

# **WALL-TO-WALL LANDSAT TM CLASSIFICATIONS FOR GEORGIA IN SUPPORT OF SAFIS USING FIA FIELD PLOTS FOR TRAINING AND VERIFICATION**

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## **ABSTRACT**

Wall-to-wall Landsat TM classification efforts in Georgia require field validation. Validation using FIA data was testing by developing a new crown modeling procedure. A methodology is under development at the Southern Research Station to model crown diameter using Forest Health monitoring data. These models are used to simulate the proportion of tree crowns that reflect light on a FIA subplot basis. The subplot crown proportions are averaged and compared to Landsat TM classifications for verification purposes. Resolution differences between field data and Landsat TM data make comparisons challenging. Positive correlations between the two types of data were recorded for 4 of the 5 FIA plots tested. Differences on the 5<sup>th</sup> plot may be attributed to mis-registration of the two data sources or mis-classification of the TM imagery.

## **BACKGROUND**

The 1974 Forest and Rangeland Renewable Resources Planning Act (RPA) requires the United States Department of Agriculture Forest Service (USDA-FS) to provide Congress with statistics on current forest land and rangeland conditions. The Southern Research Station, Forest Inventory and Analysis Program (SRS-FIA) has the RPA mandate to conduct forest inventories for all southern states from Virginia to Texas. Except for sparsely forested regions in west Texas and west Oklahoma, forested land in the South has been field inventoried over several cycles in recent history. A systematic grid of permanent re-measurement plots is employed by SRS-FIA to help meet these inventory requirements. Sample statistics for numerous variables are derived from these plot measurements and provide the basis for estimating forest/non-forest conditions at the county, unit, and state level. A key component necessary for expanding plot estimates to county, unit, and state levels, is an accurate estimate of forest and non-forest area by county. Currently, dot grids are used with National Aerial Photography Program (NAPP) photos to calculate the proportion of forested land. This proportion is multiplied by the estimate of total land area from Bureau of Census records to yield an estimate of the land area in forest and in non-forest condition. This is considered a Phase I estimate of forest area. Field plot results and results from assessments of "intensification" plots yields correction factors used to improve Phase I estimates of forest area.

FIA is interested in reducing the frequency of NAPP photo acquisition, or eliminating them entirely. It has been suggested that replacing NAPP photography with pixel based approach using Landsat Thematic Mapper (TM) data could achieve similar precision and provide state cooperators with land cover maps resulting from the TM analysis. FIA plots may provide a critical link between TM data and actual ground conditions. Information derived from FIA plots

is more detailed and specific than information that can be derived from TM data. This study examines the TM plot data from the perspective of verification of TM data classifications.

## METHODOLOGY

Field inventories in support of the Southern Annual Forest Inventory System (SAFIS) are currently underway in Georgia. FIA plot information in Georgia is geographically referenced to 'real-world' coordinates using hand-held Global Positioning System (GPS) receivers. This information can be used to locate field plots on the TM imagery. A county map of Georgia is shown in Figure 1. Brantley County was chosen as the study site for development of this methodology.

