TROPHIC STATUS OF INLAND LAKES FROM LANDSAT

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ABSTRACT

A cooperative program between the Wisconsin Department of Natural Resources and the University of Wisconsin's Institute for Environmental Studies has resulted in a first-cut assessment of the trophic status of inland lakes in Wisconsin from LANDSAT data. To satisfy the criteria of the project, a large and versatile computer program to gain access to LANDSAT data was developed. This analysis technique has proven to be a cost-effective method of classifying inland lakes in Wisconsin.

INTRODUCTION

The Wisconsin Department of Natural Resources (DNR) is required to classify the lakes in the state as to their trophic level in response to the federal legislation "Federal Water Pollution Control Act Amendments of 1972," section 314.

This paper describes a cooperative effort between DNR and the University of Wisconsin's Institute for Environmental Studies (IES) to extract LANDSAT data providing a reasonable measure of trophic status in a cost-effective manner. An additional result has been the design of a highly versatile interactive graphics computer program available for both research and agency use.

LANDSAT's multispectral scanner (MSS) simultaneously gathers data at four different wavelengths: Band 4 (.5 to .6μ), Band 5 (.6 to .7μ), Band 6 (.7 to .8μ), and Band 7 (.8 to 1.1μ). A swath 185 km (115 mi) wide is scanned during each orbit, and this is sampled at intervals so that data is recorded for discrete picture elements or pixels whose dimensions are approximately 50 x 70 M.

In this project, Band 5 data was desired because values there can be correlated fairly accurately with lake turbidity. Band 7 data was used to form "pictures" of lakes on a computer terminal. From these, the computer program allowed the terminal operator to select individual picture elements whose data values were punched on cards.

Data was extracted in this fashion for all Wisconsin lakes with areas greater than 20 acres and depths greater than eight feet -- about 3000 lakes in all. The resulting cards were sorted, and lakes within each of Wisconsin's 72 counties were ranked in order of decreasing average Band 5 values.

LAKE TURBIDITY AND LANDSAT DATA

An earlier project (1) investigated relationships between LANDSAT Band 5 brightnesses and lake turbidity. In this project, 37 lakes included in eight different LANDSAT scenes were studied (Figure 1). The northern Wisconsin lakes were generally clear and oligotrophic; those in the southern part of the state range from moderately to highly eutrophic.

Secchi depth readings for each of these lakes were obtained by DNR personnel, but it was operationally not possible to coordinate these tests with LANDSAT overflights. In some instances, over a month's difference existed between secchi depth acquisition and a suitably cloud-free LANDSAT orbit.

Figure 2 shows correlation between LANDSAT Band 5 data and secchi depths for some of these lakes. A definite correlation is evident, and much of the scatter is felt to be due to the time differences described above.

COMPUTER PROCESSING OBJECTIVES

Originally this project involved the densitometric analysis of the photographic rendition of the LANDSAT imagery for all the large lakes in Wisconsin. Difficulties with radiometric quality of 9x9 inch photography and operational problems due to extremely small image sizes of small lakes on 70mm images prompted us to begin development of computer-assisted analysis. Since then, we have expanded the program to provide a highly versatile, general purpose multispectral analysis and data acquisition tool for several users and applications.

The objectives that were envisioned in the design of the program were:

a) Access to small, highly specific subsets of large data sets was needed. We wanted to be able to select, for example, an accurately located single data point in a bay of a lake.

b) Multispectral analysis capabilities were needed for feature selection tasks.

c) Operation needed to be highly interactive, so that options could be selected or changed easily, or feature selection training criteria easily altered under operator supervision, etc.

d) Operator-recognizable displays were needed, for example, to recognize and distinguish lakes, or to estimate acceptability of an experimental classification.

e) Navigational aids were needed to help locate areas of interest.

f) Data histogramming capability was designed to assist in supervised training for feature selection.

g) Use with a variety of data types was desirable. At the moment, the program is being used both with LANDSAT data and digitized aerial photography.

h) The program had to be attractive to a wide range of users. This implied that operation should be easily learned and that the program be extremely tolerant of operator errors.

i) No capital was available for hardware. We were constrained to use existing equipment

INTERACTIVE GRAPHICS PROGRAMMING SYSTEM

We elected to design the program around an interactive graphics terminal, and the Madison Academic Computing Center's Univac 1110 computer. One reason was that several terminals are available on campus and are given excellent software and hardware support. Second, the ability to produce a television-type image during program execution, and the operator's ability to respond to the display, provided us with the man-machine interaction deemed essential. Third, graphics features allowed operator specification of data coordinates, graphical display of data histograms, and similar non-alphanumeric input and output.

