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# Report Project "Geo-Temporal Estimation and Visualization of Nitrogen in a Mixed-Use Watershed"

## USDA Program "Nutrient Science for Improved Watershed Management"

**Proposal # 2002-00501**

**PI:** Dr. S. Grunwald
**Co-PIs:** Dr. N.B. Comerford, Dr. M. W. Clark, Dr. D.A. Graetz, and Dr. R.B. Brown
**Collaborator:** Dr. R. Srinivasan

**Post-Docs:** Dr. C. Bliss and Dr. I. Lopez

**Graduate students:** S. Lamsal (Ph. D. student) and A. Sabesan (M.S. student)

**Project period** 9/2002 to 9/2003

This report summarizes the research and extension activities of the project "Geo-Temporal Estimation and Visualization of Nitrogen in a Mixed-Use Watershed" funded by USDA.

## Goals of the Project

Describe the spatial and temporal distribution of soil nitrogen across the Santa Fe River Watershed.

### Specific Objectives

- We will identify representative land use – management complexes in the Santa Fe River Watershed and measure nitrate-nitrogen within soil profiles
- We will utilize a GIS-based geo-modeling approach to upscale site-specific measurements of nitrate-nitrogen to the entire watershed of the Santa Fe River
- We will validate nitrate-nitrogen estimations at the watershed-scale
- We will link nitrogen sources and sinks to the nitrogen measured and predicted in soils and to the nitrogen measured in wells
- We will make results accessible to the general public, stakeholder groups, scientists, and government agencies via a project web page in 2D and 3D format. Stakeholder groups will be involved in the process from data collection to interpretation of results in the form of outreach and extension activities (e.g. workshops, demonstrations, and presentations)

## Research Activities:

### (1) Assembly of Non-Spatial and Spatial Datasets

We assembled readily available non-spatial and spatial datasets for the Santa Fe River Watershed (SFRW) in north-central Florida (Fig. 1). Our repository of geographic information system (GIS) data includes:

- Watershed boundaries (data source: Suwannee River Water Management District - SRWMD)
- Topography (data source USDA National Elevation Dataset)
- Soil Survey Geographic Database (SSURGO) 1:24,000 (data source: Natural Resources Conservation Service)
- Land use / land cover derived from Landsat TM imagery for 1990 and 1995 (data source: Suwannee River Water Management District (SRWMD) and St. Johns Water Management District (SJWMD))
- Monitoring stations (surface water and ground water) (data source: SRWMD)
- Stream network (data source: National Hydrography Dataset)
- Geology (data source: US Geological Survey)
- County boundaries (data source: U.S. Census Bureau)
- Parcel maps for each county (data source: County Appraiser Offices)
- Major roads (data source: Florida Department of Transportation)

(All GIS maps were standardized to Albers Equal Area projection)

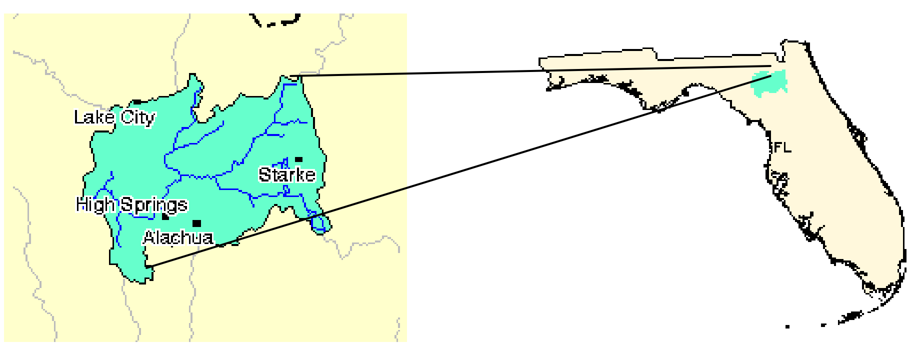



Fig. 1. The Santa Fe River Watershed is located in north-east Florida.

The SFRW extents across the following counties: Alachua, Bradford, Union, Columbia, Gilchrist, Putnam, Baker, Clay and Suwannee (Fig. 2). We characterized land use in the SFRW using the National Agricultural Statistics Service, USDA.(http://www.usda.gov/nass/) and the Florida Agricultural Statistics Service (http://www.nass.usda.gov/fl/): Corn for grain, peanuts and flue cured tobacco are grown in Alachua, Columbia and Gilchrist. In Union county corn for grain and tobacco are cultivated, although the acreage coverage is less compared to other counties. Animal husbandry (milk cow and beef cow) is popularly practiced in the SFRW. The number of cattle heads is variable in different counties, with Alachua having the highest number of beef cows followed by Gilchrist, Columbia, Union and Bradford. In the period from 1998-2002 the number of cattle decreased in all the counties. Although vegetables and fruits are sparsely cultivated in the area, the extent of cropping is not documented on a county basis. The extent of horticultural crops is negligible compared to agronomic crops. Upland cotton existed in Alachua during 1994-97 and Gilchrist in 1996, after which no cotton is reported. Union county seems to have less area under agronomic crops. According to the National Agricultural Statistics Service tobacco seems to be the only crop cultivated in Bradford county. It was grown from 1994 to 1998, after which it has not been reported. Animal husbandry (milch cow and beef cow) is popularly practiced in the Santa Fe watershed. During 1994-1997, cattle and beef cows were raised in all counties, with Alachua having the highest (52,000-54,000 milch cattle and 28,000-30,000 beef cows per year) number followed by Gilchrist, Columbia, Union and Bradford. The number of cattle varied between counties, with Alachua having the highest number (47,000-48,000 cattle heads and 25,000-28,000 beef cattle per year) followed by Gilchrist, Columbia, Union and Bradford.

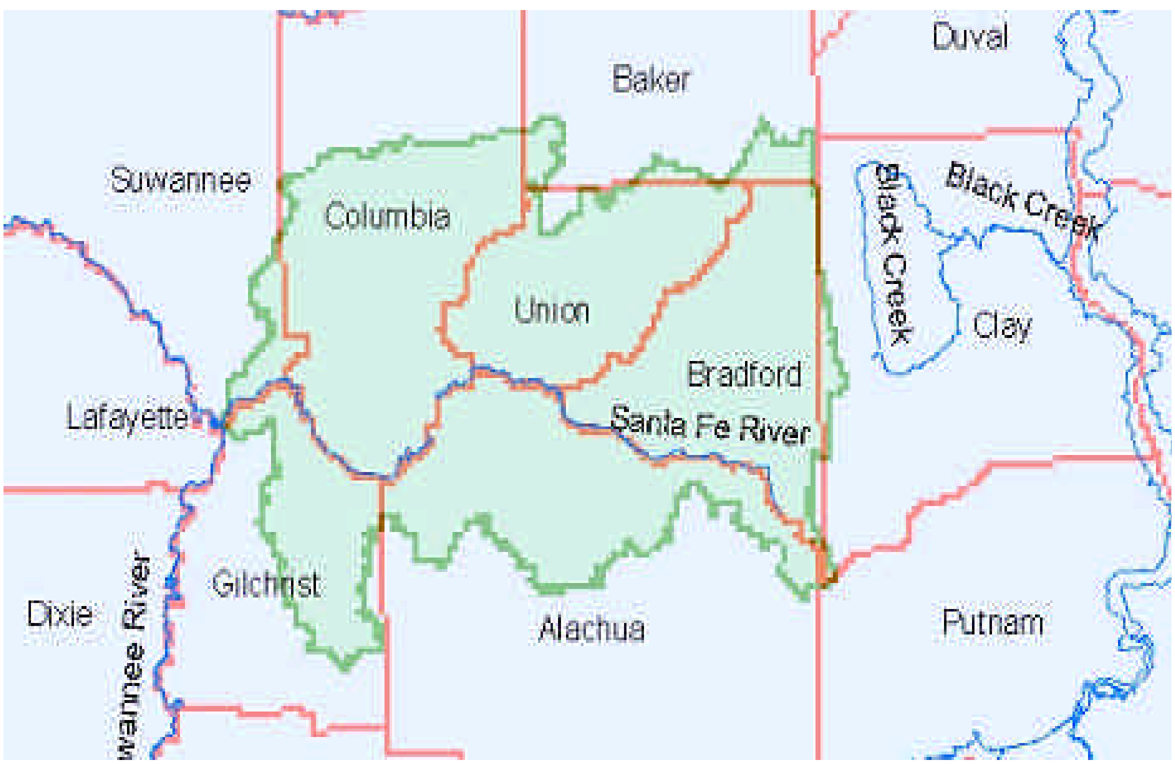


Fig. 2. Watershed boundaries of the Santa Fe River Watershed (SFRW) and county boundaries.

Surface and ground water monitoring data were assembled from the SRWMD which include nitrate-nitrogen observations. A GIS layer of geo-referenced water quality monitoring stations was created and associated with the water quality time series data. Surface water quality monitoring datasets from 1992 to present and ground water quality monitoring data from 2000 to present were assembled.

## (2) Development and Implementation of a Stratified Random Sampling Design

Soil sampling locations in the SFRW were targeted to different land-use and soil type combinations and allocated according to the geographic area covered by each combination. Our second criterion was to target samples towards land use categories of high risk for nitrogen loads. Spatially-referenced soil and land-use data covering the entire watershed were obtained to identify these areas.

We used soil data from the Soil Survey Geographic Database (SSURGO) (Natural Resources Conservation Service) and land use (LU) / land cover (LC) data derived from Landsat TM satellite images (SRWMD and SJWMD). The original datasets contained 171 individual LU/LC categories based on the Florida Land Use and Classification Code (FLUCCS). These categories were aggregated into fewer, more general categories to reduce the categories to a more manageable number. Seventeen final land-use classes were created (Fig. 3). Similarly, SSURGO soil map units were reclassified into soil orders (Fig. 4).

