

Mapping the Elizabeth City State University Campus Forest Types Using Multi-sensor Remote Sensing Methods

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Abstract- As climate change becomes more critical in the future, having access to accurate maps of forest types and conditions will allow climate modelers to more accurately predict the carbon sequestration capacity of forested landscapes. Remote Sensing tools make mapping of forest types and conditions possible. The Remote Sensing Team members of the Elizabeth City State University (ECSU) Undergraduate Research Experience (URE) program mapped the ECSU campus using both Landsat Enhanced Thematic Mapper (ETM+) data (acquired 6/12/99) and aerial photographic data (acquired from ncOneMap). Both remote sensing data sets were calibrated using a variety of field verification (ground truth) measurements acquired during the summer 2006 session. The final product, a land cover map of the campus, has been produced using unsupervised classification methods provided by MultiSpec data analysis and image processing software to evaluate the ETM+ data. The ETM+ data provided multispectral data at 30m spatial resolution, while the aerial photography provided panchromatic data at 2 meter resolution. The combination of the infrared and panchromatic data allowed identification and mapping of dominant land cover types, including forest types, non-forest vegetation, and categories of development (parking lots, roadways, buildings, campus landmarks, etc.), not possible using either data type separately. Mapping of the distribution of forest species assemblages (hardwoods, softwoods, and mixtures of the two) was also possible. Field data collection methods included the identification of: dominant forest species, forest canopy height, tree age, relative state -of-health, tree cores, and field spectral (VIRIS) data of selected tree species. Tree cores provided insight into changing growth patterns over the past century. The use of these ground data facilitated the production of accurate mapping of the ECSU campus not possible using other cartographic methods.

I. INTRODUCTION

The ice sheets of the earth are melting at rapid rates due to the increase in temperatures caused by the burning of fossil fuels and the cutting down of forests. Using remote

sensing, a scientist can observe the changes in forest conditions (Rock, *et al.*, 1986). Remote sensing is the process of obtaining data and images from satellites or aircraft. Climate modelers can use forest types and ground measurements to predict and determine how the carbon sequestration capacity will affect the earth's atmosphere and forest types in the future.

II. REMOTE SENSING METHODS

A. ECSU Forested Areas

To produce an unsupervised classification image with labeled classes and groups, Landsat Enhanced Thematic Mapper (ETM+) data and aerial photographic data were used. The aerial photograph of Elizabeth City State University was acquired from ncOneMap (ncOneMap Viewer, 2004).

The Elizabeth City State University campus contains six different forest areas. Fig. 1 shows the panchromatic aerial photographic view of these six forest areas.

B. Landsat ETM+, Landsat 7, and MultiSpec

The Landsat ETM+ data in false color image of Pasquotank County, acquired on June 6, 1999, was calibrated through MultiSpec software (Gagnon and Rock, 2005). MultiSpec was developed at Purdue University under National Aeronautics and Space Administration (NASA) support. MultiSpec is a down-loadable freeware software package <<http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/>>. It is used to examine the multispectral properties of Landsat TM data collected in seven bands sensed by the satellite (Rock, *et al.*, 1986).

MultiSpec allows one to detect infrared data, which cannot be seen with the human eye. Different reflectance levels for each spectral band were represented for each pixel in the image (see Figs. 2, 5, and 6). The ETM+ data used in this study provided the first five spectral bands for analysis.



Fig. 1. Aerial Photograph of the six forest areas evaluated.

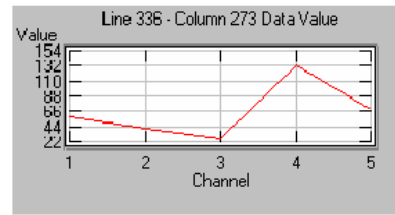


Fig. 2.

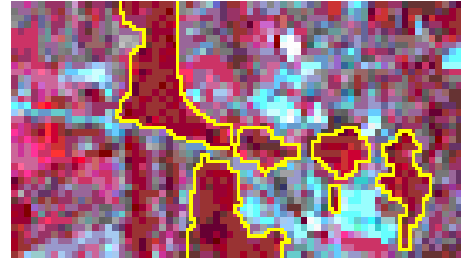


Fig. 3. Infrared Image of the ECSU Campus and surrounding area.

Using the selection graph windows in MultiSpec it was possible to distinguish the different brightness values for each of five bands for each pixel. A generic selection graph can be seen in Fig. 2. The numbers one through five refer to the blue, green, red, near-infrared, and mid-infrared wavelengths respectively. The vertical scale, ranging from zero to two hundred twenty-five, represented the relative brightness levels for each band. Bands (channels) 1 and 3 refer to the level of chlorophyll in a forested stand, while band 2 represents the level of greenness. Band 4 is a measure of the biomass and health in a forest canopy and band 5 measures canopy moisture content (Rock, *et al.*, 19896). High levels in band 4 identify deciduous trees, and low levels identify conifer trees. Latitude and longitude coordinates are shown for each pixel in the Landsat ETM+ image as are lines and columns corresponding to the pixels the image contained. The full Landsat ETM+ scene was cropped in MutiSpec (Fig. 3) and used to produce the Unsupervised Classification file. The cropped file allowed the coordinates to be displayed, as well as the lines and columns. The cropped image (Fig. 3) served as a means if interpreting the Unsupervised Classification file (Fig. 5) .