We read and decode multispectral data for a fairly large area, retaining data for whatever bands are desired and reading data tapes at any of several possible resolutions. Then a portion of this data is displayed on the terminal by means of an array of characters. Each character is displayed only if a set of tests upon the multispectral data is passed. Complete flexibility is provided in the selection of characters, bands to be tested, and test bounds; all of these can be altered at appropriate points during operation.

Displays can be located anywhere within the region for which data was extracted, and can be shown at any of several resolutions. New displays can be called at any time, perhaps at different resolutions or with different character sets or bounds.

Given a display, data can be extracted simply by pointing at desired points or blocks of points. Data for all such points is printed, punched if desired, and written into a catalogued file which is available to any other program for additional analysis.

Line printer "maps" duplicating displays and showing all extracted data points can be produced as desired.

Interactive computer terminals are becoming familiar in many applications including remote sensing data analysis. A typical terminal consists of a typewriter keyboard and some form of output device -- usually a typewriter, teletype, or cathode-ray tube display. Programs can be written so that interruptions occur at points where operator intervention is needed. Keyboard responses can allow selection of options, decisions, or input of needed data, usually in response to something computed and displayed by the terminal. Such facilities, with proper programming, can provide substantial versatility and convenience.

Graphics terminals, now becoming common, add some powerful features to basic interactive terminals. In addition to display or input of alphanumeric characters, they allow computer-produced drawings of points or line segments, and operator input of coordinate positions which can be formed into graphs, outline drawings, or complex figures. They also allow for transmission of graphical or two-dimensional data to the computer.

DATA EXTRACTION TECHNIQUES

After locating approximate coordinates of lakes by inspection of 9x9 inch imagery, data from Bands 5 and 7 was extracted. Displays were formed by "level slicing" on Band 7, since very low infrared reflectance of water causes extremely low brightnesses in that band. Although the displays were subject to a large number of geometric distortions, it proved generally easy for the terminal operator to recognize and identify lakes and to decide where to extract data.

Data points were then selected, with an average of three to five points per lake. If ground truth data were available from specified portions of a lake, or depth problems were known to exist, an effort was made to extract data from an appropriate region of the lake. Printer maps were produced to provide a documentary record; these show all lake names and data points. At the end of each run, printed and punched data output was produced.

Typically, one to three LANDSAT CCTs (each comprising a quarter of a scene) were analyzed in each day's operation -- these might include anywhere from one or two up to 50 lakes apiece. Economics of operation were highly dependent upon the number of lakes per scene since tape reading was a major part of computation expense. Detailed costs during a typical production run are shown in Figure 3. This run, lasting 75 minutes, involved loading one tape and reading only one portion of it. Ten full and partial displays, and nine printer maps (each including at least one lake) were produced. The total computation charge (using late night computer rates) was just under $6.00.

Overall, about $4,000 of computer time and $6,000 for operator salaries were required to obtain data for the 3,000 lakes.

PRODUCTS AND CONCLUSIONS

Results supplied to DNR include, first, a machine-produced tabulation of lakes in each of 72 counties, listing in order of decreasing Band 5 reflectance and therefore at least approximately in order of decreasing turbidity; and a 35mm microfilm copy of all printer maps produced, showing locations of all data points. A sample output for one county is included in Table I.

Another result has been the computer program itself, which is now being used for research activities by DNR personnel. [illegible] ...ipate that it will become an operational tool used by DNR staff for similar or related analysis.

FUTURE WORK

A much more extensive ground truth effort is now being planned, in which DNR field staff will be obtaining secchi depths and related data in conjunction with LANDSAT overflights.

Navigation procedures are being developed to allow coordinate transformations from scene to scene. These will be used to inexpensively obtain additional data over the course of a full season. Also, data from bands other than Band 5 will be incorporated. This multispectral multitemporal analysis is expected to yield better measures of trophic status.

SUMMARY

A cooperative program involving University researchers and natural resource managers has utilized LANDSAT data to produce an economical trophic status assessment of 3000 Wisconsin lakes. Computer programs have been developed which allow easy, rapid access to LANDSAT data and which can be used by non-research personnel for production data extraction. Capital expenses are low, and operating costs are very reasonable compared to expenses to acquire on-site data of comparable quality.

REFERENCES

1. F. Scarpace, L.T. Fisher, and R. Wade, "Lake Classification Using ERTS Imagery," Proc. Symp. on Remote Sensing and Photo Interp., Comm. G, ISP, Banff, Alberta, Canada, Oct. 1974.

2. A.N. Williamson, "Mapping Suspended Particle and Solute Concentrations from Satellite Data," U.S. Army Engineer Waterways Experiment Station Report (1974).

