

LANDSAT TM CLASSIFICATIONS FOR SAFIS USING FIA FIELD PLOTS¹

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Abstract—Wall-to-wall Landsat Thematic Mapper (TM) classification efforts in Georgia require field validation. We developed a new crown modeling procedure based on Forest Health Monitoring (FHM) data to test Forest Inventory and Analysis (FIA) data. These models simulate the proportion of tree crowns that reflect light on a FIA subplot basis. We averaged subplot crown proportions and compared them to Landsat TM classifications for validation. Resolution differences between field data and Landsat TM data make comparisons challenging. We recorded positive correlations between the two types of data for four of the five FIA plots tested. We attribute differences on the fifth plot to misregistration of the two data sources or misclassification 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) conducts 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 several cycles of field inventories in recent history. SRS-FIA employs a systematic grid of permanent remeasurement plots to help meet these inventory requirements. From these plot measurements sample statistics for numerous variables provide the basis for estimating forest/nonforest conditions. Necessary for expanding plot estimates to county, unit, and State levels is an accurate estimate of forest and nonforest area by county. Currently, we use dot grids with National Aerial Photography Program (NAPP) photos to calculate the proportion of forested land. Multiplying this proportion by the estimate of total land area from Bureau of Census records yields an estimate of the land area in forest and in nonforest condition. Correction factors derived from field plots and from assessments of “intensification” plots improves Phase I estimates of forest area.

FIA wants to reduce the frequency of NAPP photo acquisition or eliminate them entirely. Replacing NAPP photography with the pixel-based approach of Landsat Thematic Mapper (TM) data could achieve similar precision and provide State cooperators with land cover maps. FIA plots may provide a critical link between TM data and actual ground conditions. FIA plots yield more detailed and specific information than can be derived from TM data. This study verifies TM data classifications.

METHODOLOGY

Field inventories in support of the Southern Annual Forest Inventory System (SAFIS) are currently underway in Georgia. Using hand-held Global Positioning System (GPS)

receivers, we connect FIA plot data to “real-world” coordinates and then locate field plots on the TM imagery. A county map of Georgia in figure 1 shows Brantley County, the study site for this methodology.

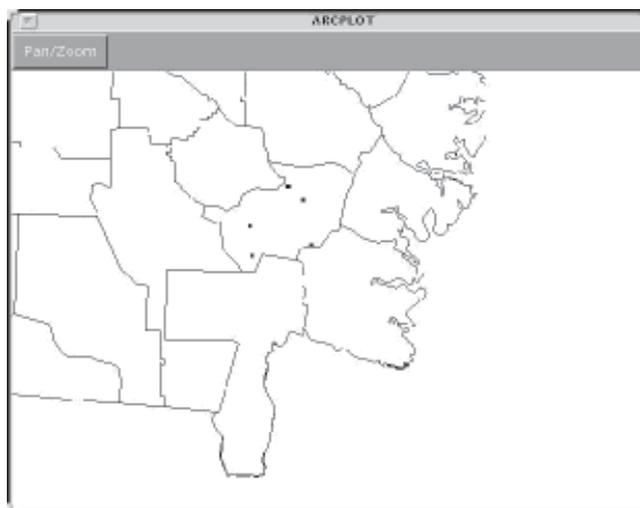


Figure 1—Plots in study site, Brantley County, GA.

Two critical questions arise when we consider FIA plots for remote sensing purposes:

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

Coregistration

Question 1 requires an examination of two sources of registration error—the imagery and the GPS reading on the plot. Problems with accurate coregistration of plots and

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satellite data result from locational errors of the satellite imagery during rectification procedures and errors of the GPS coordinate reading. Figure 2 illustrates the cumulative effect of these error sources. If the error sources are cumulative, FIA subplot 1 (plot center) could be as much as two pixels away from its real-world location.

