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WETLANDS CLASSIFICATION USING LANDSAT THEMATIC MAPPER DATA UNSUPERVISED CLASSIFICATION APPROACH

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ABSTRACT

The University of Rhode Island, Graduate School of Oceanography, Landsat Remote Sensing Center, in cooperation with the Northeast Fisheries Center of the National Marine Fisheries Service, performed a wetlands classification for Cape Cod, Massachusetts, using Thematic Mapper (TM) data from Landsat IV. The data set is a winter scene, December 8, 1982, Row 11, Path 31.

All seven bands from the TM were used for the unsupervised classification for land cover identification. The use of the TM with the increased spatial resolution for wetlands application was the primary interest for the startup of the project. The additional information that would be obtained from the blue, mid-infrared, and thermal bands was the second most important consideration for information processing. Selection of the training site was to obtain wetlands data for the western Cape Cod land and near-shore areas.

The processing was done by the software package ELAS written by the National Space Technology Laboratory, Earth Resources Laboratory. The training site chosen for classification was lines 3300 to 4500, elements 1000 to 4500 from scene E-40145-14492. The resulting unsupervised classification comprised thirty-one classes. Some of the classes were identified with the aid of aerial photography of the area.

I. INTRODUCTION

The University of Rhode Island, Graduate School of Oceanography, Landsat Remote Sensing Center, in cooperation with the Northeast Fisheries Center of the National Marine Fisheries Service, is working on a wetlands classification for Cape Cod, Massachusetts, using Thematic Mapper (TM) data from Landsat IV.

A. BACKGROUND

The wetland environment by its very nature is a very difficult area to survey from the ground. The recent use of satellite data to aid in the analysis of wetlands has been limited for the most part by the lack of surface resolution. To date the Landsat satellite has had the only satellite sensor that is even close to having the required surface resolution to study the wetland environment. The Landsat Multispectral Scanner (MSS) has a surface resolution of 80 meters or 1.1 acres; this sensor has been useful for scientific purposes, but has not been very successful for general use in wetlands cover classification. The present project has used a new Landsat sensor, the Thematic Mapper (TM), whose surface resolution is 30 meters, or 0.25 acres. The TM relies on the same technology as the MSS, but has been significantly improved to achieve greater capability and will add to the effectiveness of the Landsat sensors.

Landsat IV, launched July 16, 1982, is the fourth of the Landsat series that started obtaining land cover data in 1972 (NASA 1983). The satellite is in a nearly circular orbit from 80 degrees north latitude to 80 degrees south latitude at an altitude of 705 KM (438 miles). The period of repeat coverage is sixteen days for Landsat IV; previously it had been every eighteen days. Surface events on the land happen very slowly, making this frequency of repeat coverage perfectly satisfactory for land cover classification (Cornillon 1981). The satellite carries two sensor packages for data acquisition, a MSS and a TM. The TM sensor records electromagnetic radiation from seven different bands, also referred to as channels, as follows:

1) Blue light (0.45-0.52 micrometers)
2) Green light (0.52-0.60 micrometers)
3) Red light (0.63-0.69 micrometers)
4) Near infrared (0.76-0.90 micrometers)
5) Near infrared (1.55-1.75 micrometers)
6) Thermal infrared (10.40-12.50 micrometers)
7) Mid-infrared (2.08-2.35 micrometers)

(NASA 1982)

B. DESCRIPTION OF CURRENT STATE OF KNOWLEDGE

Satellite-derived land cover/use data has been obtained through the Coastal Habitat Assessment Research and Mensuration (CHARM) program (Finn 1981). The remote sensing processing was done by the University of Massachusetts for classification of coastal wetlands. The project was intended to classify coastal wetlands for the entire eastern seaboard of the United States. Unsupervised classification techniques using the Landsat MSS were used for the same area of Cape Cod. This study has not been completed, and no publications from the work are available except progress reports. The CHARM study does not partition out classification statistics for the study areas; instead, the classification results cover the entire State. Three main classes, 1) Water, 2) Wetlands, 3) Uplands, are identified, with the following subclasses:

Water	Wetlands	Uplands
Clear	Salt	Developed
Turbid	Low	Urban
Tidal Flat	High	Suburban
Shoreline	Brackish	Beach
	Fresh	Natural
		Softwoods
		Mixed
		Hardwoods
		Open
		Agricultural
		Bare Soil

Klemas (Klemas 1981) modeling work on marsh biomass developed relationships between spectral radiance and live plant communities in the Canary Creek salt marsh of Lewes, Delaware. This study was done utilizing Landsat MSS data and incorporated extensive verification from the ground. Klemas used a hand-held radiometer to verify the canopy radiance. Three of the channels of the radiometer matched three of the Landsat IV TM sensor. The bands were chosen for sensitivity to chlorophyll concentration, plant tissue, and leaf moisture. Regression coefficient were generated for dominant flora biomass of the area. Testing of the Klemas biomass model with independent data from other areas has been done neither by Klemas nor by other investigators. The modeling does suggest, however, that remote sensing models can be successfully applied to estimate salt marsh biomass. Furthermore, such noninstrusive surveillance techniques do not adversely affect the fragile salt marsh environment.