C. Aerial Photography

Aerial photographic data was used to distinguish the different features indicated in the Landsat ETM+ image. Although the aerial photograph was acquired in 2003 the six forest areas on campus were still recognizable. Coordinates of the campus forest areas were acquired using a GPS receiver (These coordinates can be found in Table 1 and the labeled map of the campus forest areas (Fig. 4). Fig 4 was used to assist in the identification of the boundaries of the six forest areas studied, as well as to recognize campus features, such as buildings, parking lots, and streets, when compared to the unsupervised classification file and the Landsat ETM+ image (Fig. 5).

Table 1. GPS Coordinates of Campus Forests

| Site Number | Latitude and Longitude | |
|-------------|------------------------|-------------|
| | Latitude | Longitude |
| 1 | 36° 17,03N | 076° 13,23W |
| 2 | 36° 16,93N | 076° 13,22W |
| 3 | 36° 16,88N | 076° 13,14W |
| 4 | 36° 16,93N | 076° 13,09W |
| 5 | 36° 17,05N | 076° 13,13W |
| 6 | 36° 16,83N | 076° 13,03W |
| 7 | 36° 16,75N | 076° 13,13W |
| 8 | 36° 16,71N | 076° 13,08W |
| 9 | 36° 16,83N | 076° 12,89W |
| 10 | 36° 16,70N | 076° 12,83W |
| 11 | 36° 16,76N | 076° 12,81W |
| 12 | 36° 16,69N | 076° 12,79W |
| 13 | 36° 16,75N | 076° 12,77W |
| 14 | 36° 16,80N | 076° 12,72W |
| 15 | 36° 16,79N | 076° 12,66W |
| 16 | 36° 16,82N | 076° 12,64W |
| 17 | 36° 16,82N | 076° 12,87W |
| 18 | 36° 16,93N | 076° 12,80W |
| 19 | 36° 16,86N | 076° 12,71W |
| 20 | 36° 16,92N | 076° 12,64W |



Fig. 4. Aerial photo of the ECSU campus with GPS coordinates of forest areas.

D. Unsupervised Classification

In order to map the different forest types, it was necessary to group pixels together to form a smaller spectral clusters of closely related classes and groups. Thus, the Unsupervised Classification file was created. In the Unsupervised Classification file (Fig. 5) the pixels with similar spectral characteristics were grouped into 10 clusters.

The Visible Infrared Intelligent Spectrometer (VIRIS), a portable field spectrometer, provided spectral information acquired for individual tree species collected each in both coniferous and deciduous trees on the ECSU campus. Figure 6a includes a Coniferous VIRIS curve and selection graph for a conifer stand retrieved from MutliSpec. Figure 6b. includes a Deciduous VIRIS curve and selection graph. In identifying areas in the Unsupervised Classification, the Remote Sensing Team was able to visit these areas for ground verification studies and accuracy assessments. Ground measurements were collected to accurately assess the forest types and the level of health of the trees. The lines and columns of the Unsupervised Classification provided their approximate locations. Also, there was no Latitude and Longitude option to compare the Unsupervised image to the Latitude and Longitude labeled map of the campus forest areas.

III. GROUND MEASUREMENT METHODS

A. Creating the Pixel

To have a better understanding of what *Landsat 7* images tell us regarding the make up of an area, it is necessary to go to the location in question and take ground measurements. The ground measurements that were taken included creating a 30 meter by 30 meter pixel on the ground and 1/10th acre circular plot, finding the canopy composition and closure, ground cover, determining the diameter breast height (DBH) of trees, taking tree cores and collecting foliage samples for further study.

A 30 meter by 30 meter pixel was used because the images produced by *Landsat 7* had pixels that are acquired in 30 meter squares. 30 meter pixels were started by selecting a point that was within the area for which lat/lon coordinates were determined using GPS. The first spot selected was in the Outdoor Classroom on the campus of Elizabeth City State University. 30 meters was measured out and both ends were marked. From point number two, another 30 meters was measured out and the end was marked as the third point. From point number three, 30 meters was measured out again parallel to line points one and two and the end was marked as the fourth and final point. Then point four was connected to point one to close the 30 meter by 30 meter pixel. There were four distinct corners in the shape of a square formed from these points when the team was done. The lines created from the points were straight and the corners formed four ninety-degree angles confirming a perfect pixel. This methodology is described in more detail in the Forest Watch Website <www.forestwatch.sr.unh.edu>

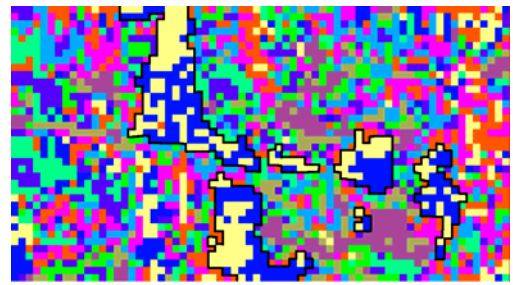


Fig. 5. Unsupervised Classification image of the ECSU Campus and surrounding area.