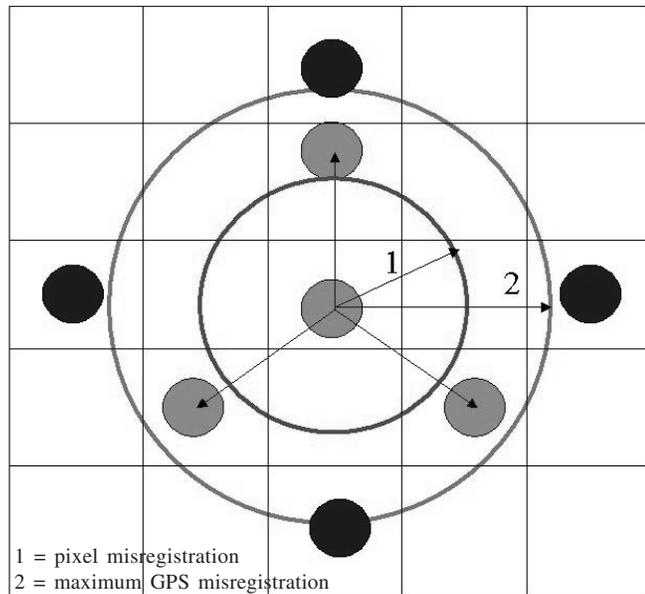


Figure 2—Sources of locational error.

Crown Modeling

Question 2 presents a challenging problem. The pixel resolution (28.5 m) of TM data restricts the useful level of detail of plot information. Within forested stands, the satellite sensor most likely images dominant, codominant and intermediate trees. More detailed information collected during field sampling [diameter at breast height (d.b.h.), 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 information utility, we developed a methodology to compare the individual tree data from FIA field plots with estimates of forest area by a 25-pixel TM window, which is large enough to allow for some of the uncertainty of misregistration.

Based on 304 measurements of trees in New Zealand, Avery (1975) documents a strong linear relationship between d.b.h. and crown diameter for *Pinus radiata* D. Don. This concept was originally designed to predict diameter of trees whose crowns could be measured on aerial photographs. For our study, we developed relationships between measured crown diameter and d.b.h. to enable prediction of crown diameter from d.b.h.

FIA field crews recorded distance and azimuth from each subplot center to each tallied tree. We used this information in a GIS system to provide a geographic reference point for a mechanical reconstruction of the tree crowns on each subplot.

Data Preparation

We reformatted raw (unedited) plot data from Georgia from ASCII files to a relational database format. We queried individual tree data for these attributes:

1. Crown class (dominant, codominant, intermediate);
2. Species (pine, hardwood);
3. Nonmapped forested plots (edge conditions);
4. No evidence of disturbance; and
5. Live trees with d.b.h. ≥ 5 in.

Other data preparation included:

1. Assigning pine/hardwood species codes;
2. Computation of each tree location referenced to Universal Transverse Mercator (UTM) coordinates on each subplot based on field measurements of distance and azimuth; and
3. Modeling crown diameter from diameter using Forest Health Monitoring (FHM) data to derive regression coefficients.

We downloaded FHM data from the St. Paul field office site of the Forest Resources Management and Forest Health Protection Web site (<http://www.na.fs.fed.us/spfo/fhm/>). As the basis for simple linear regressions, these data enabled prediction of crown diameters from d.b.h. For modeling pine crown diameter and hardwood crown diameter, we used 350 observations each. R-square values were .82 and .63 for pine and hardwood prediction models, respectively:

$$\text{Pine Model: } \text{dbh} * .531225 + 0.0094$$

$$\text{Hardwood Model: } \text{dbh} * .245801 + 2.4555$$

We drew crowns at the real-world location of each tallied live tree with d.b.h. ≥ 5 in. When a tree crown extruded beyond a subplot radius, we terminated that crown at the plot perimeter. Conversely, crowns of trees that intruded on the subplot radius are nontallied trees. We assumed that truncation of extrusive crowns and nontally of intrusive crowns represents a compensating error situation. We ignored crown overlap from a reflectance perspective and performed GIS union operations on overlapping crowns (fig. 3). This ensures that calculation of crown area per plot is a value between 0 and 1. We averaged crown proportion estimates for each subplot for the four subplots to yield crown proportion indices. Resolution differences between the Landsat data and the field data make comparisons difficult.