Table 1. Number of samples allocated to a soil order/land use combination, according to proportion of area.

| Area Covered (%) | Number of Samples |
|---|---|
| 0-2 | 4 |
| 2-4 | 5 |
| 4-6 | 6 |
| 6-8 | 7 |
| 8-10 | 8 |
| 10-12 | 9 |
| >12 | 10 |

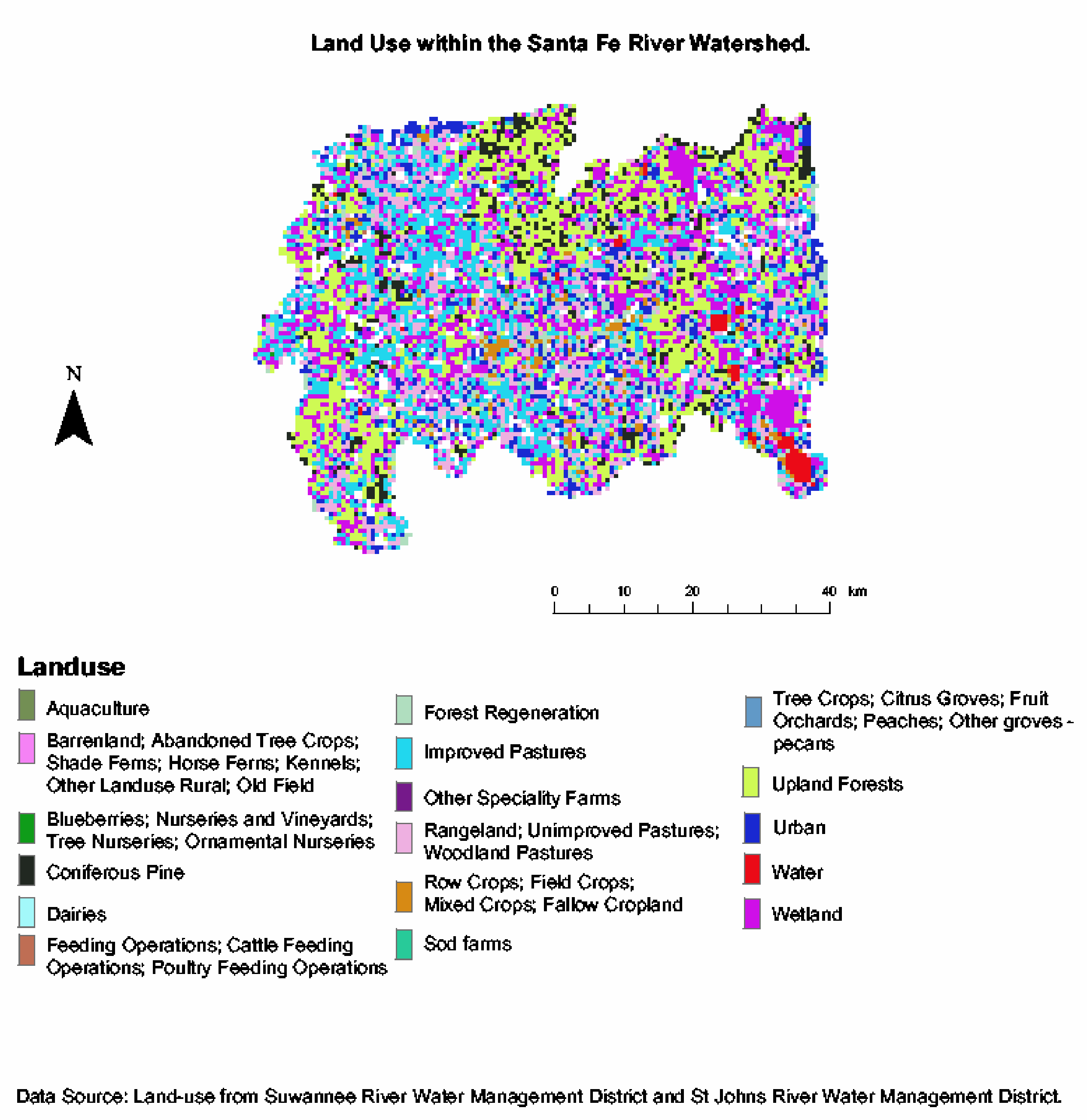



Fig. 3. Reclassified land use categories within the SFRW.

