolution element using a multispectral data set and an appropriate algorithm (6). For example, boundary elements may be composed of a mixture of water, marsh vegetation, and other components. By estimating the proportion of water in the boundary elements using the proportion technique, the accuracy of lake acreage determination and the reliability of small pond detection are improved over the signal slicing technique.

With this accurate pond mapping capability (consisting of signal level slicing augmented by the proportion estimation technique) seasonal changes in surface water can be more reliably determined. The most cost-effective method for monitoring these changes on a regional basis will very likely involve joint aircraft and satellite data collection and the use of a multistage sampling design.

5. LITERATURE CITED

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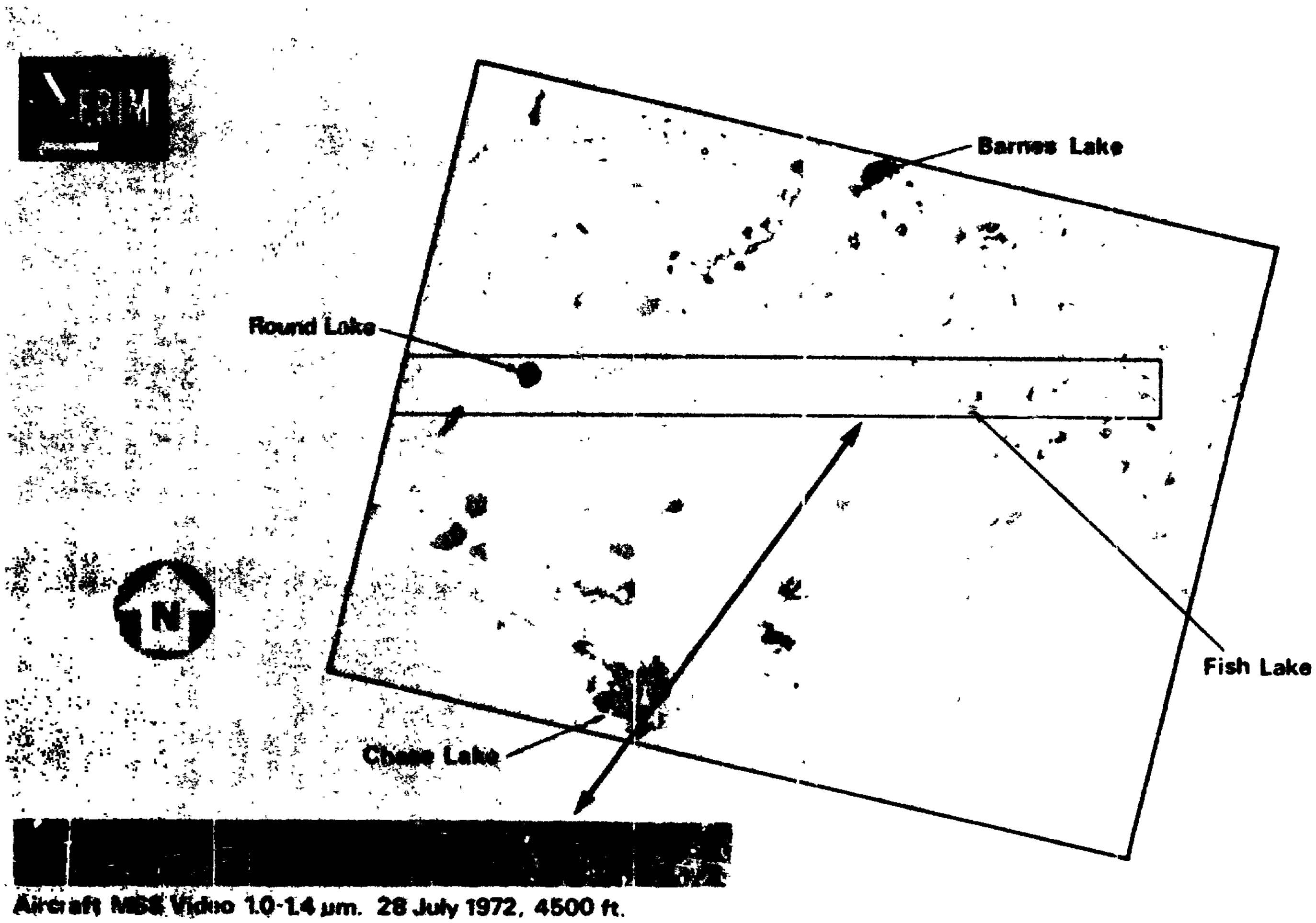

