
Everglades Restoration Canopy Species Characterization and Change Detection Analysis

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Development of a cost-effective method to study vast wetland system canopies for mitigation change in wetland restoration with minimal ground work. Geospatial analysis includes a subset of 1999 Infrared Imagery with a PCA analysis to detail observed variations. Overlay analysis of aerial sketchmapping of exotic species vegetation for 2008, 2010, 2012 and the Principal Components Analysis along with photointerpretation of 2009, 2011 imagery to identify vegetation signatures followed by field confirmation of signatures. Field confirmation completed to validate and ensure accuracy of analysis.

1 Introduction

The Environmental Resource Management Department's wetland science section within the Seminole Tribe of Florida is responsible for managing wetland permitting, enhancement activities, and mitigation monitoring. The wetland section utilizes standard scientific methodology to analyze vegetation ground, subcanopy, and canopy covers through monumented transects and quadrats. The identification of specific species within these transects determines whether the success criteria are met for federally required restoration and enhancement activities. Until recently, canopy study estimates failed to extrapolate data for entire wetland habitats. This was due to the limited number of locations for transects and diameter at breast height (DBH) measurement locations. Rather, they reflected change that occurred within the vicinity of the transects. The use of the ERDAS Imagine Remote Sensing program's Isodata classification has expanded the analysis of these wetland systems to encompass entire habitats. These habitats are critical to Everglades Restoration and endangered wildlife such as the Florida Panther.

2 Project History

Florida flood control Central and South Florida Project (CS & SF) authorized by United States Congress in 1948 was modified, due to its adverse effects to wetland habitats, under the Comprehensive Everglades Restoration Plan (CERP). CERP outlines required restoration features critical to protection and preservation of water resources in central and southern Florida. Approved by the Water Resources Development Act (WRDA) of 2000, CERP includes more than 60 elements. The purpose of these project features is to facilitate capture of fresh water and uptake of nutrients, resulting in restoration of wetland hydroperiods and improvement of water quality before flowing out to coastal waters. Big Cypress Seminole Indian reservation (BCSIR) was deemed as one of the critical areas of Everglades Restoration under CERP, the sixth most critical out of over 100 initially considered critical to ecosystem restoration. The subsequent Water Conservation Plan Project (WCP) was authorized due to critical location of Everglades Restoration.

The purposes of WCP basins are for protection against 25-year 72-hour flood events, provide supplemental irrigation water, and improve quality of agricultural water runoff within the BCSIR. Basin features include Water Resource Areas (WRAs), Irrigation Cells, levies, pumps, and canals. The WRAs and surface water management structures are located in four defined hydrologic basins are intended to

produce restoration, preservation, and protection benefits. These benefits are the removal of phosphorus and other pollutants from reservation lands that flow to the Everglades Protection Area (EPA), restoration of more natural hydroperiods in the Big Cypress National Preserve and the BCSIR Native Area, and mimic historic timing and distribution of flows. Water received north of the reservation is pumped into the Basin project features and WRAs, the forested wetland system components, before flowing south to the Native Area which contains six Wetland Enhancement Areas. The Native Area totaling 14,000 acres is composed of mosaic upland and wetland habitats such as Pine forests, Cypress forests, Wetland hardwoods, Oak hammocks, Sloughs, Wet prairies, and Marshes. United States Army Corps of Engineers permit and Wetland Management Plan detail success criteria and monitoring requirements of the Water Conservation Project. The performance criteria are as follows:

- ❖ Vegetation
 - Canopy mortality in each WRA to be less than 10%
 - Demonstrate evidence of natural recruitment of canopy and subcanopy seedlings of Native Facultative Wet or Obligate (FACW/ OBL) wetland species
 - Demonstrate dominance of Native FACW/ OBL wetland indicator groundcover and shrub stratum
- ❖ Hydrology
 - Wetland exhibits hydroperiod/stage that supports the existing wetland system; or,
 - Water stage is less than 2.5 feet or within historic seasonal high water level elevations, for 100 to 300 days annually in each WRA, during normal rainfall
- ❖ Exotic/Nuisance Species
 - Less than 5% coverage of exotic/nuisance vegetation in any stratum, by FLUCCS community
- ❖ Threatened and Endangered Species/Wildlife
 - Evidence of macroinvertebrate, amphibian, and/or forage fish populations
 - Evidence of use by mammals and reptiles
 - No evidence of adverse impacts to federally listed wildlife
- ❖ Water Quality
 - Water quality discharged from the WRAs will average 50 ppb, or less, of total phosphorus
- ❖ WRAP
 - Wetland Rapid Assessment Procedure calculations shall indicate functional lift above the baseline monitoring event

3 Purpose

The use of ERDAS Imagine program for remote sensing has expanded the potential to study the vast canopy systems of the Water Resource Area (WRA) and Storm Water Attenuation (STA) features of the Water Conservation Project (WCP) by utilization of remote sensing and characterization analysis. Study of canopy species is no longer constrained to random transects and annual measurements of DBH at specified trees locations. Quadrat vegetation plot locations for quantitative analysis of groundcover and subcanopy species are still depended upon for field monitoring. The results of these species study areas are then extrapolated to entire transects along which those quadrats are placed. Typically field monitoring is confined to the location of monitoring transects, though all species (ground, subcanopy, and canopy) are noted qualitatively while traversing the monumented transects. The use of the ERDAS program has enhanced capabilities of the Environmental Resource Management Department Scientists to study vast expanses of canopy strata. The advantage of spectral infrared digital imagery signature analysis is the capacity to distinguish between different wavelengths produced by individual species of plants and thereby allows for Scientist to expand the mapping range and distribution to the entire study area. Final characterization results of species provide a new device to affirm mitigation performance criteria have been met for the federal agencies. The ERDAS Imagine software has been utilized to identify and characterize native species and species which are wetland Facultative Wet (FACW) or Obligate (OBL), dead or moribund canopy, and species of exotic vegetation in the canopy stratum. ERDAS characterization analysis was performed on 1999 Color Infrared Digital Ortho Quarter Quads (CIR DOQQ) and 2012 SPOT (Système Pour l'Observation de la Terre) (lit. "System for Earth Observation") Imagery (Figures 1 and 2). Change detection analysis between the 1999 and 2012 imageries were

visually interpreted on WRA 1 east and west features to determine what change the canopy systems of the WRAs have undergone since construction of the Basin 1 in 2008. The available imagery from 1999 was previously spectrally enhanced and could not be spectrally compared through ERDAS change detection due to correction disparities between that and the 2012 image. As a result, a modified analysis and procedure was developed to compensate for these differences. The analysis and procedural steps will be presented henceforth in this paper.

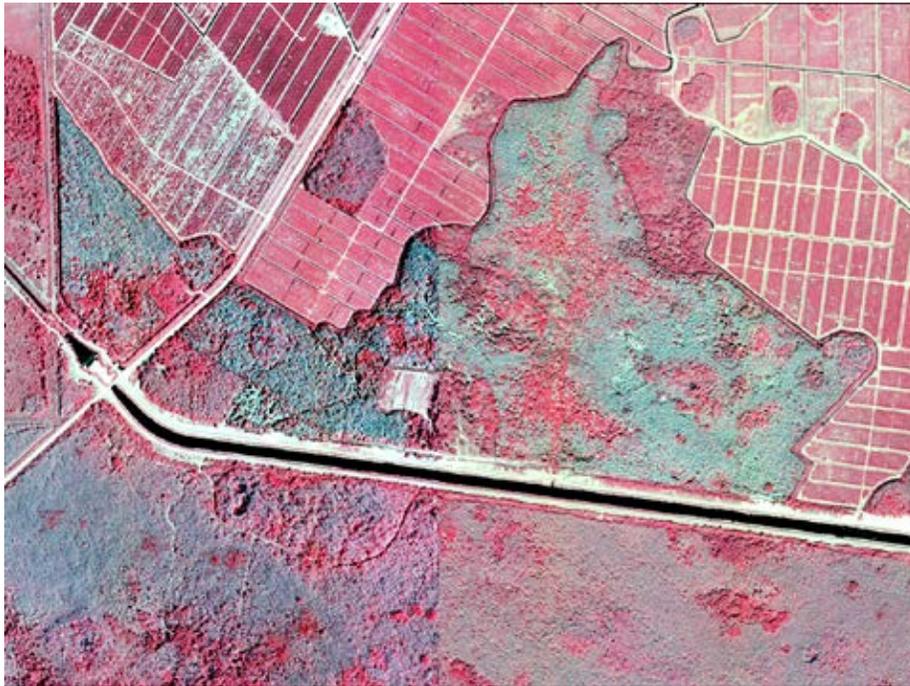


Figure 1 1999 CIR DOQQ Imagery Basin 1 Features Color Infrared Digital Ortho Quarter Quads



Figure 2 2012 SPOT Imagery Basin 1 Features 16 bit, 50 cm ortho-mosaic

4 Methodologies of Canopy Studies Analysis

Creating Subset AOI

A subset Area of Interest (AOI) image was created to consolidate the canopy study area to the boundaries of the WRA 1 east and west sections. The boundary data file shapefile was created in ArcMap and was bounded closely to the canopy of the study feature components. WRA 1 east and west sections were selected, and an AOI was created. Under the Raster tab select geometry group, the subset and chip function of create subset image was processed with the following parameters selected: ignore zeros in output, AOI to viewer, and the default option of 1:4 layers. The resulting image created a subset of the WRA 1 east and west features to facilitate analysis within the WRA and project boundaries for both imagery years of 1999 and 2012 (Figures 3 and 4).