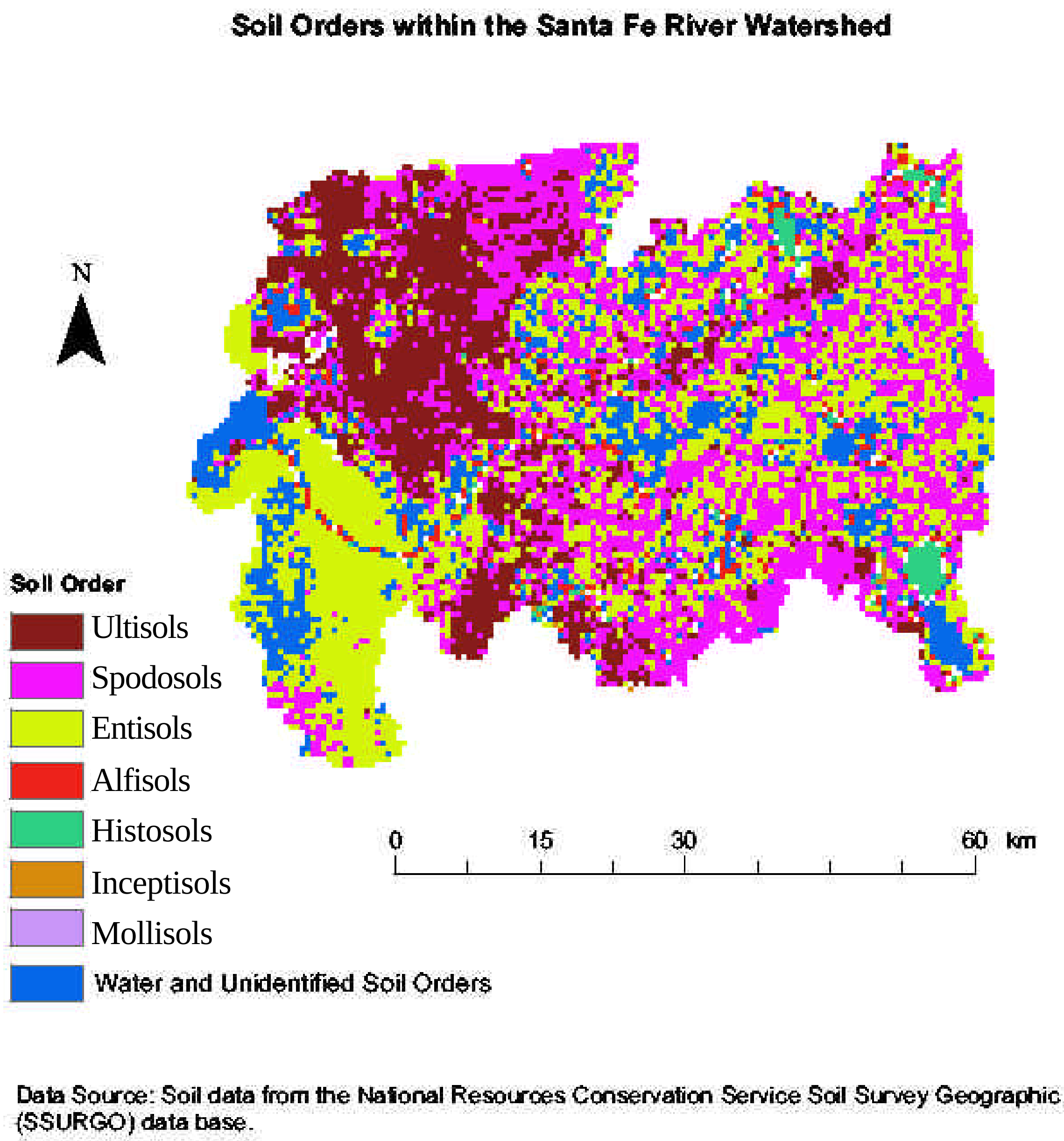


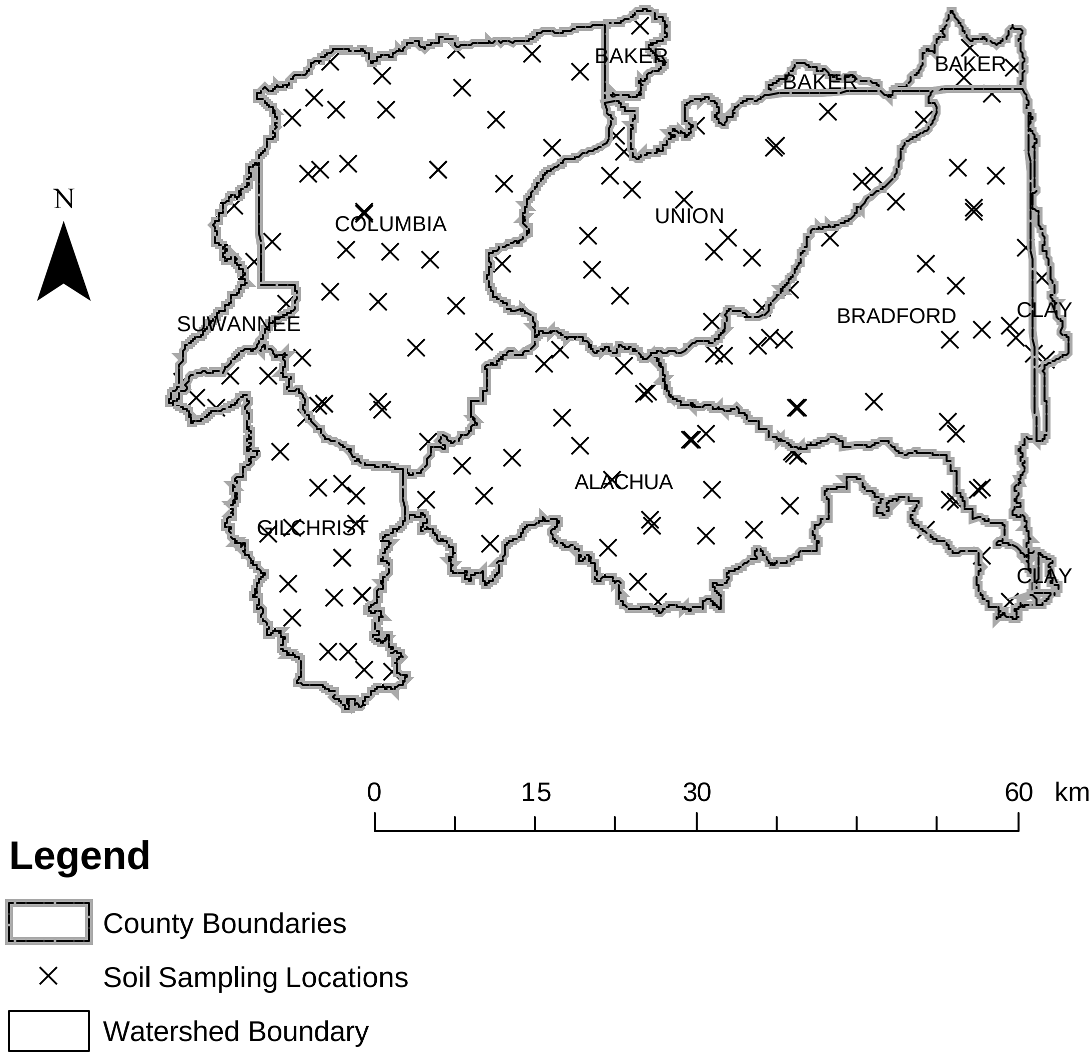

Fig. 4. Soil orders within the SFRW.

Table 2. Number of samples allocated to each soil order/land use combination.

| Land Use | Soil Order | | | |
|---|---|---|---|---|
| | Ultisol | Spodosol | Entisol | Histosol |
| Coniferous pine | 10 | 10 | 6 | |
| Upland forests | 8 | 5 | 6 | |
| Wetland | 5 | 5 | 4 | 5 |
| Improved pastures | 9 | 4 | 5 | |
| Rangeland/unimproved Pastures/woodland pastures | 4 | 5 | 5 | |
| Urban | 6 | 5 | 5 | |
| Forest regeneration | 5 | 5 | 4 | |
| Row crops/field crops/mixed Crops/fallow cropland | 5 | 4 | 4 | |
| Tree crops/citrus groves/fruit Orchards/peaches/other Groves/pecans | 4 | | | |
| Feeding operations/cattle feeding Operations/poultry feeding Operations | | 4 | | |
| Dairies | | | 4 | |
| Total (n: 151) | 56 | 47 | 43 | 5 |

The geographic area covered by each land-use/soil combination was calculated and expressed as a percentage of the entire watershed area. Those land uses that covered an area of less than 1% of the watershed were excluded from sample allocation, with the exception of: dairies; cattle feeding operations; poultry feeding operations; tree crops; citrus groves; fruit orchards; and pecans. These were considered to be potential major sources of nitrate-N within the watershed. In these cases, sample sites were allocated only to the soil order/land use combination which covered the greatest area of land.

The percentage area coverage of each soil order/land use was recalculated as a percentage of the total area covered by all combinations. The number of samples allocated to a particular soil order/land use combination was based on these percentages. Corresponding sample numbers are given in Table 1. Table 2 contains the number of samples allocated to each soil order/land use combination. In all, a total of 151 samples were allocated (Fig. 5). Actual sampling locations were selected randomly within each soil order/land use combination. Figure 5 shows the location of all selected soil sampling sites within the watershed.




Data Source: Santa Fe River Watershed boundary from Suwannee River Water Management District.
County boundaries from United States Census Bureau.

Fig. 5. Sampling locations within the SFRW.

For each selected site the x and y coordinates were retrieved using ArcGIS software (Environmental System Research Institute, Redlands, CA). Before taking soil samples at identified geographic locations it was necessary to contact land owners and ask for permission to access their property. The parcel GIS maps, online and CD appraiser databases were used to retrieve land owner addresses. Phone numbers of land owners were identified using online search routines (e.g. www.yellowpages.com).

We used a multi-tier approach to receive permissions from land owners to take soil samples on their property: (i) We mailed letters to land owners and asked for permission; (ii) After about 3 weeks of mailing out letters we contacted land owners who did not respond to our letters by phone and email and asked for permission; (iii) For land owners who did not give us permission we identified "replacement" sites. For each "rejected" site we randomly selected 3 potential "alternative" sites which complied with the previously identified land use / soils categories and repeated to mail out letters and stamped postcard to make it most convenient for land owners to respond to our request. Numerous phone calls were made to discuss land owners concerns; (iv) We contacted county extension agents who have established contacts to local clientele; their contacts enabled us to receive permission of land owners operating feeding operations and managing crops and rangeland sites; (v) We submitted permission forms to get access to State-owned land (e.g. State prison, State Parks, Wildlife areas, etc.).

Numerous land owners in this watershed which we contacted are concerned about regulations which might result from this research study. The fear that State Agencies such as the Department of Environmental Protection and the SRWMD use results of this study to develop new regulations limiting their land use activities in the SFRW is high. Several extension agents were not supportive of our research study because our focus is nutrient management and environmental quality. In the rural parts of the SFRW many land owners are neoconservative and perceive any kind of sampling as a threat to their property.

All land owner data were integrated in a MS Access database and shared between project participants. From June to the end of August 2003 we visited each of the 150 sampling sites for which we received permission for sampling. Geographic coordinates were recorded at each site with a Trimble Pathfinder GPS and to characterize each site. At each site a digital photograph was taken with a digital camera. Small adjustments had to be made to some sites because they the digital GIS data were inaccurate and / or not up-to-date due to land use changes (e.g. conversion from rangeland into urban land, misclassification of the land use categories identified from the Landsat TM imagery). In such cases we had to identify a "replacement" site with similar land use / soils characteristics. The site characterization dataset and digital photographs will be used for ground truthing of the remote sensing images.

## (3) Sampling Protocol

We developed a sampling protocol to address quality assurance and to fulfill all requirements for the geostatistical analysis (stochastic simulation) which we plan to employ in this research project.

<u>Outline of the Sampling Protocol</u>:

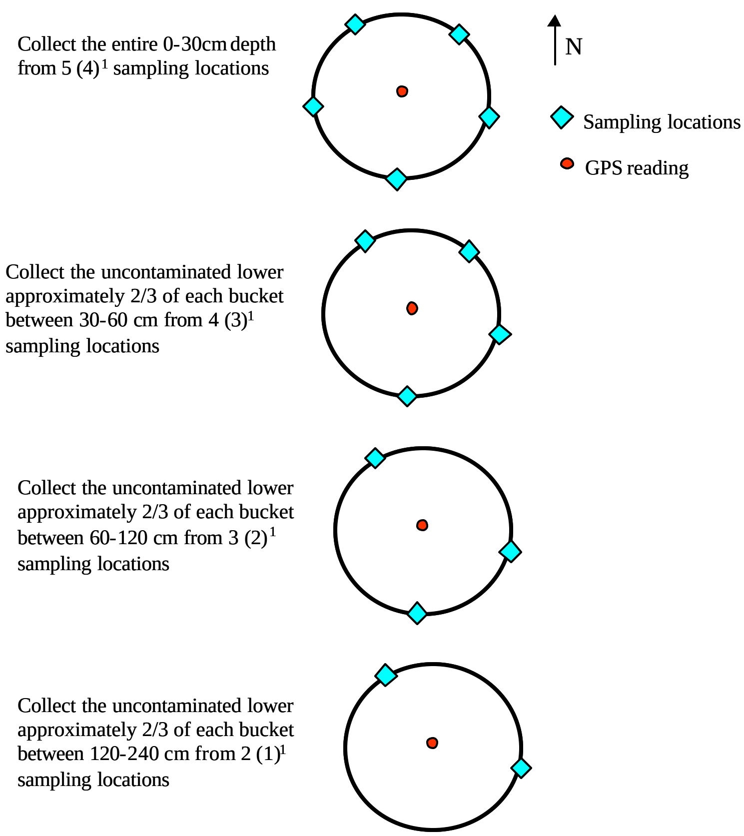
| | |
|---|---|
| **Size of sampling area** | 3 m radius around GPS point. |
| **Composite samples** | compare Fig. 6 |
| **Augers** | |
| *Bucket size* | about a 3” bucket |
| *Sample Handling* | Collect the entire 0-30cm depth and the uncontaminated lower approximately 2/3 of each bucket between 30-60, 60-120 and 120-240 cm depths from each of the three holes. As the soil is removed it is put into a plastic bucket lined with a heavy-duty garbage bag. There is a bucket for each depth increment. After all three holes are sampled, the soil in each bucket is mixed by hand and approximately 400 g are put in a *Fisherbrand* plastic bag. The bags are transferred to a cooler holding ice and samples are stored in this fashion until returned to the laboratory where they will be extracted the following day. |
| **Additional field equipment** | GPS to mark and relocate site.<br>Plastic sampling bags<br>High quality, sturdy coolers (6)<br>Marking pens<br>Electronic Field Sheet for each site<br>Clinometer for slope measurement |
| **Electronic Field Sheet Data** | GPS location<br>Date of sampling; time of day<br>Names of sampling crew<br>Vegetation if different from original notes<br>Current stage of management if different from original notes<br>Comments section |

In our sampling protocol we addressed the issue of sample support. To conduct the geostatistical analysis it is necessary that all collected soil samples have the same support. Otherwise observations at different geographic locations are not comparable. Our intention was to select soil samples at 0-30 cm, 30-60 cm, 60- 120 cm, and 120-240 cm depth. The sampling support in the upper profile is smaller than in the lower profile. Different supports in the upper and lower soil profile would result in different standard error of the mean (SE) for $NO_3$-N (or other soil properties) measured in the upper and lower profile, respectively. The SE is used to express the precision of our sampling.

$$SE = \frac{s.dev}{\sqrt{n}} \qquad \text{Eq. (1)}$$

Assumed we use 1 auger hole at each GPS sampling location:
e.g. the expected standard deviation (std.dev) of $NO_3$-N is high in the upper profile and the sample size (n) small, which results in an expected SE which is high
e.g. the expected std.dev of $NO_3$-N is low in the bottom profile and the sample size (n) large, which results in an expected SE which is small.

