Air Photointerpretation and Satellite Imagery Analysis Techniques for Mapping Cattail Coverage in a Northern Everglades Impoundment

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Abstract

Color-infrared aerial photography taken in 1991 and 1995, and SPOT satellite imagery taken in 1991, were utilized to create cattail coverage maps for Water Conservation Area 2A (WCA2A), an impounded portion of the remnant Everglades. Cattail stands were delineated and classified using conventional air photointerpretation and digital image processing techniques, respectively. Four interacting confounding factors (i.e., water depth/color, impacts from fire, periphyton species composition, and growth morphology within a single species) are implicated as possible elements that complicated vegetation classification. Photointerpretation techniques showed an increasing trend in cattail encroachment from 421.6 hectares of monotypic cattail in 1991 to 1646.3 hectares in 1995. A 1991 SPOT classified image appears to have overestimated cattail coverage due to the interacting confounding mechanisms. Overall accuracies for 1995 air photointerpreted map and 1991 SPOT classified image were 95.2 and 83.4 percent, respectively.

Introduction

The remnant Everglades ecosystem is influenced by an extensive system of levees and canals which have significantly altered the natural hydroperiod and flow of water (Light and Dineen, 1994). Much of the area has been impounded into three Water Conservation Areas (Figure 1). These impoundments, originally designed for water storage and flood protection, receive surface water inflows from agricultural and, to a lesser extent, urban runoff, in addition to occasional discharges from Lake Okeechobee. Research has shown widespread encroachment of cattail (*Typha spp.*) into sawgrass (*Cladium jamaicense*) marsh and other plant communities within the Water Conservation Areas (Davis, 1991; SFWMD, 1992; Urban *et al.*, 1993; Newman *et al.*, 1998; Wu *et al.*, 1997). Disturbances, such as increased nutrient inputs and alteration of hydroperiod, have been implicated as factors in the development and proliferation of these cattail stands. The Everglades Water Conservation Areas are viewed as an important ecological component of on-going Everglades restoration efforts, and monitoring and controlling the encroachment of cattail will be critical to this restoration.

In an initial attempt to describe the vegetation communities of one of these areas, Rutchey and Vilchek (1994) utilized a hybrid supervised/unsupervised clustering technique to classify a 10 August 1991 multispectral SPOT satellite scene (Plate 1a) of Water Conservation Area 2A (WCA2A) into 20 wetland categories using ERDAS software. The thematic accuracy of this 20-wetland-class image, determined by analyzing 241 stratified random ground reference points located using global positioning system (GPS) instruments, was 70.9 percent. A final consolidation of these 20 classes to form a 12-class image gave an overall accuracy of 80.9 percent (Rutchey and Vilchek, 1994).

The methods used in the Rutchey and Vilchek (1994) study were chosen because (1) there was a need to assess the utility of satellite imagery for mapping Everglades wetlands; (2) the equipment (both software and hardware) were available; (3) it was more economical than using photointerpretation; and (4) the results could be digitally reproduced. Overall, the accuracy results were modest for this type of digital classification. Considering the heterogeneous nature of the Everglades vegetation communities and the limited range of feature types (100 percent wetland), they concluded that this accuracy may be the best that can be expected using satellite imagery analysis.

Jensen *et al.* (1995) used the 1991 SPOT classified image created by Rutchey and Vilchek (1994) as a base from which to analyze historical trends in WCA2A cattail coverage. Landsat Multispectral Scanner data (1973, 1976, and 1982) and SPOT High Resolution Visible (HRV) multispectral data (1987) were normalized to the base year's (1991 SPOT) radiometric characteristics. Statistical clusters extracted from each image were found in relatively consistent regions of multispectral feature space (using red and near-infrared bands) and labeled using a core cluster approach. Wetland classification images for each year were analyzed using post-classification comparison change detection techniques which revealed an increasing trend in cattail coverage from 1973 to 1991.

In this study, two new cattail coverage maps were developed utilizing photointerpretation techniques on color infrared aerial photography. The dual objectives of this study were first, to compare the accuracy of air photointerpretation and satellite imagery analysis techniques for mapping cattail in Everglades wetlands, and second, to document trends in cattail distribution over a four-year period using photointerpretation methods. Changes in cattail distribution is one of several ecological indicators being used to track the progress of ongoing Everglades restoration efforts.