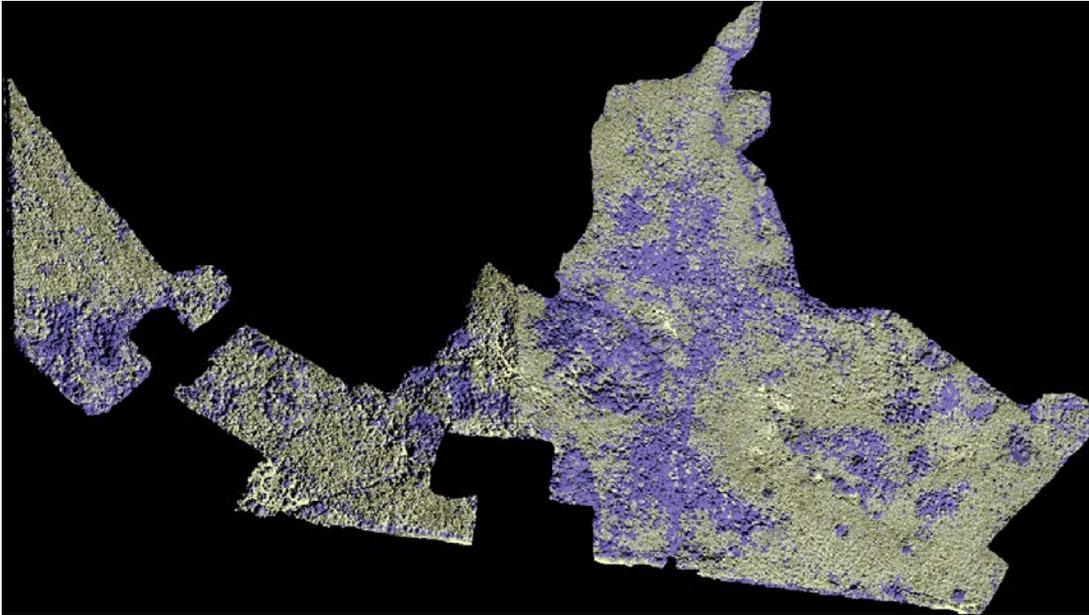


Figure 3 AOI Subset of 1999 CIR DOQQ Imagery

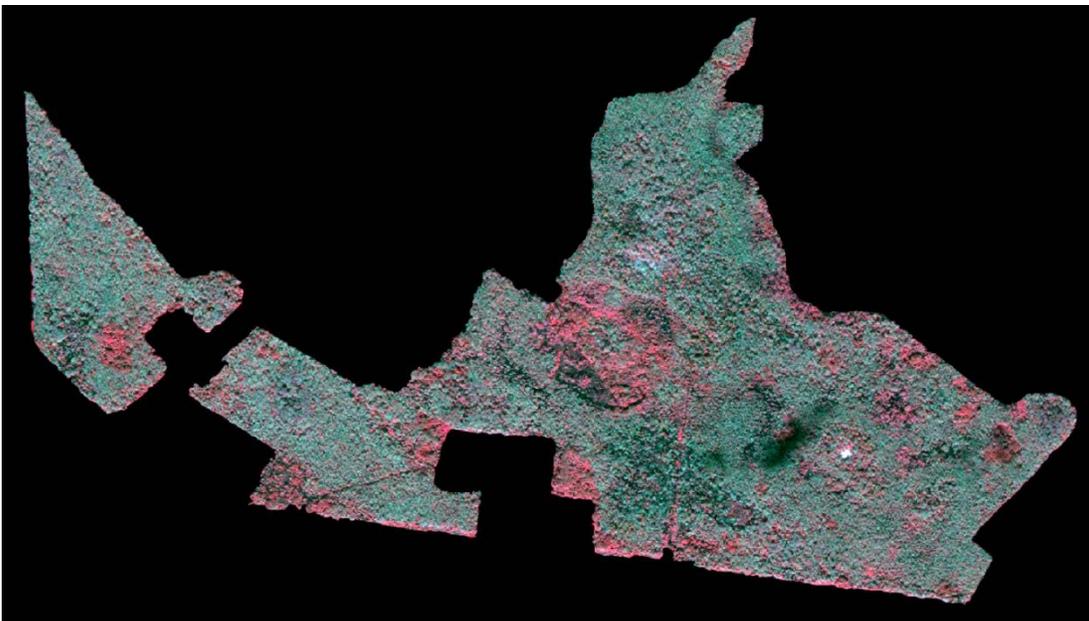


Figure 4 AOI Subset of 2012 SPOT 16 bit 50 cm ortho-mosaic Image and WRA 1 modified boundary polygon shapefile

Principal Component Analysis

The raster spectral enhancement process known as Principal Component Analysis (PCA) was performed on both 2012 and 1999 WRA 1 Images. PCA was chosen due to its imagery processing abilities of compressing redundant data into fewer bands resulting in data dimensionality reductions. Additional included PCA data processing functions extract new bands to facilitate improved visual interpretation as well as, the application of mathematical transforms and algorithms. PCA also enhances the three color spectrums Red, Green, Blue (R, G, B) so they are displayed in wider variations of information. “The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data” (Jensen, 1996; Faust, 1989). The value of PCA was demonstrated when unsupervised classifications were completed on the 1999 and 2012 imagery without first completing PCA on the original raster images. The result (without PCA applied) was a poorly interpretable isodata clustering, especially for the 2012 raster (Figure 5). Subsequent processing was completed with isodata clustering on the PCA applied raster images, resulting in a more interpretable image.

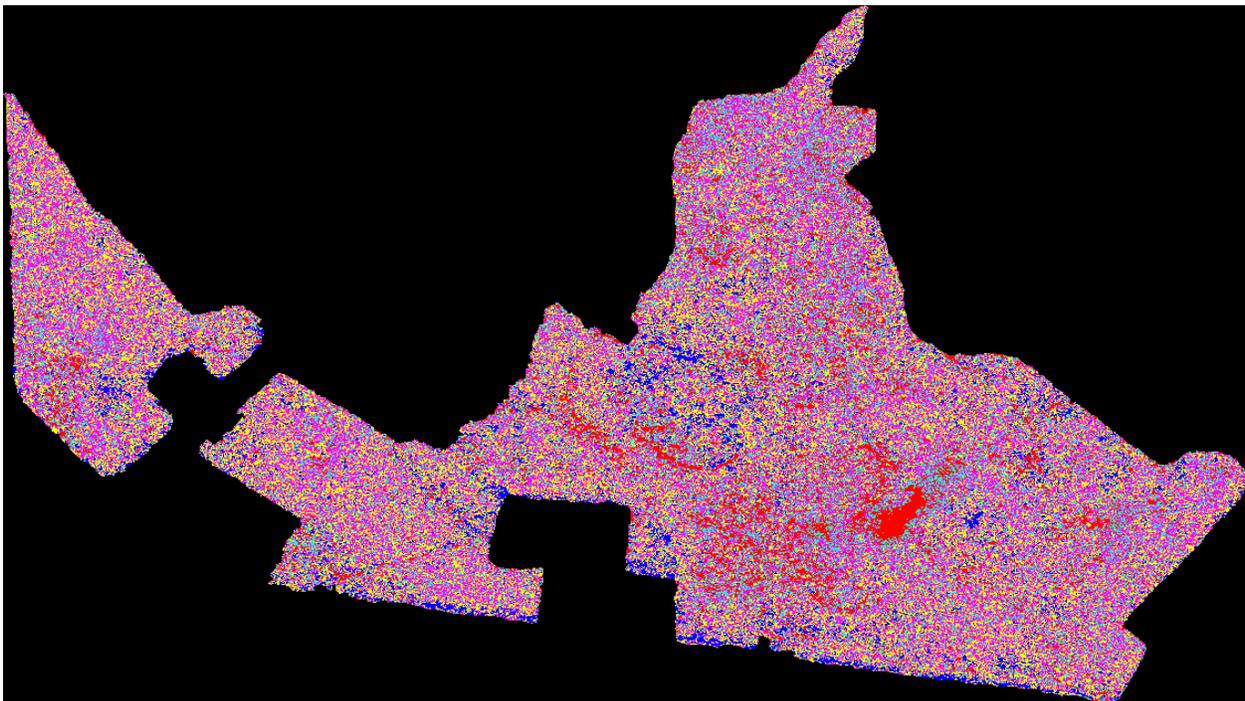
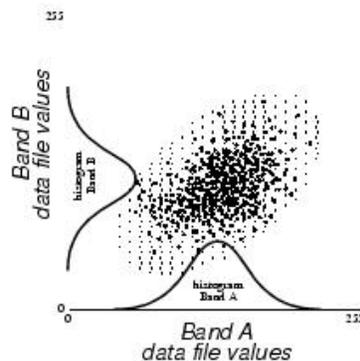


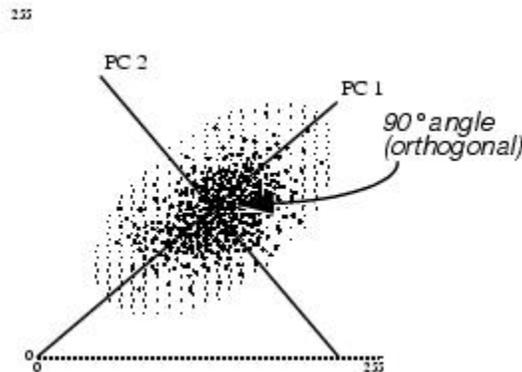
Figure 5 Unsupervised classification of 2012 subset AOI without first completing PCA analysis resulted in redundancy of bands with similar spectral features

An example of PCA data processing containing two bands is shown in the two-band scatterplot example:



The values of each band during PCA processing are plotted against each other on a scatterplot. If both bands have normal distribution the ellipse shape is resulting. The widest orthogonal (perpendicular) transect of the ellipse is held by the second principal component. The largest amount of variance of the imagery is contained in the second principal component along the minor axis of the ellipse, data that is not captured in the first (Taylor, 1997). There is a principal component for each dimension, successive n-dimensional components decreases the variation not accounted for by the previous (Taylor, 1997). Although there may be multiple bands, the first few bands account for the highest variance in the data compressing the data and resulting in more interpretable imagery.

For each principal component the variation of the data is decreased and continues to decrease upon each thereafter. The second principal Component scatterplot of the ellipse is detailed below.



Principal Component Analysis Processing Procedural Steps:

The Stretch option was set to unsigned 8 bit and zero was ignored in stats. The 2012 SPOT imagery contains 4 bands and as such, number of components was set to 4. The 1999 CIR DOQQ imagery contains 3 bands and number of components was set to 3. Principle component analysis was then processed (Figures 6 and 7). The linear scatterplot transformations eigenvectors and eigenvalues of the 4 and 3 principal components are mathematically produced from the covariance matrix of the following algorithm:

$$E Cov E^T = V$$

Cov = covariance matrix

E = matrix of eigenvectors

T = transposition function

V = diagonal matrix of eigenvalues, all nondiagonal elements are zero and ordered from v_1 to v_n

$$V = \begin{bmatrix} v_1 & 0 & 0 & \dots & 0 \\ 0 & v_2 & 0 & \dots & 0 \\ & & \dots & & \\ 0 & 0 & 0 & \dots & v_n \end{bmatrix}$$

The equation:

Source of algorithm and equation: Faust, 1989

The eigenvector (E) is the description of unit length vector in spectral space and exhibits the directional ellipse axis of the principal component. The following eigenvector algorithm transforms the original WRA 1 subset image into a principal component value of that image.