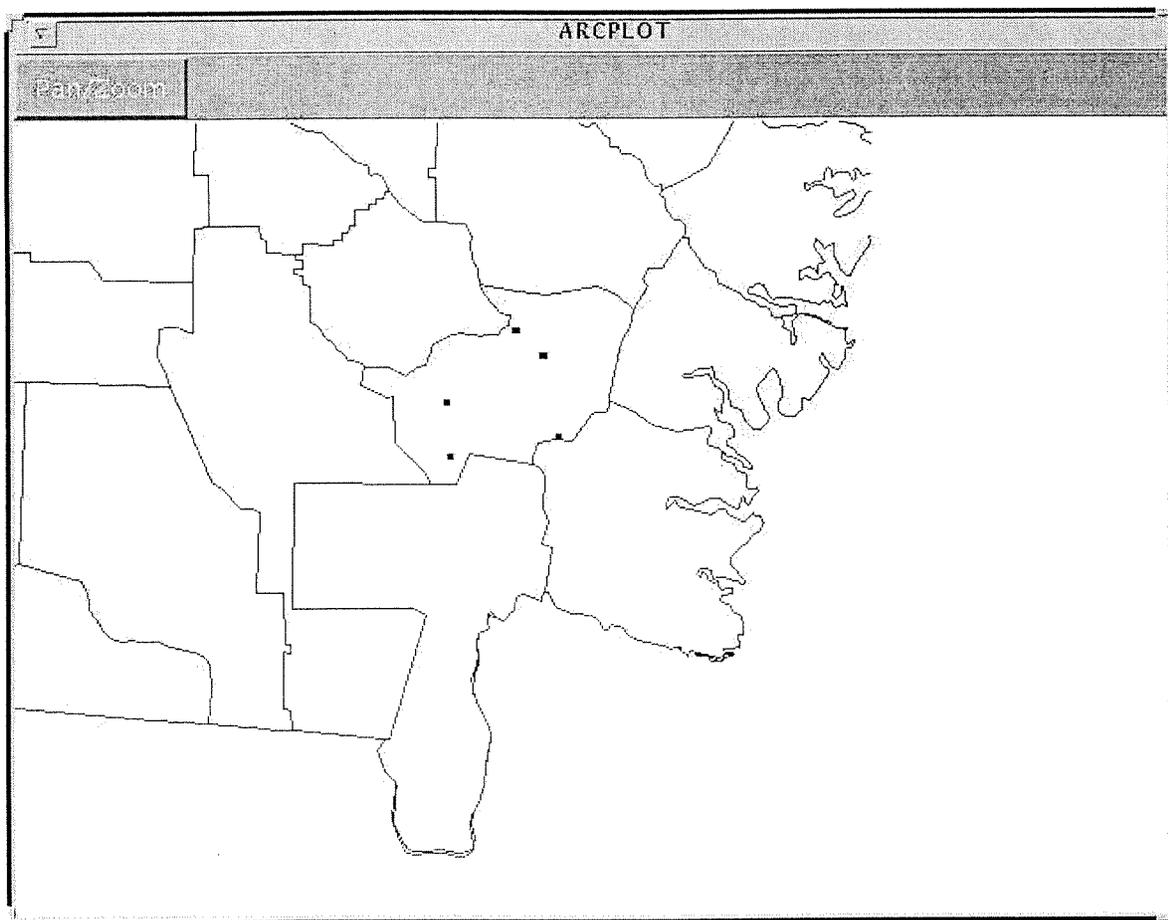


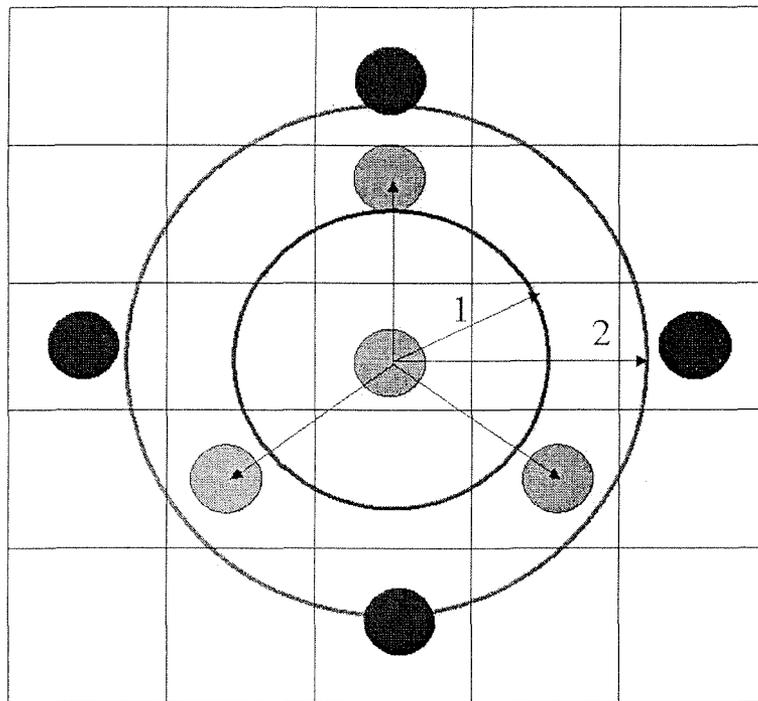
Figure 1. Plots in study site, Brantley county, Georgia.

