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HISTORIC WETLANDS ASSESSMENT USING COMPUTERIZED MICRODENSITOMETRIC ANALYSIS OF AERIAL PHOTOGRAPHS

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I. ABSTRACT

A technique has been designed and tested that permits the quantitative assessment of historic marsh conditions from black and white aerial photography. Utilizing a computerized scanning and writing Rotating Drum Microdensitometer (RDM) system, baseline marsh data has been derived by combining present day field data with computer analysis of present day and historical aerial photography. Quantitative information on the marsh grasses studied (Spartina alternifora - tall and short growth forms, Salt Hay - a mixture of Spartina patens and Distichlis spicata), their distributional patterns, and surface water locations were established.

The RDM technique relates subtle optical density differences in a film emulsion to actual field conditions. Algorithms are then used to classify and map the marsh variables being studied. In this investigation, photographs were scanned using picture elements (pixels) as small as 25 um per side. For 1:12,000 scale photographs, this translates to a ground equivalent area of 0.96 square feet.

The RDM system measures the optical density of each pixel and assigns it one of 256 different density levels. This is approximately an order of magnitude greater than the human eye's ability to differentiate subtle shades of gray. Once computer analysis is completed, the RDM system then prints the classification categories on to an emulsion, producing a film image that maps the marsh variables.

Classification maps were produced by the RDM system for two geographically separate saline marshes. Each marsh was in excess of 100 acres. Using a Zoom Transfer Scope, the RDM classification maps were transferred and compared to historic wetland maps produced from manual interpretation of color infrared photographs and then extensively field surveyed. The wetland maps were produced by the New Jersey Department of Environmental Protection.

Except for a few small areas where S. alterniflora was misclassified, vegetative cover classes were correctly classified. The vegetational boundaries and land/water interfaces were located with great accuracy.

II. INTRODUCTION

To facilitate the protection and sound utilization of coastal wetlands, numerous state and federal statutes typically require that wetlands be inventoried and their use regulated. As part of this process, many regulatory/planning agencies must establish the condition of the wetlands in their present or former state. Then, when an alteration is proposed, the projected impact on the wetland area can be assessed and a basis can be established for the approval or denial of the alteration.

Quantitative information concerning the vegetation present, their boundaries, surface water present, and other characteristics of wetlands are required. Many wetland managers responsible for collecting and assimilating this data have found that conventional field techniques are of limited use in dealing with large wetland areas. Instead, they have adopted remote sensing techniques to provide coverage of extensive marsh areas.

Because of the small resolution requirements that many agencies have in assessing the wetlands, many have shied away from using Landsat data and the associated digital processing techniques available. Instead, many agencies rely on manual API methods. This approach has proven to be successful when COL or CIR photography has been used. Unfortunately, when historic panchromatic photography is used, the limited dymamic range of the human eye does not permit the subtle descrimination required to identify vegetative species and demark their boundaries.

In order to overcome this human failing, a computer assisted technique has been designed and tested that permits the quantitative assessment of historic marsh conditions from panchromatic aerial photographs. Utilizing a computerized scanning and writing Rotating Drum Microdensitometer (RDM) system, baseline marsh data has been derived by combining present day field data with computer analysis of present day and historic aerial photography. Quantitative information on the marsh grasses (Spartina alterniflora and salt hay - a mixture containing Spartina patens and Disticlis spicata) were studied. Vegetative distributional patterns and surface water locations were also established.

III. APPROACH

This investigation was conducted in two phases. In the first phase, a RDM was tested to see if relationships could be detected between different optical density ranges obtained from a panchromatic photograph and marsh data obtained for selected marsh variables. In this investigation, the marsh variables were: 1) vegetative species identification; 2) species boundary demarcation; 3) land/water demarcation; 4) standing water identification; and 5) bare sand identification.

Because of the positive results obtained in the first phase, a second phase was initiated. In this phase, a methodology was designed and tested that permitted the investigator to make use of available field data and relate it to the optical density data contained within historic photographs.

IV. RDM SYSTEM DESCRIPTION

For this investigation, the Optronic's International Inc.'s C-4500 Coloration Mark II system was used. This system is a RDM scanning and writing system. In the scanning mode, the C-4500 operates as a high-speed RDM designed for the quantitative separation and digitization of each emulsion layer of color film or for monochromatic digitization of black and white film. In the writing mode, the C-4500 utilizes digital data to reconstruct a hard copy color or black and white film image of the processed data.