To adjust the sampling support we decided on the following sampling protocol: To collect composite samples with more samples 5 (4) in the upper profile (depth 0 – 30 cm) while few samples 2 (1) are used in the lower profile (120 – 240 cm depth) (Fig. 6). This sampling design results in a similar expected SE in the upper and lower profile.




[1] Alternative numbers for reduced sampling

Fig. 6. Design for composite soil sampling at each site.

## (4) Land Use / Land Cover Characterization Using 2001 Satellite Images

Land use/ land cover images (Landsat Enhanced Thematic Mapper 7+ images from April 26, 2000 and Sept. 17, 2000) for the study area was obtained from the EROS Data Center, **edcimswww.cr.usgs.gov**. Data were corrected both radiometrically and geometrically. The format of the image is standard Hierarchical Data Format (HDF). The number of rows of data in the image was 7221 for both the April and September scene. The number of columns in the April scene was 8221 and the September scene 8201. The images were projected to WGS84_UTM_Zone 17N. The data contained 6 bands: TM1, TM2, TM3, TM4, TM5 and TM6. Details of the band are summarized in Table 3.

Table 3. Spectral bands and range, nominal spectral location, and ground resolution of images.

| **Spectral Band** | **Spectral Range (mm)** | **Nominal Spectral Location** | **Ground Resolution (m)** |
|---|---|---|---|
| 1 | 0.45- 0.52 | Visible Blue | 30 |
| 2 | 0.52 – 0.60 | Visible Green | 30 |
| 3 | 0.63 – 0.69 | Visible Red | 30 |
| 4 | 0.76 – 0.90 | Near infrared | 30 |
| 5 | 1.55 – 1.75 | Mid-infrared | 30 |
| 6 | 10.4 – 12.5 | Thermal infrared | 120 |
| 7 | 2.08 – 2.35 | Mid-infrared | 30 |

**April Image:**

| | | |
|---|---|---|
| Scene Id | - | L71017039-03920010426 |
| Path | - | 017 |
| Row | - | 039 |
| Date of Acquisition | - | 26 April, 2000 |
| Correction level | - | Systematic |
| Rows | - | 7221 |
| Columns | - | 8221 |
| Bin number | - | 14 |
| Format | - | HDF |

**September Image:**

| | | |
|---|---|---|
| Scene Id | - | L71017039-03920010917 |
| Path | - | 017 |
| Row | - | 039 |

| | | |
|---|---|---|
| Date of Acquisition | - | 17 September, 2000 |
| Correction level | - | Systematic |
| Rows | - | 7221 |
| Columns | - | 8201 |
| Bin number | - | 14 |
| Format | - | HDF |

**Image Processing:**
Before processing the image, reference files were downloaded from Florida Geographic Data Library (FGDL). These files were used as the ground truth data for the classification.

General description of Reference data: This dataset contains the 1995 Level 3 land use from Southwest Florida Water Management District.

| | | |
|---|---|---|
| Data Source | : | Southwest Florida Water Management District |
| Scale of Original Source maps | : | 1:24,000 USGS Quads, 1:4000 Aerial Photos |
| Date of Automation | : | 1994-1995 |
| Geodataset Extent | : | Southwest Florida Water Management District, counties include all or parts of: Levy, Marion, Citrus, Hernando, Pasco, Pinellas, Hillsborough, Sumter, Polk, Manatee, Sarasota, Charlotte, Hardee, and De so Highlands. |

The SFRW was clipped out from the land use thematic layer.

**Processing:**
We reprojected the images from UTM-WGS 84 to Albers Equal Area Conic projection and North American Datum 83 (NAD-83). The projection parameters are listed below:

Albers
False Easting: 400000.000000
False Northing:0.00
Central-Meridian: -84.00
Standard Parallel_1:24.00
Standard Parallel_2 : 31.500000
Latitude of Origin: 24.00
GCS_North_American_1983
Datum:D_North_American_1983
Prime Meridian:0
Pixel size: 30
No.of bands: 6
Data Type:Unsigned Integer

**Classification**

The classification of the images was performed using the ERDAS IMAGINE 8.5. This software uses the ISODATA algorithm for Unsupervised Classification. ISODATA stands for "Iterative Self-Organizing Data Analysis Technique." It is iterative in that it repeatedly performs an entire classification (outputting a thematic raster layer) and recalculates statistics. "Self-Organizing" refers to the way in which it locates the clusters that are inherent in the data. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set, and each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration.

The ISODATA utility repeats the clustering of the image until either:

- a maximum number of iterations has been performed
- A maximum percentage of unchanged pixels have been reached between two iterations.

The processing options used for unsupervised classification were:

**Number of classes: 80**

**Maximum iteration: 31 –** This will perform the number of maximum times that the ISODATA utility should recluster the data. This parameter prevents this utility from running too long, or from potentially getting "stuck" in a cycle without reaching the convergence threshold.

**Convergence Threshold: 0.95** - The convergence threshold is the maximum percentage of pixels whose cluster assignments can go unchanged between iterations. This threshold prevents the ISODATA utility from running indefinitely.

By specifying a convergence threshold of .95, you would specify that as soon as 95% or more of the pixels stay in the same cluster between one iteration and the next, the utility should stop processing. In other words, as soon as 5% or fewer of the pixels change clusters between iterations, the utility will stop processing.

**Skip Factors X=1 and Y=1** - For faster (although less accurate) processing you can enter an X and Y skip factor.

**X:** Enter the X skip factors to use when processing. Entering a 1 will process all pixels, 2 will process every other pixel, 3 every third pixel, and so forth.

**Y:** Enter the Y skip factors to use when processing. Entering a 1 will process all pixels, 2 will process every other pixel, 3 every third pixel, and so forth.

The initially 80 groups of land use were grouped into 8 FGDL groups. Then, the grouped data was narrowed down to five land use/land cover categories because the remaining 3 groups occupied a small area compared to the other 5 groups.

Since Upland forest and Wetland forest were difficult to separate, they were considered one land use.

**Summary of the five groups:**
**April Image:**

Class 1: water-cloud shadow
Class 2: Forest
Class 3: Wetlands
Class 4: Urban-Transport
Class 5: Agriculture

**September Image:**

Class 1: water-cloud shadow
Class 2: Clouds-Cloud shadow
Class 3: Forest
Class 4: Wetland
Class 5: Urban-Transport
Class 6: Agriculture

Finally, the area occupied by each land use category was calculated for both images (compare Table 4 and 5).

**Table 4. Area of land use categories identified using the April image.**

| Class | Area ,ha |
|---|---|
| None (Unclassified) | 818.73 |
| Water-cloud shadow | 12,342.6 |
| Forest | 379,031.8 |
| Wetland | 418,49.55 |
| Urban-Transport | 564,35.31 |
| Agriculture | 234,751.5 |

Total Area of the study area = 722,111.04 ha

**Table 5. Area of land use categories identified using the September image.**

| Class | Area ,ha |
|---|---|
| None (Unclassified) | 10,976.49 |
| Water-cloud shadow | 9,894.24 |
| Clouds-Cloud shadow | 10,972.08 |
| Forest | 414,951.48 |
| Wetland | 105,879.15 |
| Urban-Transport | 57,115.8 |
| Agriculture | 126,767.34 |

Total area of the study area = 742,785.12ha

We plan to employ a supervised multi-temporal classification method using Landsat ETM+ imagery to characterize the land use / land cover in the SFRW. The red-green-blue channels of raw imagery in April and September 2000 are shown in Figure 7 and 8, respectively. A preliminary unsupervised classification using the April and September satellite scenes showed promising results (Fig. 9). We expect more accurate results using the supervised classification technique which is in progress.