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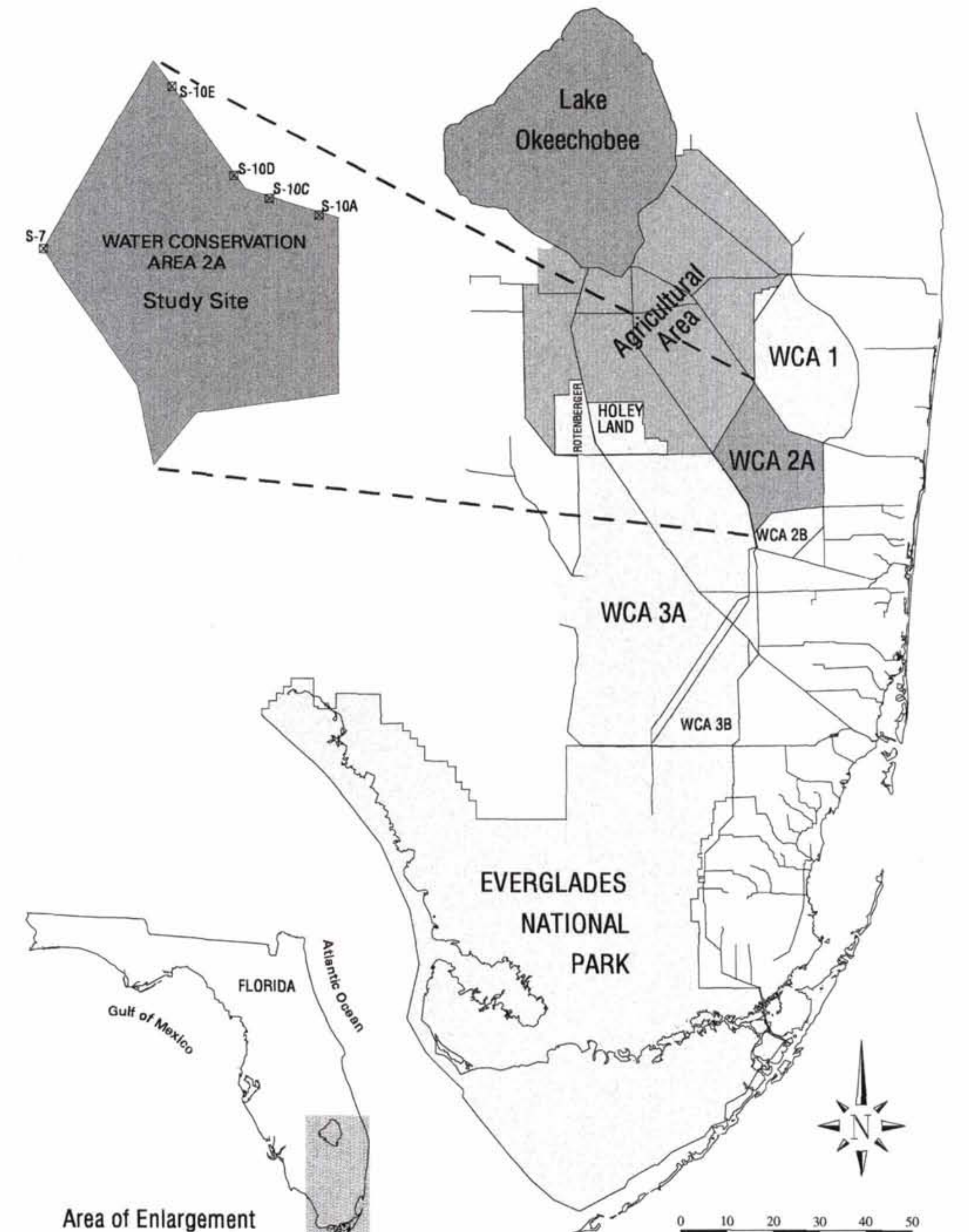

Figure 1. A location map of Water Conservation Area 2A situated in south Florida. Inflow structures are noted as S7, S10A, S10B, S10C, S10D, and S10E.