$$P_e = \sum_{k=1}^n d_k E_{ke}$$

e = number of principal components

P_e = output principal component value for principal component number e

k = a particular input band

n = the total number of bands

d_k = an input data file value in band k

E_{ke} = the eigenvector matrix element at row k , column e

Source of the eigenvector algorithm, Gonzalez and Wintz, 1977

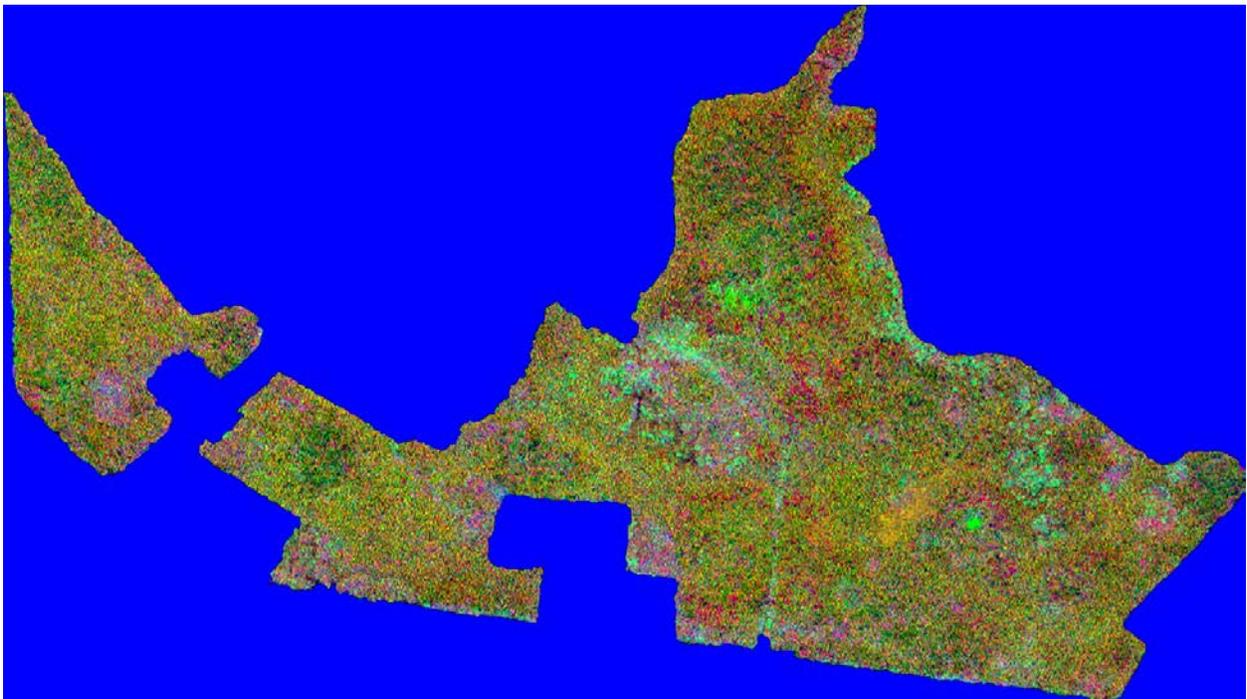


Figure 6 Principal Component Analysis (PCA) 2012 SPOT Imagery

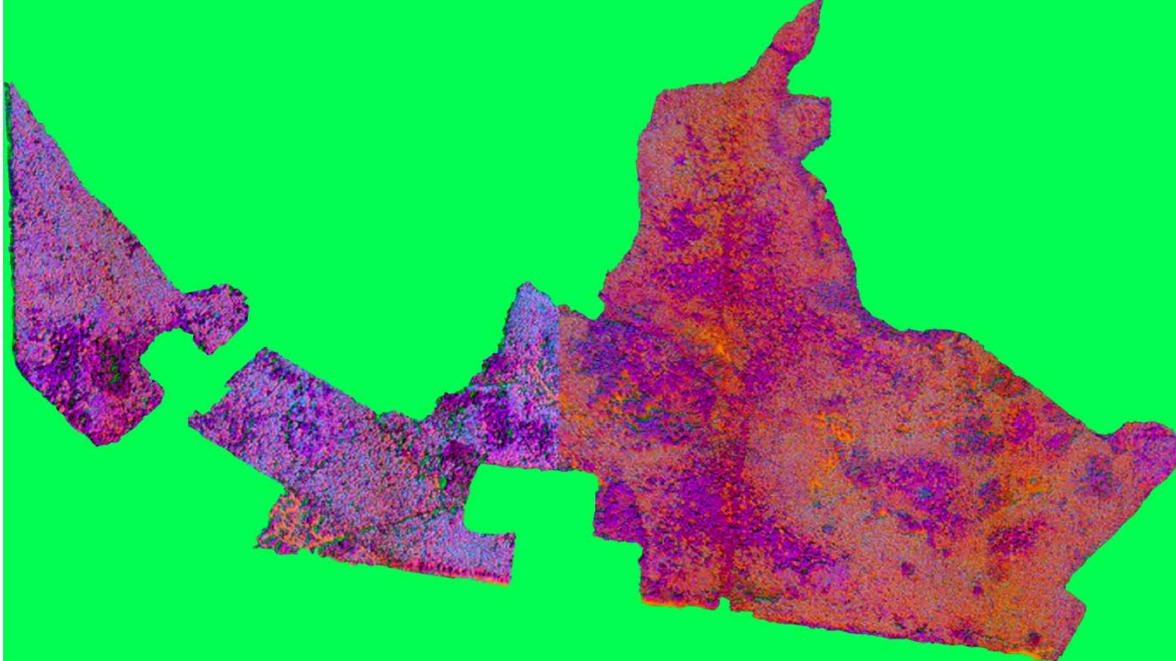


Figure 7 Principal Component Analysis (PCA) 1999 CIR DOQQ Imagery

Ground Truth PCA Field Verifications

After the PCA was completed, field verification commenced to validate the signatures. The 2012 SPOT imagery was utilized, evidently due to its proximity to the current year. Trimble GeoXT units were selected to collect point data of canopy species and other appropriate signatures. Shapefiles were created on the Trimble GeoXT and documented the species and pertinent information such as extent and size of species and signatures observed. Shapefiles were created in NAD 1983 HARN StatePlane Florida East FIPS 0901 (US Feet). The PCA 2012 SPOT image with GPS points overlay is shown below (Figure 8).

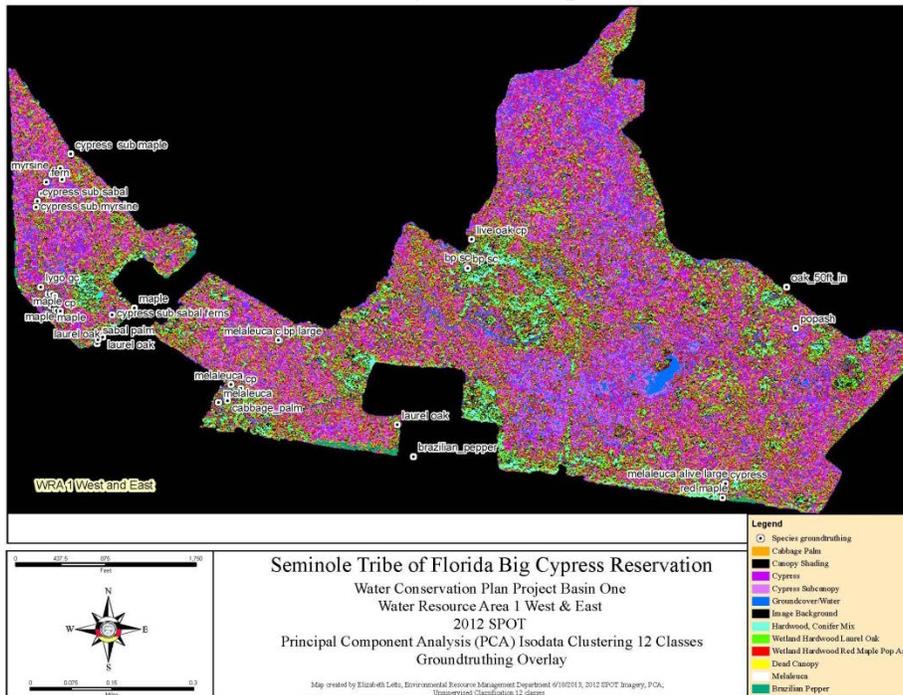


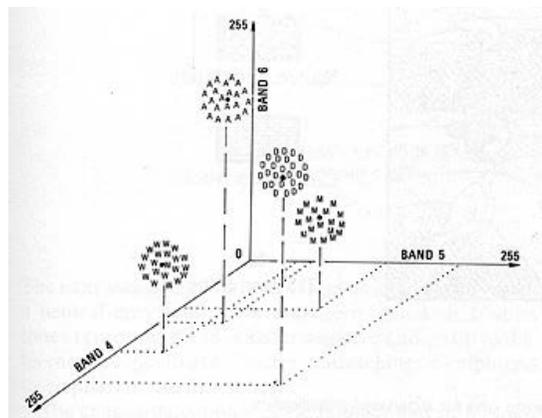
Figure 8 PCA 2012 with Trimble GeoXT shapefile GPS points of signature locations overlaid

Isodata Clustering, Unsupervised Classification

Once the Principal component analysis was finalized for both WRA 1 2012 and 1999 images, an isodata clustering analysis was completed on each PCA. A variation of classification class numbers were tested to ensure that sufficient canopy species characterizations and canopy health were identified. Class test trial numbers varied from 4, 5, 6, 7, 9, 11, 12, and 14. The maximum number of clusters (N) was determined based on the trial and error of the testing period. Isodata processing began by the determination of N arbitrary cluster means, eliminating clusters deemed unnecessary. The convergence threshold (T) is the maximum percentage of pixels whose class values are allowed to be unchanged between iterations and maximum number of iterations to be performed (M). Upon completion of iteration, a new mean for each cluster is calculated and is fundamental to the pixel spectral locations and is no longer like the initial arbitrary calculation. New means define the next clusters in the iteration and processing continues until diminutive change remains between iterations (Swain, 1973). The initial cluster is distributed along a vector that runs between $(\mu_1-\sigma_1, \mu_2-\sigma_2, \mu_3-\sigma_3, \dots, \mu_n-\sigma_n)$ point at spectral coordinates and the coordinates $(\mu_1+\sigma_1, \mu_2+\sigma_2, \mu_3+\sigma_3, \dots, \mu_n+\sigma_n)$. The initial cluster mean is distributed between $(\mu_A-\sigma_A, \mu_B-\sigma_B)$ and $(\mu_A+\sigma_A, \mu_B+\sigma_B)$. Fifteen (15) iterations were processed for both 2012 and 1999 images. The following canopy species signatures were identified for the final number of classes, 12:

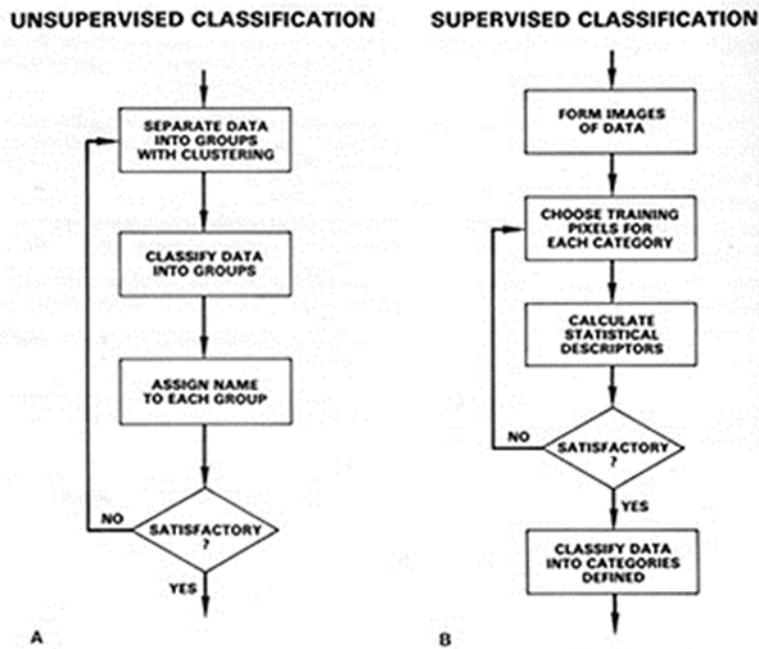
- ❖ Cypress canopy: *Taxodium distichum*, Native Obligate wetland species
- ❖ Cypress subcanopy: *Taxodium distichum*, Native Obligate wetland species
- ❖ Hardwood, Conifer mix: *Pinus elliottii* and *Quercus laurifolia*, Native Facultative Wet species
- ❖ Wetland Hardwood, Red Maple and Pop Ash: *Acer Rubrum* and *Fraxinus caroliniana* Native Facultative Wet and Obligate species
- ❖ Wetland Hardwood, Laurel Oak: *Quercus laurifolia*, Native Facultative Wet Species
- ❖ Cabbage Palm: *Sabal palmetto*, Native Facultative Species
- ❖ Brazilian Pepper: *Schinus terebinthifolius*, Non-native Facultative Species
- ❖ Melaleuca: *Melaleuca quinquenervia*, Non-native Facultative Species
- ❖ Canopy Shading: Shadows or shading of the canopy
- ❖ Groundcover/ Water: Water on ground or open groundcover vegetation
- ❖ Dead Canopy: Moribund or dead canopy

In the unsupervised classification procedures (isodata) image pixels are analyzed beginning at the top left corner and left to right by each block. Spectral distance between the pixel undergoing processing and every cluster mean is calculated and that pixel is assigned to the cluster with the closest mean. Once isodata function is completed an output image file is created with a thematic raster layer and/or signature file (.sig) with the final clustered pixels for all programmed iterations. For each iteration, pixels whose clustering is unchanged in previous iterations reaches the convergence threshold (T) and the programming is terminated.