Two critical questions arise when FIA plots are considered for remote sensing purposes:

1. How accurately can the FIA plots be located on the ground and on the TM imagery?  
This is a co-registration problem.
2. Which characteristics of the FIA plot data are useful for remote sensing purposes?  
This is a crown modeling problem.

## Co-registration

Question one requires an examination of two sources of registration error, the imagery and the GPS reading on the plot. Problems with accurate co-registration of plots and satellite data result from locational errors of the satellite imagery during rectification procedures and errors of the GPS coordinate reading. The cumulative effect of these error sources is illustrated in Figure 2. FIA subplot 1 (plot center) could be as much as two pixels away from its real-world location if sources of error are cumulative.



1 = pixel misregistration  
2 = maximum GPS misregistration

Figure 2. Sources of locational error.

## Crown modeling

Question two presents a challenging problem. The pixel resolution (28.5m) of TM data restricts the level of detail of plot information that is useful. Within forested stands, dominant, co-dominant and intermediate trees are most likely to be imaged by

the satellite sensor. More detailed information collected during field sampling (dbh, height, etc) is less useful. Holmgren and Thuresson 1998, point out that satellite images seldom contain enough information to support the decision process in applied forestry.

To address these problems, a methodology was developed to utilize the information contained in the individual tree data from FIA field plots that facilitate comparison with estimates of forest area with a 25-pixel TM window, a window area large enough to allow for some of the uncertainty of mis-registration.

Avery (1975) documents a strong linear relationship between DBH and crown diameter for *Pinus radiata* based on 304 measurements of trees in New Zealand. This concept was originally designed to predict diameter of trees whose crowns could be measured on aerial photographs. For this study, relationships were developed between measured crown diameter and DBH that would enable prediction of crown diameter from DBH.

Distance and azimuth from each subplot center to each tallied tree is recorded in the field. This information was used in a GIS system to provide a geographic reference point for a mechanical reconstruction of the tree crowns on each subplot.

### **Data preparation**

Raw (unedited) plot data from Georgia was reformatted from ASCII files to a relational database format. Individual tree data were queried for these attributes:

1. Crown class (dominant, co-dominant, intermediate)
2. Species (pine, hardwood)
3. Non-mapped forested plots (edge conditions)
4. No evidence of disturbance
5. Live trees with  $DBH \geq 5''$

Other data preparation included:

1. Assigning pine/hardwood species codes
2. Computation of each tree location referenced to UTM coordinates on each subplot based on distance and azimuth
3. Modeling crown diameter from diameter using FHM data to derive regression coefficients.

Forest Health Monitoring data was downloaded from the St. Paul field office site of the Forest Resources Management and Forest Health Protection web site (<http://willow.ncfes.umn.edu/>). These data were the basis for simple linear regressions enabling prediction of crown diameters from DBH. 350 observations each were used for modeling pine crown diameter and hardwood crown diameter. R-square values were .82 and .63 for pine and hardwood prediction models respectively.

Pine Model:  $dbh * .531225 + 0.0094$

Hardwood Model:  $dbh * .245801 + 2.4555$

Crowns were drawn at the real-world location of each tallied live tree with  $DBH \geq 5''$ . When a tree crown extruded beyond a subplot radius, that crown perimeter was terminated at the plot radius. Conversely, crowns of trees that intruded on the subplot radius are non-tallied trees. The

assumption is made that truncation of extrusive crowns and non-tally of intrusive crowns represents a compensating error situation. Crown overlap is ignored from a reflectance perspective and GIS union operations are performed on overlapping crowns (Figure 3). This ensures that calculation of crown area per plot is a value between 0 and 1. Crown proportion estimates for each subplot were averaged for the 4 subplots to yield crown proportion indices. Resolution differences between the Landsat data and the field data make comparisons difficult.