Materials and Methods

Vegetation mapping was accomplished by utilizing 1:24,000-scale color-infrared positive transparencies (23- by 23-cm format) acquired in October of 1991, and in June and November of 1995. Because of poor weather conditions, the 1995 aerial photography mission for WCA2A was flown in two phases (June and November of 1995). The photography missions were flown by the same contractor using the same camera system for both dates. This lag of five months between the two photography data sets could have been problematic. However, photointerpretation of the two sets of photography did not pose any technical problems for mapping cattail distribution for 1995.

Each photography data set (1991 and 1995) contained 35 stereo pairs and was used to create 1991 and 1995 cattail coverage maps for the 41,998-ha WCA2A impoundment. One photo of each stereo pair was covered with clear stabilene mylar. Cattail coverage was interpreted with the use of a Bausch & Lomb SIS-95 stereoscope. Neat lines were added to define the working area on each photograph and to match the boundaries of polygons from adjacent photos. Neat lines, cattail area boundaries, ground control points (GCPs), and as-

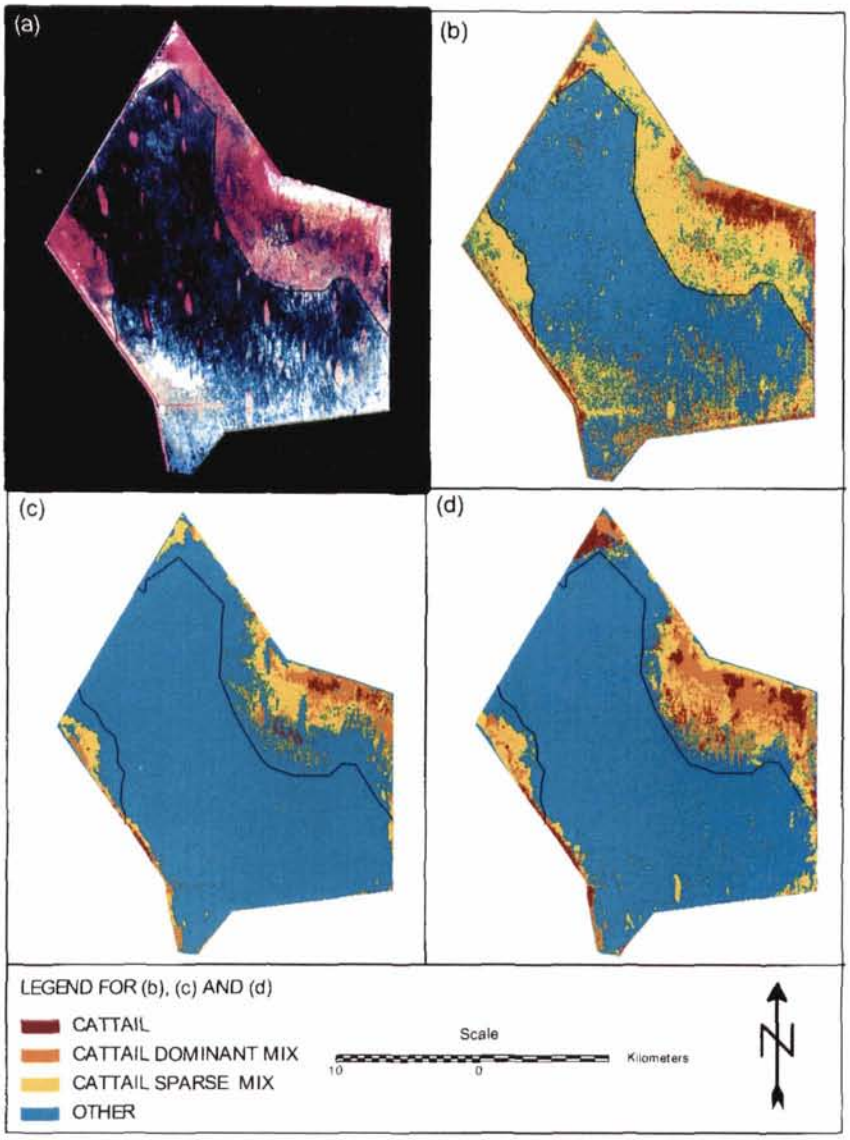

Plate 1. (a) Color-infrared composite of SPOT HRV XS captured on 10 August 1991 and used to create original 1991 20-class image. (b) Recoded 1991 SPOT image. (c) 1991 photointerpreted cattail map. (d) 1995 photointerpreted cattail map. Note: Black line on interior area of all images depicts the approximate cattail encroachment fringe as observed on recoded 1991 SPOT image.

sociated annotations were delineated under stereo directly on the mylar overlays using a 0.25-mm Rapidograph (Koh-I-Noor) drafting pen.

