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A Technique for Evaluating Inland Wetland Photointerpretation: The Cell Analytical Method (CAM)

Interpretation of false-color infrared aerial photographs produces more accurate wetland delineations than can be obtained from soils maps.

Abstract: *A procedure for objectively analyzing the inland wetland photointerpretation of several investigators is discussed. Comparisons are made between wetland photointerpretations, soils mappings, and ground truth. The technique, which permits mathematical treatments of cell-encoded wetland delineations, was developed to test inland wetland mapping methods.*

Results indicate that interpretation of false-color infrared (FCIR) aerial photographs produces more accurate wetland delineations than can be obtained from soils maps, especially at a mapping unit level useful in wetlands management.

Desirable qualities of photointerpreters who are to perform wetland delineations are discussed as are the relative merits, in terms of wetlands characterization, of aerial photography from different seasons.

Introduction

The protection and regulation of inland wetlands, a vital hydrologic and biologic resource, the importance of which has been known for some years now, has received widespread legislative recognition only in the last few years. In the Northeast, Connecticut, Massachusetts, Rhode Island, and New York have all enacted laws requiring the delineation and regulation of inland wetlands, and the U.S. Army Corps of Engineers and the U.S. Department of the Interior are currently undertaking wetland surveys.

Presently, Connecticut inland wetlands and watercourses are defined as "land, including submerged land, . . . which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial, and floodplain by the National Cooperative Soils Survey . . . 'Watercourses' means rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial. . ." (State of Connecticut, 1972).

After a year-long study of definitions of inland wetlands conducted at this University (Helfgott *et al.*, 1976; Lefor and Kennard, 1977), it was concluded that inland wetlands are best defined and delineated by vegetation and seasonal water table level. Throughout our region, the definitions of inland wetlands are not consistent among the various states. New York and Rhode Island use a combination of vegetation and water table; Massachusetts uses vegetation alone; and Connecticut defines inland wetlands according to soil type. While the use of vegetation, depth to water table, and presence of surface water in a wetland definition lends itself to delineation of wetlands via remote sensing, the use of soil type does not. The use of soil data as distributed by the United States Department of Agriculture, Soil Conservation Service (USDA-SCS) in the glaciated northeast does not appear to delineate inland wetlands accurately (Hill, 1973).

Sufficient research has been conducted into the use of remote sensing data in detecting and delineating coastal wetlands so that the criteria for the recognition of the photographic images of these natural resources are well established. The coastal wetlands of Connecticut were delineated (Lefor and Tiner, 1972, 1974) in 1970-1972 by field survey and simultaneous interpretation of black-and-white aerial photographs. The efficiency of mapping the vegetation of coastal marshes using both conventional color and false-color infrared (FCIR) films for aerial photography at large and intermediate scales has been noted (Seher and Tueller, 1973). Low-altitude FCIR aerial photography has been used to delineate the coastal wetlands of New Jersey (Anderson and Wobber, 1972).

Massachusetts and Rhode Island have been subjects of freshwater wetlands inventories using 1:12,000 black-and-white aerial photography as a source of information (MacConnell, 1973 and 1974). Delineations were transferred from the photos to 1:24,000 USGS topographic maps. The minimum mapping unit was 3 acres (1.2 ha), and classification was by means of a modified version of the 1953 Fish and Wildlife Service system (Martin *et al*., 1953). In a similar project, the State of New York is using black-and-white aerial photographs (1:20,000 and 1:24,000) to inventory its inland wetlands at a scale of 1:24,000 and with a minimum mapping unit of 0.5 acres (0.2 ha). Ground truth studies indicate that the delineations are about 90 percent accurate (Fish and Wildlife Service, 1976).

FCIR aerial photography has been used in the delineation of the vegetation of a freshwater tidal marsh in Maryland (Shima *et al*., 1976). Images of plant communities were classified according to the criteria of color, texture, and contrast. In a study on remote sensing of inland wetlands, high altitude (60, 000 ft) FCIR photography was used to delineate the extent of wetlands and associated wildlife habitats in the Lake Dakota Plain in eastern South Dakota (Best and Moore, 1976). In that study, the gentle topography of the region contributed to the accuracy with which inland wetlands could be manually identified and classified. These procedures require substantial training, experience, and a large degree of subjective judgement on the part of the interpreter, who often may not clearly define his criteria for land feature classification.