II. METHOD OF ANALYSIS

A. DATA

The data is from the TM scene E-40145-14492, Row 11, Path 31, dated December 8, 1982. The scene is 185 kilometers long by 185 kilometers wide with the center point around Chatham, Massachusetts. The computer compatible tapes (CCT's) are recorded at a density of 1600 bits per inch, with one tape per channel of data. Storage of an entire scene would require 290,858,000 bytes. Each scene is 6967 elements by 5964 lines for each of seven channels. The TM data used for this study is considered Engineering Data by NASA, and NASA makes no guarantee as to its accuracy. Due to the engineering problems aboard the satellite, the TM has not been operational since February 14, 1983. Therefore, this TM data is the only TM data available for the area.

B. SOFTWARE

The Landsat data was processed using the software package ELAS written by the Earth Resources Laboratory of NASA's National Space Technology Laboratory, Bay St. Louis, Mississippi (Junkin 1980). This package comprises 105 modules, with each module being responsible for a specific type of processing. The software is interactive and specializes in the use of color image display and manipulation. The ELAS software operates under a control file environment, and this control file structure "keeps track" of all processing results from each module that has been used during the processing. This information is stored in the control files for reuse and update. All such files can be used by other ELAS modules as input or intermediate information required to perform their tasks.

C. PROCESSING

Site selection for this wetlands classification was done according to the following method. A data window from the full TM scene was selected to encompass the westernmost portion of Cape Cod, Massachusetts. This window comprises lines 3300 to 4500 and elements 1000 to 4500. The window was chosen by ingesting the entire scene for channel one of the TM scene and then selecting the lines and elements of interest from the image display system. The display system cursor was positioned on the screen at the corner points for the desired subscene, and then the line and element numbers were recorded. The initial line (IL), last line (LL), initial element (IE), and last element (LE) were supplied to the ingesting module TCCT.

The module TCCT reads the computer compatible tapes and re-formats the data into a disk file for direct access by the other ELAS software modules. The tapes are mounted on the tape drive, and the TCCT module prompts the user for processing information. The window paramters (IL, LL, IE, LE) are input to the module, and then all seven channels are read in for this area of interest, one channel of TM data from a single tape.

The ELAS routine SRCH is used to obtain training site statistics. The routine SRCH passes a window three lines by three elements through all seven channels of data to compute homogeneous training field statistics. The statistical data is stored in a subfile of the control file for later use by other ELAS modules. The spectral signatures for this classification were defined as follows: the standard deviation in each channel had to fall between a lower bound of 0.1 and an upper bound of 1.0; and the mean value times the coefficient of variation could not exceed five percent.

The statistical output (Table 1) represents the land cover classes that were clustered from this window of data. The final statistical results are those merged statistics that have the smallest scaled distance between any pair that exceeds the minimum scaled distance of 3.0. The mean values for each channel (electromagnetic band) are then plotted and the resulting curve is the spectral signature which characterizes each class within the data. This signature is used to recognize ground cover type by pattern recognition or clustering, through the use of maximum likelihood techniques.

The unsupervised classification was performed using the ELAS routine MAXL. Each pixel is assigned a class value according to Bayes' rule; that is, in accordance with the probability of its occurrence within that class. The mean vector and covariance matrix from the training site statistics computer by the SRCH routine are used to determine the best fit assignment for each classification. Each input pixel is then assigned a class from the statistic into which that pixel best fits. The ELAS algorithm maximizes the natural logarithm of the probability and assigns that pixel to a class based upon this likelihood that the pixel belong to that class. A disk file containing the classified pixels is then written for image display and analysis.