Cattail (*cattail coverage 90 percent or greater*), **Cattail-Dominant-Mix** (cattail equal to or greater than 50 percent and less than 90 percent, mixed with other species or open water), **Cattail-Sparse-Mix** (cattail less than 50 percent mixed with other species or open water), and **Other** (all other species or open water coverages lumped together — no cattail discernible) were delineated as separate categories. A minimum mapping unit of one hectare was chosen based on work done by Obeysekera and Rutchey (1997). Consistency of photointerpretation was of primary importance in the compilation of the 1991 and 1995 cattail maps. The delineation of vegetation polygons for both maps was performed by a single photointerpreter. In order to prevent the recording of false or misleading trends, each 1991 photograph was paired with its geographically corresponding 1995 photo(s) and analyzed under stereo. Quality control was performed by having a second photointerpreter review all delineated linework under stereo.

Water Conservation Area 2A was extracted from 1991 and 1995 SPOT panchromatic images and rectified to the Universal Transverse Mercator (UTM) coordinate system using 20 GCPs per image obtained from a GPS survey. Planimetric accuracy of the extracted 1991 and 1995 rectified SPOT images was root-mean square error (RMSE_{xy}) of ±1.0 pixel or ±10 metres on the ground. A total of 66 and 58 UTM coordinates were obtained from each of the 1991 and 1995 geocoded SPOT images, respectively, and used to establish GCPs for each of the two sets of photos (Welch *et al.*, 1995). A minimum of four GCPs were identified and numbered on each air photo with at least one GCP located in each corner of a photo. In addition, each GCP selected had to meet the criteria of having a common GCP

TABLE 1. CROSS TABULATION (HECTARES) OF MIGRATION FROM RUTCHEY AND VILCHEK (1991) SPOT CLASSIFIED IMAGE RECODED TO FOUR-CLASS CATTAIL MAP

	4-Class Cattail Map			
Rutchey and Vilchek (1991) SPOT Classified Image	Cattail	Cattail Dominant Mix	Cattail Sparse Mix	Other
Sawgrass – Dense				8230.1
Sawgrass – Moderate				7895.8
Sawgrass – Sparse				3330.1
Sawgrass/Cattail Mix – Dense			3758.1	
Sawgrass/Cattail Mix – Sparse			4557.3	
Sawgrass/Cattail (<30%)/Brush Mix			724.0	
Sawgrass/Brush Mix 1				1031.9
Sawgrass/Brush Mix 2				247.3
Sawgrass/Broadleaf/Cattail Mix			657.1	
Cattail (>70%) – Dense	2777.7			
Cattail (>30 and <70%) – Moderate		80.6		
Cattail (<30%) – Sparse			1602.9	
Cattail (>50%)/Brush Mix		810.7		
Brush Mix				50.1
Brush/Cattail (<30%)			288.4	
Tree Island				186.2
Slough/Open Water				433.9
Broadleaf Emergent/Brush Mix				232.1
Polygonum/Brush Mix				43.5
Periphyton				5060.6
TOTALS	2777.7	891.3	11587.8	26738.7

Note: Breakdown for cattail in Sawgrass/Cattail Mix Dense and Sparse not available.

in the overlap with adjacent photos. Planimetric error of individual photos ranged from ±1.05 to ±12.42 and ±0.86 to ±26.91 m on the ground for the 1991 and 1995 photography, respectively. The averages for all photos were ±5.75 and ±9.22 m on the ground for 1991 and 1995, respectively.

In order to correlate the spectral signature of cattail on the photo to field conditions, a total of 154 ground-truth sites were selected from the 1995 photography. The entire project area was examined for representative signatures. Ground control points for each photo containing ground-truth sites were digitized and a set of rectification coefficients were generated, which allowed X,Y ground coordinates to be determined for each site (Welch *et al.* 1995). A point coverage of the 154 ground-truth sites was created using ARC/INFO Version 7.0.3 (ESRI, 1982–95) geographic information system (GIS) software. These points were then loaded into the GPS unit and visited in the order of the shortest route generated in ARC/INFO. Field reconnaissance was performed by helicopter navigation to field sites utilizing a Trimble (Sunnyvale, California) PRO XL GPS receiver and a realtime ProBeacon unit for real-time differential corrections. A single observer accomplished field verification by hovering above the site and visually estimating the percent areal cover of cattail within an approximated 20- by 20-metre grid square.