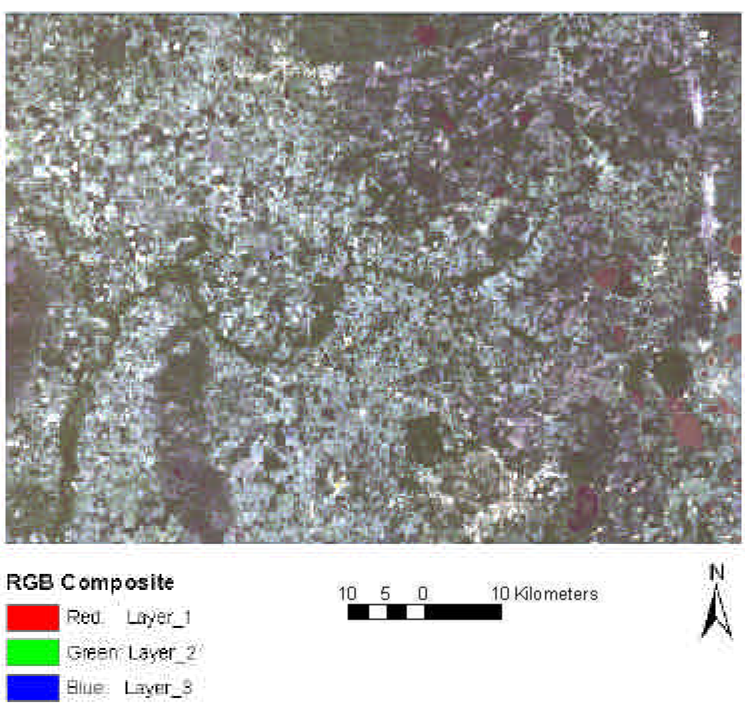



Fig. 7. Red (R) - Green (G) – Blue (B) channels of a Landsat ETM7+ satellite image covering the SFRW in April 2001.

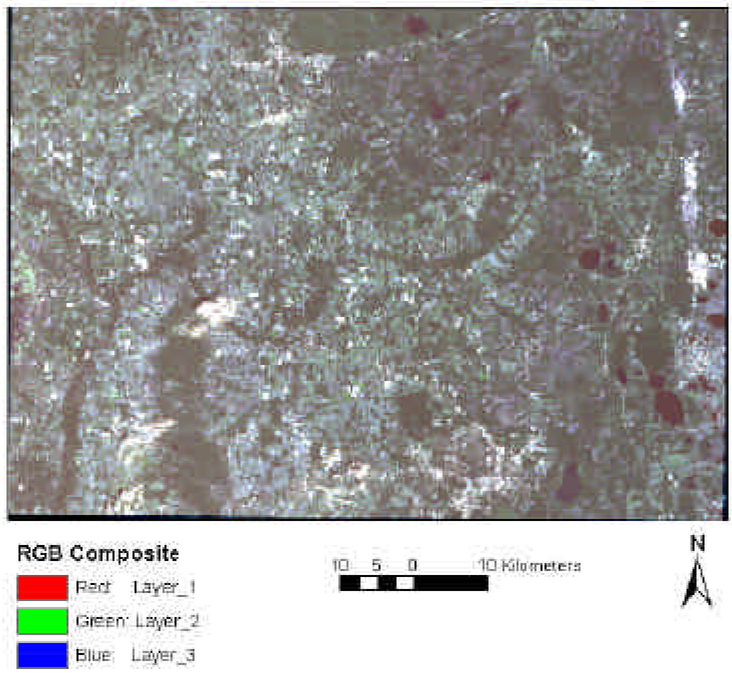



Fig. 8. Red (R) - Green (G) – Blue (B) channels of a Landsat ETM7+ satellite image covering the SFRW in September 2001.

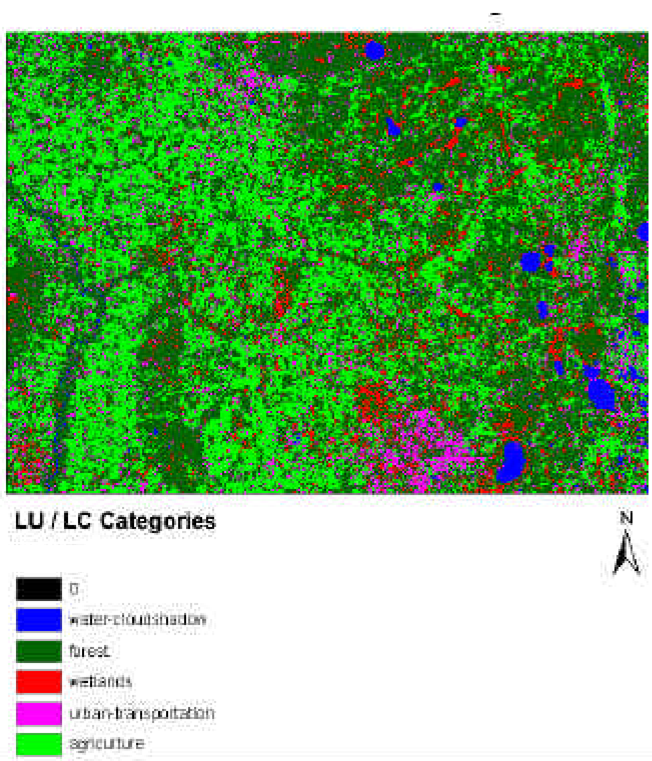



Fig. 9. Result of land use / land cover categories using unsupervised classification and a Landsat ETM7+ images.

## (5) Land Use / Land Cover Characterization Using 1984 & 1998 Satellite Images

We used Landsat satellite images from 1984 and 1998 to characterize the land-use dynamics in the SFRW. The following procedures were used to document the trends of land use change with in the Santa Fe River Watershed (SFRW). The completed module will document changes from 1984 to 2003. This document explains the procedures of the study between 1984 and 1998. Software used: ERDAS-IMAGINE 8.5, ENVI 3.5, ArcGIS8.2.

The basic objectives of this sub-project are:

- To observe historic trends in Land cover / Land use change (LCLUC)
- To estimate the long term water quality consequences , given the observed trend.

Data Acquisition

LANDSAT TM and LANSAT ETM+ from 1984 through 2003 are obtained from the NASA data archives at the Department of Geography. The SFRW lies in the North-Central part of Florida. The study area falls under Path 17 and Row 39 of LANDSAT track. Figure 10 and Figure 11 show the Path 17 and Row 39 imageries of 1984 and 1998, respectively.

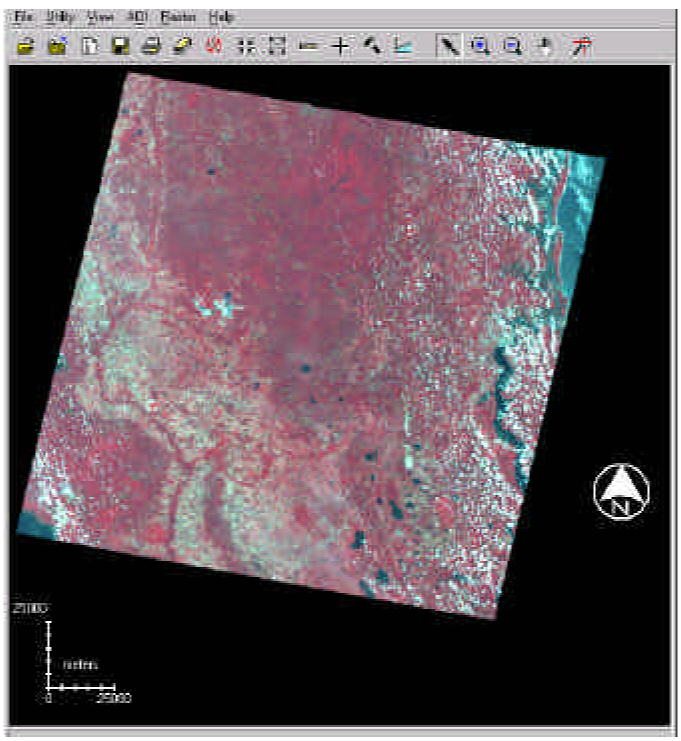


Fig. 10. Path 17 Row 39 of 1984 LANDSAT TM Track.

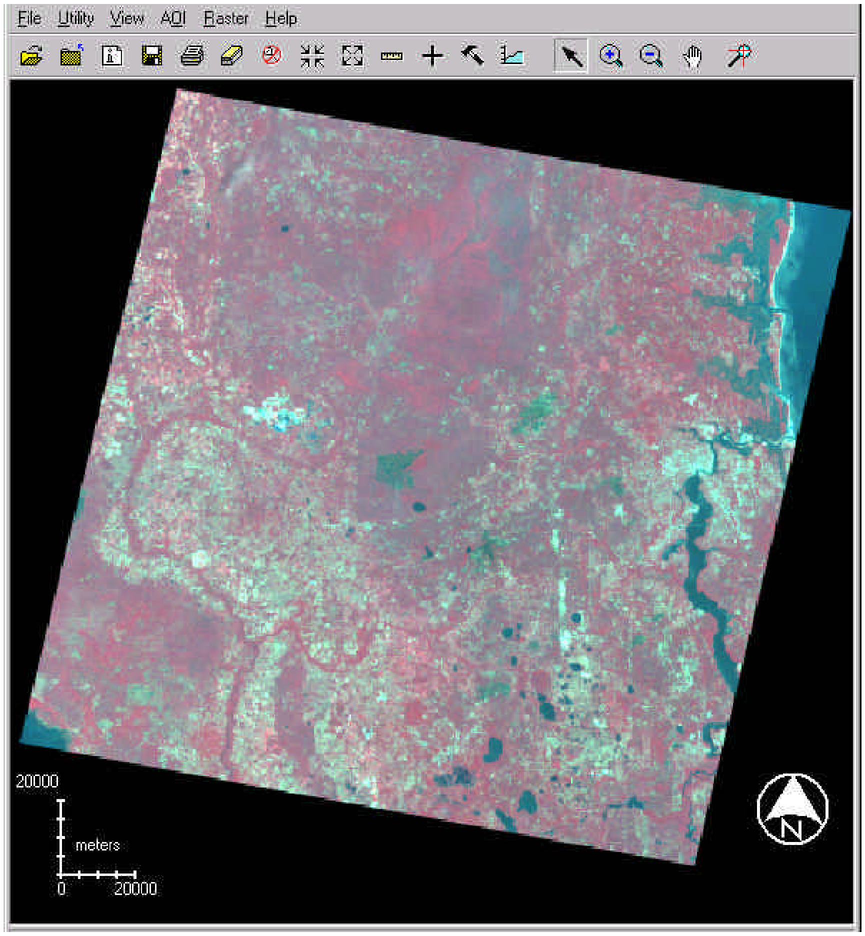



Fig. 11. Path 17 Row 39 of 1998 LANDSAT TM track.

