REMOTELY SENSED PINE STANDS IN THE PINE BASKET OF VIRGINIA

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ABSTRACT

Landsat 7 TM imagery was classified and used to identify areas of Virginia's piedmont and coastal plain, known as the "Pine Basket," that present a high susceptibility to Bark Beetle infestation. The imagery was classified to the land cover types of Pine, Hardwood, Mixed forest, Harvested forest, Water, Agriculture, Marsh, and Urban using a binning classification methodology. The forest classes were then reclassified using an index classification where thresholds were set to classify Pine, Mixed, and Hardwood forest types. The forest type thresholds were determined to approximate the FIA definition for forest types, which uses the percentage of pine and hardwood in a stand to determine forest type. Pixels classified as pine were then aggregated using four orthogonal neighbors and sieved at one acre. The total acreage of aggregated pine was calculated and compared to FIA estimates of pine in the Pine Basket. The accuracy of the classification was also assessed using a selection of forested FIA points. A confusion matrix for the pine classification was produced and then accuracy by pine stand age groups was considered.

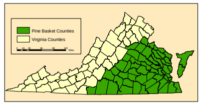
INTRODUCTION

Accurate characterizations of forest resources are necessary for informed management. In Virginia, more than three-quarters of forestland is in private ownership. Effective and efficient protection of pine forests from bark beetles hinges on periodic detection monitoring and targeted communications with affected landowners. Knowing the locations of susceptible pine forests is a first step.

A long-established source of plot-based statistics for forest trees has been the national Forest Inventory and Analysis Program. Geographic information systems and satellite technology now allow the relatively efficient addition of spatial information on a large scale. We developed a procedure for classifying Landsat 7 TM 30-meter imagery to identify pine stands of an acre or more in size that are at least old enough to be approaching crown closure. This is the first step in using subsequent change detection to estimate tree age as well as to monitor pine regeneration and harvesting. Ultimately, this process will enable service foresters to provide targeted pine management and protection information directly to appropriate landowners.

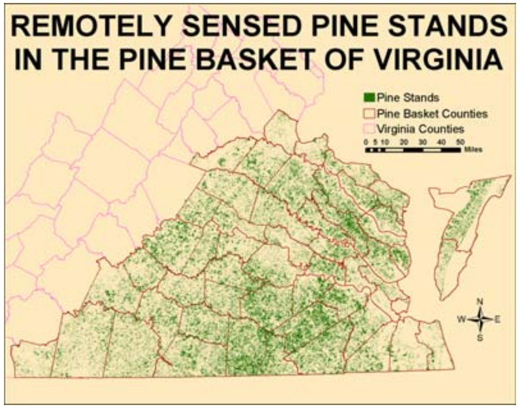
STUDY AREA

The study area for this classification is the "Pine Basket" of Virginia, which consists almost entirely of Virginia's piedmont and tidewater counties.



Location of Study Area

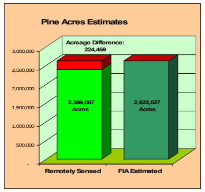
RESULTS



We assessed the quality of the remotely sensed Pine Basket pine stand map using FIA data in three ways. The first was a comparison of total remotely sensed pine acreage to acreage estimated by the FIA program. Second was an accuracy assessment using a select set of FIA points. Third was an accuracy assessment by stand age using the same FIA points.

COMPARISON WITH FIA PINE ACREAGE ESTIMATES

The total acreage of remotely sensed pine stands one acre or larger was about 2.4 million acres, while the summation of FIA estimated pine acreage for counties in the Pine Basket was about 2.6 million acres. The remotely sensed pine acreage was 8.55% less than that estimated by the FIA program. While the accuracy of the FIA estimates is questionable at the county level, we expect that the summation of the county estimates for the Pine Basket provides a more reliable comparison.



The remotely sensed pine acreage total for the Pine Basket is 8.56% less than the FIA pine acreage estimate.

ACCURACY ASSESSMENT

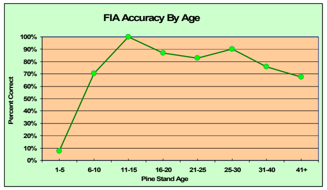
A select set of FIA points was used to test the accuracy of the Pine Basket pine map, though there are comparative limitations between the two datasets (see the Conclusions section). For an FIA point to be used, all of its conditions had to be forest, and every condition within a point had to be all pine, all mixed or all hardwood. This selection criteria was determined to help avoid assessment errors due to registration issues. The rationale is that assuring a uniformity of conditions within a selected FIA point reduces the chance that a point will fall on a type boundary on the pine map. Under such conditions a mis-registration of less than one pixel could cause a false error.

A confusion matrix was produced comparing pine to non-pine. The overall accuracy was 84.35%.

Confusion Matrix For Remotely Sensed Pine Stands Using FIA Points

		Remote Sensing			
		Pine	Non-Pine	FIA Totals	Producer's Accuracy
FIA	Pine	227	87	314	72.29%
	Non-Pine	54	533	587	90.80%
	RS Totals	281	620	901	84.35%
	User's Accuracy	80.78%	85.97%	84.35%	

The breakdown by age groups showed what type of errors are reducing the overall accuracy. For age group 1 to 5 years the accuracy was 7.7%. This poor accuracy is due to the fact that pine stands prior to crown closure (less than 6 to 10 years old) will appear remotely first as harvest, then hardwood, and finally mixed. However, as stands mature the accuracy increases rapidly to 100% for the age group 11 to 15 years, then continues to remain above 80% until the age group of 31 to 40 years is encountered. As Pine stands get older, mortality and successional forces can reduce the contribution of pine in a canopy causing a stand's spectral signature to move toward the mixed class.