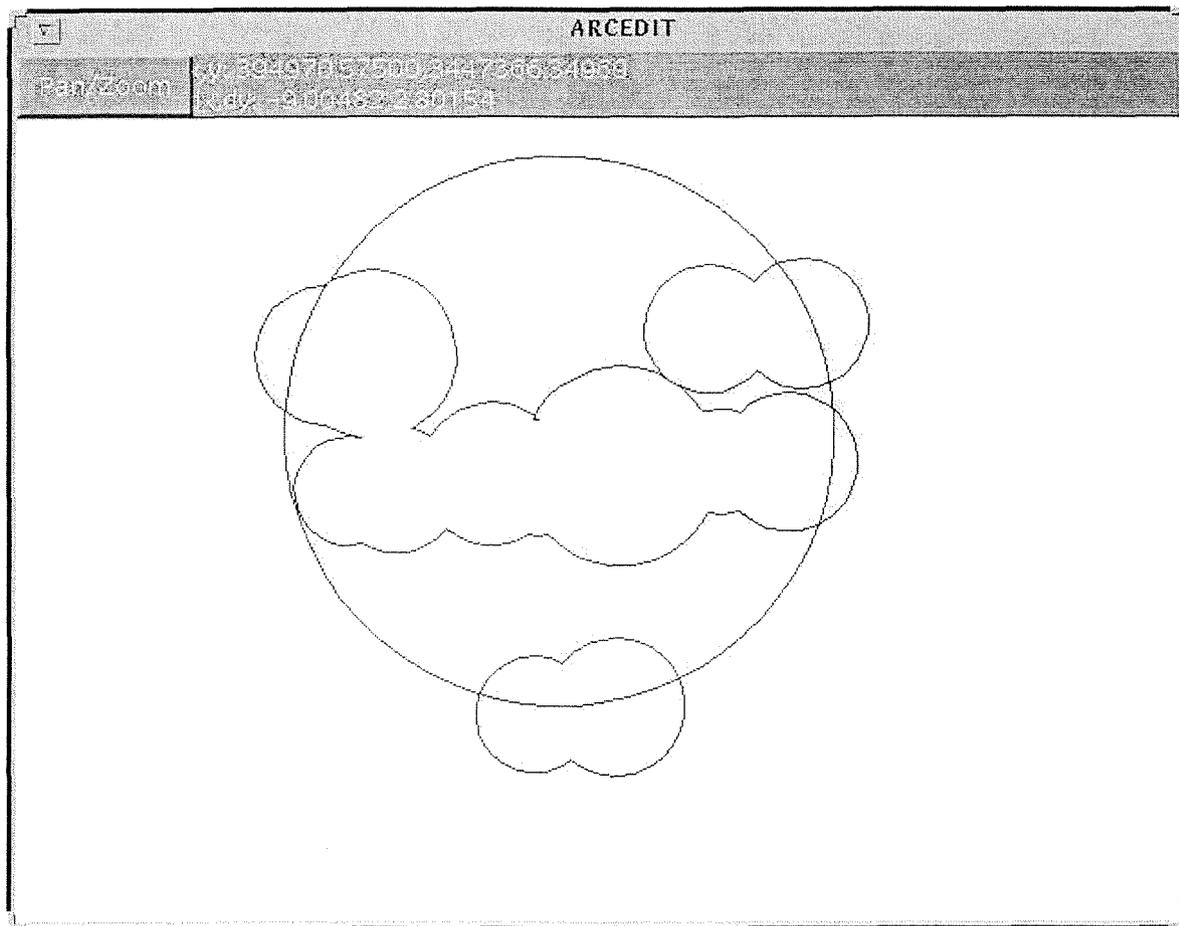


Figure 3. GIS union operation to merge crowns prior to calculating crown proportion.

Figure 4 illustrates the unique problem of comparing field data to image data. To facilitate comparisons, plot index values were compared to 5x5 pixel windows on classified Landsat data acquired on 12-17-96.

Proportions were calculated for the 5x5-pixel window that was most closely centered on the field plot. Table 1 illustrates these comparisons.