Unsupervised classification detail (Sabins, 1987)

Unsupervised classification was determined for use due to the benefits as described with comparison to supervised classification (Sabins, 1987):



Under the Raster tab unsupervised classification was chosen. Clustering options were initially set to 9 and file statistics was selected to principal axis. The standard deviations were set at 2 and maximum iterations at 15. Color Scheme Options were set to approximate true color 3:2:1 (Red: Green: Blue) and the process was identical for both 2012 and 1999 images (Figures 9 and 10).

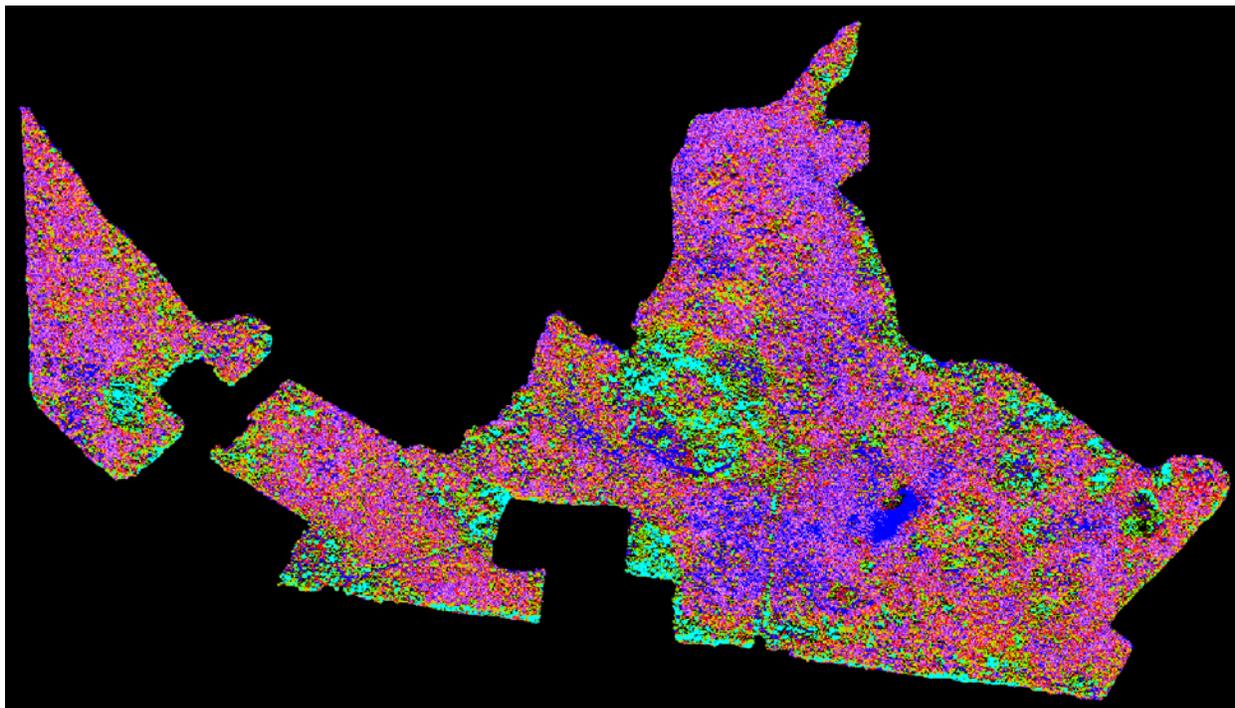


Figure 9 2012 SPOT Image PCA Unsupervised Classification 9 classes

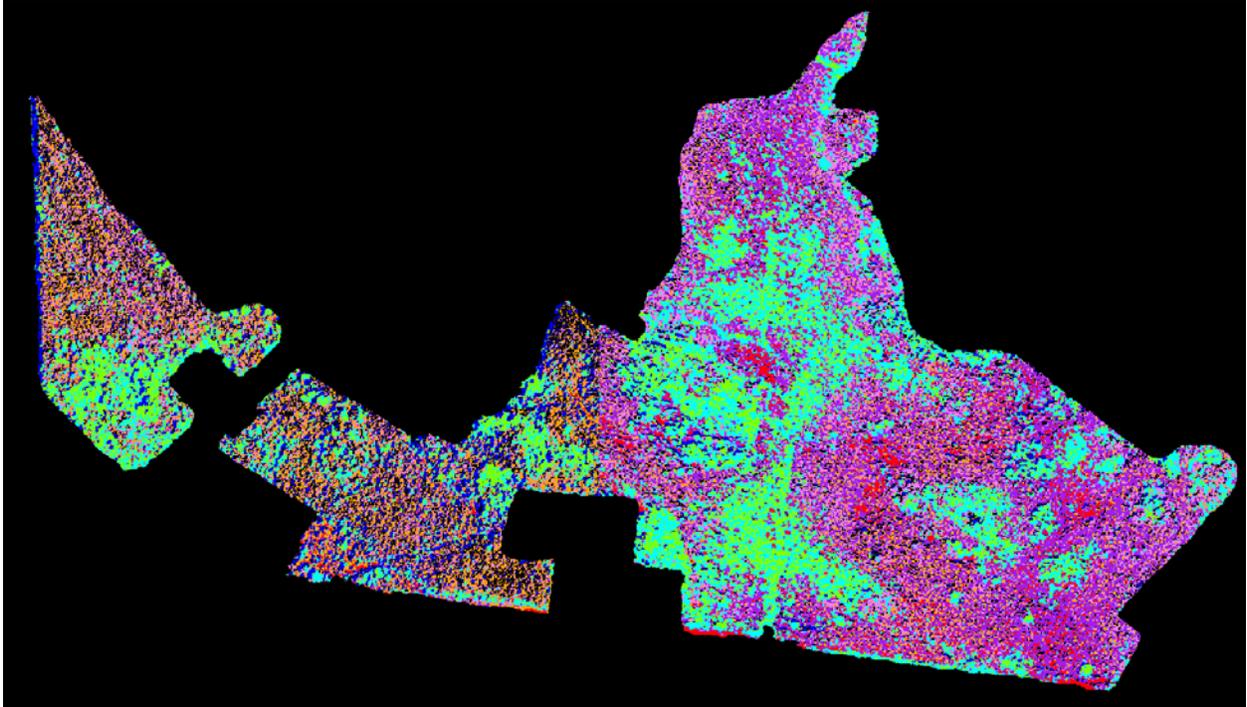


Figure 10 1999 CIR DOQQ Image PCA Unsupervised Classification 9 classes

Visual interpretation of data found that signatures of hardwood conifer mix were more abundant in the 1999 imagery than the 2012. This is theorized to be due to dramatically increased hydroperiods in the WRA 1 east and west sections. The change assessed demonstrates a higher dominance in the wetland hardwoods and cypress canopy in the 2012 imagery. Additional signatures were visually interpreted and manually reclassified based on ground truth observations completed in 2012 and 2013. It was also noted that the conifer mix signature appeared to have a similar signature as that of the exotic Brazilian pepper. Previous South Florida Water Management District exotic species sketchmapping event in 2006 was utilized to determine the areas of infestation for the 1999 image, the 2006 mapping event was the earliest completed for this site. Sketchmapping was also utilized for the 2008, 2010, and 2012 exotic species mapping surveys. Photointerpretation of 2009 and 2011 images were also compared and contrasted with the PCA Unsupervised Classification of 2012 and 2009 images. The swipe, two view, sync, and link features were heavily utilized with all previously mentioned mechanisms until characterization signatures were validated and finalized. The 2012 image was interpreted first due to its recent relevance, the 1999 was dated most available ground validations and other techniques were not available. Following are the resulting images for the finalized 2012 and 2009 images.

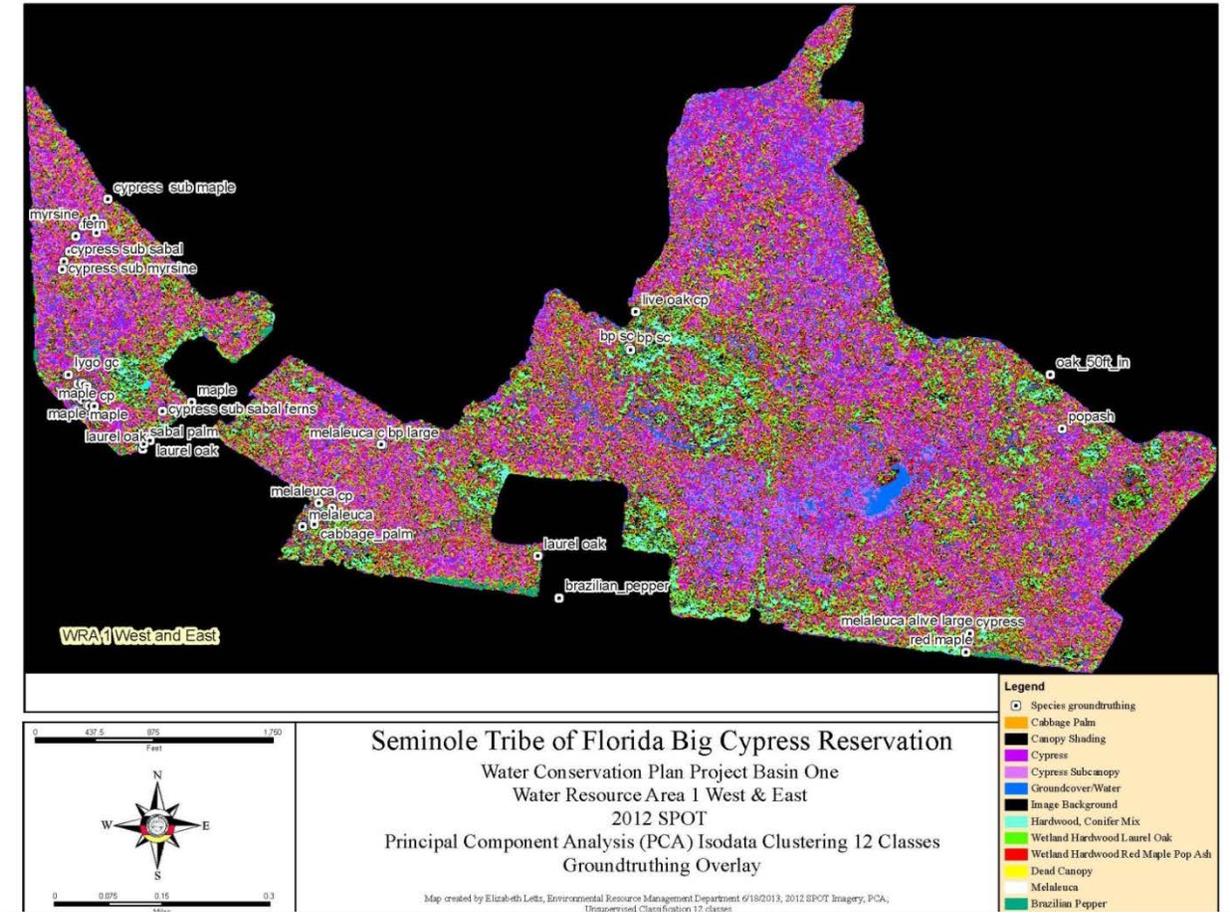


Figure 11 Photointerpretation of identified 2012 signatures were compared to groundcover validations of signature classes. The resulting characterization class identification finalized based on validation of events and comparison to raw imagery.