Figure 4 illustrates the unique problem of comparing field data to image data. To facilitate comparisons, we compared plot index values to 5 by 5 pixel windows on classified Landsat data acquired on December 17, 1996. We calculated proportions for the 5 by 5-pixel window that was most closely centered on the field plot (table 1).

DISCUSSION

Tables 1 and 2 compare plot and TM. Table 3 references complete breakdowns of crown proportion by subplot.

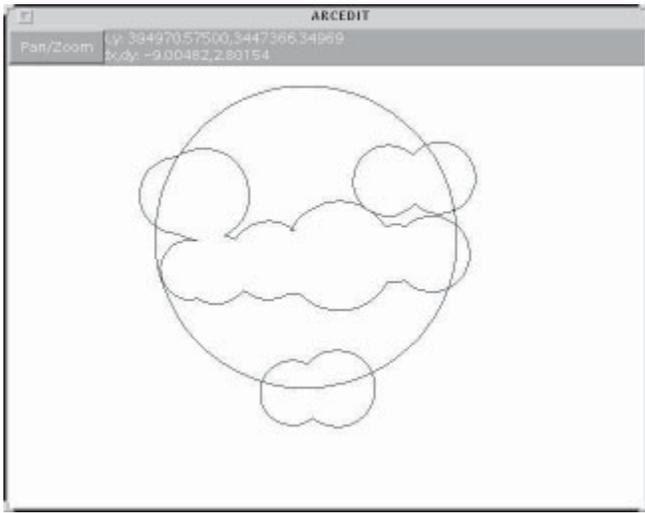


Figure 3—GIS union operation to merge crowns prior to calculating crown proportions.

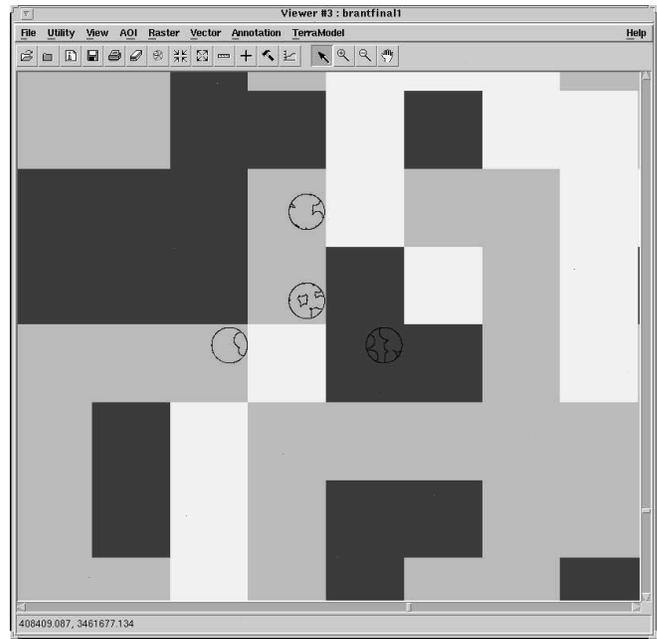


Figure 4—Resolution differences between field plots and Landsat TM imagery.

Table 1—Comparison of Landsat Thematic Mapper (TM) classification with Forest Inventory and Analysis (FIA) plot data

Forest type	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
	TM	FIA	TM	FIA	TM	FIA	TM	FIA	TM	FIA
	<i>Percent</i>									
Pine ≥ 5 in. d.b.h.	68	100	35	0	80	100	100	100	42	100
Hardwood ≥ 5 in. d.b.h.	32	0	65	100	20	0	0	0	58	0
Crown (FIA)		54		49		71		41		65

Table 2—Count of trees with d.b.h. < 5 inches

Forest type	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

Subplot	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
	CA	CP								
1	81.78	.49	120.24	.72	99.10	.59	73.19	.44	137.89	.82
2	84.49	.50	30.26	.18	122.03	.73	71.59	.43	147.92	.88
3	95.49	.57	50.39	.30	121.29	.72	84.64	.50	111.34	.66
4	104.25	.62	127.11	.76	134.33	.80	48.15	.29	35.88	.21
Mean CP/plot	.54		.49		.71		.41		.64	

CA = Crown area per subplot in m²; CP = Crown proportion per subplot calculated by CA/plot area (168.11 m²).