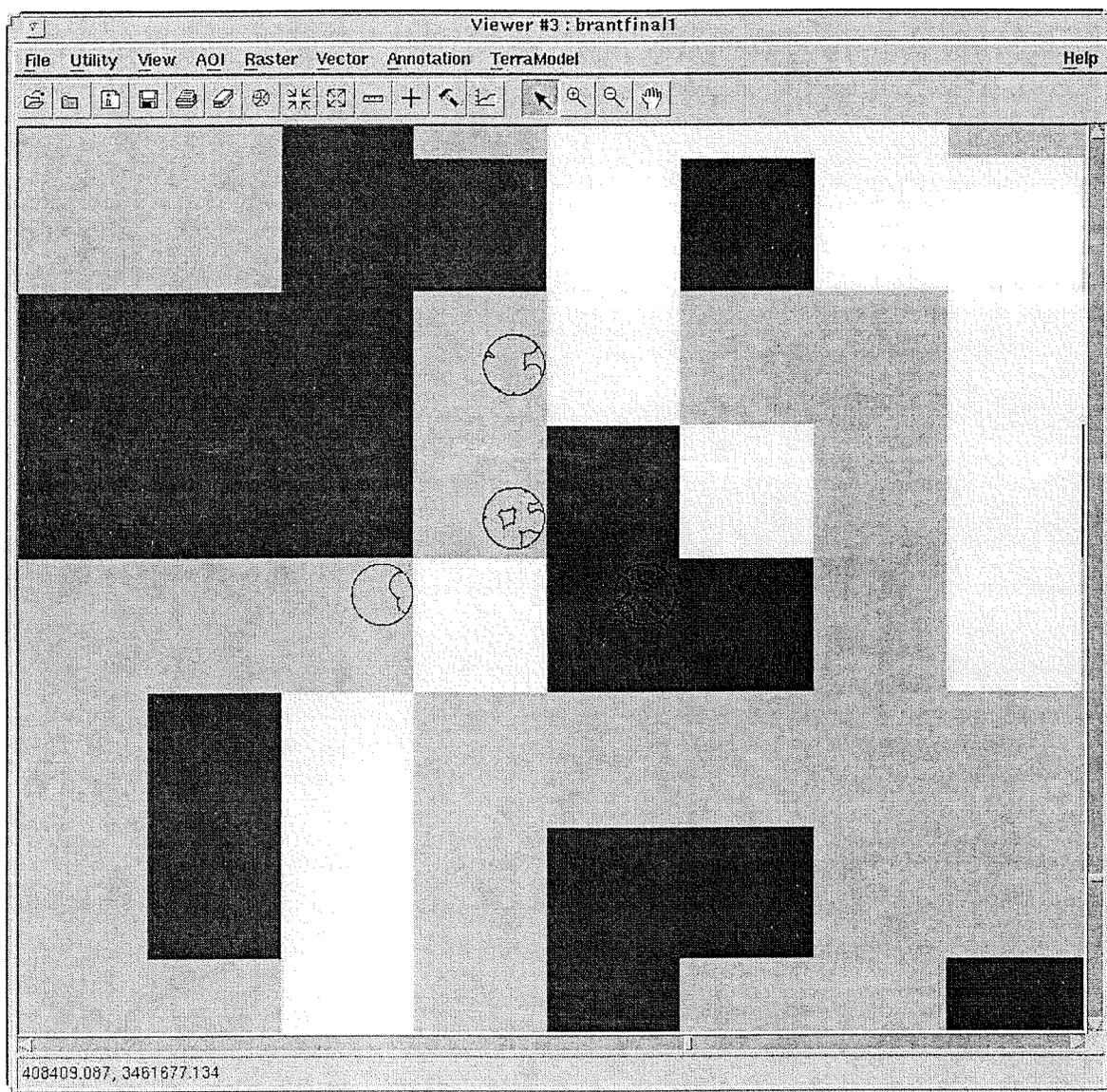


Figure 4. Resolution differences between field plots and Landsat TM imagery.

## DISCUSSION

Plot and TM comparisons are referenced in Table 1 and Table 2. Complete breakdowns of crown proportion by subplot are referenced in Table 3.

Table 1. Comparison of TM classification with FIA plot data.

	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
	TM	FIA								
%Pine	68	100	35	0	80	100	100	100	42	100
%Hardwood	32	0	65	100	20	0	0	0	58	0
%Crown (FIA)		54		49		71		41		65

Table 2. Count of trees with DBH < 5".

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Pine	3	0	1	2	0
Hardwood	0	14	0	1	12

Table 3. Breakdown of crown proportion by subplot.