Table 1. Spectrail signatures, Cape Cod, Massachusetts

		BANDS						
	pixels	1	2	3	4	5	6	7
CLASS 1	2772.	50.58	18.17	17.34	22.75	27.35	11.61	56.32
CLASS 2	627174.	51.13	16.53	13.15	8.10	4.78	3.19	70.78
CLASS 3	4734.	55.70	21.01	17.19	8.66	4.81	3.14	67.55
CLASS 4	774.	59.32	23.14	19.14	8.77	4.89	3.22	67.87
CLASS 5	495.	51.87	18.64	18.48	24.75	31.62	13.42	58.82
CLASS 6	1701.	50.03	17.99	16.41	24.47	22.15	9.19	57.82
CLASS 7	54.	94.74	45.24	55.39	50.87	89.43	59.02	63.15
CLASS 8	108.	54.42	19.86	20.46	26.26	33.95	15.24	61.07
CLASS 9	567.	51.11	18.32	18.57	22.09	35.06	15.45	56.64
CLASS 10	954.	55.16	18.19	15.38	9.92	7.25	4.60	68.95
CLASS 11	1017.	51.04	18.24	17.85	21.45	30.67	13.42	55.94
CLASS 12	99.	90.70	36.82	40.09	33.52	53.23	31.38	54.55
CLASS 13	189.	55.40	21.47	24.02	28.68	51.68	23.61	61.63
CLASS 14	153.	56.36	22.14	26.10	30.61	56.34	25.87	62.03
CLASS 15	45.	64.60	26.69	27.42	23.22	12.71	5.44	65.87
CLASS 16	54.	57.30	23.31	22.48	25.89	6.93	3.46	66.43
CLASS 17	126.	49.55	17.52	16.29	19.66	23.87	10.55	53.55
CLASS 18	315.	57.24	23.16	25.68	36.65	54.60	23.74	61.83
CLASS 19	81.	62.54	25.85	22.57	9.95	4.70	3.09	67.59
CLASS 20	81.	49.48	17.51	16.85	18.53	29.25	13.28	53.99
CLASS 21	117.	53.45	19.43	18.74	26.80	25.65	10.94	60.34
CLASS 22	180.	54.44	20.45	22.23	26.54	45.72	21.00	61.52
CLASS 23	162.	57.46	19.25	17.48	11.46	10.28	5.98	68.44
CLASS 24	234.	52.01	18.90	19.87	23.40	41.35	18.54	59.91
CLASS 25	9.	73.00	32.11	36.67	32.00	30.11	13.78	58.78
CLASS 26	117.	50.07	17.78	18.06	19.05	33.12	16.22	57.49
CLASS 27	54.	82.26	31.98	34.54	28.15	46.33	27.57	57.30
CLASS 28	72.	96.50	39.40	43.85	37.03	60.90	36.60	52.46
CLASS 29	18.	73.78	27.28	27.11	20.78	32.33	22.61	57.28
CLASS 30	72.	77.12	35.29	40.10	34.11	57.83	41.40	61.83
CLASS 31	27.	66.70	23.48	22.85	17.41	22.67	13.37	63.04

III. RESULTS

Thirty-one classes of land cover were identified with the statistical constraints mentioned above. The present unsupervised classification of Cape Cod is at the stage where it needs additional corroboration from the surface to aid in the completion. Aerial photography of the Falmouth harbor area was a great help in identifying the land cover for the classification to date. In addition to the land cover data, shoreline length and shoreline density for the training site have been obtained. They are stored as digital overlay by the software package. For the December scene, water has been very easy to identify, and some subsurface features have been tentatively identified as sandbars. Docks, parking lots, and piers can be distinguished in the scene, as well as the grassy medians separating highways. The cooling tower of the Plymouth power plant is thermally visible in the data also.

A. COLOR TABLES

The color display of a Landsat image can cause some misconceptions of the imagery due to the contrast between the way people naturally perceive color and the non-traditional ways that Landsat images are colored. The computer controls how much color is produced by sending a signal that sets the intensity for each of the monitor's three color guns, and this intensity is represented as a number in a color-lookup table. Each of the color guns can be addressed individually by the computer, producing a seemingly limitless range of available colors by the variety of combinations of colors and intensities possible.

Landsat imagery has been traditionally displayed in color in two ways. With the arrival of the Thematic Mapper, there will soon be three. The first method is known as "false color," and entails the shifting of three of the measured bands from their true color position in the spectrum to one color band up in the spectral ladder. This shifted data band is then displayed only from its color gun representation; that is, green is shifted into the blue color gun, red is shifted into the green color gun, and infrared is shifted into the red gun. This displayed output is the false color representation of the three bands of data. The second method is called "pseudo-coloring." The colors displayed in pseudocolor have nothing to do with the real color of the data itself. They are determined by the person performing the display in such a way as to best represent the data being displayed. The third method is true color, where the true color is represented on the correct color gun of the image display system. One might think that true color would be the best system to choose, but in fact the true color of Earth is not only rather dull, but not particularly informative.

Several pseudocolor classification color tables have been worked out for the display of the land cover types. A color table is the method of coloring all of the data within a class consistently one color. These colors are then used to describe the land cover at the surface (see Photos). A color table should help identify the classification for human interpretation.

B. RESOURCE REQUIREMENTS

A breakdown of the computer use and disk storage requirements for this classification of the data window stated above are as follows:

Item	Resources
Storage	13,144,064 Bytes
Computer processing	454 CPU minutes 3 I/O minutes 419 connect minutes

C. DISCUSSION

For the New England area, most of the difficulty for remote sensing has come from the density and rapid boundary transition from one class to another of the various types of ground cover. The TM demonstrates an ability to resolve these difficulties. Wetland areas on Cape Cod are not of the preferred fifty acreas for agriculture field classification, and have been successfully classified in the scene.

Future use of the TM classified wetlands data can be implemented by Geographic Information Systems (GIS) (Campbell 1983) by State and local planners to provide such information as density corridors, parking proximity, water line usage, socioeconomic prospective for recreation, and change detection, among others.

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