TABLE 1.- SAMPLE OUTPUT SUPPLIED TO DNR: ALL LAKES IN COLUMBIA COUNTY RANKED IN DECREASING ORDER OF AVERAGE BAND 5 REFLECTANCE

RANK	LAKE NAME	NUMBER OF POINTS	BAND 5 AVERAGE	BAND 5 RANGE	SCENE IDENTIFICATION
1	Swan	4	16.50	16 - 18	1378-16151 3
2	Long	2	15.50	14 - 17	1378-16151 3
3	Lazy	3	14.67	14 - 15	1378-16151 3
4	Park	4	14.50	14 - 15	1378-16151 3
5	Spring	3	14.00	14 - 14	1378-16151 3
6	Lake Wisconsin	9	14.00	13 - 15	1378-16151 3
7	Becker	2	13.50	13 - 14	1378-16151 3
8	Silver	2	13.50	13 - 14	1378-16151 3
9	George	2	13.50	13 - 14	1378-16151 3
10	Wyona	2	13.50	13 - 14	1378-16151 3
11	Crystal	1	13.00	13 - 13	1378-16151 3

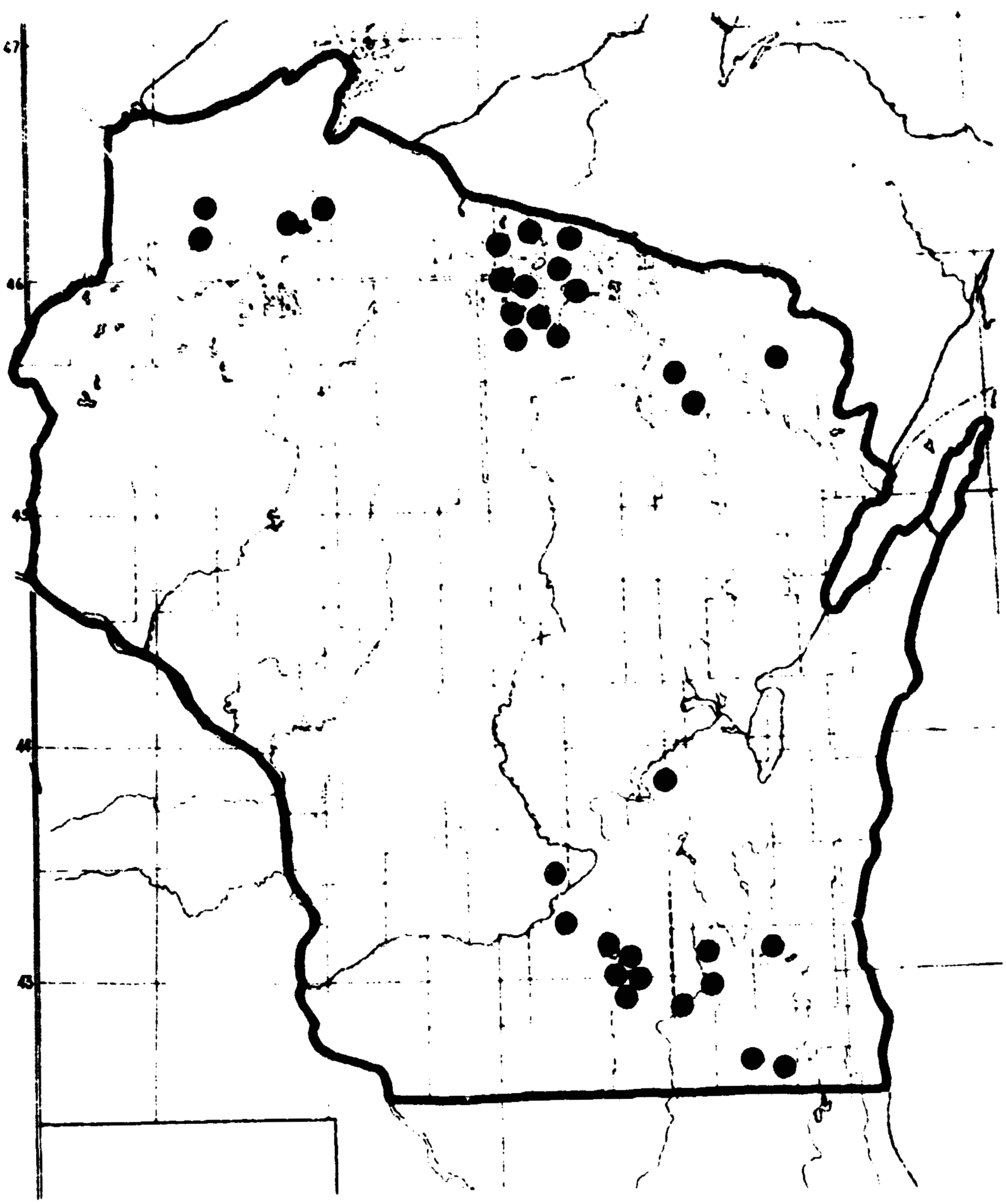

Figure 1--Map of Wisconsin Showing Locations of Lakes Sampled by the Wisconsin Department of Natural Resources