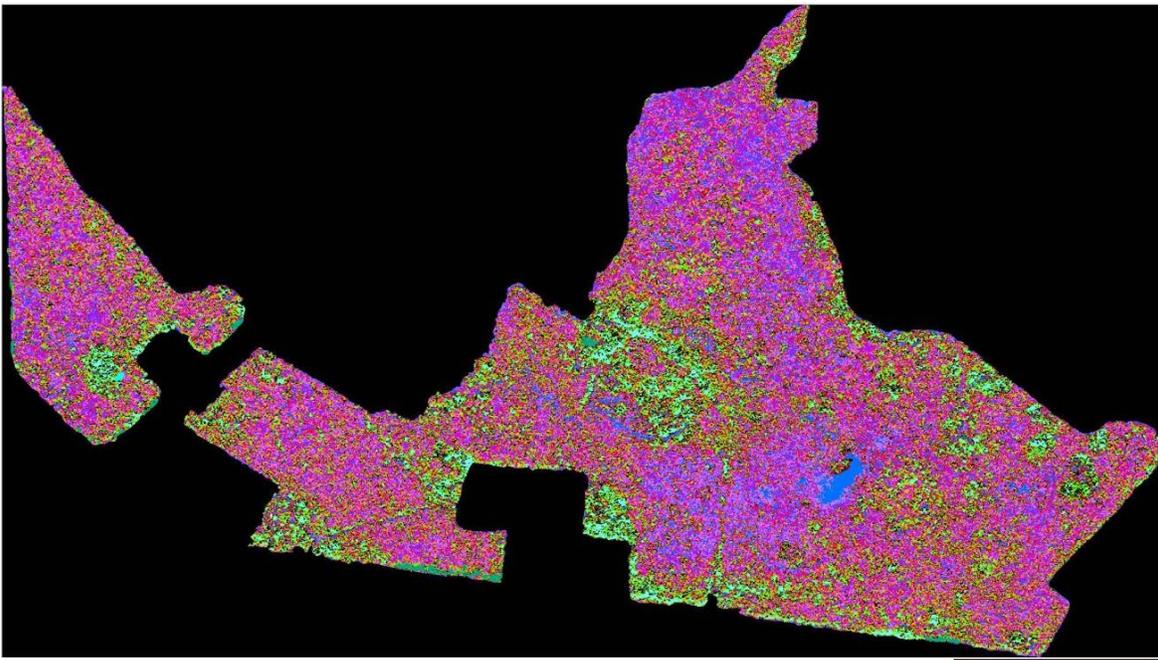


Figure 12 Final 2012 PCA Unsupervised

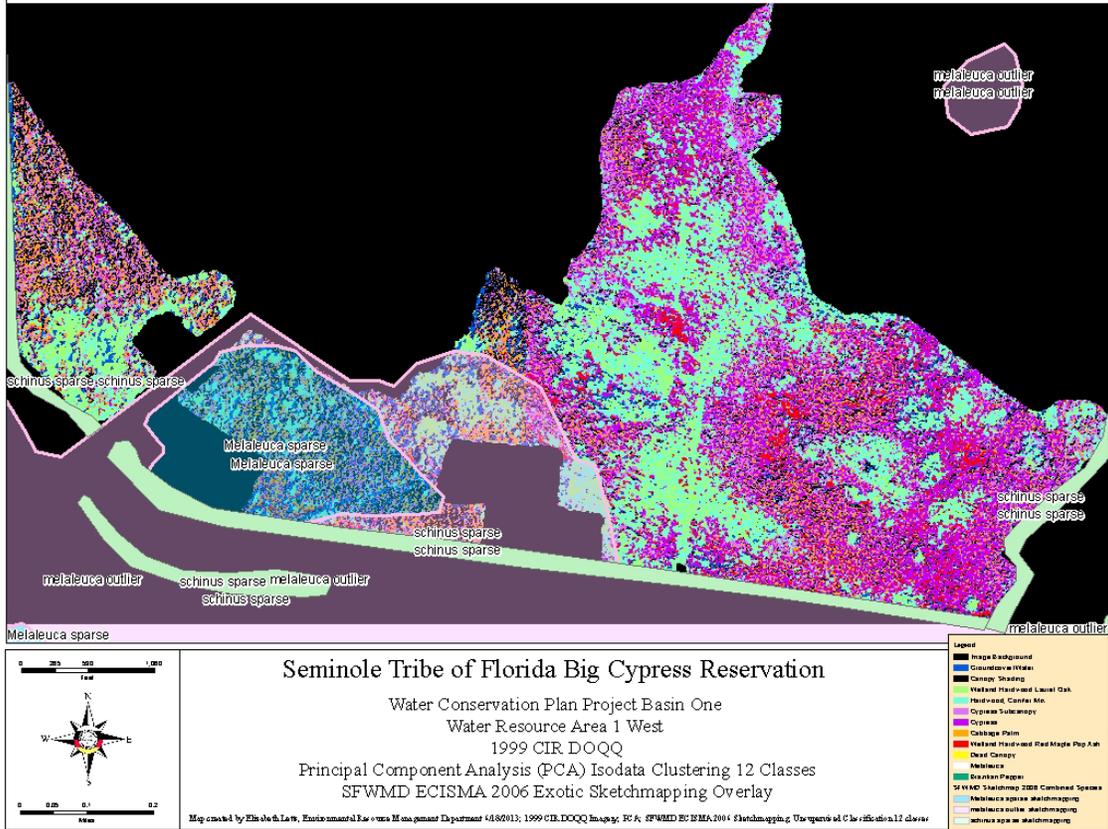


Figure 13 Photointerpretation of 1999 identified signatures were compared to the 2012 finalized signatures and sketchmapping events of exotic vegetation species completed by SFWMD

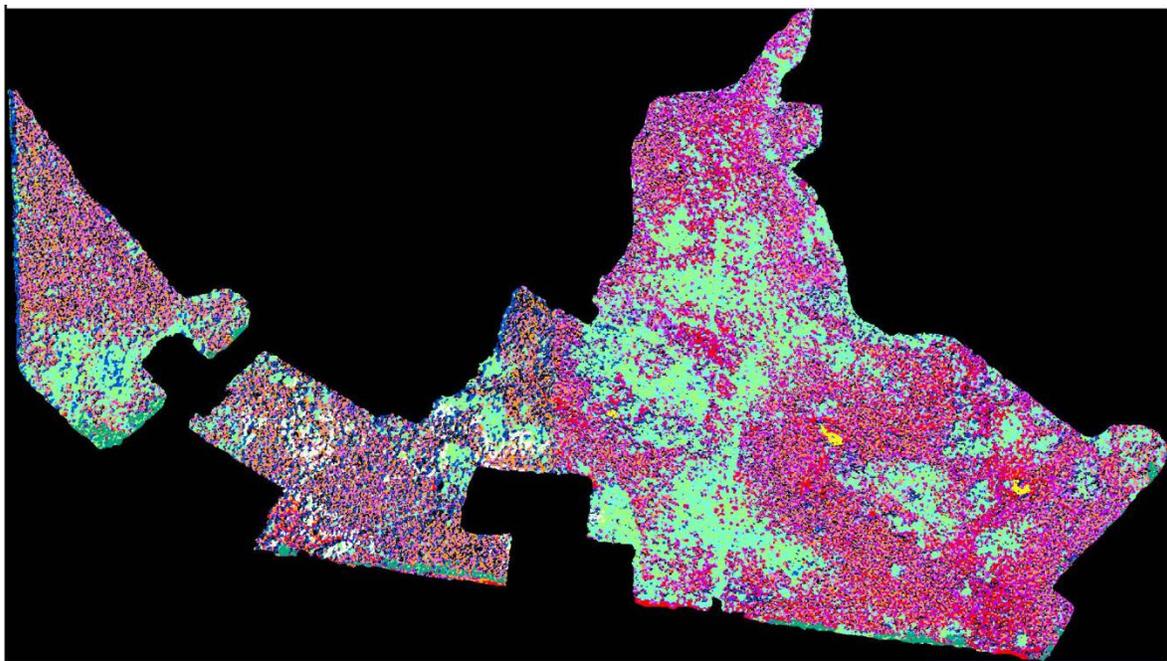
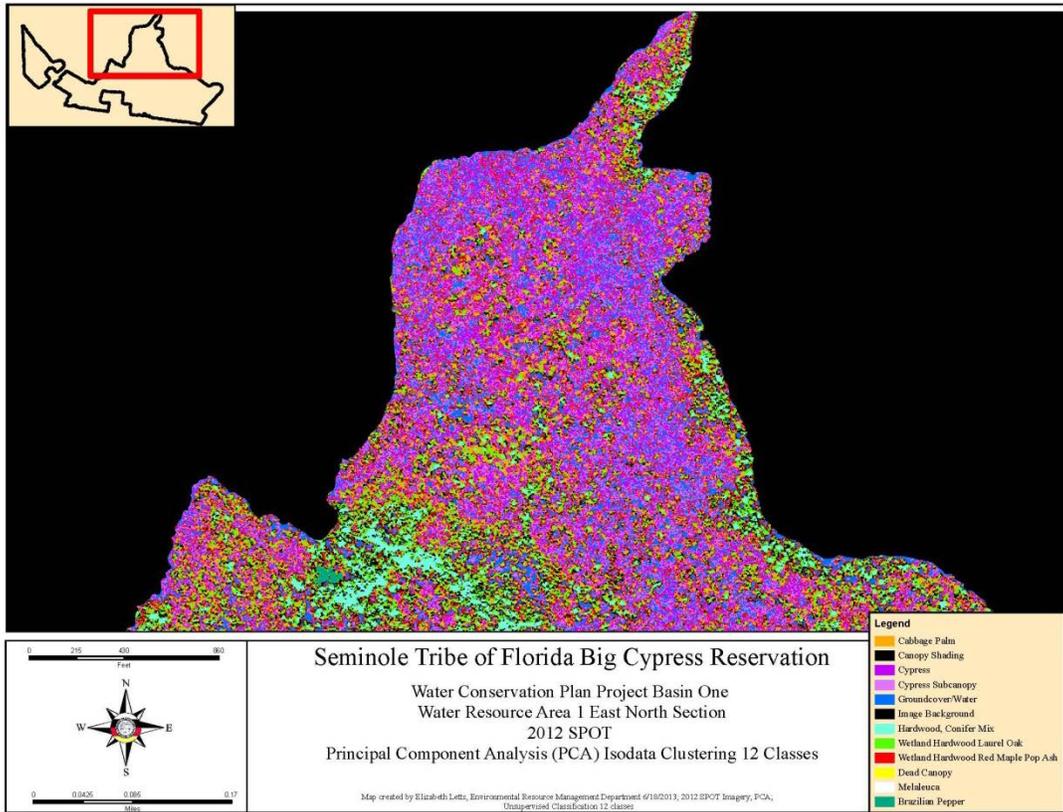
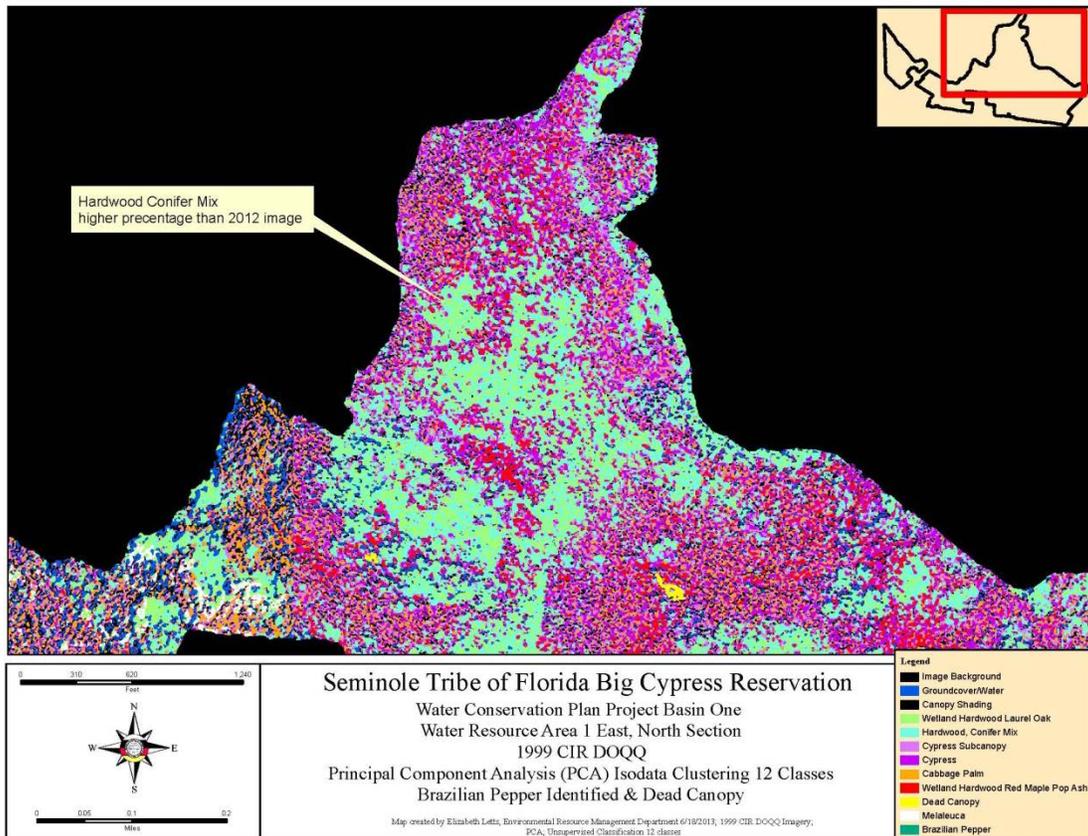


