Photointerpretation Key for the Everglades Vegetation Classification System

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Abstract

The University of Georgia's Center for Remote Sensing and Mapping Science, the National Park Service's South Florida Natural Resources Center at Everglades National Park, and the South Florida Water Management District have cooperated in the development of a new Everglades Vegetation Classification System and associated photointerpretation key for mapping south Florida vegetation. The hierarchical classification system was required for a detailed geographic information system (GIS) vegetation database and 1:15,000-scale maps produced by the above agencies for over 12,000 km² of preserved federal and state lands. Vegetation for this extensive area was mapped from color-infrared (CIR) aerial photographs using ground truth information collected by helicopter and airboat to verify the identification of plant communities. A total of 89 classes are included in the Everglades Vegetation Classification System and can be used in combination with 13 additional numeric modifiers indicating factors affecting vegetation growth such as hurricane damage, abandoned agriculture, intensive off-road vehicle (ORV) use, and altered drainage. A digital photointerpretation key was developed that documents photo signatures of the vegetation classes. This key includes (1) scanned sections of aerial photographs that are representative of major plant communities; (2) associated ground and helicopter oblique photographs illustrating vegetation conditions in the field; and (3) text descriptions of photo signatures such as color, tone, texture, pattern, relative height, shape, and context. The key is used to train new photointerpreters, as well as to provide users of the vegetation database with further information on photo details and field characteristics associated with Everglades vegetation classes.

Introduction

The collaborative effort between the Center for Remote Sensing and Mapping Science at The University of Georgia, the South Florida Natural Resources Center at Everglades National Park, and the South Florida Water Management District to construct a detailed geographic information system (GIS) vegetation database for south Florida parks and preserves has led to the development of a new Everglades Vegetation Classification System and associated photointerpretation key. The classification system and key were required to map vegetation patterns to the plant-community level within a 12,000-km² area including Everglades National Park, Big Cypress National Preserve, Biscayne National Park, the Florida Panther National Wildlife Refuge, and South Florida Water Management District Water Conservation Area (WCA) 3 (Figure 1).

Based on previous experience with remote sensing of wetland vegetation using both satellite image data and aerial photographs, it was determined that Everglades vegetation communities and species could be mapped from 1:40,000-scale U.S. Geological Survey (USGS) National Aerial Photography Program (NAPP) color-infrared (CIR) aerial photographs acquired in 1994/1995 of the federal parks and preserves and 1:24,000-scale CIR photographs recorded by the South Florida Water Management District over WCA 3 in 1994/1995 (Welch *et al.*, 1988; Welch *et al.*, 1992; Remillard and Welch, 1992; Rutchey and Vilchek, 1994; Jensen *et al.*, 1995). It was apparent at the onset of the database/mapping project that existing vegetation classification systems such as the USGS *Land-Use and Land-Cover Classification System for Use with Remote Sensor Data* (Anderson *et al.*, 1976), the U.S. Fish and Wildlife Service Cowardin System for *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin *et al.*, 1979), and the Florida Land Use and Cover Classification System (FLUCCS) employed by the Florida Department of Transportation (FLUCCS, 1985) would not be adequate for compiling a vegetation database and associated maps of the plant communities. These systems are national or statewide in scope and do not include the desired level of detail for south Florida vegetation.

Late in the first year of the Everglades vegetation mapping project, an additional classification system was released by The Nature Conservancy (TNC), Arlington, Virginia, and ESRI, Redlands, California, for use in the USGS Biological Resources Division (BRD)/National Park Service Vegetation Mapping Program (TNC, 1994). The objective of this program is to develop a uniform hierarchical vegetation classification system to generate vegetation maps for most of the park units under National Park Service management. Although this system was considered for use in the Everglades, several factors led to the decision to develop a new Everglades Vegetation Classification System for this mapping project: (1) the interpretation of the NAPP aerial photographs was well underway when the TNC final draft was made available, (2) the degree of community-level information in the national vegetation classification system was not complete and required further refinement, and (3) the unique floristic composition of the south Florida Everglades warranted special attention to plant

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Photogrammetric Engineering & Remote Sensing,
Vol. 65, No. 2, February 1999, pp. 171–177.