Image Pre-Processing

The data obtained were at different temporal intervals, hence adequate pre-processing techniques need to be subjected before image classification.

Image Registration

The images are geometrically corrected, however they are not registered to each other. Image registration can be defined as the process used in aligning two or more images of different temporal resolutions. As a first step, projection was specified for both the images. The images were projected in Universal Transverse Mercader (UTM) under Zone 17. GRS1980 and NAD83 were the Spheroid and Datum respectively.

Image registration was done by collecting Ground Control Points (GCP's) from both data sets. The GCP's were points that are precisely identifiable in both the images. Examples include road intersections, roads, building edges and others. The collection of the GCP's forms a critical step in analysis. This is done to make sure that the pixel and row columns correspond to the same location on the ground. Around 15 GCP's were collected with a RMS error of less than 0.5. This implies that the accuracy of registration is ±1 pixel.

Image Subset

For more effective computation and detailed study, the SFRW was cut from the imagery. The location of the SFRW on the LANDSAT TM 1984 Imagery is shown in Figure 12. The Geo-metrically corrected images of the study are for the two years is shown in Figure 13 and Figure 14.

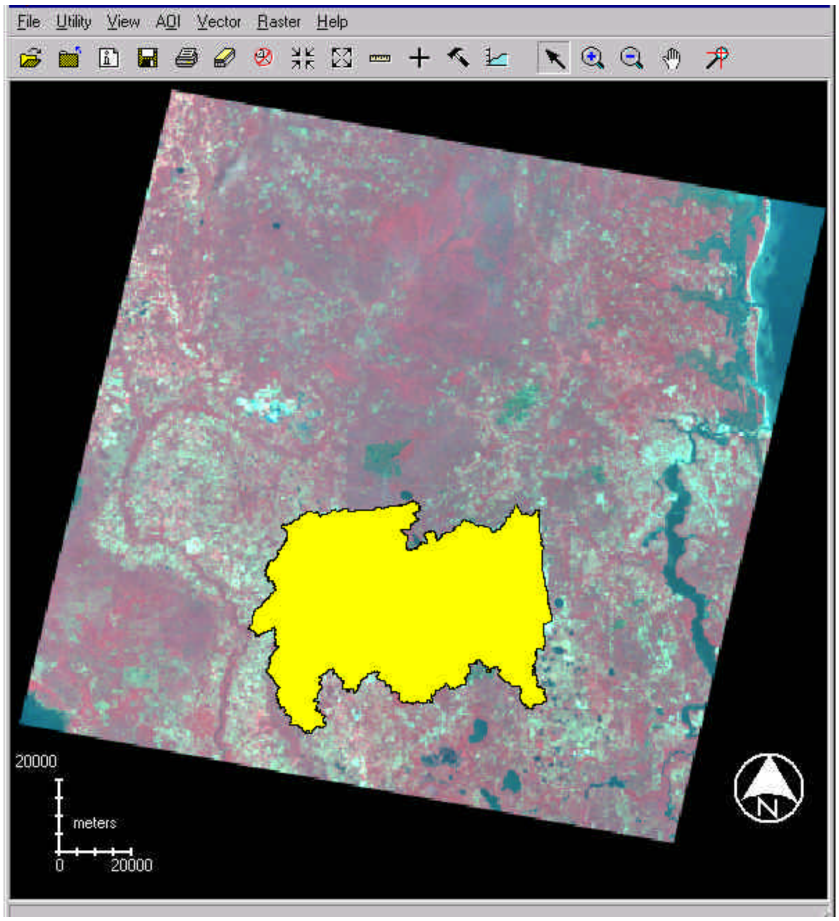
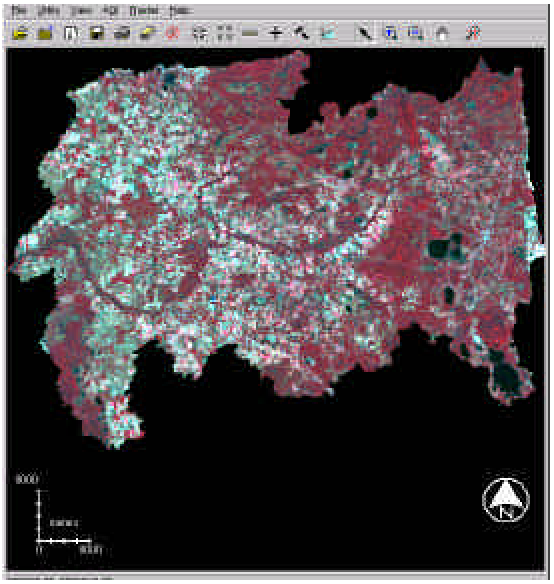



Fig. 12. Location of the SFRW on the imagery.



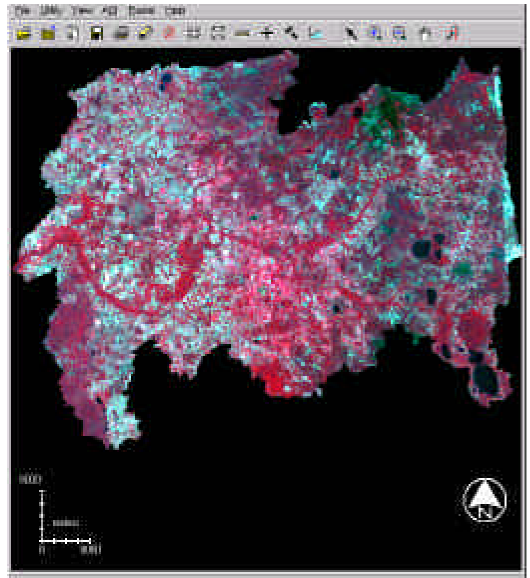


Fig. 13.
1984 SFRW

Fig. 14.
1988 SFRW

Radiometric Correction

Radiometric corrections are important in the case of a multi-temporal image analysis. Multi-temporal change detection techniques do not usually employ anniversary dates and hence may have varying sun angle, viewing geometry, earth-sun distance. All these factors tend to influence the radiance measurements received at the sensor. Hence these images were normalized so that the effects of the varying atmosphere are minimized and the differences between the pixel values are caused due to actual Land Cover/ Land Use Changes (LCLUC).

Two normalization models were built using the 'Model Maker' option in ERDAS-Imagine

The radiometric normalization was conducted in two steps

Recalculating 'at-satellite' radiance.

Infra red data are not affected by atmospheric scattering as the visible range data. A view of the histograms showed that the minimum value in the visible range bands are greater than the infra-red bands. These variations are corrected by introducing 'Gains' and 'Bias' to the DN values of the raw data.

Calculating 'at-satellite' reflectance.

The atmospheric variations caused due to viewing geometry, sun-angle and others were corrected using this model.

The output of this step-wise models were the pixels measured in actual reflectance. Figure 15 illustrates the output.

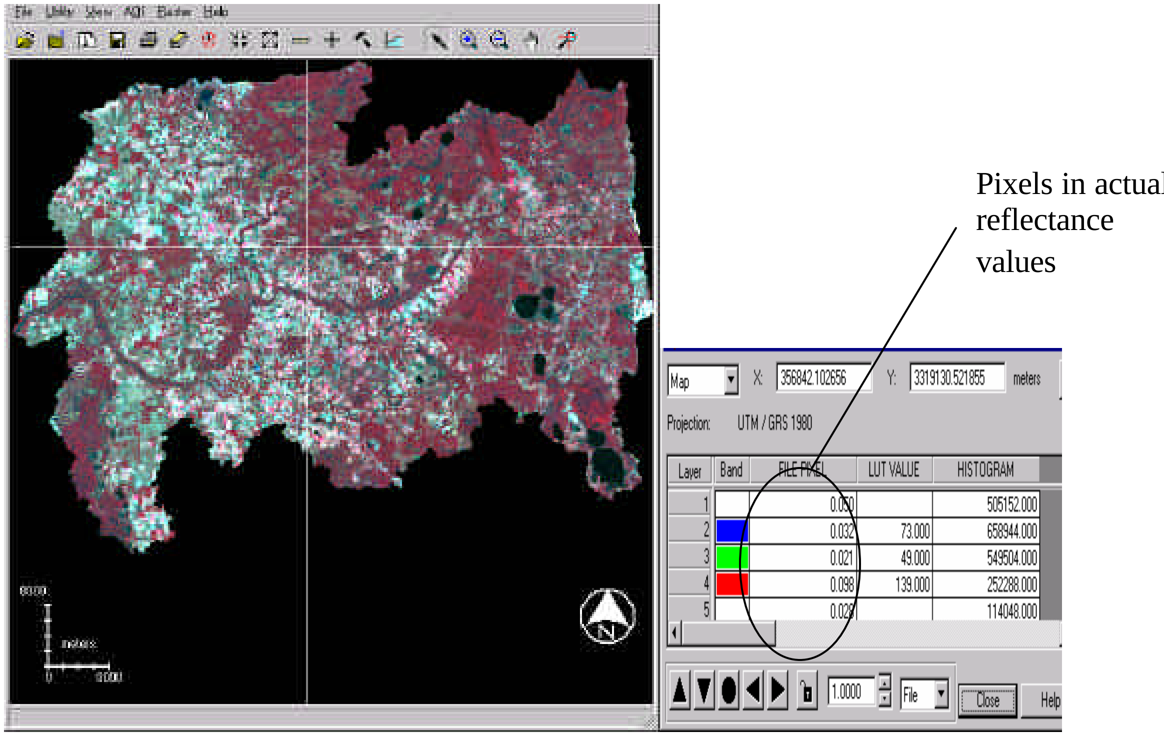



Fig. 15. Output of the atmospheric normalization models.