Figure 14 Final 1999 PCA Unsupervised



Figures 15 and 16 Noted higher percentage of Hardwood conifer mix in 1999 than 2012 in WRA 1 E North



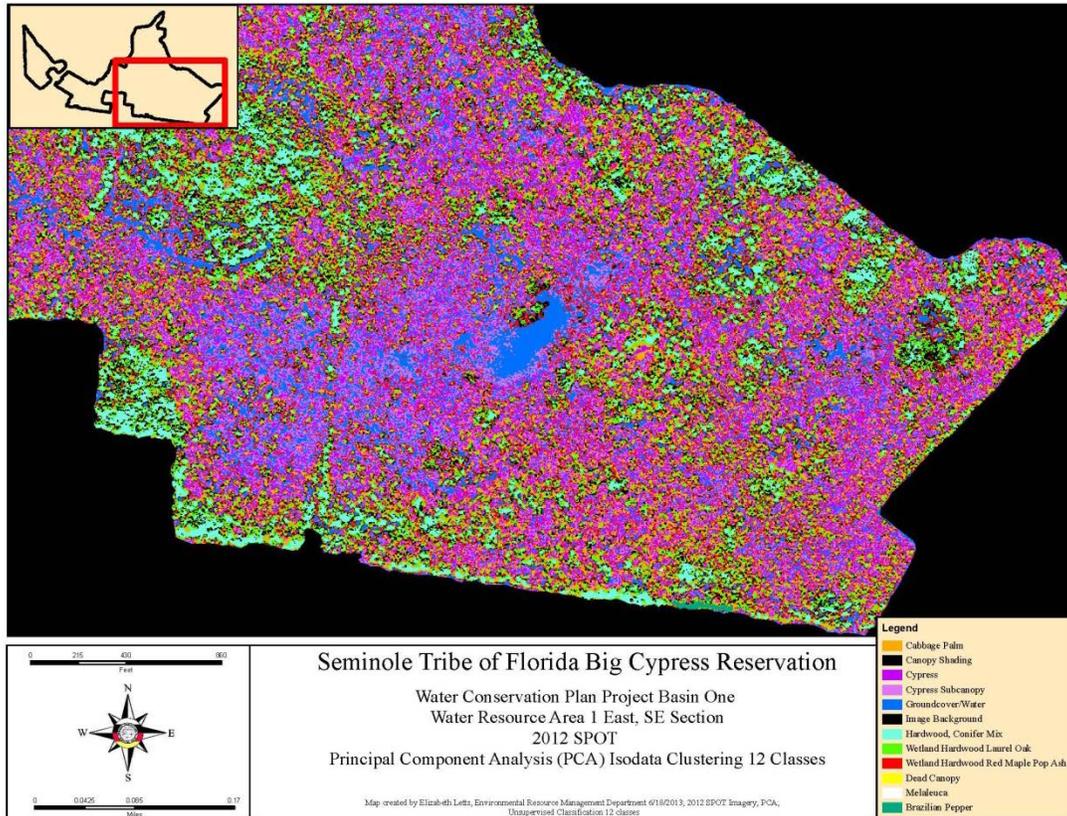
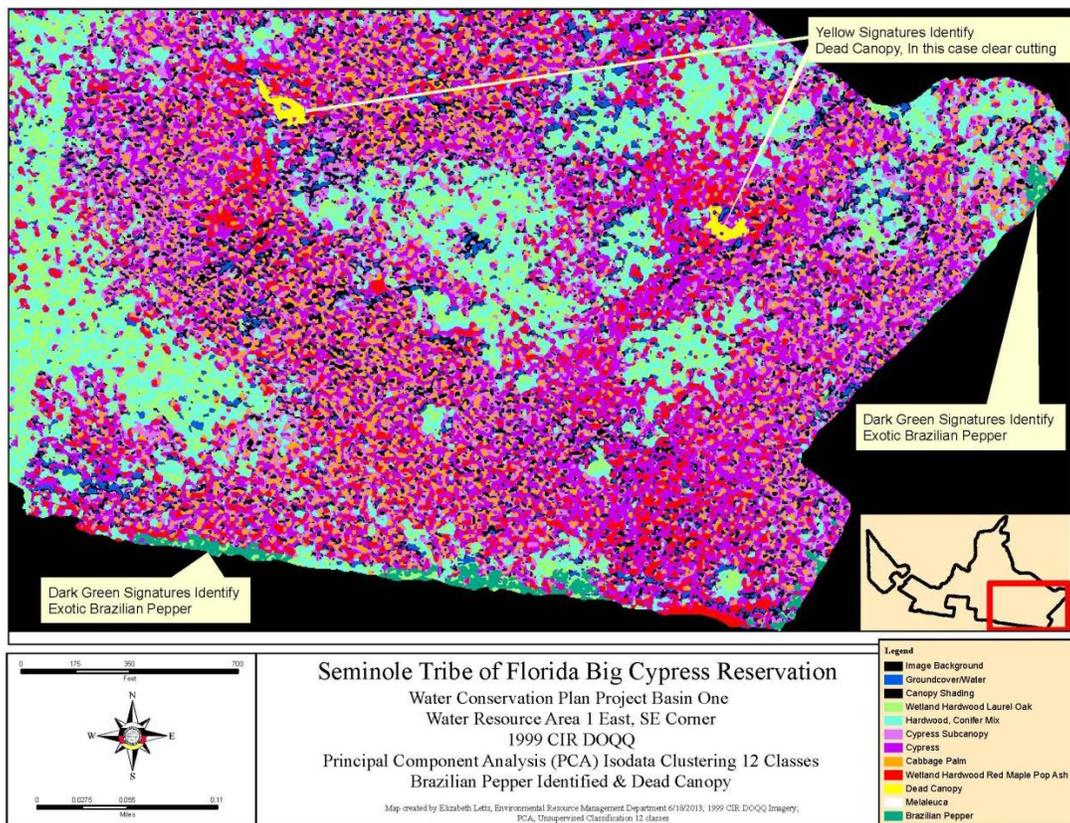


Figure 17 and 18 Noted higher percentage of exotic Brazilian pepper infestation in 1999, clear canopy cut also in 1999



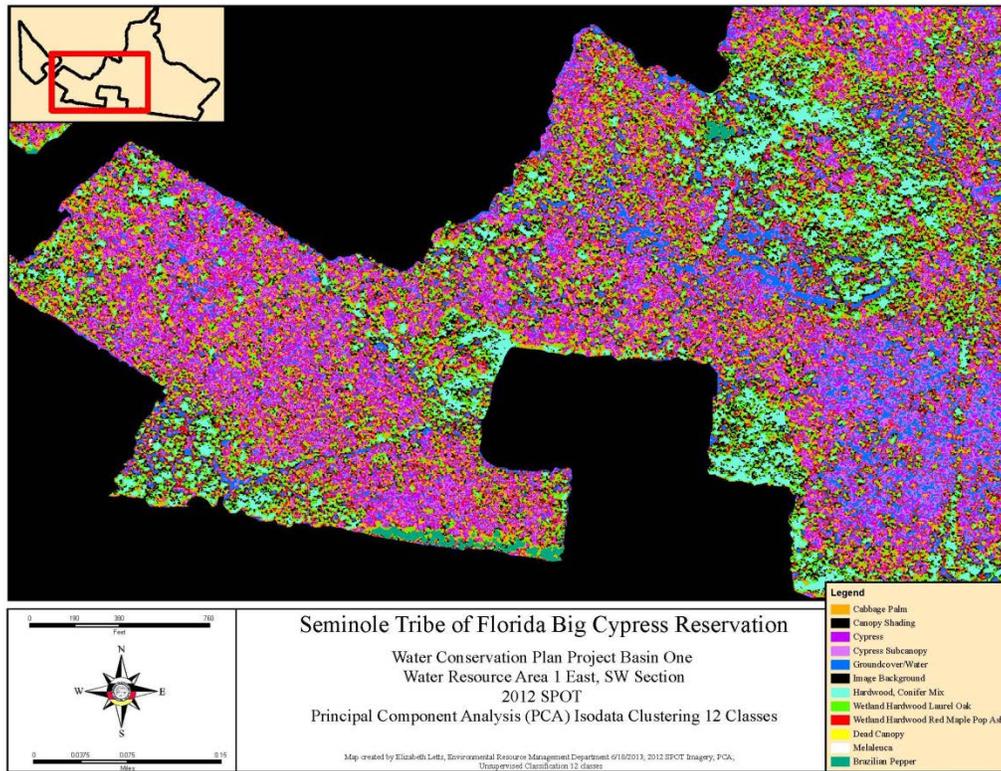
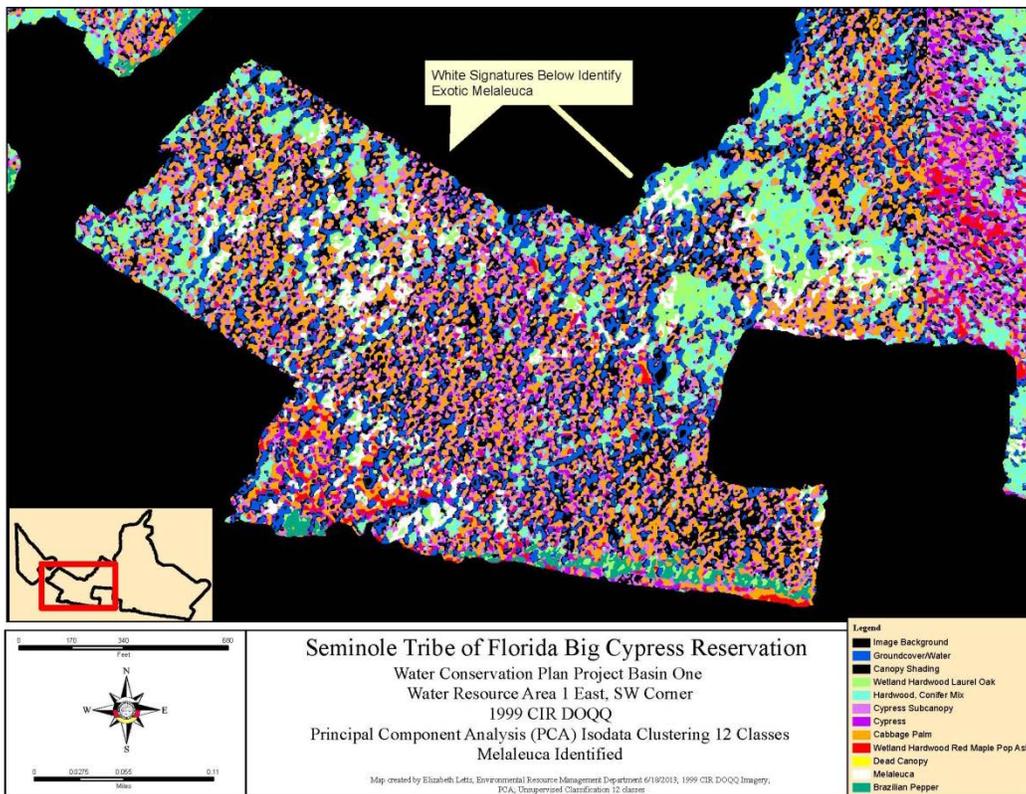