0099-1112/99/6502–171$3.00/0

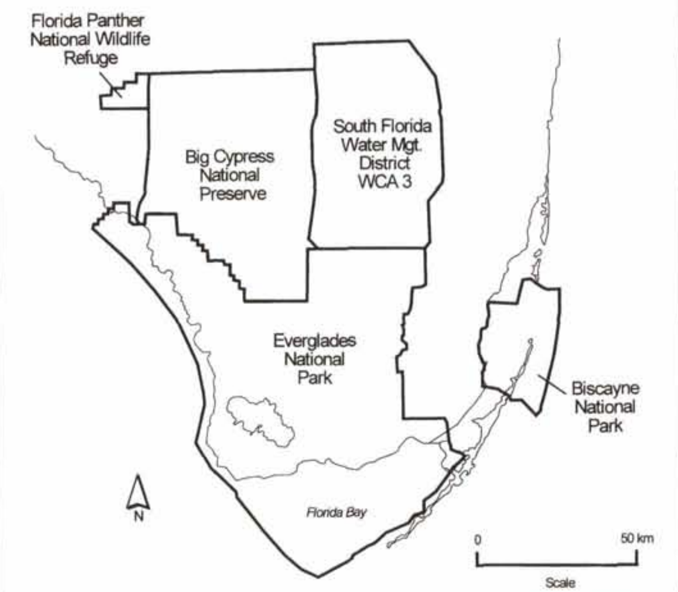

Figure 1. The study area covered by the Everglades vegetation database/mapping project includes Everglades National Park, Big Cypress National Preserve, Biscayne National Park, Florida Panther National Wildlife Refuge, and Water Conservation Area 3.

species and communities that do not occur elsewhere in the conterminous United States. Because the TNC and Everglades Vegetation Classification Systems are similarly structured, the two classification systems can be integrated as required. Both are hierarchical and combine physiognomy at the highest level (i.e., the coarsest level is based on the height, spacing, and life form of the dominant species) and floristics at the lowest level (i.e., the finest level groups species as associations or plant communities). Plant community classes in the Everglades Vegetation Classification System are therefore compatible with the "community element" level of TNC's Standardized National Vegetation Classification System.

In addition to the development of a new Everglades Vegetation Classification System, it was necessary to compile a photointerpretation key linking CIR air photo signatures with each of the vegetation classes and numeric modifiers. Such keys have been used since World War II to aid the photointerpretation process (Colwell, 1946; Colwell, 1997). The keys serve as training material and provide a means for maintaining consistency in interpretation, especially in large mapping projects involving more than one interpreter (Lund, 1997).

Two types of photointerpretation keys include dichotomous or elimination keys and selection keys. Dichotomous keys present two contrasting choices at each step and, by a process of elimination, the user determines the class that best fits a set of environmental and photographic characteristics. Although desirable, dichotomous keys are most useful where vegetation types are homogeneous and clearly fit a predetermined definition (Lund, 1997). In large areas such as the Everglades, where there is considerable variation in species composition and environmental conditions within classes, selection keys are more appropriate.

Selection keys generally allow users to examine diagrams or photographic examples along with accompanying text for comparison with the photos being interpreted. Because variations within plant communities and photographic signatures of Everglades vegetation precluded the development of a dichotomous key, a selection-type key was deemed suitable for illustrating typical photo signatures of major vegetation classes.

Specific objectives in the creation of a classification system and a photointerpretation key for Everglades vegetation were

- development of a detailed, hierarchical Everglades Vegetation Classification System for use in mapping Everglades vegetation to the plant-community level from CIR aerial photographs; and
- compilation of a photointerpretation key that includes scanned aerial photographs and accompanying ground and helicopter shots of the plant communities, along with text descriptions of the vegetation signatures.