In the present study, the 45 square mile town of Mansfield, Connecticut was used as the test site. Mansfield is representative of the general physiogeographic region of southern New England and adjacent New York in type and extent of wetlands. Baseline imagery was obtained from recent low-level (6,000 ft) aerial photographic overflights (spring and fall) of the test area in false-color infrared (FCIR). Ground truth parameters studied were soil pH, depth to water table, soil moisture tension, soil organic matter content, soil type, and plant species distribution, all on a series of transects (Anderson, 1977). Results of the ground truth studies were correlated with photographic interpretations of the spring and fall images (Kennard and Lefor, 1977).

Results indicate that certain classes of inland wetlands (wooded, shrub, and herbaceous) can be readily delineated in the field using classical techniques of vegetation analysis, and that these delineations are well correlated with those made on FCIR imagery in our region (Kennard and Lefor, 1977). Since inland wetlands are of such widespread and discontinuous occurrence, it is obvious that the traditional methods of field determination of wetland boundaries cannot be employed economically over an extensive area.

Background

A procedure was developed to analyze quantitatively the wetland photointerpretations performed by investigators associated with a project designed to evaluate freshwater wetlands definitions. It was intended to improve the criteria and techniques for identifying and delineating inland wetlands.

Using conventional photointerpretation procedures to delineate wetlands (i.e., drawing lines on the photographs or overlays to mark wetland boundaries) is difficult in the glaciated northeast because the actual wetland boundaries are not always discrete. Many wetlands, as well as drainage areas and transition zones, do not have a clearly defined edge, but progress gradually from wetland to non-wetland. Because of this phenomenon, the lines delimiting wetlands deviate somewhat randomly from one photointerpretation to the next in certain areas. Objective comparison of these different delineations is difficult.

Given a small portion of an aerial photograph to work with, an interpreter using the properly established photointerpretation criteria can make a professional judgement as to whether or not a wetland occupies all or part of that area. By placing many of these small areas, or cells, in a matrix, a grid-like wetland map is derived. This type of end-product allows a more objective approach in comparing the actual wetlands delineations as well as the criteria used in making those determinations. The Cell Analytical Method (CAM) is a technique that allows such objective treatment of aerial photograph interpretations. CAM was developed to test and compare present inland wetland mapping practices; at this time it is not intended to be used as a substitute for established delineation procedures.

Methods and Analysis

Two low-altitude false-color infrared (Kodak Ektachrome Infrared Aero film #2443) aerial photograph (1:12,000) missions were flown at 6,000 feet using a Wild RC-10 camera equipped with a Wild 500 MV 2x AV 1.4x filter. The two flights over the test area were made September 24, 1974 and April 22, 1975, both cloud-free low haze days. Because the photographs were taken in two seasons, wetland investigations could be conducted by utilizing both the vegetation information present in the early fall imagery and the ground surface hydrology information present in the early spring imagery. The photographic information was supported by extensive ground truth data.

Four frames were selected for study from each overflight on the basis of their representative land feature content (e.g., topography, hydrology, ecology, land use, etc.) and their high degree of registration between corresponding frames of the two overflights. Also, they fell within an area of a high altitude (60,000') U-2 false-color infrared photograph (Kodak film type #3443)* scheduled to be digitized for future computer assisted analyses.

An effective area (EA) of 3.6 inches square (91 mm square) in the approximate center of each 9-inch square print was selected as the working area. This area was chosen in order to minimize the errors introduced by image displacement away from the photograph principal point (PP) and by color degradation due to general increases in density near the photograph's edges. An anti-vignetting filter was used on the camera to provide uniform image-plane irradiance but deficiencies were still observable. The EA was then subdivided into a 36 × 36 grid, each "cell" representing about 100 × 100 feet (30.5 × 30.5 m). This corresponds rougly to an area of about 0.23 acres, or 0.09 hectares per cell. This grid was then handruled and scribed into an acetate overlay; the width of the divisional lines was nominal. Fiducial marks from a 9 × 9 in. (22.8 × 22.8 cm) spring frame were marked on the overlay to serve as standard referenced alignment points. Each fall frame was registered as closely as possible with its respective spring frame and any displacement noted on additional acetate overlays.