Figure 1.
DIGITAL WATER RECOGNITION MAP OF APPROXIMATELY 3% OF AN ERTS FRAME

DATA COLLECTED 31 JULY 1972 • C N45-17/W099-27 • TAPE C, LINES 1140-1540, POINTS 1-610

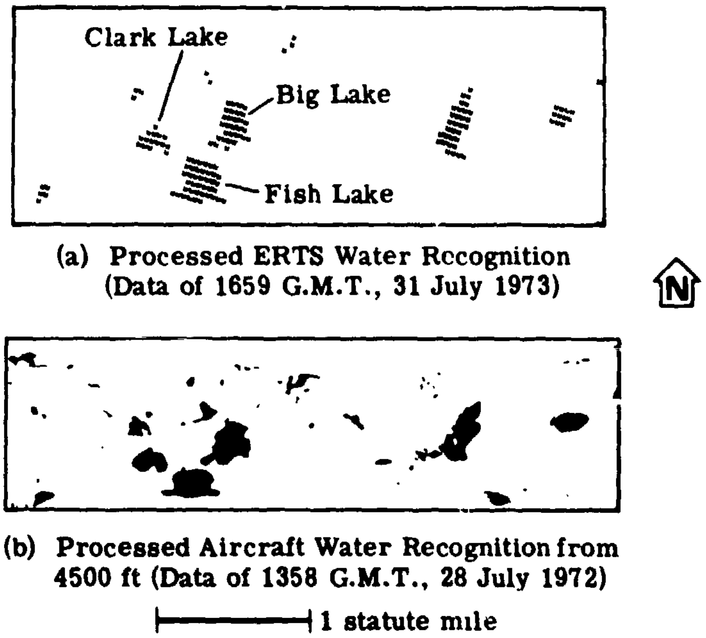

Figure 2. Comparison of details in ERTS-1 and aircraft recognition maps of ponds and lakes near Woodworth, North Dakota.

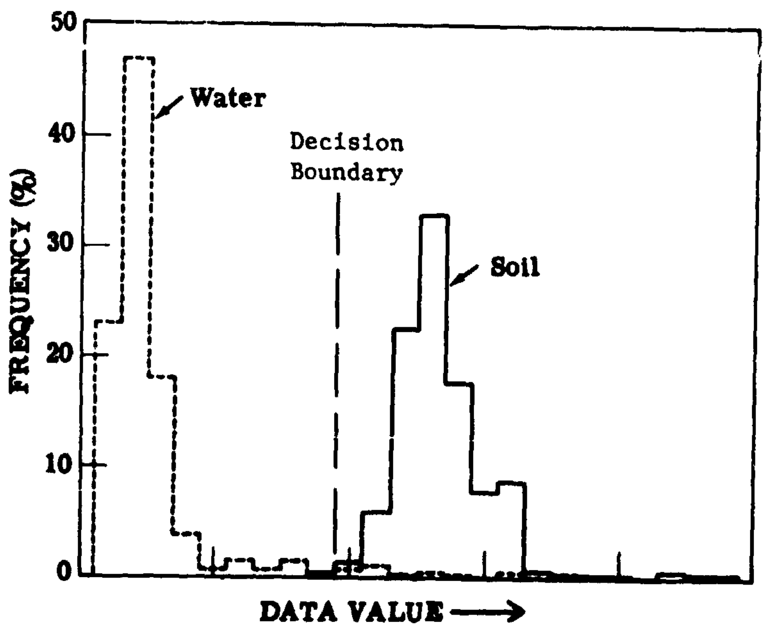

Figure 3. Histograms of reflectance values for water and soil test areas near Woodworth, North Dakota using ERTS-1 data collected at 1659 GMT, 31 July 1972.