Ground-truthing for the 1991 photography was not performed as part of this study. Instead, use was made of 370 ground-truth and accuracy assessment sites visited in 1991 and 1992 during the compilation of the 1991 SPOT classified image. These sites were also located using the GPS and differential corrections. These 370 ground-truth sites, 1991 color infrared National Aerial Photography Program (NAPP) photos, as well as the 1:24,000-scale 1995 aerial photography data set, were used as support tools for creating the 1991 cattail map.

All mylar overlays with delineated linework were scanned digitally using a Howtec Scanmaster III at 600 dpi with line arc scanning at an intensity of −26, contrast of 0.5, and gamma of 0.45. Resulting scan lines were inverted digitally so that background and linework pixels were set to "0" and "1," respectively. Final output for scanned files were in "tif" file format. The ARC/INFO "imagegrid" and "gridline" commands were used to convert the "tif" files into vector coverages. ARC/INFO tolerances were set and the ARC/INFO vector files were transformed to a UTM projection using the GCPs marked on the photo mylars. Vector files were then edited in the ARC/INFO ArcEdit module to remove label annotation and clean up any artifacts or gaps in the linework resulting from the scanning process. All ARC/INFO vector files from each photography data set were edge-matched and appended together to form one 1991 and one 1995 vector coverage. Having each GCP meeting the criteria of including a common GCP on the overlap with adjacent photos resulted in a limited amount of edge-matching to append the individual photo vector files together. Label points were then added to the coverages and attributed according to delineated linework annotation. ARC/INFO arc macro languages (AMLs) were developed and used to automate the process of converting scanned image data to a vector format with minimal human intervention.

Quality control of the digital coverage was accomplished in two ways. First, each coverage was checked for proper labeling by using the ARC/INFO "dissolve" command. The dissolved coverage was then checked to see if any adjacent polygons were joined because of either a photointerpretation or ARC/INFO labeling error. Second, all mylar labeling annotations were verified against the final vector coverages to check for any discrepancies.

The classified 1991 SPOT image created by Rutchey and Vilchek (1994) was recoded in ERDAS Imagine software so that it could be compared to the 1991 and 1995 air photointerpreted cattail maps (Table 1). The image was then imported into ARC/INFO using the "imagegrid" command and vectorized using the "gridpoly" command. A common border for the 1991 SPOT classified image and the 1991 and 1995 cattail maps was created in ARC/INFO and used to clip each coverage to the same geographic boundary. A small portion of the very southern tip of WCA2A was not covered by the 1991 SPOT satellite data. In order to be consistent in areal extent, this small portion was eliminated from the 1991 and 1995 cattail photography maps. The boundary mask maintained a constant area for each of the coverages, which was important for computing change or making comparisons.

It was determined that accuracy assessment required using a minimum of 204 points to check for an 85 percent accuracy level with an error of ±5 percent. This minimum number was based on binomial probability formulas (Snede-

TABLE 2. AREA (HA) OF CATTAIL CATEGORIES FOR 1991 PHOTOINTERPRETED MAPS AND RECODED 1991 SPOT IMAGE

	Cattail	Cattail Dominant Mix	Cattail Sparse Mix	Other	Total Hectares
1991 Photointerpreted	421.6	2287.3	2760.9	36528.6	41998.4
1995 Photointerpreted	1646.3	3944.0	3721.7	32686.5	41998.4
1991 Recoded SPOT Image	2777.7	891.3	11587.8	26741.6	41998.4

cor and Cochran, 1978). Accuracy assessment for the recoded 1991 SPOT classified image was repeated with the same 241 stratified random sampling points used in evaluating the accuracy of the original 20-class image. Map accuracy assessment for the 1995 air photointerpreted cattail map was performed by generating 210 stratified random sampling points using ERDAS Imagine software. (The 1995 cattail vector map was rasterized using the ARC/INFO "polygrid" command, and then converting to ERDAS "img" format using the ERDAS Import module.) These 210 points were located on the 1995 SPOT panchromatic satellite image and then visually correlated and located on the 1995 photography. Two photointerpreters independently viewed and classified the 210 random points on the photography under stereo. All points that were classified the same by the two photointerpreters were used, but not ground-truthed. All points that were classified differently were ground-truthed. All points that could not be located confidently on the SPOT satellite image also were ground-truthed using GPS. A total of 34 accuracy, ground-truth sites were visited in the field.