The actual test involved a 'yes' or 'no' decision for each cell ($n=1296$) of the grid on each of the eight frames (four from each of the two flights). A 'yes' indicated that a cell was wholly or partially occupied by a wetland feature and was so noted by the photointerpreter in placing a dot in the respective cell on another clear piece of acetate. A 'no' indicated that a particular cell did not qualify as wetland and it was therefore left blank. The cell area covering wetlands as defined by each photointerpreter over-estimates the actual wetland area as he sees it; the maximum wetland boundary discrepancy was something less than 141 feet (43 m) and most commonly was in the order of 25 to 50 feet (7.6 to 15.2 m).

The decision criteria given to the photointerpreters were based upon earlier work in which field studies were conducted in different classes of wetlands in the study area (Anderson, 1977). Data were recorded on parameters such as vegetation, soil moisture, topographic position, soil pH, and depth to groundwater. Following, a photointerpreter correlated the observable field conditions with their respective images on both the spring and fall aerial photographs. A set of guidelines was developed for the identification and delineation of wetlands and surface water features based upon the characteristic colors, textures, sites, and associations of the images (Kennard and Lefor, 1977). The

* Earth Resources Aircraft Project imagery U2 74-119 frame 281, EROS Data Center, Sioux Falls, SD.

explained by the presence of a basin of shrub growth that did not readily meet the photo/wetland color-associative criteria. Although the study was intended to evaluate photointerpretation performance using only tonal, textural, and contextual information, the use of stereovision with these photographs (S5-6 and F5-6) probably would have substantially improved classification results.

On the basis of the analysis it could be concluded that photointerpretation of FCIR photography is a more accurate means of identifying wetlands than is the use of conventional SCS maps. A contributing factor is that the cell size in CAM was 0.23 acres (0.09 ha) while the SCS minimum mapping unit is approximately 2 acres (0.81 ha).

This disparity in the resolution cell size affects the comparative accuracies of the two techniques. Theoretically, in order to evaluate the wetlands characterization of each data source, the mapping cells must be a common size (i.e., the mapping unit originally used to generate wetlands delineations). Therefore, the FCIR photograph and soils map cellular wetland delineations were aggregated by a factor of nine (as was the ground truth information). In doing so, the mapping unit for each data source became 2 acres (0.81 ha). Hence, a comparison between the FCIR aerial photography and the SCS soil map was made at the level of precision used by soil scientists in their mapping procedures. The wetlands delineations from the two sources, the FCIR photos and the soils map, therefore, more closely approximated one another. Even at this mapping level, the FCIR photointerpretations represented ground truth more accurately than did the soils information (except in photographs S5-6 and F5-6 as noted previously). Overall, FCIR wetlands delineations were 3.8 percent more accurate than those derived from the soils map. The average data for the agreement with ground truth at the 2-acre cell size level are shown in Table 2.

However, it should be noted that wetland mappings at the 2-acre unit level have limited utility in the management of Connecticut's inland wetlands. Many analyses used in decision-making are made at the level of precision and accuracy achievable by the interpretation of the FCIR aerial photographs. Such analyses are not possible using SCS soils maps.

Another area of concern was, "Are there special qualities required of a photointerpreter before he can achieve reliable wetlands delineations?" Initially, an attempt was made to answer this question with statistical evaluations by correlating an investigator's level of experience (expertise) with his degree of agreement with ground truth. Six parameters were identified as being potential contributors to a photointerpreter's performance. These included experience with false-color infrared aerial photography, levels of training in both soils and plant sciences, engineering background, and familiarity with both the test sites and the CAM procedure. However, it was found that these variables were not only difficult to quantify, but also were only a few of the many that affect a photointerpreter in his analytical processes. Therefore, a more qualitative approach was used.

It was noted that the four photointerpreters with the highest level of training with FCIR aerial photos (all with more than six months experience) had the highest average agreement with wetlands ground truth (see photointerpreters A, C, D, and J in Table 1). Further, the investigator with the highest average Index of Conformity (*IC*) with ground truth is both an instructor of a course in aerial photointerpretation and a long-time resident of the area; two other photointerpreters who were very familiar with the study areas but did not have an extensive background in air photointerpretation (in fact, this test was their introduction to false-color infrared imagery) did not perform as well.