Figure 19 and 20 The 1999 image classified a higher percentage of groundcover/ water than the 2012. Heavy infestation of exotic species *Melaleuca quinquenervia* was also observed in 1999 image, minimal was identified in 2012 image



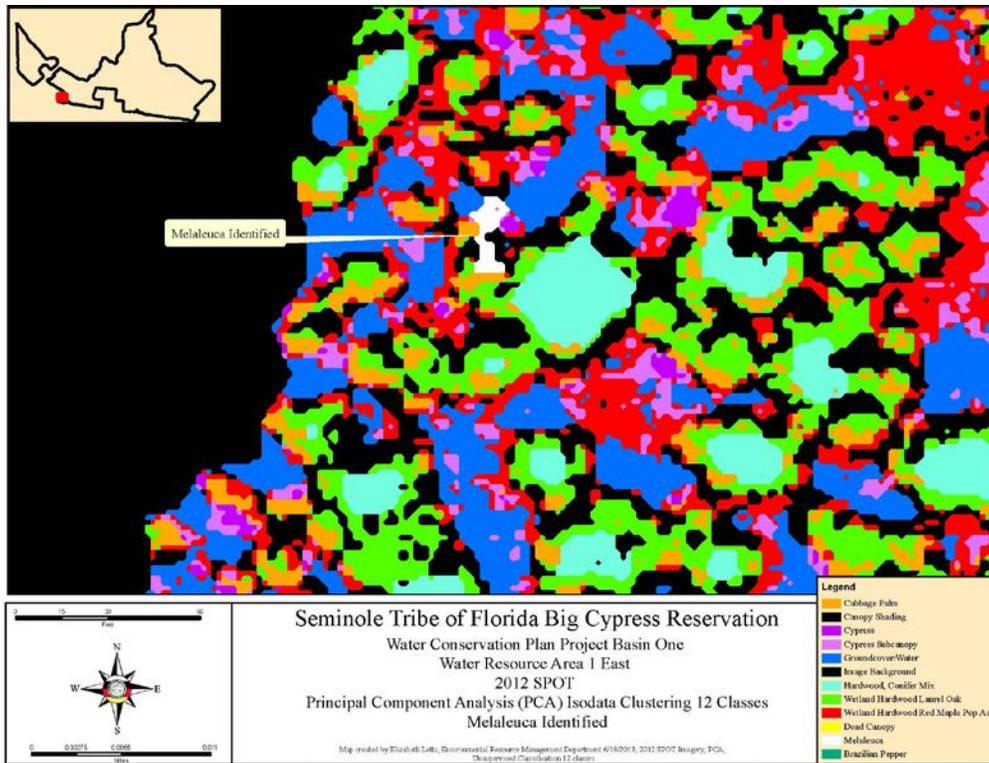
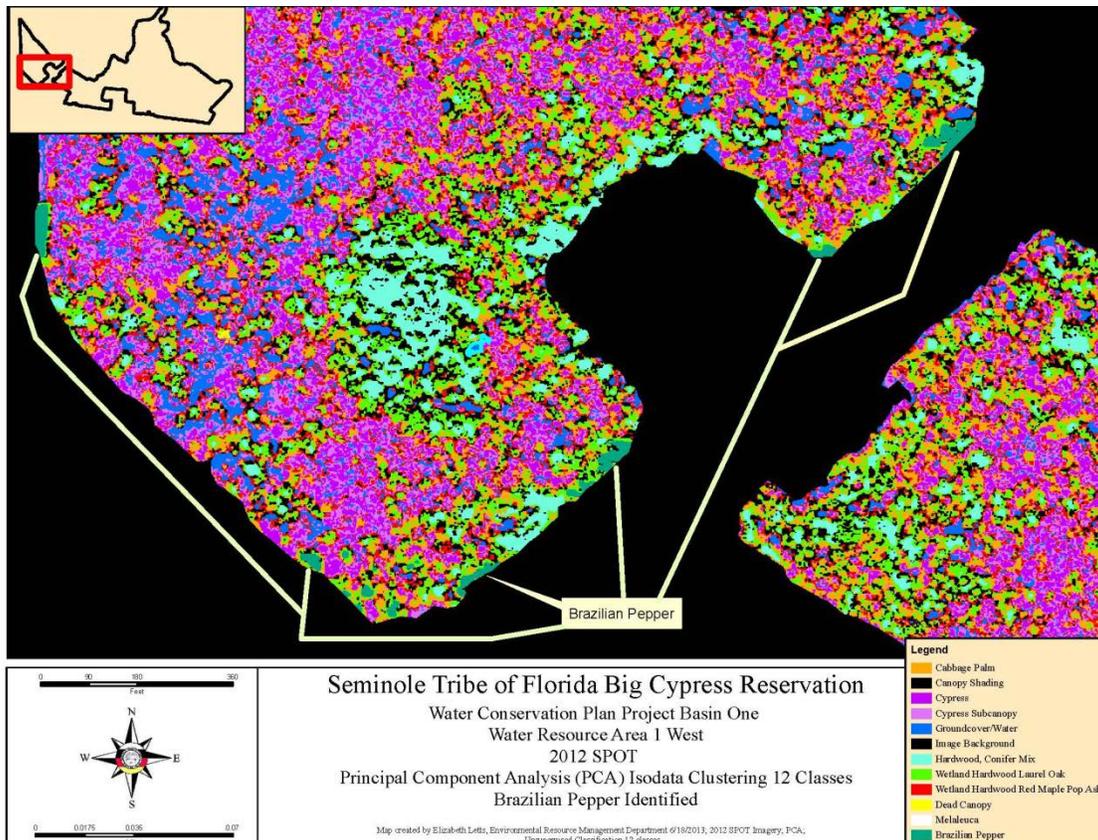


Figure 21 and 22 Exotic Melaleuca in the WRA1 E 2012 classification, validated by ground truth, though infestation is minimal
 Exotic Brazilian pepper identified in WRA 1 W 2012 though infestation is minimal



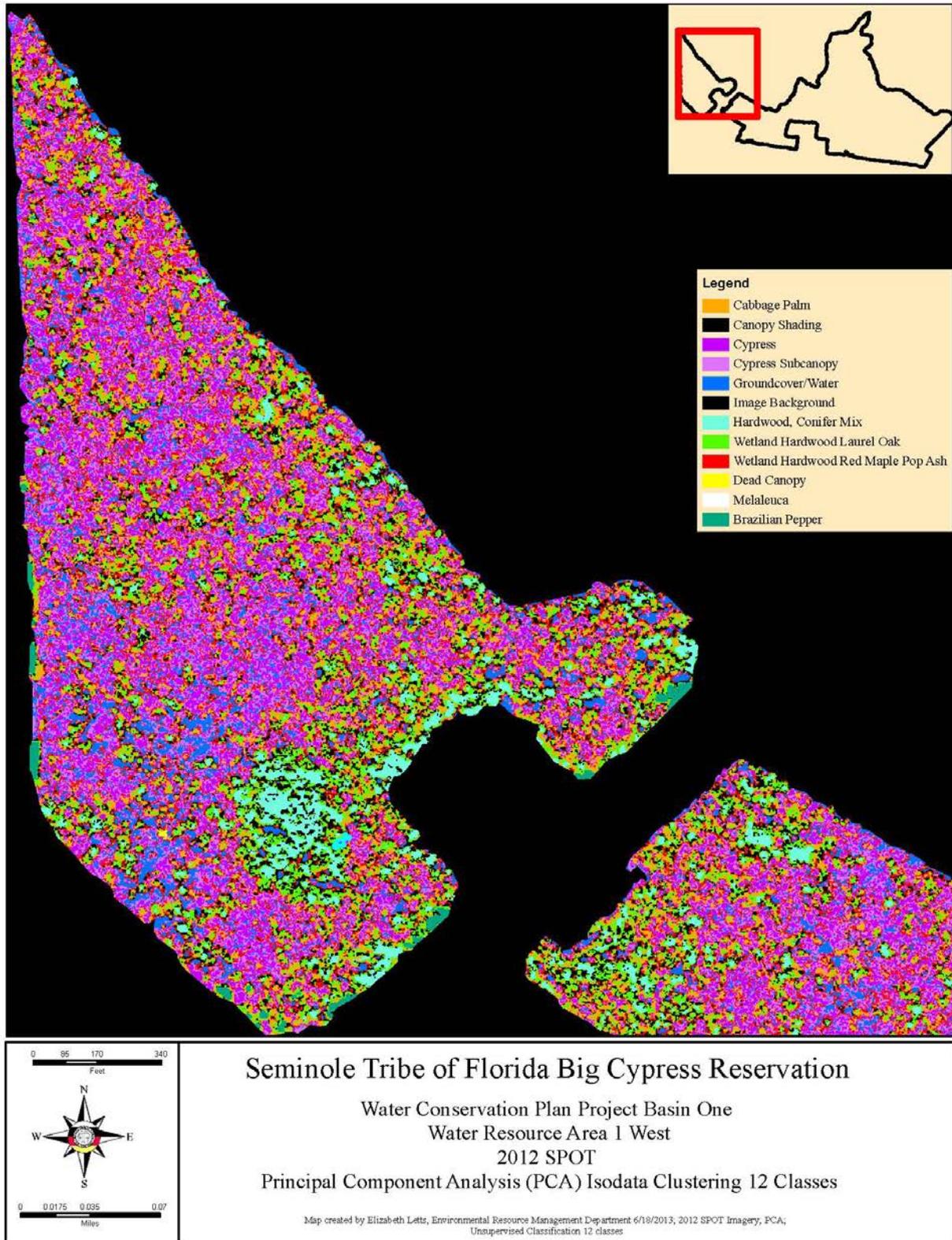


Figure 23 Exotic Brazilian pepper noted to be encroaching in WRA 1 W 2012 imagery, validated by groundtruthing, retreatment event completed post receipt of imagery, 2013 retreatment planned to eradicate infestation