The main components of the system consist of scanner/writer sections, a dedicated mini-computer, a magnetic tape drive, and an operator console. The system can also be interfaced with such options as:

1) Interactive display - a color or black and white CRT can be used to immediately display the scene generated by the computer. This allows the user to see initial results without having to print them on film.

2) Large scale computer - allows for faster manipulation of data along with increased memory capacity.

3) Disk storage - greatly increases memory capacity and permits high speed retrival of data.

4) Line printer - permits preliminary analysis of data prior to film generation.

The RDM process begins when an operator clamps a film emulsion over an opening in the rotating drum. He then sets the filter and the pixel size to be used, types the scan command to the computer, and defines the coordinates of the photograph to be scanned

Interference filters within the path length of a white light source are used to split out a narrow spectral band corresponding to the absorption peak on each emulsion layer. Koehler optics are then used to focus the light through a sqaure illuminating aperature and onto the film emulsion. The light transmitted through the emulsion is picked up by a photo-multiplier tube incorporated in the receiving optics assembly. The photo-multiplier is matched in sensitivity to the interference filter being used. The Photo-multiplier transforms the magnitude of the transmitted light into an equivalent voltage which is then routed through an analog to digital (A/D) converter to produce an eight bit (256 level) digital signal corresponding to the optical density of the film at the particular spot on the emlusion. With each revolution of the drum, the light source is recalibrated, thus providing a drift-free light source.

As each spot is scanned, the digital signals generated are read into a temporary storage buffer within the controlling minicomputer. The buffer contents are then transferred to magnetic tape as a single record after each scan line is completed.

With each revolution, a lead screw advances the housing containing the emitting and receiving optics and thus, the entire emulsion can be scanned. Scanning ends when the optic housing moves just past the end of the scan coordinates defined by the user in the beginning. The housing then resets itself at the zero raster starting point and is ready to repeat the above process again but at a second color setting. Finally, this procedure is repeated for a third time for the last emulsion layer. At the completion of the three scans, a magnetic tape has been generated that contains three files of eight bit data, one for each emulsion layer of color.

These process can be run with black and white films however a LED clear filter is then used. In this mode, only a single file of data is generated.

It should be noted that when each spot on the emulsion is scanned repeatedly for color file generation, the positional accuracy of the pixel is $\pm$ 2 um rms/cm.

The size of the pixel used to resolve a photograph can range from 12.5 um to 400 um square. The ground equivalent area of each pixel size for photographs with scales of 1:12,000 and 1:20,000 is given in Table 1.

Once the data is stored on magnetic tape, the user may utilize numerous software packages that exist commericially to classify the objects of interest. After classification analysis is completed, the user may then use the RDM system to reconstruct, on film, the newly classified scene. To accomplish the above, an unexposed piece of film is securely mounted over the writing drum. The drum, film, and optical path are contained in a light proof cassette which may easily be removed for film processing in a darkroom

With the film mounted, the user inputs operational commands to the computer. Such commands define the aperature setting, the film coordinates, and the assigned color shades or gray tones that represent the different classsification categories.

For color generation, the film is repetitively exposed by pulse modulation of a light beam from a white light source focused onto the film plane through selected blue, green, or red filters. Monochromatic image reconstruction is also possible as an LED clear filter is proved.

The film may be exposed at every raster point along the circumference of the drum. After each rotation, the optical carriage is stepped in the axial direction until the total area of interest has been exposed. The dynamic optical range of the film is about 2.5 with an associated low fog level.

The use of high-speed film allows very short exposure times resulting in high recording rates up to 40,000 data points (pixels) per second. Thus, at a 50 um pixel setting, it takes approximately eight minutes to generate a reconstructed 9" x 9" photograph.

V. METHODOLOGY

A. PHASE 1

In this first phase , a New Jersey saline wetlands area was selected that contained three distinct marsh types (pioneer, building, and mature). The test site was located near the Borough of Rumson, New Jersey, where the Shrewsbury and Navasink rivers meet.