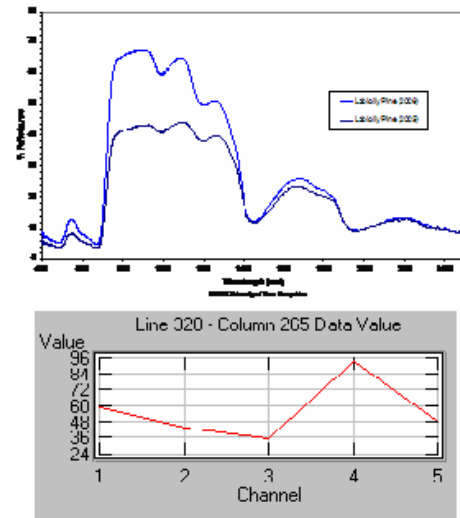


Fig 6a. Coniferous VIRIS Curve Chart and New Selection Graph

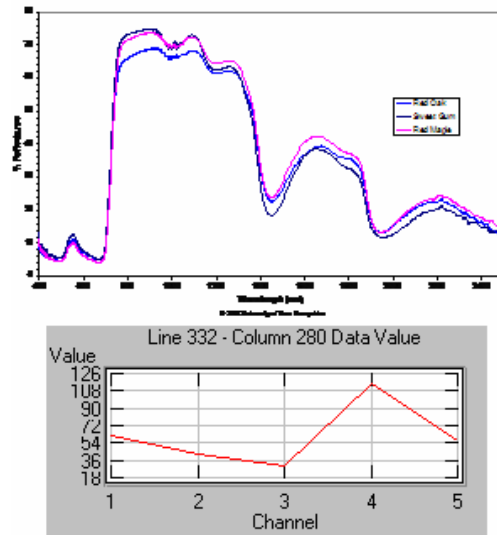


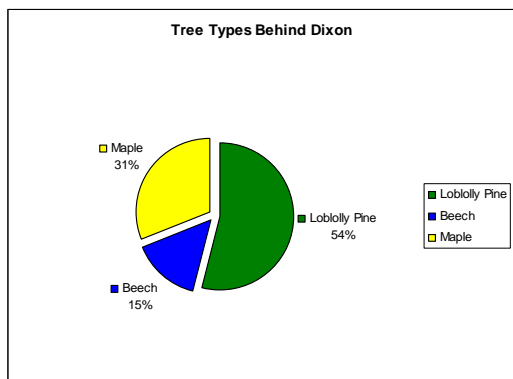
Fig. 6b. Deciduous VIRIS Curve Chart and New Selection Graph

The canopy closure and ground cover was taken across the diagonals of each pixel. The center point where the two diagonal lines intersected was where the Global Positioning System (GPS) measurements were taken. The GPS measurement of the center point of the pixel in the Outdoor Classroom was 36° 16.88N, 076° 12.82W. The 1/10th acre circular plot was then established around the pixel center point.

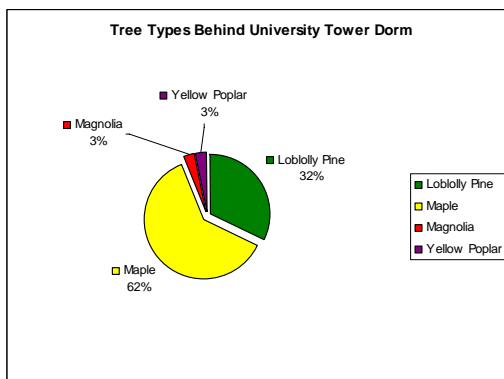
IV. FINDINGS

A. Extrapolating Circular Plot Data with MultiSpec

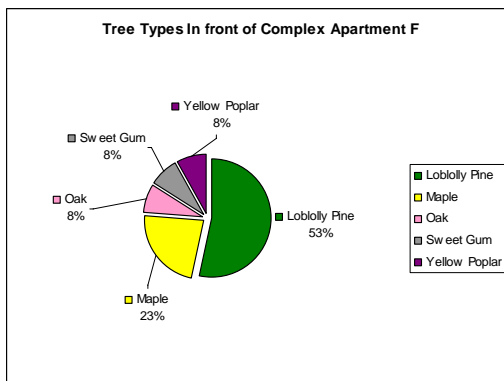
For the 1/10th acre circle, at the center point of the pixel, 11.3 meters was measured out creating the radius of the circle. At that point, the markers were placed every two to four meters to form the actual circle. Within the circle formed, all the trees were counted, their height measured, diameters determined, and tree cores collected from the largest trees. An example of how the pixel looked is shown in Fig. 7. The circular plots within each forest area were evaluated before the completion of the ECSU campus map of forest types. Each forested area was assessed at a specific location for species composition, and the coordinates of each circular plot were gathered. Through *MultiSpec*, the original Landsat ETM+ image provided the 5 band selection graphs for each pixel and was used to compare with tree types identified within the six forest areas determined by each circular plot.(see Pie Charts). The location of each forest area, lat/lon coordinates, and circular plot attributes are features provided for each selection graph (Fig 7). The first graph provides reflectance levels for the Landsat pixel while the second graph provides reflectance levels for all pixels representing the entire forest area. For each forested area, a pie chart was created to represent the percentage of each tree species within the area. In the forested area behind Dixon (pie chart 1), 15% were Beech trees, 31% were Maple trees, and 54% were Loblolly Pine trees. Behind the University Tower Dorm (pie chart 2), the forested area consisted of 3% Magnolia, 3% Yellow Poplar, 32% Loblolly Pine, and 62% Maple trees. The forested area in front of Complex Apartment F (pie chart 3) included 8% Yellow Poplar, 8% Sweet Gum, 8% Oak, 23% Maple, and 53% Loblolly Pine trees. In the Stream Forest Area (pie chart 4), 13% were Beech, 13% Cypress, 31% Maple, and 43% Oak trees. Behind the football field (pie chart 5), 6% were Loblolly Pine, 7% Sweet Gum, 7% Beech, 17% Fern, 62% Maple trees.