Plot 1

FIA data indicated 100 percent of all trees ≥ 5 in. d.b.h. were pines. Classified TM data from the 25-pixel window resulted in 68 percent pine and 32 percent hardwood. The mean crown proportion for plot 1 was .54. Table 2 results indicate a fairly even distribution of crowns over the four subplots.

Plot 2

FIA data indicated 100 percent of all trees ≥ 5 in. d.b.h. were hardwoods. Classified TM data from the 25-pixel window resulted in 35 percent pine and 65 percent hardwood. The mean crown proportion for plot 2 was .49. Table 2 results show an uneven distribution of crowns over the four subplots. Subplots 1 and 4 have more than 70 percent crown saturation and subplots 2 and 3 have less than 30 percent crown saturation. Table 2 records 14 hardwoods < 5 in. d.b.h., which indicates possible hardwood reflectance from untallied trees on this plot.

Plot 3

FIA data indicated 100 percent of all trees ≥ 5 in. d.b.h. were pines. Classified TM data from the 25-pixel window resulted in 80 percent pine and 20 percent hardwood. The mean crown proportion for this plot was .71. Subplots 2, 3, and 4 have more than 70 percent crown saturation and subplot 1 has more than 60 percent crown saturation. Subplot 1 is relatively homogeneous, and the TM results are in agreement with a homogeneous land cover situation.

Plot 4

FIA data indicated 100 percent of all trees ≥ 5 in. d.b.h. were pines. Classified TM data from the 25-pixel window resulted in 100 percent pine. The mean crown proportion for plot 4 was .41. Distribution of crown saturation across the subplots is fairly consistent except for subplot 4, which has less than 30 percent crown saturation. Table 2 indicates that there are only two pines and one hardwood with unmodeled 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 percent of all trees ≥ 5 in. d.b.h. were pines. Classified TM data from the 25-pixel window resulted in 42 percent pine and 58 percent hardwood. The mean crown proportion for plot 5 was .64. Subplots 1 and 2 had more than 80 percent crown saturation. Subplot 3 had more than 60 percent crown saturation and subplot 4 had roughly 20 percent crown saturation. Two possible reasons for the nonagreement between FIA and TM results are pixel/plot misregistration or incorrect classification results. Examination of the classified imagery reveals that a one-pixel shift to the northwest would result in 60 percent pine and 40 percent hardwood. High pine crown proportions in subplots 1 and 2 further strengthen the argument for misregistration. Results shown in Table 2 strengthen the argument for incorrect classification results. Twelve hardwood trees < 5 in. d.b.h. that were not modeled for canopy proportion estimates and the location and diameter of these stems/crowns should have been modeled. If the

majority of these trees are growing beneath the overstory, misregistration is likely. If the majority of these trees are growing in dominant canopy positions, misclassification is likely.

CONCLUSIONS AND RECOMMENDATIONS

Resolution differences between the FIA field data and the TM data show that we are attempting to "compare apples and oranges." On the basis of our limited study, there appears to be good correlation between the results of the modeled canopies and the TM classification. However, misregistration and misclassification errors are difficult to quantify. Excluding stems < 5 in. d.b.h. from the crown modeling process was a mistake. In future modeling efforts, if tallied stems < 5 in. d.b.h. are overtopped, we will not model them on the basis of the canopy position constraint. If stems < 5 in. d.b.h. are in a dominant, co-dominant, or intermediate crown position we will model them. This methodological change should provide useful information on plot surface reflectance. We could bridge resolution problems between the two data sources by using LIDAR data or large-scale aerial photography.

This is a preliminary study 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 being tested include species, age, density, crown class, landscape position, and other variables as possible predictors of crown size. These models may improve quantification of crown proportion estimates by subplot.

REFERENCES

- Avery, T.E. 1975. Natural resources measurements. New York: McGraw-Hill. 339 p.
- Holmgren, P.; Thuresson, T. 1998. Satellite remote sensing for forestry planning—a review. *Scandinavian Journal of Forest Research*. 13: 90–110.