Field data for this area consisted of two forms. One form was the result of an extensive field survey conducted by the author in 1978. Thirty sites were established within the wetlands area and sampled throughout the 1978 growing season. The second form of field data was a 1972 Wetlands Map produced by the New Jersey Department of Environmental Proctection. This map was produced by using API techniques on 1971 COL and CIR photography and then extensively field checked to verify the map's accuracy.

The photography selected for RDM analysis was an October, 1971 panchromatic photograph with a scale of 1:35,000. A RDM aperature setting of 100 um was selected and, for the above mentioned photograph, produced a pixel with a ground equivalent area of 132.25 square feet (11.5' x 11.5').

A small isolated marsh toward the northern edge of the wetlands area was selected as the control area. Field data for this area was tabulated and provided for RDM analysis. By comparing the field data to the optical density ranges provided by the RDM, distinct optical density values were identified and associated with the marsh variables being studied.

Utilizing these density ranges, a classification image mapping the marsh variables for the entire wetlands area contained in the photograph was derived. The accuracy of the classification image was then determined by comparing the rest of the field data against the classification image. The results and their discussion is reserved for the Results section of this paper.

B. PHASE 2

Because of the positive results achieved in the initial phase of this investigation, a second phase was instituted. In this phase, a methodology was designed and tested which allowed the investigator to use existing field data to assess the historic conditions of marshes throuh the use historic photography. The methodology is summarized in the following steps:

1) Through the use of historic photographs, maps, or charts a stable marsh area within the wetlands is located. This area is defined as the control area. Field data is gathered documenting the existing marsh conditions for the wetlands area.

2) Using a recent panchromatic photograph, a RDM scan of the control area is conducted. Using a portion of the field data collected, the optical density ranges of the marsh variables are defined for the control area. These optical density ranges are then applied to the entire wetlands area contained within the photograph and a classification image is produced. A comparitive study is then conducted between the RDM results and the remaining field data. If the results are positive, the next step is followed. If the results are negative, and the optical density ranges can not be adjusted to account for the misclassifications, then the technique fails and plans for historical analysis are aborted.

3) If the RDM classification of the wetland area compared favorably to the field data, the above step is repeated but now on an interim period photograph (i.e., 5, 10, 15 years earlier then the first photograph). The classification results obtained from this photograph are then compared to the results obtained in Step 2. If the results are similar in nature, then the photograph which depicts the wetlands area for the earliest period of interest is selected and mounted on the RDM for digitization. If the results obtained from the interim period photograph are not similar to the results achieved in Step 2, and the discrepencies can not be accounted for, plans for further analysis are aborted.

4) Once the earliest historical photograph is digitized and the optical density ranges

are defined for the control area, a classification image mapping the marsh variables for the wetlands area is produced by the RDM. Again, the results are compared to those achieved in Steps 2 and 3. If the comparisions are favorable, the classification process is completed and the marsh variables are mapped. If the comparisons are not favorable, and the differences can not be accounted for, the historical analysis is aborted.

In this investigation, the methodology was tested on a second New Jersey saline wetlands area. This second site is located along Abescon Inlet and adjacent to Atlantic City, New Jersey. This marsh area is representative of many of the marshes located behind the barrier islands that protect the New Jersey mainland.

The photography selected for analysis consisted of a 1977 (July) black and white internegative of CIR film, a 1971 (August) black and white internegative of CIR film, and a 1957 (April) panchromatic photograph. The scales of the 1977 and 1971 internegatives were 1:12,000 and the scale of the 1957 photograph was 1:20,000.

The RDM aperature size was set at 25 um for the 1977 internegative, 50 um for the 1971 internegative, and 50 um for the 1957 panchromatic photograph. This produced pixels with ground equivalent areas of 0.96 $feet^2$, 3.88 $feet^2$, and 10.76 $feet^2$, respectively.

Field data again was in two forms. A brief field survey was conducted in 1980 to identify species and note their location relative to a 1977 photographic base map (scale of 1:2,400). The second form of field data consisted of another 1972 Wetlands Map produced by the State in the same manner as discussed earlier.

Each of the three photographs were scanned, analyzed, and produced classification images in accordance with the methodology outlined above. Their results are discussed in the following section of this paper.

VI RESULTS

The results achieved in the first phase of this investigation were highly favorable. Of the twenty-seven stations established outside of the control area (three stations were used in defining the optical density ranges within the control area), all were correctly classified by the RDM technique. Field observations on areas of exposed sand and tidal ponds compared favorably also. The results are presented in Table 2.