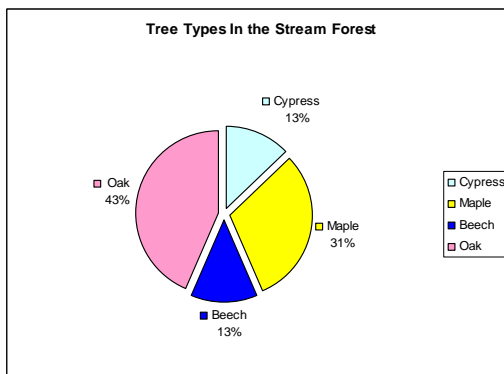
Pie Chart 1: Tree Types Behind Dixon



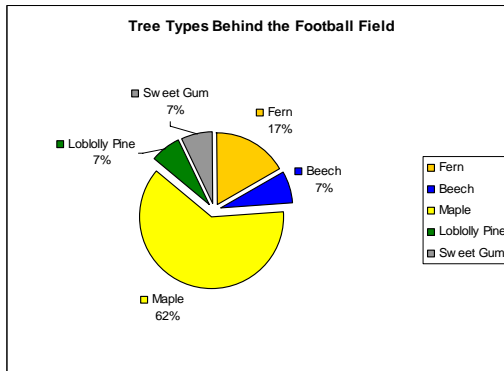
Pie Chart 2: Tree Types Behind University Tower Dorm



Pie Chart 3: Tree Types In Front of Complex Apartment F



Pie Chart 4: Tree Types In the Stream Forest

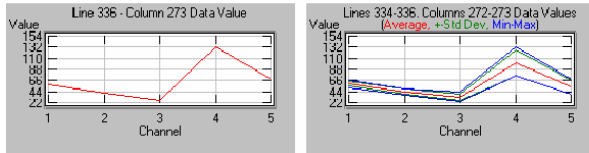


Pie Chart 5: Tree Types Behind the Football Field

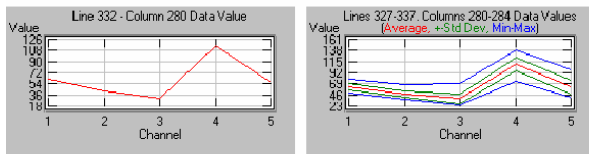
B. Canopy and Ground Cover

Within a pixel, *Landsat 7* picked up varying levels of chlorophyll, but sometimes the chlorophyll levels detected were produced from grass and not the canopy cover. The Remote Sensing Team used field methods described in Rock and Lauten, 1996 (determination of canopy closure, ground cover amount and type, etc.). Tree species types were identified using a simple dichotomous key (Rock, 1996) and tree cores were collected and processed following methods described by Spencer and Rock (1998).

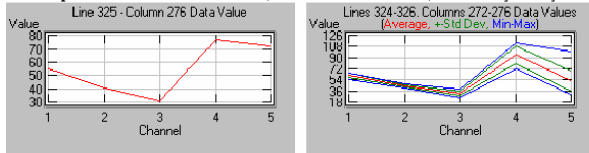
Location: Behind Dixon Hall
 Coordinates: 36° 07' 16.70" N 36° 07' 12.81" W
 Circular plot attributes: High level of water, dominance of deciduous trees, good health



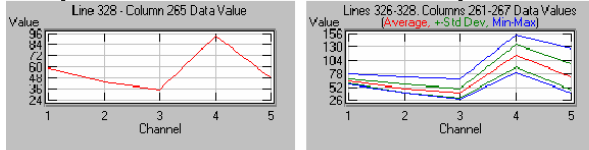
Location: Behind University Tower- Residence Hall
 Coordinates: 36° 07' 16.80" N 36° 07' 12.63" W
 Circular plot attributes: High level of water, dominance of deciduous trees, good health



Location: In Front of Student Apartment Complex/ Southern part of Outdoor Classroom
 Coordinates: 36° 07' 16.87" N 36° 07' 12.74" W
 Circular plot attributes: Low level of water, dominance of conifer trees, not relatively healthy



Location: Stream Forest (forest area in between outdoor classroom and football field)
 Coordinates: 36° 07' 16.83" N 36° 07' 12.89" W
 Circular plot attributes: Good amount of water, dominance of conifer trees, good level of health



Location: Near Football Field
 Coordinates: 36° 07' 16.96" N 36° 07' 13.25" W
 Circular plot attributes: High level of water, dominance of deciduous trees, good level of health

Fig. 7. Reflectance Levels for Each Plot and Forest Area

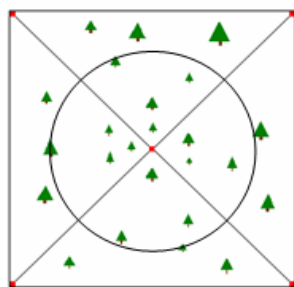


Fig. 8. Diagram of the 30 meter by 30 meter Pixel and 1/10th acre circular plot

It was indicated in the Outdoor Classroom pixel, on the diagonal line going from point one to point three that tree leaves made up most of the canopy cover. The ground cover for the same diagonal had an equivalent number of regions with grass covering as regions with dirt. The diagonal going from point two to point four also had a canopy covering consisting mostly of tree leaves. The ground cover of this diagonal, however, only had one region with grass covering.