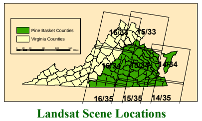


METHODOLOGY

1. Classify Landsat 7 TM Imagery into Binned Land Cover Types

a. Portions of eight Landsat 7 TM Scenes in three paths, one for each date, where used as the source imagery for the Pine Basket land cover classification.

Path 14, Scene 34 and 35:	February 19, 2002
Path 15, Scene 33, 34 and 35:	November 6, 2001
Path 16, Scene 33, 34 and 35:	November 13, 2001



Landsat Scene Locations

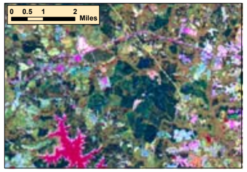
b. Scenes in the same Path where mosaicked together before classification, though each path was classified separately and mosaicked after the final pine classifications, most recent on top.

c. A 3-band "Transformation Image" was derived from the TM image. The image enhances the spectral differences in vegetation types.

Band 1 = TM Band 5 – (2 * TM Band 4) + TM Band 3

Band 2 = TM Band 5 – TM Band 3

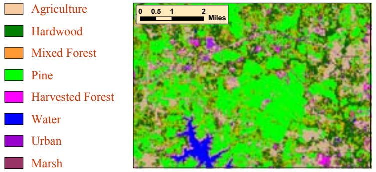
Band 3 = TM Band 2



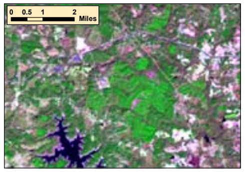
Transformation Image

d. Each Path was classified separately using a semi-automated procedure. Step 1 of the procedure uses an algorithm that we developed. The algorithm finds homogenous regions in the Transformation image and chooses a selection of those regions whose means are evenly distributed throughout feature space. Step 2 requires a human classifier to extract the selected regions to signatures and create a minimum distance classification. Simultaneously, the classifier views the regions and assigns a land cover classification to each region and, by extension, to each class in the classified image. In step 3, the classes that result from this binning classification, often in the hundreds, are recoded to new values, a unique value for each land cover type encountered.

The land cover types detected by the binning algorithm in the Pine Basket were:



Land Cover Classification

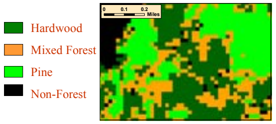


30-meter TM Reference Image

2. Reclassify Forest Types Only Using an Index Classification

a. The FIA definition of the Mixed forest class is forest that contains between 25% hardwood to 75% hardwood, the rest being pine. The Hardwood and Pine classes each have less than 25% of the opposite type in them. A binned classification can be difficult to compare meaningfully to an index classification. Consequently, we transformed the Hardwood, Mixed and Pine classes in the above binned land cover classification to an index classification where thresholds were set. It was important to first separate forest from non-forest to prevent inclusion of non-forest types in the index.

b. The first band of the transformation image provides a good index for forest types. The Hardwood type occupies the highest values, the Mixed type lies below Hardwood, and the Pine type occupies the lowest values. By converting the first band in the transformation image to a thematic layer, and using 1-meter aerial imagery to visually determine the percentage of hardwood and pine in forest stands, we were able to approximate threshold values that represent the FIA threshold definition of forest types.



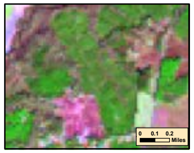
Forest Index Classification

1-Meter Aerial Reference Image

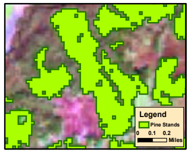
3. Reclassify Index Classification to Pine\Non-Pine and Mosaic TM Paths

4. Clump and Sieve Pine Pixels at One Acre

The clumps were sieved at one acre to conform to the FIA definition that forest land must be larger than one acre.



30-meter TM Reference Image



Remotely Sense Pine Stands

5. Sum Acreage of Pine Pixels Within Pine Basket or Sub-Regions

CONCLUSIONS

There is a recognized correlation between stand density and the susceptibility of pines to bark beetles. Similarly, there is a strong relationship between pine stand density and crown closure. The ability to detect pine stands remotely is directly related to the amount of crown closure in a stand. Consequently, where remotely sensed pine is most accurately detected is also where bark beetle infestation is most likely to occur.

Whereas remote sensing detects percentage of crown contribution to a forested pixel, FIA data classes are determined primarily by stocking. It is important to question the utility of the FIA data as a reference dataset. Though the two classifications are clearly correlated, there are occasions where classifications from the ground and air may correctly differ. Nonetheless, FIA data still provide a good beginning for assessing the quality of remotely sensed data.

Once produced, a pine stand map can be incorporated into a geographic information system along with a digitized tax map and used automatically to identify and contact landowners who need to be informed of stand management options. Also, periodic reclassification of pine can be used to allow remote tracking of pine planting, harvesting and estimation of stand age. It is expected that remote sensing will rapidly become an essential part of maintaining the health of forests.

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