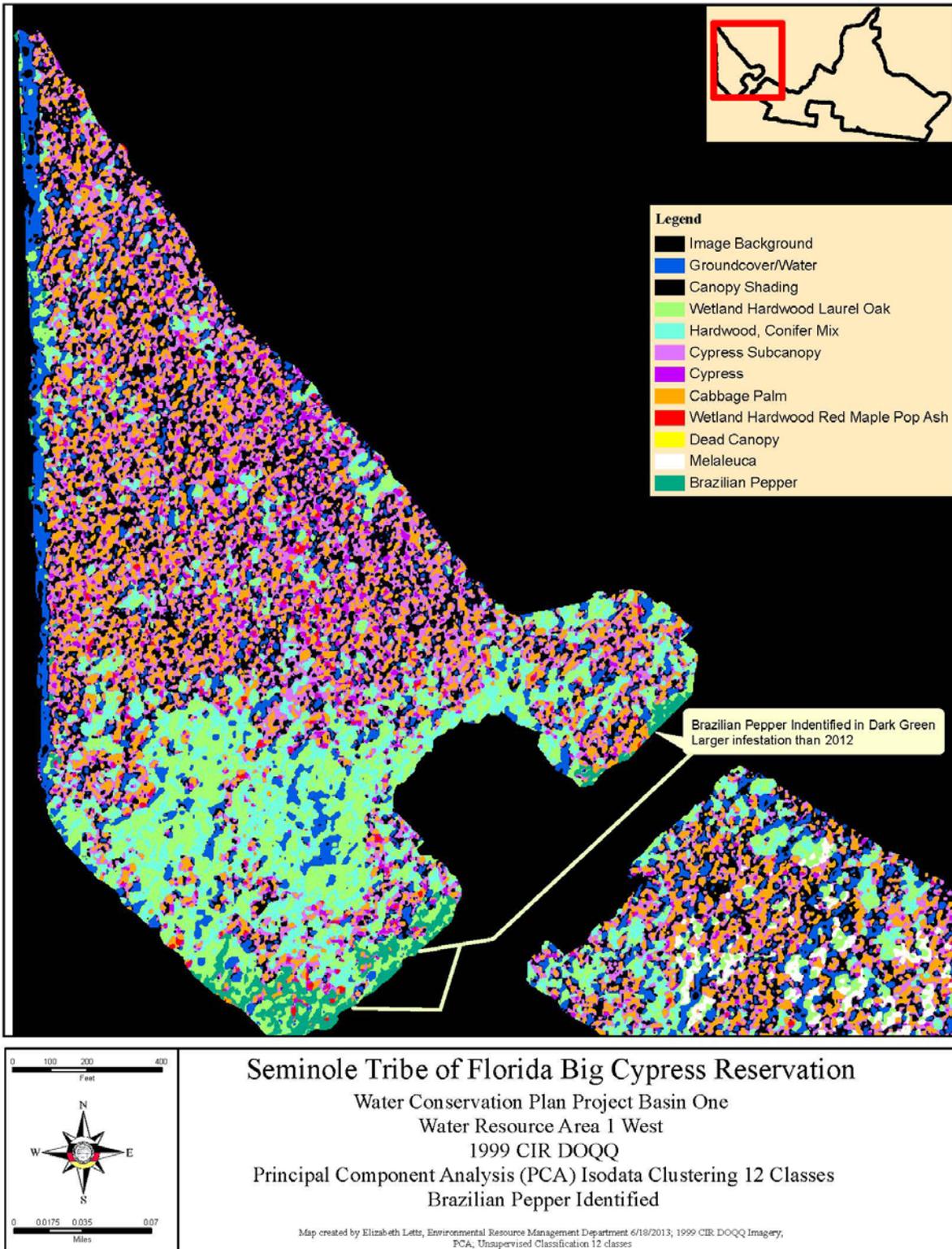


Figure 24 Exotic Brazilian pepper infestation heavier in WRA 1 W 1999 image, initial treatments on site began in 2009

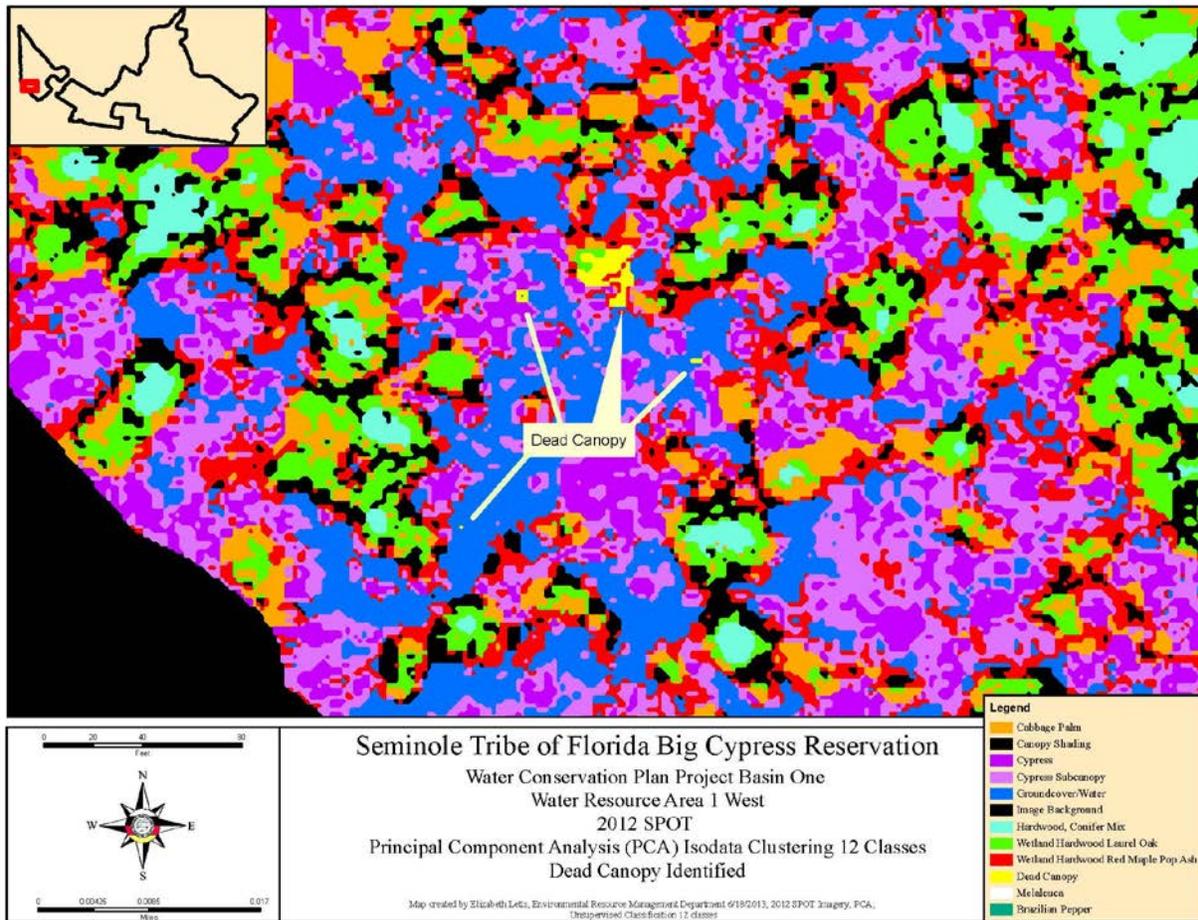


Figure 25 Dead canopy trees noted during ground truth validation event in WRA 1 W 2012 image, the native species appeared to be Laurel Oak (*Quercus laurifolia*) a FACW species that cannot withstand high water conditions for long periods of time, a result of heavily inundated conditions. Groundcover canopy native saplings noted during field inspections were of Cypress (*Taxodium distichum*) and Red Maple (*Acer Rubrum*) OBL and FACW species.

5 Synopses

In synopses, the ERDAS Imagine software was confirmed to be a valuable tool in the identification of canopy vegetation species and signatures relevant to this study. The spectral analysis processes permitted the study of the entire WRA 1 boundary with a limited amount of field verification required to finalize data.

Spectral analysis combined with photointerpretation noted the following changes in the 2012 imagery as compared to the 1999:

- ❖ Cypress (OBL) canopy has increased in the 2012 imagery
- ❖ Wetland Hardwood Canopies (FACW and OBL) have increased in the 2012 imagery
- ❖ Hardwood Conifer Mix has decreased in the 2012 imagery due to high inundation periods
- ❖ Cabbage Palm (FAC) has decreased in the 2012 imagery
- ❖ Exotic species Brazilian Pepper and Melaleuca are minimal in the 2012 imagery in comparison to heavier infestation in 1999 imagery
- ❖ Groundcover or water has decreased in the 2012 imagery, indicative of higher canopy growth
- ❖ Minimal presence of dead canopy species were identified in the 2012 imagery and were field verified

The limitation of working with enhanced 1999 images inhibited the potential to run the software's change detection analysis. WRA 1 will require new imagery every five years, according to permit criteria.

Change detection analysis will then be performed on the same radiometrically and spectrally processed SPOT Imagery (16 bit, 50 cm ortho-mosaic) for the software's change detection analysis. Exotic vegetation removals being completed prior to canopy study spectral analysis also made the classification more challenging. Basin 4 is the next Water Conservation Plan site planned for ERDAS canopy study analysis, the studies will be completed prior to any exotic removals onsite. Analysis of the 2012 and 1999 PCA isodata clustering demonstrated that performance criteria are being met. Continued maintenance of the site via exotic removal events will be required in perpetuity to maintain this wetland habitat as a healthy ecosystem. Ground monitoring will continue to be utilized for groundcover estimates.



Wildlife camera photographs in WRA 1 W, capturing your typical ground monitoring events and endangered Florida panther (*Puma concolor coryi*) utilizing the area and affirming that enhancement activities must continue in these critical Everglades habitats.



References

2012. *ERDAS Field Guide*. Norcross, Georgia: 2012 ERDAS, Inc.

Everglades Cooperative Invasive Species Management Area (ECISMA) sketchmapping South Florida Water Management District (SFWMD)

Faust, N. L. 1989. Image Enhancement. Volume 20, Supplement 5 of *Encyclopedia of Computer Science and Technology*. Ed. A. Kent and J. G. Williams. New York: Marcel Dekker, Inc.

Gonzalez, R. C., and P. Wintz. 1977. *Digital Image Processing*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Jensen, J. R. 1996. *Introductory Digital Image Processing: A Remote Sensing Perspective*. 2d ed. Englewood Cliffs, New Jersey: Prentice-Hall.

Sabins F.F. Jr. 1987. *Remote Sensing: Principles and Interpretation*. 2nd ed. New York City: Reproduced by permission of W.H. Freeman & Co.

Short, N. M., Phd. 1982. *The Landsat Tutorial Workbook: Basics of Satellite Remote Sensing*. United States: National Aeronautics and Space Administration. Scientific and Technical Information Branch, Goddard Space Flight Center

Swain, P. H. 1973. *Pattern Recognition: A Basis for Remote Sensing Data Analysis* (LARS Information Note 111572). West Lafayette, Indiana: The Laboratory for Applications of Remote Sensing, Purdue University.

Taylor, P. J. 1977. *Quantitative Methods in Geography: An Introduction to Spatial Analysis*. Boston, Massachusetts: Houghton Mifflin Company.

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