H. Tree Coring and Measurement

A large tree inside of the 1/10th acre circular plot was chosen and starting from the base of the tree, measured upward 1.35 m, the diameter breast height (DBH). The diameter of the tree was measured with Diameter tape. The team measured the eye height of the person who looked through a clinometer to determine the height of the tree. Using the clinometer, the team member located the top of the tree and determined the angle to the top of the tree. The angle was converted to its equivalent tangent and multiplied by the distance from the tree, which gave the baseline measurement. The height of the tree was found by adding the baseline times the tangent angle, and then adding the eye height. In the 1/10th acre circular plot of the first pixel, there were two loblolly pines, a cypress, red oak, sweet gum, red maple, and tulip tree.

The first loblolly pine had an angle measurement of 61°, equivalent to a tangent of 1.80. The DBH recorded was 63.5cm, the baseline was 70 feet, and the eye height was 5.45 feet. Using this information, the team concluded that the first loblolly pine was 131.45 feet high. The second loblolly pine had a DBH of 57.6cm, and a height of 123.31 feet. A tulip tree had a DBH of 78cm, and a height of 78.8 feet. From this data, the team was able to determine that these two loblolly pines were the tallest trees in the pixel.

The health of the trees within the pixel was determined by taking tree core samples. The corer was assembled and a spot on the tree without deformations was found. To determine how far the tree needed to be cored to reach the pith the extractor was held next to the tree. The team began to turn the corer clockwise, applying pressure to the corer to get it started and continued until the center of the tree was reached. If the corer did not seem to be progressively moving into the tree, there was the possibility that the tree was rotten, which was the case for the team's first core extracted. Coring stopped once the center was reached, and the core was extracted. The team slowly withdrew the extractor and wood core, and placed the wood core sample into a soda straw, taped the ends, and labeled it, noting which end of the core is the bark end. When the team took the first core from a yellow poplar tree, it was found that the tree was rotten. The outer bark gave the impression that the tree was healthy, but the core sample proved otherwise. From the cores, the group found that one loblolly pine was 102 years old, and the other loblolly pine was 57 years old. The age of the yellow poplar could not be determined.

I. Carbon Sequestration

All of the other trees within the pixel were healthy according to the tree core samples extracted. The tree core of the first loblolly pine indicated that it generally had a consistent amount of growth throughout its 102 year life. Only the rings closest to the outer bark were clustered, indicating that the rate of growth for the tree had slowed down in the past few years. The tree core of the second loblolly pine showed that it also had a consistent amount of growth during its earliest years, and ring clustering during its latter years. Tree rings located near the pith were wider and contained more wood than the older or outer rings. The rings of a tree also indicate how much wood the tree produced in a year. The amount of wood produced is based on the amount of carbon dioxide the tree intakes within a certain period of time. All tree core samples demonstrated a high amount of carbon sequestration in the inner rings near the pith, but that within the past 20 years the amount of carbon being stored has decreased. The Team learned a great deal about tree structure and function with this part of the study. Background materials were provided via diagrams (Rock, 2005). Similar results were also described for trees in the Czech Republic (Stutz, 2005).

V. CONCLUSIONS

The Elizabeth City State University (ECSU) Campus Map of Forest Types was successfully produced using unsupervised classification methods provided by *MultiSpec* data analysis, Landsat Enhanced Thematic Mapper (ETM+) data (acquired 6/12/99) and aerial photographic data (acquired from *ncOneMap*). *MultiSpec* has capabilities to classify reflectance levels at 30 meter resolution, allowing the Remote Sensing team to identify three forest types: hardwoods (maple, oak, sweet gum, etc.), softwoods (loblolly pine and cypress), and mixed forest stands of both hardwoods and softwoods (called mixels). The mixels had a wide range of species variability and several reflectance levels, based on the selection graph plots. Because the Landsat image had only 30 meter resolution, the objects displayed in the unsupervised classification image are impossible to distinguish from other objects in the same pixel. For this reason, the 2 meter spatial resolution of the aerial photograph proved very useful in identifying features that can be seen on the ground. Smaller objects within a particular ETM+ pixel will cause the reflectance level to vary based on the areal percentage the pixel contains. Large areas, such as the forest areas, allow *MultiSpec* to reliably distinguish forest types and/or similar reflectance levels. The labeled coordinates on the false color IR image (Fig. 9b) correspond to the same numbers on the Unsupervised Classification image (Fig. 9a) and were used for verification of the forest parameters. Field verifications derived during the course of the project were collaborated and used to verify that there were indeed the three forest types classified by *MultiSpec*. The deciduous trees can be identified by blue pixels and the conifer trees by yellow pixels. Once the selection graph is derived for sparse populations of deciduous and non-deciduous trees, the range on the vertical axis is much less than in a more monolithic area of a large percentage of trees. These sparse or low density areas can be identified by

pink and orange pixels in the Unsupervised Classification. Pie Charts of the different tree species through out all six forest areas on campus are provided on the produced ECSU Campus map of Forest Types. (The final Unsupervised Classification Image with pixel break down can be found in Fig. 10 and the Final Campus Map with forest area and tree type breakdown can be viewed in Fig. 11).