Two photointerpreters had very similar

TABLE 2. PHOTOINTERPRETERS' INDICES OF CONFORMITY WITH GROUND TRUTH AT THE 2-ACRE CELL-SIZE LEVEL

	Frames[1]								
	S4-5	S4-7	S5-6	S6-6	F4-5	F4-7	F5-6	F6-6	Mean
Photo-interpreters	0.8749	0.9250	0.8645	0.9333	0.8749	0.9417	0.8854	0.9687	0.9086
SCS[2]	0.7500	0.9167	0.9167	0.9167	0.7500	0.9167	0.9167	0.9167	0.8750
Δ%[3]	+16.6	+0.9	−5.7	+1.8	+16.6	+2.7	−3.4	+5.7	+3.8

[1] Frames: S denotes Spring; F denotes Fall
[2] SCS: Index of Conformity between ground truth and Soil Conservation Map
[3] Δ%: (100 (Mean − SCS)/SCS): Change in accuracy relative to SCS mapping methods

characteristics with respect to remote sensing procedures and familiarity with the study areas. However, the professional training of one involved natural resources analysis (with emphasis on wetlands assessment) while the other was a transportation engineer; the former (Photointerpreter A) had an *IC* with wetlands ground truth of 0.8669 while the latter (Photointerpreter I) had an *IC* of 0.7917 (Table 1).

It is evident that photointerpretation is a multifaceted procedure and to typify the ideal photointerpreter is impossible. However, based upon these studies, one might conclude that desirable qualities would include a substantial degree of experience with the imagery type, a working understanding of the image-feature relationships (which includes knowledge of the natural system being studied), and some familiarity with the study area(s).

Because wetlands are constantly changing in nature and extent, it is difficult to evaluate FCIR photographs taken at one time of the year over those taken at another in terms of identifying wetlands. Although the spring imagery (22 April 1975) seems to have far greater information content (drainage, streams, depressions, etc.) than does the fall (24 September 1974) because surface hydrology conditions can be detected in the leafless season, the wetlands and associated hydrologic features may not be at their peak at that time. Similarly, even though wetlands might be at their full extent in the fall, a photointerpreter might not be able to detect the actual delineation on the basis of the vegetation's spectral characteristics. These discrepancies in wetlands delineations can be seen between Figures 1 and 2.

We concluded, then, that wetland mappings should be based upon combinations of detections and delineations made in both the season of optimal characterization and the season which shows maximum ground detail in the photography. It should be noted that more than two flights may be required to achieve maximum classification accuracy. Also, an alternative to multi-season flights is to obtain FCIR photography in the wettest part of the leafless season; however, this is often difficult because of unpredictability of the cloud-free weather necessary for high quality aerial photography.

Summary and Conclusions

The Cell Analytical Method (CAM) is an excellent tool for comparing wetland delineations derived from several photointerpreters and map sources. The technique developed permits both graphic representations and statistical analyses of cell-encoded, aerial photograph- and map-derived wetland information.

In applying CAM to false-color infrared (FCIR) aerial photographs and a Soil Conservation Service (SCS) map, at the 0.23-acre (0.09 ha) mapping level, it was found that, overall, the photointerpreters' delineations had an agreement with wetlands ground truth of 85.6 percent. The SCS map provided only a 78.7 percent accuracy.

Much of the difference in relative accuracies can be explained in the disparity between the mapping units; CAM utilized a 0.23 acre cell, while SCS maps are based upon a 2-acre minimum mapping unit practice. However, the high degree of precision and accuracy with which inland wetlands can be detected, identified, and delineated from FCIR aerial photographs is desirable for comprehensive wetlands management; the data from soils maps cannot provide this level of detail.

Qualities desirable in a photointerpreter engaged in wetlands mapping include a substantial degree of experience with the remote sensing imagery type, a working knowledge of the image-feature relationship, and some familiarity with the study area.

Absolute wetland boundary extent should be determined from a combination of delineations made from FCIR aerial photographs taken in different seasons so that the temporal character of wetlands and related hydrologic systems can be observed.

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