The method utilized for checking the accuracy of the 1995 air photointerpreted cattail map afforded an economical alternative to excessive ground-truthing expense. Hourly helicopter costs averaging $500.00 and an efficiency rate of about 15 ground truth sites per three to four hours flight time would have made this ground-truthing effort cost prohibitive if all 210 sites had to be visited in the field.

Results for producer, user, and overall accuracy, as well as Kappa coefficient of agreement, were computed using ERDAS Imagine software. Tau coefficients for accuracy assessment were computed using equations presented in Ma and Redmond (1995).

Results

Aerial photointerpretation techniques show that the area occupied by **Cattail** has increased from 421.6 in 1991 to 1,646.3 hectares in 1995 (Table 2; Plates 1c and 1d). This same time period also shows a trend of increasing area for both the **Cattail-Dominant-Mix** (2,287.3 to 3,944.0 ha.) and **Cattail-Sparse-Mix** (2,760.9 to 3,721.7 ha.). The areal extent of cattail over this four-year period appears to be spreading adjacent to and further downstream of inflow structures. In addition, the aerial photointerpretation of the 1991 photo set reveals that the total area of **Cattail** and **Cattail-Sparse-Mix** is less than that reported from the recoded 1991 SPOT classified image (Table 2; Plates 1b and 1c). Similarly, a comparison of the recoded 1991 SPOT classified image with the 1995 air photointerpreted map suggests a net loss in both **Cattail** and **Cattail-Sparse-Mix** and a gain in **Cattail-Dominant-Mix** hectares (Table 2; Plates 1b and 1d).

A higher level of overall accuracy was achieved for the 1995 photo map (95.2 percent) than the 1991 SPOT recoded image (83.4 percent) (Table 3). The 1995 photo map classification agrees better with the reference data than does the 1991 recoded SPOT image (Table 3, Kappa Coefficients 91.3 and 70, respectively). Similarly the classifier for the 1995 photography had higher accuracy (in comparison to random assignment) than the classification for the SPOT recoded image (Table 3, Tau coefficients 93.6 and 77.9, respectively).

Comparing the vegetation patterns of the 1991 air photointerpreted map and recoded 1991 SPOT image (Plates 1b and 1c), it is apparent that the cattail fronts in the northeast and west portions of the recoded 1991 SPOT classified image extended further into the interior marsh than that shown for the 1991 photo map. This visual cue also can be seen on the original 1991 SPOT image (Plate 1a) used to create the original 20-class image.

Discussion

The ultimate goal of this study was to define cattail distribution within an artificially controlled wetland impoundment over a four-year period utilizing air photointerpretation techniques and to compare these results with a previous vegetation classification study done of the same area using 1991 SPOT multispectral data. The results utilizing air photointerpretation techniques clearly show that cattail has substantially spread downstream of, and adjacent to, the inflow structures within WCA2A over the period from 1991 to 1995. There is also a high degree of confidence in the 1995 photointerpreted map with an overall accuracy of 95.2 percent (Kappa and tau coefficients are 91.3 and 93.6, respectively). In comparison, the recoded 1991 SPOT classified image reveals that the total hectares for **Cattail** and **Cattail-Sparse-Mix** are more than that shown for the 1991 photointerpreted map. In addition, results also show an apparent decrease in

TABLE 3. ERROR MATRICES FOR (A) THE RECODED 1991 SPOT AND (B) THE 1995 PHOTOINTERPRETED

(a)		1991 Recoded SPOT Image					
		Ground Truth Class				Row Total	Users Accuracy
		1	2	3	4		
1	Cattail	13	1	2	3	19	68.4
2	Cattail Dominant Mix	0	9	0	0	9	100.0
3	Cattail Sparse Mix	1	3	50	20	74	67.7
4	Other	1	1	8	129	139	92.8
	Column Total	15	14	60	152	241	
	Producers Accuracy	86.7	64.3	83.3	84.9		
	Points Sampled					241	
	Observed Misclassifications					40	
	Overall Accuracy					83.4%	
	Kappa (× 100)					70.0	
	Tau (T_e) Coefficient (× 100)					77.9	