It should be noted that the above comparision is sample site specific and provides no information on the ability of the RDM technique to demark boundary locations between vegetative species or the land/water interface. To determine the ability of the RDM technique to locate such boundaries, a comparision was made between the RDM classification image and the 1972 Wetlands Map.

The comparision was conducted utilizing a Zoom Transfer Scope with the classification image being enlarged to a scale of 1:2,400. The results of this comparision showed that, except for two small areas, the RDM correctly identified the species present and achieved a demarcation accuracy of ±2.1 pixels (24.15 feet at a scale of 1:35,000 and an aperature size of 100 um). The boundary line accuracy was determined by measuring the line differences at 100 randomly selected transects along the mapped boundary lines. For the land/water interface, an accuracy of ±0.8 pixels was obtained (±9.2 feet).

For the two area misclassified, each was less than 1000 square feet. The RDM technique classified these areas as <u>S. alterniflora</u> - short form, when in fact, they were areas containing salt hay. Based on visual observations made during the 1978 field ssurvey, the author believes the misclassifications were due to the presence of <u>Salicornia virginica</u>. This vegetation was not accounted for during the initialization of the optical density ranges and could have masked the spectral effects of the salt hay.

It should be further noted, that the classification image contained many areas of mainland that fell within the optical density ranges of the different marsh species. An observer of the classification image can readily distinguish between marsh and mainland areas, but many of the tree canopies have optical densities that fall within the range defined for S. alterniflora - tall. Perhaps through further analysis of the optical densities, a discrimination between such features may be obtained. However, this was not attempted in this investigation.

In the second phase of this study, results similar in nature to those achieved in the first phase were obtained. For the 1977 internegative, except for three small areas where the RDM technique classified S. alterniflora - tall as the short phenotype, vegetative boundaries were within ±11.4 pixels (±11.17 feet at a scale of 1:12,000 and an aperature of 25 um). Land/water interfaces were located within ±3.0 pixels (±2.94 feet).

For the 1971 internegative, vegetative boundaries located by the RDM technique were within ±4.2 pixels (±9.06 feet at a scale of 1:12,000 and an aperature of 50 um), with all vegetated areas correctly identified when compared to field data. Land/water interfaces were located within ±0.7 pixels (1.38).

For the 1957 panchromatic photograph, vegetative boundaries were within ±1.7 pixels (±5.58 feet at a scale of 1:20,000 and an aperature of 50 um) were achieved with all vegetated areas correctly identified. Land/water interfaces were within ±0.8 pixels (±2.62 feet).

VII. CONCLUSION

A methodology has been designed and tested that permits the assessment of historical marsh conditions from the combined use of existing field data and historic photography. Prior to the utilization of the RDM technique, the extensive marsh data contained within a panchromatic historical photography has not been fully exploited. Through the use of computer analysis, man's abiltiy to differeniate subtle shades of grey has been expanded by approximately an order of magnitude. This permits discriminations to be made where, if the human eye had been used, none were previously found.

VIII TABLES

TABLE 1. GROUND EQUIVALENT AREAS FOR PIXEL SIZES 12.5 UM TO 400 UM SQUARE

Pixel Size (in um) per side	Ground Equivalent Area (per side values) 1:12,000 Photo	Ground Equivalent Area (per side values) 1:20,000 Photo
12.5	5.91" (0.49')	9.84" (0.82')
25	11.81" (0.98')	19.69" (1.64')
50	23.63" (1.97')	39.37" (3.28')
100	47.24" (3.94')	78.74" (6.56')
200	94.49" (7.78')	157.48" (13.12')
400	188.98" (15.75')	314.96" (26.25')

TABLE 2. COMPARISON BETWEEN FIELD STATION RESULTS AND RDM CLASSIFICATION RESULTS FOR VEGETATIVE SPECIES IDENTIFICATION.

	Number of Stations With S. alterniflora (tall)	Number of Stations With S. alterniflora (short)	Number of Stations With Salt Hay	Number of Sites With Bare Sand	Number of Sites With Tidal Ponds
Field Station Results	13	9	5	5	7
RDM Classification Results	13	9	5	5	7
Classification Accuracy	100%	100%	100 %	100 %	100 %

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