Everglades Vegetation Classification System

Development of the new Everglades Vegetation Classification System was based on vegetation classification systems previously used by researchers mapping portions of Everglades National Park and Big Cypress National Preserve (e.g., Davis 1943; McPherson, 1973; Gunderson and Loope, 1982; Olmsted *et al.*, 1983; Rose and Draughn, 1991). Used in combination with detailed descriptions of Everglades vegetation such as those provided by Egler (1952), Craighead (1971), Duever *et al.* (1986), and Davis and Ogden (1994), a list of possible vegetation classes was compiled. The 1:40,000- and 1:24,000-scale CIR aerial photographs were then carefully examined to determine if these classes could indeed be identified. Classes that could not be distinguished on the photographs were eliminated from the system, and the remaining classes were organized hierarchically under eight major vegetation types: forest, scrub, savanna, prairies and marshes, shrublands, exotics, additional class headings, and special modifiers (Jones *et al.*, 1999).

Each of the eight major classes is further divided into classes corresponding to plant communities. In cases where individual species can be discerned on the aerial photographs (e.g., red, black, and white mangrove), a third level of detail was included in the classification system. Table 1 illustrates the hierarchical arrangement of forest classes (e.g., mangrove, buttonwood, and subtropical forests) and subclasses, with additional detail provided within the attached footnotes. All class names are abbreviated for labeling database and map products. For example, red mangrove forest is designated FMr. Samples of the Everglades vegetation maps labeled with these classes are provided in Welch *et al.* (1999) and Rutchey and Vilchek (1999) in this issue.

In order to accommodate the complex vegetation patterns that are found in the Everglades and generally maintain a minumum mapping unit of one hectare, a three-tiered scheme was developed for attributing vegetation polygons (Welch *et al.*, 1995; Obeysekera and Rutchey, 1997). Using this scheme, photointerpreters can annotate each polygon with a dominant vegetation class accounting for more than 50 percent of the vegetation in the polygon. Secondary and tertiary vegetation classes are then added as required to describe mixed plant communities within the polygon. In addition, one or more of 13 numerical modifiers can be attached to *each* dominant, secondary, and tertiary vegetation label to indicate factors such as human influence, hurricane damage, altered drainage, and extensive off-road vehicle (ORV) use that might influence vegetation growth and distribution (Table 2). Other modifiers provide information about the vegetation distribution (e.g., scattered individuals) and important environmental characteristics (e.g., periphyton, numerous ponds, or exposed pinnacle rock).

Extensive fieldwork was conducted as part of this project to verify vegetation identification on the aerial photographs and, in doing so, document plant communities in the Everglades Vegetation Classification System. Between November

TABLE 1. HIERARCHY OF THE FOREST VEGETATION CLASS—ONE OF EIGHT MAJOR CLASSES WITHIN THE EVERGLADES VEGETATION CLASSIFICATION SYSTEM

I. FOREST[1]	F
A. Mangrove Forest	FM
1. Red (*Rhizophora mangle*) Mangrove	FMr
2. Black (*Avicennia germinans*) Mangrove	FMa
3. White (*Laguncularia racemosa*) Mangrove	FMl
4. Mixed Mangrove[2]	FMx
B. Buttonwood (*Conocarpus erectus*) Forest[3]	FB
C. Subtropical Hardwood Forest[4]	FT
D. Oak-Sabal Forest[5]	FO
E. Paurotis Palm (*Acoelorrhaphe wrightii*) Forest	FP
F. Cabbage Palm (*Sabal palmetto*) Forest	FC
G. Swamp Forest	FS
1. Mixed Hardwood Swamp Forest[6]	FSh
2. Cypress Strands[7]	FSc
a. Cypress Domes/Heads[8]	FSd
3. Cypress-Mixed Hardwoods[9]	FSx
4. Mixed Hardwoods, Cypress and Pine[10]	FSa
5. Cypress-Pines[11]	FSCpi
6. Bayhead[12]	FSb