(b)		1995 Photointerpreted					
		Ground Truth Class				Row Total	Users Accuracy
		1	2	3	4		
1	Cattail	17	1	1	0	19	89.5
2	Cattail Dominant Mix	0	27	1	0	28	96.4
3	Cattail Sparse Mix	0	3	24	0	27	88.9
4	Other	0	0	4	132	136	97.1
	Column Total	17	31	30	132	210	
	Producers Accuracy	100	87.1	80.0	100		
	Points Sampled					210	
	Observed Misclassifications					10	
	Overall Accuracy					95.2%	
	Kappa (× 100)					91.3	
	Tau (T_e) Coefficient (× 100)					93.6	

Cattail and **Cattail-Dominant-Mix** between the 1991 SPOT image and the 1995 photo map. The remainder of this paper discusses the possible reasons and explanations for these inconsistencies.

The authors postulate that there are at least four interacting, confounding factors that complicate vegetation classification in the Everglades, especially when using satellite imagery analysis techniques. These factors are hydrology (water depth/color), impacts from fire, periphyton species composition, and macrophyte species-dependent growth morphology.

The Everglades is one of the most extensive wetland ecosystems in the world with water depth and hydroperiod playing a major role in the historic development and present condition of the area (Gleason and Stone, 1994; Gunderson, 1994). Water Conservation Areas 2A is a shallow, impounded component of this system with water levels that can fluctuate from approximately one metre to just below the sediment surface. These shallow water depths have proven to be a challenge in satellite image analysis because background noise (e.g., substrate composition) and changes in landscape micro-topology alter the spectral reflectance of vegetation (Rutchey and Vilchek, 1994). Huete *et al.* (1985) studied the spectral response of plant canopies using ground-based spectral measurements and demonstrated that the influence of soil background seriously hampered the assessment and characterization of vegetated canopy covers.

Fire has been, and remains, an important ecological process in the Everglades and is a primary factor shaping Everglades vegetation patterns (Wu *et al.*, 1996). Most fires in the Everglades occur over standing water and burn only the emergent vegetation. In general, the vegetation responds to fire by resprouting from below-ground parts, rapidly reaching pre-fire species composition and biomass (Gunderson and Snyder, 1994). Visible scars can be observed in both satellite images and aerial photography for up to two years after a fire event has occurred. These scars pose a problem for both air photointerpretation and satellite imagery analysis methods. Scars have been particularly troublesome for satellite imagery analysis, especially if the fire was fairly recent (e.g., within six months). Burned areas often are classified as open water/slough areas when using remote sensing classification algorithms, even though the area in question may have originally been densely vegetated. Through photointerpretation techniques, the user usually is able to differentiate between a burn and an open water/slough community. However, the user will not know what the vegetation was unless the user (1) performs field reconnaissance or (2) uses subjective inference based on examining the vegetation surrounding the fire area to determine the composition of the burned vegetation.

Periphyton is the term used to describe the microfloral growth upon substrata (Wetzel, 1983). Everglades periphyton tend to rise to the water surface in the late summer and frequently form large floating masses around the stems of wetland macrophytes (Craighead, 1971). Rutchey and Vilchek (1994) concluded that much of the inaccuracy of their 1991 classified SPOT satellite image was due to the unique spectral reflectance characteristics of periphyton. New research by McCormick *et al.* (1996) and McCormick and O'Dell (1996) have documented that changes in the periphyton species composition along a water quality gradient in WCA2A is strongly correlated with changes in surface water phosphorus concentrations. These periphyton composition changes appear to precede the cattail front documented by Jensen *et al.* (1995). The zone of cattail expansion is one to three kilometres up-gradient of the zone of periphyton composition change. It is possible that the spectral effect caused by the periphyton species composition change at the down-gradient end of the nutrient front may have led to the misclassification of cattail along the leading edge of encroachment.