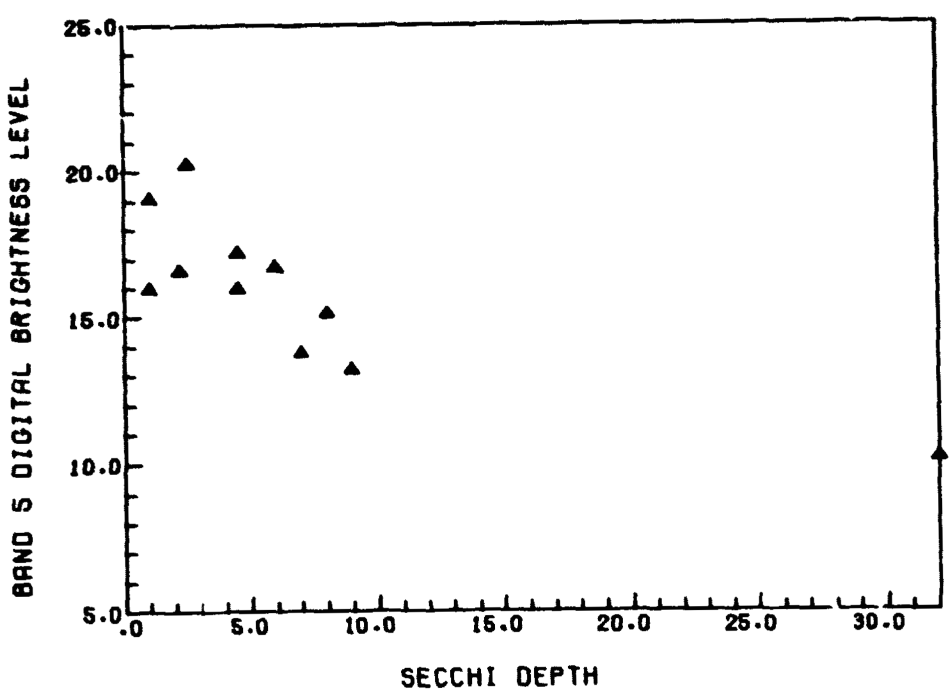

Figure 2--Correlation Between Band 5 Brightnesses and Secchi Depths for 17 Test Lakes

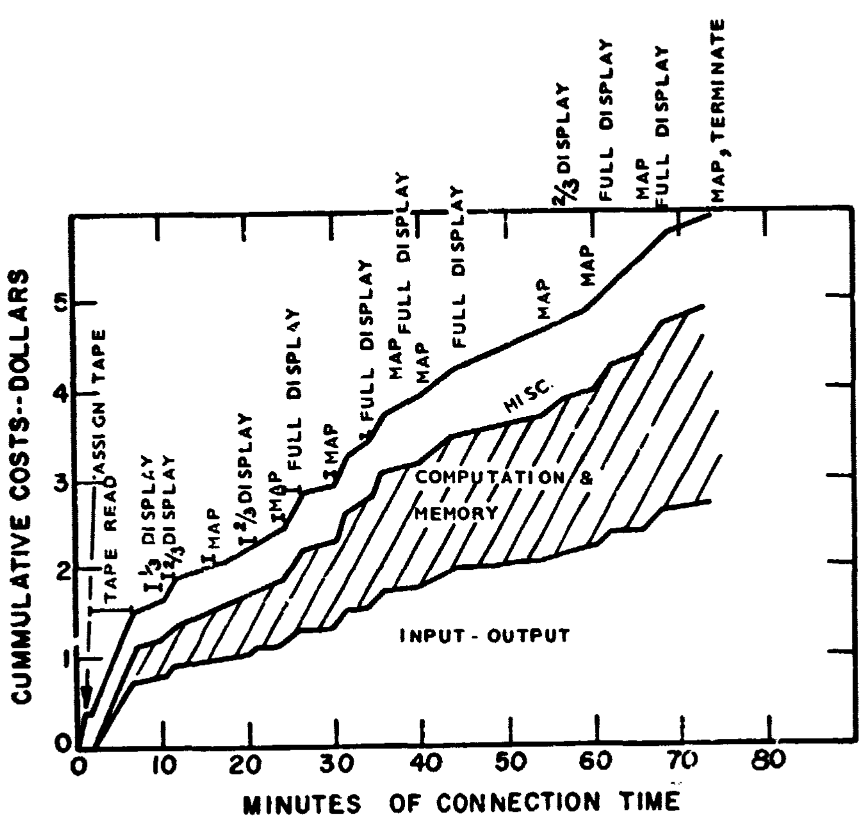

Figure 3--Computer costs for a Typical Production Run for Lake Classification.