[1]High-density stands of trees with heights over 5 m.
[2]Specific mixtures of mangrove species, when identified, will be distinguished as subgroups.
[3]*Conocarpus erectus* with variable mixtures of subtropical hardwoods.
[4]*Lysiloma latisiliquum, Quercus virginiana, Bursera simaruba, Mastichodendron foetidissimum, Swietenia mahagoni*, among others.
[5]*Quercus laurifolia, Q. virginiana, Sabal palmetto.*
[6]*Quercus virginiana, Q. laurifolia, Acer rubrum, Sabal palmetto, Fraxinus caroliniana.*
[7]*Taxodium ascendens, T. distichum*; Cypress strands may contain an understory of species such as *Annona glabra, Chrysobalanus icaco*, and *Fraxinus caroliniana.*
[8]*Taxodium ascendens, T. distichum*; Cypress growing in a depression such that trees in the center are tallest and give the characteristic dome shape. Domes may contain a fringe of short cypress less than 5 m.
[9]*Taxodium ascendens* and *T. distichum* with variable mixtures of subtropical and temperate hardwoods.
[10]Mixture of subtropical hardwoods with *Taxodium distichum* and occasional *Pinus elliottii* var. *densa.*
[11]*Taxodium distichum* with *Pinus elliottii* var. *densa* and a mixed hardwood scrub understory.
[12]*Magnolia virginiana, Annona glabra, Chrysobalanus icaco, Persea borbonia, Ilex cassine, Metopium toxiferum*, among others.

of 1994 and February of 1997, personnel from the Center for Remote Sensing and Mapping Science, Everglades National Park, and Big Cypress National Preserve spent a total of 42 days in the field conducting ground and helicopter surveys. Helicopter reconnaissance and verification flights alone totaled over 120 hours at an average charge of $550 per hour for helicopter rental.

During the fieldchecking missions, staff botanists from the parks and preserves accompanied University of Georgia field crews to assist in plant species identification and documentation of Everglades plant communities. This data collection effort in the vast wetland area required the integrated use of GPS, image processing, and database management software. Specifically, the FieldNotes (PenMetrics, Inc.) software package loaded on a laptop computer and interfaced via a serial connection with a Trimble Basic or Pathfinder Professional GPS unit enabled the current ground position to be superimposed on a SPOT satellite image backdrop (Welch *et al.*, 1995; Welch and Remillard, 1996). When this system was used in the helicopter, the track of the helicopter position appears as a flashing cross against the satellite image display. The operator can click the mouse on the flashing cross at any time to enter a fieldcheck data point and open a database entry form. Information on plant species identified by the Everglades botanists was typed in a free-form memo field, allowing an unlimited amount of text to be recorded at each field point. It is estimated that over 2,000 of these field points were collected and entered into the Everglades fieldchecking database over a three-year period. Additional helicopter and airboat surveys were conducted by South Florida Water Management District personnel, with over 1,000 sites documented in the Water Conservation Areas.

In addition to text records describing plant species identified in the field, numerous 35-mm photographs were obtained on the ground and from the helicopter during the fieldchecking missions. These photos document the individual species that make up the various plant communities listed in the Everglades Vegetation Classification System, as well as the appearance of the plant communities. They also provided the basis for linking Everglades vegetation classes with CIR aerial photographic signatures for the creation of a photointerpretation key.

Development of a Digital Photointerpretation Key

Color slides of Everglades plant communities photographed during the fieldchecking missions were scanned at 600 dots per inch (dpi) in 24-bit color using an Epson Expression 836 XL scanner. The resulting digital images were saved in Tagged Image File Format (TIFF) for incorporation into the Everglades photointerpretation key. Examples of typical air photo signatures corresponding to these plant communities were then identified on the 1:40,000-scale CIR positive transparencies (23- by 23-cm format) and 1:10,000-scale enlarged prints of the NAPP photos. Selected portions of the 1:40,000-scale positive transparencies were scanned in a manner similar to the ground and helicopter photographs for use in the Everglades photointerpretation key. Color Plate 1 illustrates typical ground/helicopter photos and associated CIR air photo signatures for representative plant communities within each of the eight major vegetation type classes in the Everglades Vegetation Classification System.