<u>Tasseled-cap transformation</u>

Tasseled cap transformations are special transformations performed to enhance the spectral interpretability and highlight feature types such as vegetation, soil and moisture content. The idea behind the tasseled cap transformation is to take an image and perform a transformation and output three axes of information that explains 99% of the variation in the scene. The three important output axes of the tasseled cap transformation are Brightness Index, Greenness Index and Wetness Index. The Brightness index is the weighed sum of the pixel values in all the bands. The Greenness index represents the green vegetation and the Wetness index represents the moisture content in the scene. A plot between the brightness and greenness index will give an plane of soils, a plane of vegetation and a plane of transition between these two planes. Hence, in the case of deforestation, the pixel value will move from the plane of greenness to the plane of soils in the time interval. The vice-versa is applicable in the case of re-growth. The tasseled cap is thus an ideal transformation to study land use dynamics and specifically vegetation dynamics within a scene. The tasseled cap transformations of the 1984 and 1998 scenes are shown in Figure 16 and Figure 17.

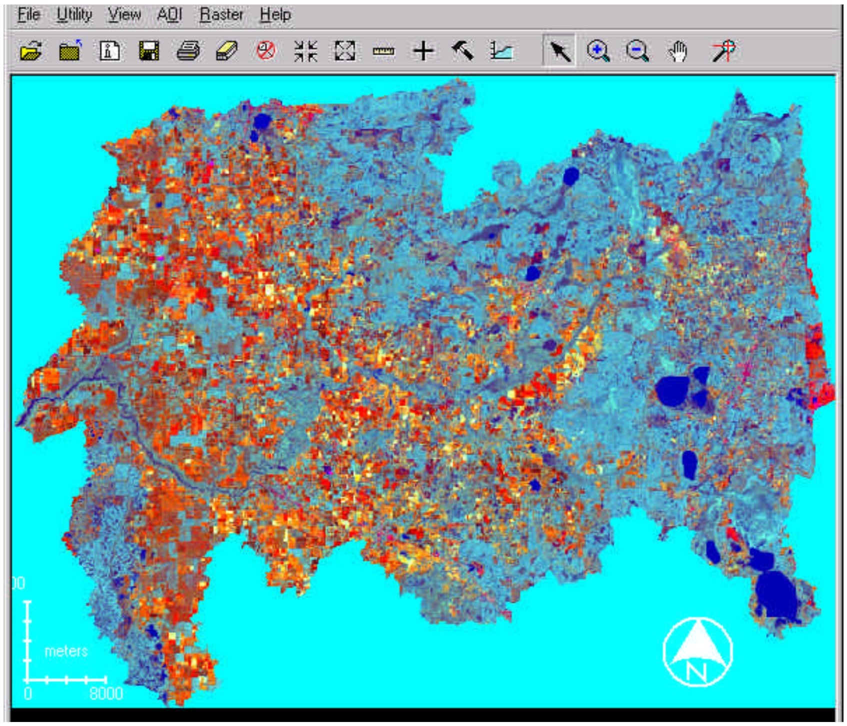



Fig. 16. Tasseled cap transformation on 1984 image.

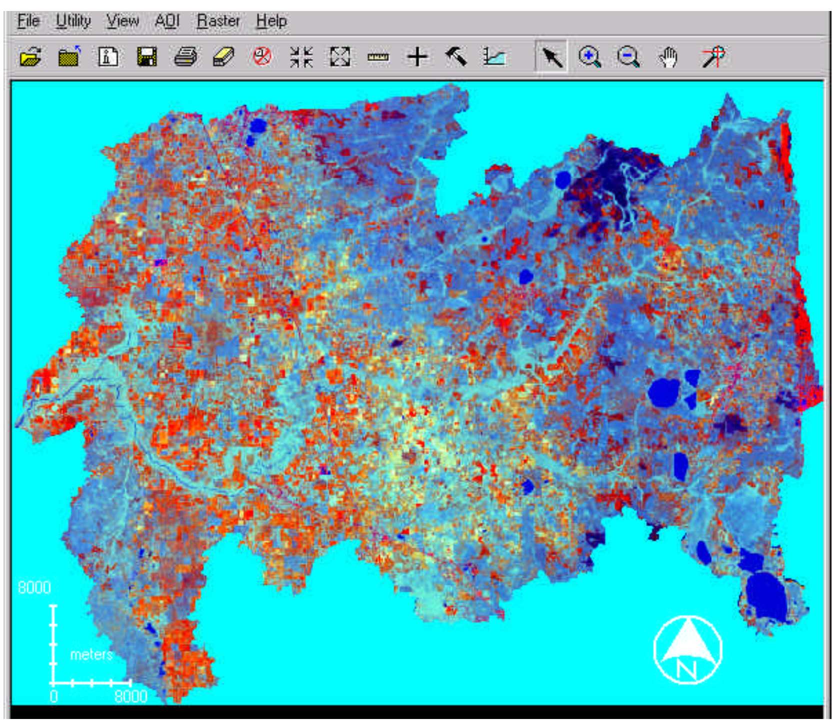



Fig. 17. Tasseled cap transformation on 1998 image.

Unsupervised Image Classification

An unsupervised classification was initially performed to determine the clusters present in the dataset. The tasseled cap transformed image is used as an input for the classification. The number of classes specified in this case are nine for both years. A reference land use classification map of study area was used for comparison.

The unsupervised classification output of the 1984 tasseled cap image of the SFRW is in Figure 18. The statistics are shown in Table 1.

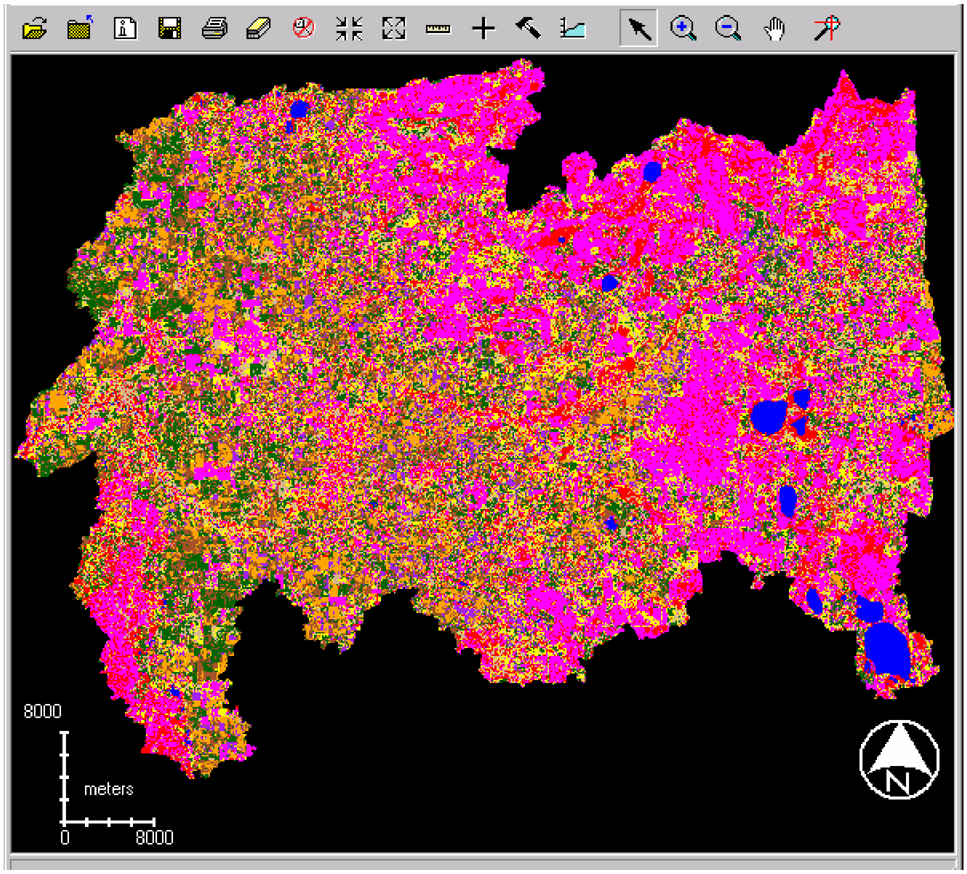



Fig. 18. Unsupervised image classification – 1984 SFRW.

Table 6. Summary statistics for 1984 land use pattern.

| Class # | > | Signature Name | Color | Red | Green | Blue | Value | Order | Count | Prob. | P | I | H | A | FS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | > | Water | | 0.000 | 0.000 | 1.000 | 1 | 1 | 59834 | 1.000 | X | | X | | |
| 2 | | Rangeland | | 0.824 | 0.706 | 0.549 | 4 | 4 | 407676 | 1.000 | X | | X | | |
| 3 | | Coniferous Pine | | 1.000 | 0.000 | 1.000 | 5 | 5 | 1028833 | 1.000 | X | | X | | |
| 4 | | Forest regeneration | | 1.000 | 1.000 | 0.000 | 6 | 6 | 479439 | 1.000 | X | | X | | |
| 5 | | Upland Forest | | 0.000 | 0.392 | 0.000 | 7 | 7 | 522473 | 1.000 | X | | X | | |
| 6 | | Urban | | 0.627 | 0.322 | 0.176 | 8 | 8 | 387974 | 1.000 | X | | X | | |
| 7 | | Row Crops | | 1.000 | 0.647 | 0.000 | 9 | 9 | 266183 | 1.000 | X | | X | | |
| 8 | | Improved Pasture | | 0.627 | 0.125 | 0.941 | 10 | 10 | 165366 | 1.000 | X | | X | | |
| 9 | | Wetland | | 1.000 | 0.000 | 0.000 | 11 | 11 | 656015 | 1.000 | X | | | | |

The unsupervised classification of 1998 image is shown in Figure 19 along with the statistics in Table 6.