Everglades land-cover patterns occur as a result of the complex interactions between hydrology, climate, fire, soil type, topography, and natural and anthropogenic nutrient inputs (Gunderson, 1994). These variates interact to form and change the patch dynamics of the ecosystem. In doing so, the vegetation is shaped into a mosaic of plant assemblages. Growth morphology for any single species can be unique. For instance, cattail can occur in stands that are sparse to dense, short to tall, and clumped to monotypic (Miao and Sklar, in press). These variations in growth pattern and transitions to and from each other within a single vegetation species are difficult to capture and classify correctly using satellite imagery analysis techniques. Rutchey and Vilchek (1994) found that one cause of lower classification accuracy levels was subtle signature changes within differing densities of the same species.

Hectare discrepancies for **Cattail-Dominant-Mix** and **Cattail-Sparse-Mix** categories in the 1991 recoded classified satellite and the 1991 air photointerpreted data may also be attributed partially to the methods of recoding the 1991 SPOT classified data (Table 1). Two of the classes, "Sawgrass/Cattail - Dense" and "Sawgrass/Cattail - Sparse" are described as a mixture of sawgrass and cattail greater than or equal to 60 percent (dense) areal coverage or less than 60 percent (sparse) areal coverage. Unfortunately, there was no percentage breakdown for cattail versus sawgrass in these classes. These two categories, which encompass 8315 hectares, were recoded to **Cattail-Sparse-Mix**. Undoubtedly, some portion of the total area would have been **Cattail-Dominant-Mix**. However, based on the descriptions for these two classes, they were recoded into the **Cattail-Sparse-Mix** class.

Conclusion

Given the high percentage value of 95.2 for overall accuracy for the 1995 photointerpreted cattail map, we conclude that air photointerpretation techniques currently offer a preferable tool for mapping Everglades vegetation. We also conclude that the increasing cattail encroachment trend depicted in the 1991 to 1995 air photointerpreted maps is accurate and that the 1991 SPOT classified data overestimated the distribution of cattail because of the confounding, interacting mechanisms previously discussed. Relative changes in the Jensen *et al.* (1995) cattail trend images are accurate. However, based on this new research, the actual amount and distribution of cattail hectares may have been overestimated. Just as humans are somewhat limited in their ability to evaluate spectral patterns, computers are somewhat limited in their ability to evaluate complex spatial patterns such as these just discussed. Satellite image classification methods have been based primarily on the multispectral characteristics of individual pixels without considering spatial context, that is, relations among neighboring pixels (Argialas and Harlow, 1990). Thus, they result in characterization of spectral classes rather than object identification and description, which are at the core of photointerpretation techniques.

Satellite imagery analysis can make excellent use of a computer in deriving land-cover information from large remotely sensed digital data sets and has been used with success in mapping wetlands within a landscape (Brondizio *et al.*, 1996; Hodgson *et al.*, 1987; Jensen *et al.*, 1993). Conversely, visual photointerpretation techniques make use of the human mind's excellent ability to qualitatively evaluate spatial patterns in a scene (Lillesand and Kiefer, 1987). The ability to make subjective judgements based on selective spectral elements, together with the interpreter's reasoning power and the capacity to draw on past experience, is essential in many interpretation efforts. However, visual interpretation techniques may have certain disadvantages because of the limited ability of the eye to discern tonal values and the difficultly for a photointerpreter to simultaneously analyze numerous spectral images.

It is difficult, if not impossible, to do quantitative comparisons between air photointerpretation and satellite imagery analysis methods. These two approaches rely on very different mechanisms for classifying ground cover data. There have been significant advances in digital image processing of remotely sensed data for scientific visualization (Jensen, 1996). However, the overwhelming majority of these computer-assisted image processing techniques appears to depend primarily on the tone and color of individual pixels. In addition to tone and color, air photointerpretation utilizes size, shape, height, pattern, texture, site, and association (Lillesand and Kiefer, 1987). It is the combination of these factors that enables a skilled photointerpreter to accurately recognize the complex mosaic of the Everglades. The Federal Geographic Data Committee (1992) evaluated the application of satellite data for mapping and monitoring wetlands. They reported that satellite imagery analysis as a stand-alone tool was not adequate for mapping wetlands as part of the National Wetlands Inventory program. However, when used in conjunction with digital data derived from aerial photography and other sources, the combination provided products with greater wetland evaluation and monitoring capabilities than either type of data used alone. It is anticipated that advances in softcopy image processing systems ultimately will provide a combination of both photointerpretation and digital enhancing tools that will prove beneficial in mapping valuable resources such as the Everglades.

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