Text descriptions of air photo signatures also were written for each of the plant community classes included in the photointerpretation key (Table 3). These descriptions assume the use of late fall, winter, and early spring photographs because the air photos employed in the Everglades vegetation database project were acquired in January, March, and December of 1994, and January and October of 1995. Corresponding to the normal dry season (November to May) in south Florida, the air photos, for the most part, document conditions when water levels are at their lowest and infrared reflectance from plant communities such as graminoid prairies and marshes is not reduced by wet backgrounds. Additionally, some trees and shrubs such as cypress (*Taxodium ascendens* and *T. distichum*), willow (*Salix caroliniana*), and other temperate plant species lose their leaves during this

TABLE 2. SPECIAL NUMERIC MODIFIERS ADDED TO VEGETATION LABELS IN THE EVERGLADES VEGETATION CLASSIFICATION SYSTEM

VIII. SPECIAL MODIFIERS	
A. Hurricane Damage Classes	
1. Low to medium (0% to 50% damage)	−1
2. High (51% to 75% damage)	−2
3. Extreme (>75% damage)	−3
B. Low Density (Scattered individuals)	−4
C. Human Influence	−5
1. Abandoned agriculture	−6
2. Altered drainage	−7
3. High density ORV trails	−8
D. Periphyton	−9
E. Treatment Damage (e.g., Herbicide treatment)	−10
F. Other Damage (e.g., Freeze damage)	−11
G. Ponds	−12
H. Exposed Rock (i.e., Pinnacle rock)	−13