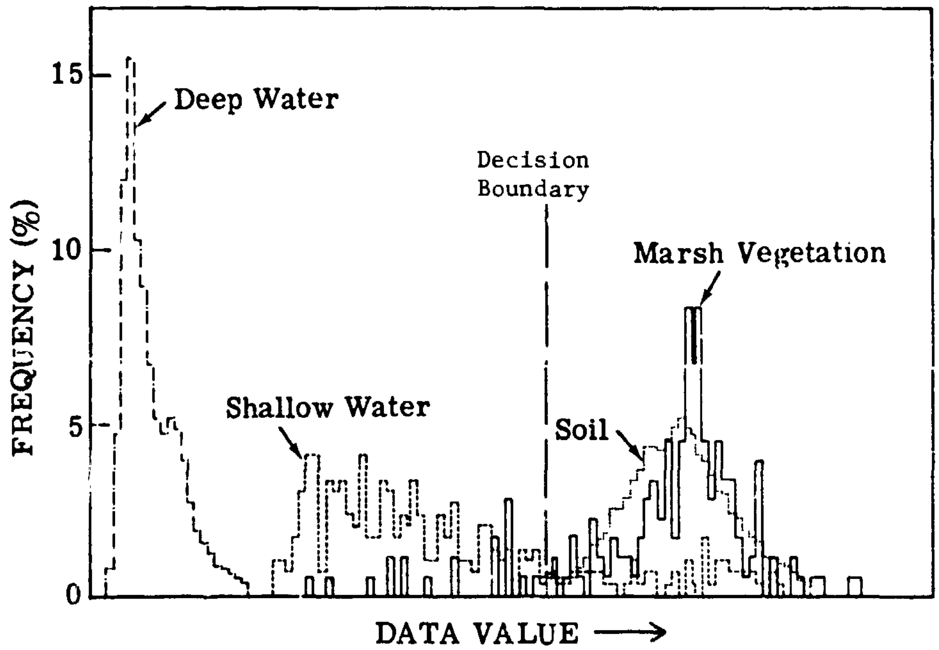

Figure 4. Histograms of reflectance values of test areas near Woodworth, North Dakota using aircraft data collected on 28 July 1972 from 4500 feet.

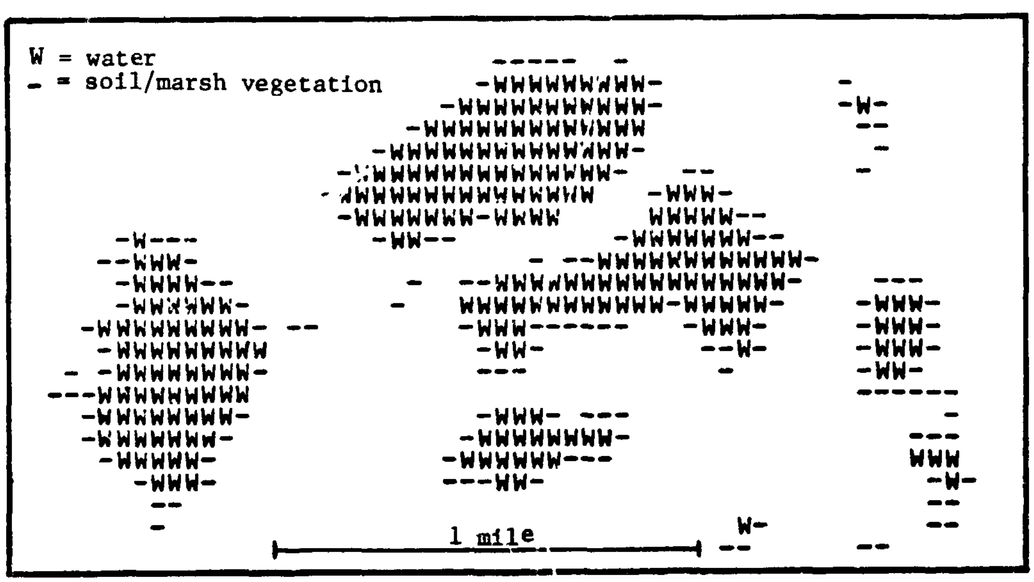

Figure 5. Example of boundary effect associated with recognition maps of ponds and lakes near Woodworth, North Dakota using ERTS-1 data collected at 1659 GMT on 31 July 1972.