	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
	CA	CP								
Sub-plot 1	81.78	.4865	120.24	.7152	99.10	.5894	73.19	.4353	137.89	.8202
Sub-plot 2	84.49	.5026	30.26	.1800	122.03	.7259	71.59	.4258	147.92	.8799
Sub-plot 3	95.49	.5680	50.39	.2997	121.29	.7215	84.64	.5035	111.34	.6623
Sub-plot 4	104.25	.6201	127.11	.7561	134.33	.7990	48.15	.2864	35.88	.2134
Mean CP/plot	.5443		.4877		.7089		.4127		.6439	

CA = Crown Area per subplot in square meters

CP = Crown Proportion per subplot calculated by CA/Plot Area (168.11 m<sup>2</sup>)

### Plot 1

FIA data indicated 100 % of all trees ≥ 5" DBH were pines. Classified TM data from the 25-pixel window resulted in 68% pine and 32% hardwood. The mean crown proportion for this plot was .5433. Table 2 results indicate a fairly even distribution of crowns over the four subplots.

### Plot 2

FIA data indicated 100% of all trees ≥ 5" DBH were hardwoods. Classified TM data from the 25-pixel window resulted in 35% pine and 65% hardwood. The mean crown proportion for this plot was .4877. Table 2 results show an uneven distribution of crowns over the four subplots. Subplots 1 and 4 are have more than 70% crown saturation and subplots 2 and 3 have less than 30% crown saturation. Table 2 indicates 14 hardwoods <5" DBH. This indicates possible hardwood reflectance from un-tallied trees on this plot.

### **Plot 3**

FIA data indicated 100% of all trees  $\geq 5$ " DBH were pines. Classified TM data from the 25-pixel window resulted in 80% Pine and 20% hardwood. The mean crown proportion for this plot was .7089. Subplots 2,3, and 4 have more than 70% crown saturation and subplot 1 has more than 60% crown saturation. This plot is relatively homogeneous and the TM results are in agreement with a homogeneous land cover situation.

### **Plot 4**

FIA data indicated 100% of all trees  $\geq 5$ " DBH were pines. Classified TM data from the 25-pixel window resulted in 100% Pine and 0% hardwood. The mean crown proportion for this plot was .4127. Distribution of crown saturation across the subplots is fairly consistent except for subplot 4, which has less than 30% crown saturation. Table 2 indicates that there are only 2 pines and 1 hardwood with un-modeled crowns on this plot. Since crown saturation is low, it would be interesting to know what features of the landscape are causing pure pine classification results.

### **Plot 5**

FIA data indicated 100% of all trees  $\geq 5$ " DBH were pines. Classified TM data from the 25-pixel window resulted in 42% Pine and 58% hardwood. The mean crown proportion for this plot was .6439. Subplots 1 and 2 had more than 80% crown saturation. Subplot 3 had more than 60% crown saturation and subplot 4 had roughly 20% crown saturation. Two possible reasons for the non-agreement between FIA and TM results are pixel/plot mis-registration or incorrect classification results. Examination of the classified imagery reveals that a one-pixel shift to the northwest would result in 60% pine and 40% hardwood. High pine crown proportions in subplots 1 and 2 further strengthen the argument for mis-registration. The argument for incorrect classification results is strengthened by results shown in Table 2. There are 12 hardwood trees  $< 5$ " DBH which were not modeled for canopy proportion estimates. The location and diameter of these stems/crowns should have been modeled. If the majority of these trees are growing beneath the overstory, mis-registration is likely. If the majority of these trees are growing in dominant canopy positions, mis-classification is likely.

## **CONCLUSIONS and RECOMMENDATIONS**

Resolution differences between the FIA field data and the TM data present great challenges. This study shows clearly that we are attempting to 'compare apples and oranges'. On the basis of this very limited study, there appears to be good correlation between the results of the modeled canopies and the TM classification. Mis-registration and mis-classification errors are difficult to quantify. Excluding stems  $< 5$ " DBH from the crown modeling process was a mistake. In future modeling efforts, if tallied stems  $< 5$ " DBH are overtopped they will not be modeled on the basis of the canopy position constraint. If stems  $< 5$ " DBH are in a dominant, co-dominant, or intermediate crown position they will be modeled. This methodological change should provide

useful information on plot surface reflectance. Resolution problems could be bridged between the two data sources by using LIDAR data or large-scale aerial photography.

This is a preliminary study primarily designed to test the usefulness of FIA plot data for verifying Landsat TM classifications. Now that methodologies are established and automated, numerous plots will be tested.

Finally, new canopy prediction models are being tested that include species, age, density, crown class, landscape position, and other variables as possible predictors of crown size. These models should improve the quantification of crown proportion estimates by subplot.

#### LITERATURE CITED

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