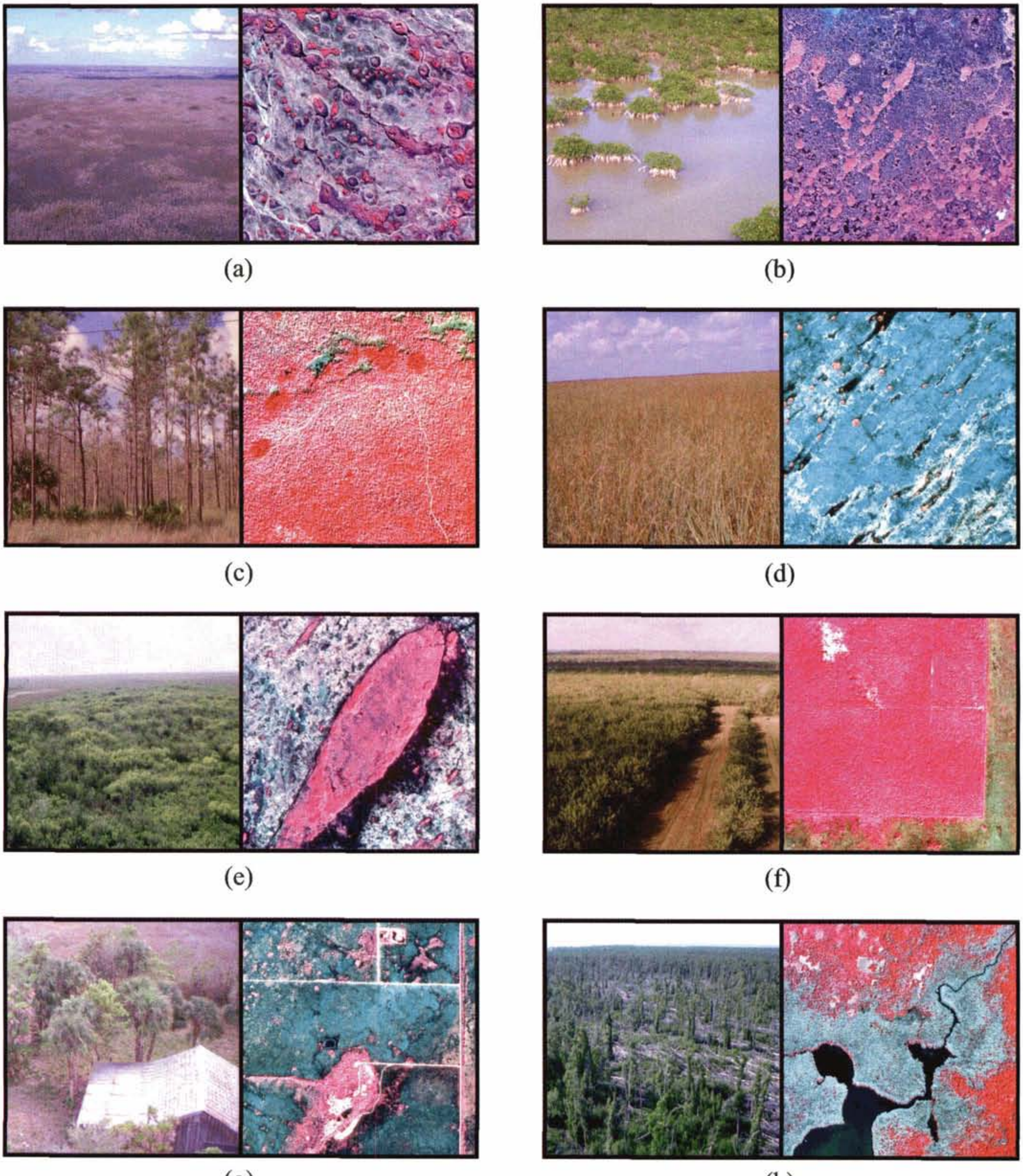

Plate 1. Sample of images contained in the Everglades photointerpretation key. Ground or helicopter views of eight Everglades plant communities and corresponding signatures on CIR aerial photos are representative of the vegetation classes listed in Table 3: (a) cypress forest, (b) red mangrove scrub, (c) pine savanna, (d) sawgrass prairie, (e) willow shrubland, (f) exotic Brazilian pepper, (g) cultural features, and (h) hurricane damage.

time and exhibit greater contrast with adjacent vegetation such as evergreen pines (*Pinus elliottii* var. *densa*) and subtropical hardwoods (e.g., live oak (*Quercus virginiana*)). It is important to note that the characteristics of winter/dry sea-

TABLE 3. DESCRIPTIONS OF PHOTO SIGNATURES FOR SELECTED EVERGLADES VEGETATION CLASSES

Vegetation Class*	Color	Tone	Texture	Pattern	Height	Shape	Context
Forest (a) Cypress (*Taxodium* spp.)	White to gray	Light	Coarse	Dense canopy	Medium to tall	Expansive strands or domes	Freshwater swamp, often flooded
Scrub (b) Red Mangrove (*Rhizophora mangle*)	Red	Medium	Smooth to medium	Scattered to dense	Short	Clumps to broad areas	Coastal saline, inland to freshwater
Savanna (c) Pine (*Pinus elliottii* var. *densa*)	White to pink	Light	Fine to medium	Open canopy	Medium to tall	Irregular	Relatively drier sites
Prairie/Marsh (d) Sawgrass (*Cladium jamaicense*)	Blue to beige	Light to medium	Very fine	Homo-geneous	Very low	Broad areas	Long hydroperiod prairies
Shrublands (e) Willow (*Salix caroliniana*)	Pink to purple	Light to medium	Fine	Thin to dense thickets	Medium	Small and circular to broad	Small depressions, along roads
Exotics (f) Brazilian Pepper (*Schinus terebinthifolius*)	Pink to magenta	Medium	Medium to coarse	Usually dense	Medium	Square patches to irregular	Remnant agriculture and disturbed areas
Additional (g) Cultural Features (Structures and cultivated lawns)	Pink to red	Light to medium	Fine to medium	Medium to dense	Low to high	Square patches	Buildings, lawns and introduced exotics
Modifiers (h) Hurricane Damage	White, gray to pink	Bright to light	Coarse	Scattered to dense	Low to high	Broad areas to small patches	Mainly on west and south coasts

*Plant communities listed here (a–h) are depicted in Plate 1.

son vegetation signatures such as those listed in Table 3 can vary widely from signature characteristics seen in air photos acquired in the summer/wet season.

Application of the Everglades Vegetation Classification System and Photointerpretation Key

Development of the Everglades Vegetation Classification System was an evolutionary process in that use of the system during the course of the vegetation database/mapping project resulted in the refinement of several individual vegetation classes. For example, a major vegetation type class, hammock, was eliminated and combined with the forest class because the difference between the two was not floristic composition but defined size (with hammocks being essentially small forest islands). Some plant community classes such as Florida thatch palm (*Thrinax radiata*) forest were eliminated from the classification system because of only occasional occurrence in the Everglades landscape. In other cases, classes such as bayhead-hardwood scrub were added to describe the vegetation in complex transition areas between saline and freshwater environments.