VI. ACKNOWLEDGMENTS

We would like to thank Dr. Linda B. Hayden for allowing us this opportunity to participate in the Undergraduate Research Experience in Ocean and Marine Science 2006 program with the Remote Sensing team. It is an honor for us to be able to partake in such a distinguished program to gain more experience in research. We thank Mrs. Keisha Wilkins for educating us on the many uses of *ArcGIS*, and how to use the global positioning systems (GPS) which played a vital role in enabling us to complete our project. We appreciate Mr. Jeff Wood for teaching us how to make our web pages by using *DreamWeaver* and *FireWorks*. We acknowledge Ms. Eunice Smith and Ms. Karitsa Williams for keeping the labs open for us and lending a helping hand. We are thankful for Mr. Joal Hathaway for taking excellent pictures of our team's hard work and for the boat rides. We would also like to thank Mr. Lee Hayden for taking us to the Elizabeth City Waterfront when it was time for us to go boating. We are very grateful for our wonderful mentor, Dr. William Marquitz, for spending many hours assisting us with our project. Last, but certainly not least, we would like to give a special thanks to Dr. Barrett Rock from traveling down from New Hampshire to be a part of the remote sensing team. To everyone who helped but we did not name, we thank you for your time and energy that contributed to making the project of the Remote Sensing team a success.

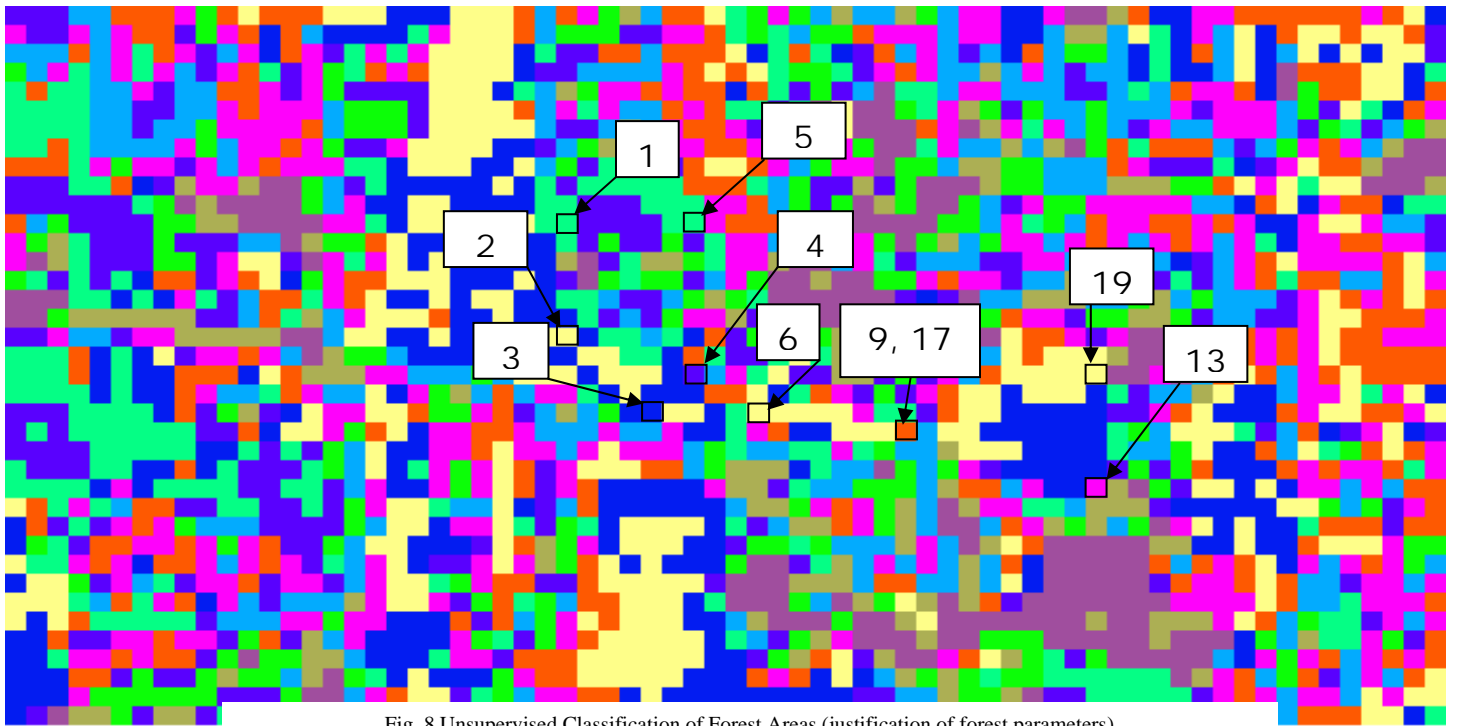


Fig. 8 Unsupervised Classification of Forest Areas (justification of forest parameters)