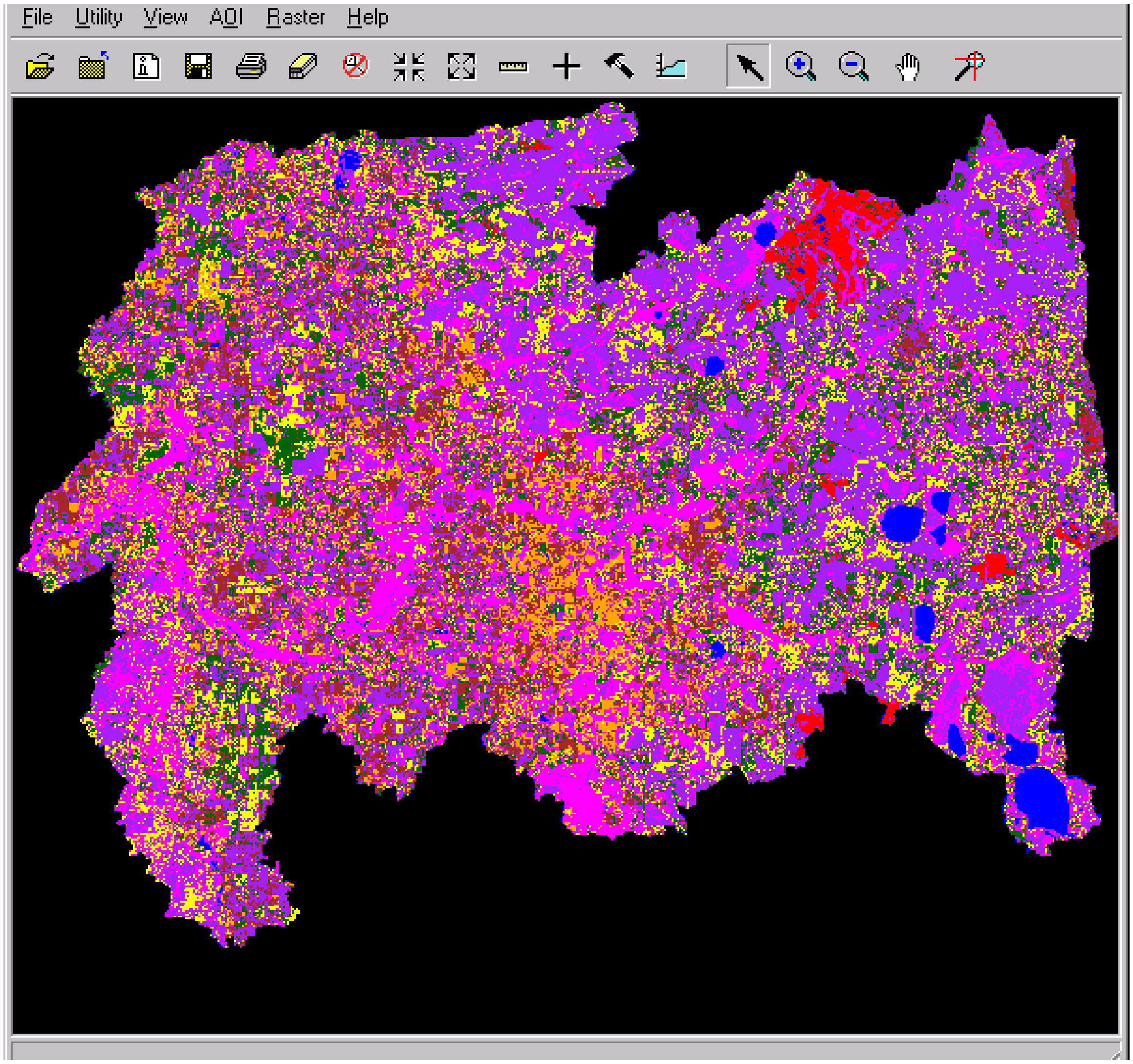



Fig. 19. Unsupervised classification – 1998 SFRW.

Table 7. Summary statistics of land use pattern –1998 SFRW.

| Class # | > | Signature Name | Color | Red | Green | Blue | Value | Order | Count | Prob. | P | I | H | A | FS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | > | Water | | 0.000 | 0.000 | 1.000 | 1 | 1 | 64928 | 1.000 | X | | X | | |
| 2 | | Wetland | | 1.000 | 0.000 | 0.000 | 2 | 2 | 80893 | 1.000 | X | | X | | |
| 3 | | Improved Pasture | | 0.627 | 0.125 | 0.941 | 3 | 3 | 418764 | 1.000 | X | | X | | |
| 4 | | Upland Forests | | 0.000 | 0.392 | 0.000 | 4 | 4 | 502806 | 1.000 | X | | X | | |
| 5 | | Forest Regeneration | | 1.000 | 1.000 | 0.000 | 6 | 6 | 535217 | 1.000 | X | | X | | |
| 6 | | Rowcrops | | 1.000 | 0.647 | 0.000 | 8 | 8 | 268206 | 1.000 | X | | X | | |
| 7 | | Coniferous Pine | | 1.000 | 0.000 | 1.000 | 11 | 11 | 1707211 | 1.000 | X | | | | |
| 8 | | Urban | | 0.627 | 0.322 | 0.176 | 5 | 12 | 395768 | 1.000 | X | | | | |

Table 8. Summary of land use change (1984 to 1998).

| **Land use** | **1984 (%)** | **1998 (%)** |
|---|---|---|
| Water | 1.88 | 1.82 |
| Wetland | 20.64* | 2.26* |
| Improved pasture | 5.20 | 11.70 |
| Upland forest | 16.44 | 14.05 |
| Forest regeneration | 15.09 | 14.96 |
| Row crops | 8.38 | 7.50 |
| Coniferous pine | 32.37 | 47.71 |
| Total | 100% | 100% |

*Change in wetlands from 1984 to 1998 is under investigation

We will continue to characterize historic and current land use / land cover characteristics in the SFRW using a change detection analysis.

## Extension Activities:

We developed a project web page which can be viewed at: http://santafemodvis.ifas.ufl.edu/.
A Research Brief (handout) was developed which summarizes the project. The Research Brief was posted on the Soil and Water Science Department, University of Florida web page (http://soils.ifas.ufl.edu/research/briefs.html) and used to inform land owners, extension agents, state agency personnel and others about our study including the goals and expected results.

The study was introduced to the people in the north-eastern region of Florida in a newspaper article which appeared in the Gainesville Sun (Dec. 6, 2002). The title of the article was "A watershed effort – UF study to track nitrogen in Santa Fe River". The newspaper article drew a lot of attention resulting in phone calls of interested citizens of Florida. It also enabled to share our project with state agencies, local working groups, and a variety of regional stakeholder groups.

Contacts to forest corporations which operate extensive pine plantations in the watershed were established. These include Rayonier Inc., Plum Creek Timberlands, and Loncala Inc. We also established contact to the Santa Fe Springs Working Group (Chair: Fay Baird) and the Florida Forest Association (contact: Phil Barneky) which invited us both to introduce our project in a workgroup meeting.

We strengthened collaboration with the Suwannee River Water Management District (contacts: Warren Zwanka and David Hornsby). A presentation was given at the District to (Oct. 2002) share the goals and expected results with the District. A field trip on March 6, 2003 with the research team including graduate students, Post-Docs and staff from the SRWMD was used to discuss the project. Ongoing efforts of the SRWMD include a water quality study of springs in the Ichetucknee State Park which is partly located within the SFRW. These data will provide additional information about the environmental quality within the watershed.

County extension agents were contacted and informed about the study. A list of county extension agents is provided below:
Baker County - Michael S. Sweat, County Extension Director
Alachua County - William (Bill) Brown, County Extension Director
Bradford County - David Dinkins, County Extension Director
Clay County - Muriel Turner, County Extension Director
Columbia County - William Thomas, County Extension Director
Gilchrist County - Marvin Weaver County Extension Director
Union County - Jacque Breman, County Extension Director
Suwannee County - Meridith Taylor, County Extension Director

Contact to an environmental consulting company Karst Environmental (contact: Pete Butt) and Coca-Cola North America Corp. (contact: Brian McCord), which is involved in bottling water and water quality monitoring in north-central Florida, proofed mutually beneficial. We agreed to share sampling locations. At shared sampling locations Karst Environmental monitors water quality and we collect soil samples.

## Summary

We successfully completed the first phase of the project. Due to reservations of some land owners to participate in our project we had to delay our first sampling period. Our goal is to describe the spatial distribution and variability of soil nitrogen across the watershed. Such watershed-scale studies are challenged with land ownership issues. The extension component in this project is important to enable unbiased sampling and research while increasing the awareness of land owners towards environmental quality in the watershed.

## Project Planning – Second Phase

We will start soil sampling Sept. 1, 2003 and analyze soil samples for nitrate-nitrogen. Stochastic simulation will be employed for spatial modeling of nitrate-nitrogen. We will proceed with the remote sensing analysis to characterize land use in the SFRW. We will form a stakeholder group to support our extension activities.