In addition to refining the structure of the Everglades Vegetation Classification System, personnel from the Center for Remote Sensing and Mapping Science, Everglades National Park, Big Cypress National Preserve, and the South Florida Water Management District met several times to cross-correlate vegetation classes required for mapping the federal parks, preserves, and state conservation areas. These meetings resulted in the redefinition of some vegetation classes to incorporate broader class descriptions encompassing plant species and conditions found within the entire study area. A few classes also were added to the Everglades Vegetation Classification System such as disturbed fish camp sites and artificial deer islands built on spoil areas to accommodate special needs for mapping the South Florida Water Management District water conservation areas.

In the end, representatives of the various federal and state agencies generally were in agreement that the Everglades Vegetation Classification System adequately portrayed the vegetation communities of south Florida. Photointerpreters also felt that the classification system provided appropriate choices for assigning vegetation classes to plant communities that they identified on the photos and verified in the field. Flexibility in describing the often complex vegetation patterns found in the Everglades where only a few centimeters of elevation change results in variable plant growth was enhanced by (1) the hierarchical organization of the classification system that allowed interpreters to identify vegetation to the individual species level or to more general vegetation classes as appropriate, (2) the three-tiered labeling scheme permitting delineated vegetation polygons to be annotated with up to three vegetation classes, and (3) the use of special numeric modifiers that convey additional information on vegetation in a concise and consistent format. These classification conventions provided a powerful mechanism for symbolizing a substantial amount of detail on vegetation, land use, and disturbance history. Indeed, it was found that more detailed information could be discerned from the aerial photographs than could be displayed and efficiently labeled on the 1:15,000-scale hardcopy maps (see Welch *et al.* (1999) in this issue).

The photointerpretation key is extremely useful in documenting examples of the plant communities described in the Everglades Vegetation Classification System. It provides users of the Everglades vegetation database with illustrations of typical species assemblages, field conditions, and associated CIR air photo signatures and proved to be especially important in an area such as south Florida where there is a high diversity of plant communities, including temperate, subtropical, and endemic (i.e., unique to this area) plant species. The key also was used to train new interpreters and substantially decrease the learning curve that normally accompanies the initiation of a photointerpreter to a new vegetation mapping project. As with the Everglades Vegetation Classification System, the photointerpretation key was expanded during the project to include examples of photographs depicting variations in species composition within plant communities, vegetation signatures under stressed conditions, and differences in plant growth over the extensive south Florida study area. Access to the key was enhanced by Hu (1999) when hyperlinks were added to the Everglades Vegetation Classification System to allow users to click on vegetation class names and retrieve the corresponding ground, helicopter, and air photo images.

Conclusion

The development of a detailed, hierarchical Everglades Vegetation Classification System and associated photointerpretation key proved to be vital to the success of mapping Everglades vegetation to the plant-community level from CIR aerial photographs. It is believed that, in spite of the existence of previous vegetation classification systems used in wetland vegetation mapping, it was necessary to create a new system specific to the Everglades in order to maximize the amount of information on plant communities that could be extracted from the CIR aerial photographs. The associated photointerpretation key augments the Everglades vegetation database with scanned sections of CIR aerial photographs, scanned ground- and helicopter-based photographs, and text descriptions of vegetation signatures. This key facilitates training and instruction of new photointerpreters and is useful in conveying a better understanding of the interpretation process to users of the digital vegetation database. Together, the Everglades Vegetation Classification System and photointerpretation key provide enhanced descriptions of vegetation in this unique area of south Florida and establish a basis for comparison of future changes in the Everglades ecosystem.

Acknowledgments

This study was conducted as a part of mapping efforts for federal parks and preserves conducted under Cooperative Agreement No. 5280-4-9006 between Everglades National Park and The University of Georgia Research Foundation. Assistance by staff at the Center for Remote Sensing and Mapping Science at The University of Georgia; the South Florida Natural Resources Center at Everglades National Park and Big Cypress National Preserve is most appreciated. Tom Armentano, Robert Doren, William Robertson, Ken Rutchey, Frank Sargent, and James Snyder reviewed the Everglades Vegetation Classification System and provided many helpful comments for which the authors are most grateful. The mapping of the Water Conservation Area 3 was funded and supported by the Everglades Systems Research Division of the South Florida Water Management District.

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