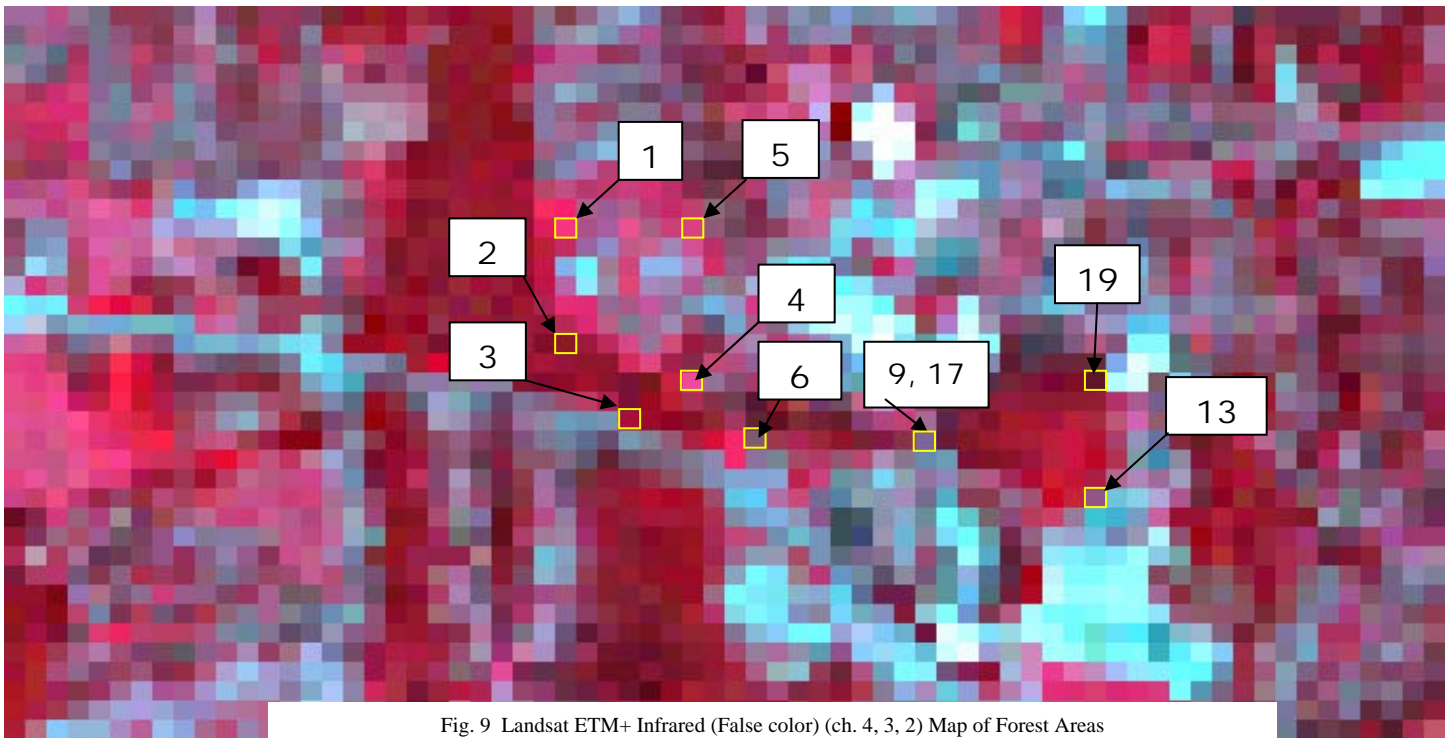


Fig. 9 Landsat ETM+ Infrared (False color) (ch. 4, 3, 2) Map of Forest Areas

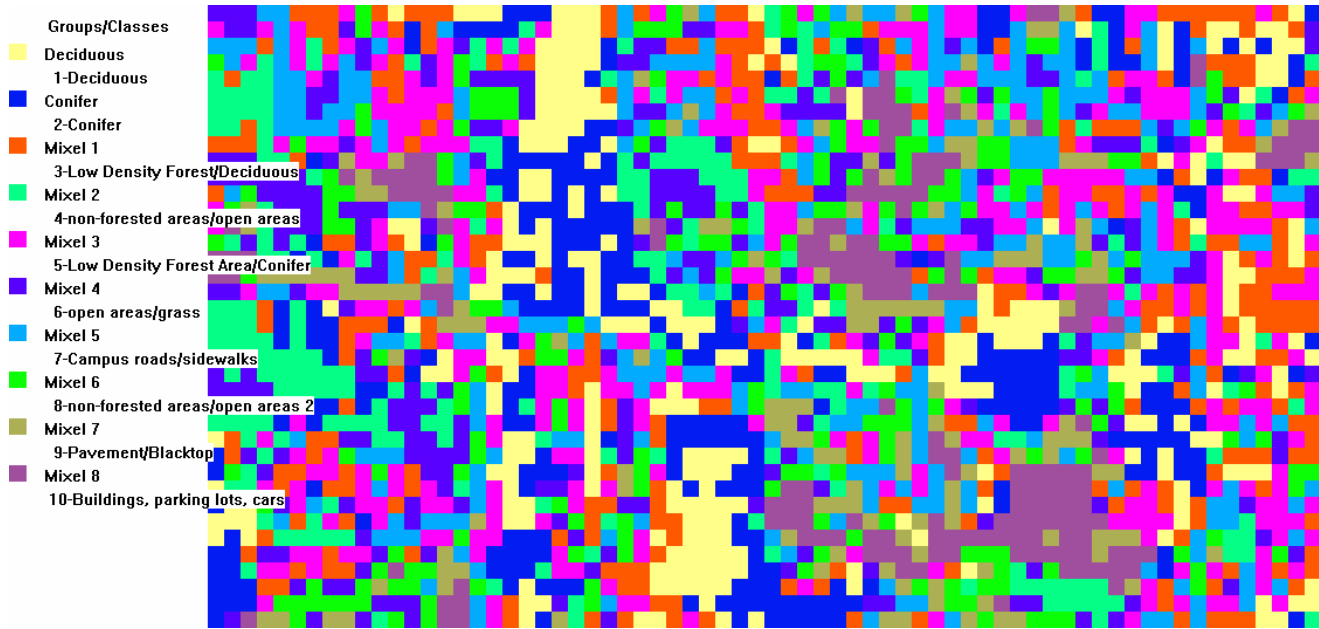


Fig. 10 Final Unsupervised Classifications

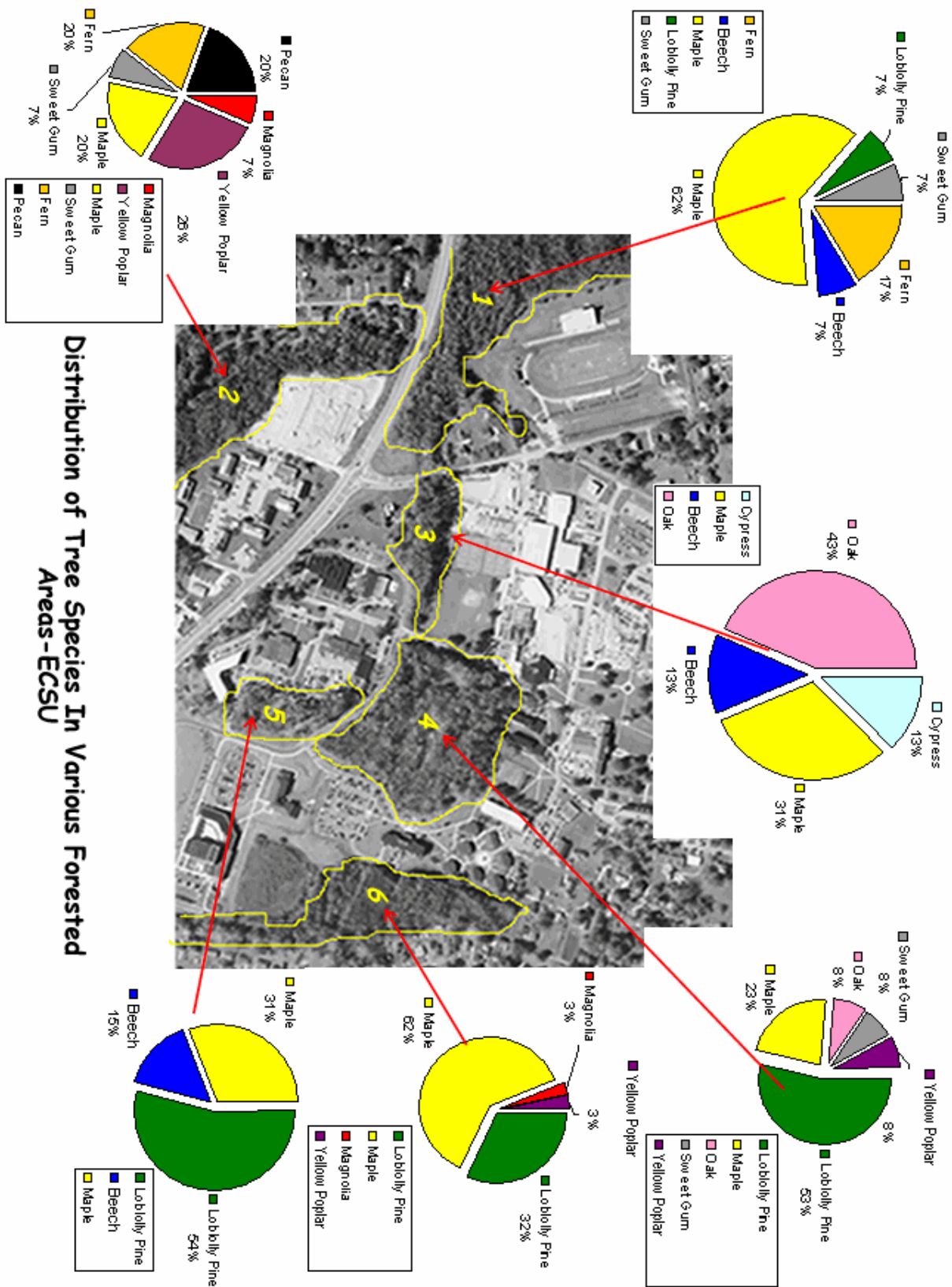


Fig. 11 Final Campus Map

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