MAPPING FOREST STRUCTURE USING POLARIMETRIC RADARSAT-2 DATA IN WESTERN NORTH CAROLINA

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1. INTRODUCTION

Remote sensing measurements provide valuable information for many terrestrial applications including land cover classification, crop monitoring and forest mapping [10]. This research uses RADARSAT-2 data for mapping deciduous forests in the Southern Appalachian Mountains of western North Carolina. In this region, deciduous forests are important for timber extraction as well as conservation and preservation of ecosystem functions. Results of this work will contribute to management of forest health and carbon sequestration models.

Radar backscatter is determined by (a) topography, (b) surface target type and geometry, and (c) dielectric content (e.g., reflectivity due to water content and/or metallic content). Studies that explore information extraction using radar data in mountainous environments are strongly encouraged by NASA through the ROSES program in 2009. Topography has a significant impact on the backscatter from forests in the mountains of North Carolina and is the first variable that was accounted for in data collection and analysis. Surface target geometry (forest structure) of the deciduous forests related to scattering mechanisms is the second variable explored in this project.

Polarimetric data may provide unique information on forest canopy based on the scattering mechanisms. The relative contribution of each scattering mechanism is dependent on the nature of the canopy and image parameters (e.g., incidence angle and wavelength). Research shows that L-band data is more effective for mapping forests [4], because longer wavelengths (e.g., L- or P-band) are capable of penetrating through moderately dense vegetation [11]. L-band data is useful for detecting forest structure because its response is dominated by volume scattering, where C-band data is dominated by surface scattering. However, C-band data can provide information on forest structure based on canopy and sub-canopy relationships [4] [1]. Wollersheim and Collins [11] suggest that there is potential for C-band SAR measurements to extract sub-canopy parameters. They found that C-band Convair-580 data (image parameters equivalent to RADARSAT-2 parameters) was most related to volume and basal area for a mixed mature forest (e.g., pines, spruce, poplar, red oak).

The goal of this project is to explore RADARSAT-2 data potential for mapping forest structure in a mountainous environment. Wishart supervised classification using multi-polarization (HH-HV-VV) data and Wishart unsupervised classification using polarimetric data (entropy [H] and dominant scattering mechanism [σ]) are used in this study. The classification procedures were done using ESA PolsarPro4.0 software and accuracy assessment done in ArcGIS 9.3. Results of the radar classifications are assessed using forest species data for Balsam Mountain Preserve provided by Forest Stewards, Inc [2].

2. METHODOLOGY

2.1 Study Area

The study area is a 4,400 acre private development called Balsam Mountain Preserve, which is located in Jackson County, western North Carolina. This development is in the eastern portion of the 249km^2 RADARSAT-2 image acquired on September 4, 2008. Jackson County, North Carolina is a rural county with small communities situated in the Southern Appalachian Mountains. Elevation ranges from 609 m to 1523 m and precipitation ranges from 107 cm to 279 cm annually [6]. Using Bailey's ecoregion descriptions, Jackson County is classified as a Humid Temperate Domain, Hot Continental Regime Mountains Division, and Central Appalachian Broadleaf Forest-Coniferous Forest Meadow Province [6].

In the summer of 2007, Forest Stewards, Inc. (FSI) conducted a forest stand inventory and generated a land-cover map of forest cover types and stand ages. FSI collected forest stand measurements at 469 plots located throughout Balsam Mountain Preserve. Overstory data collected by FSI included; species, tree diameter at breast height, grade (trees over 12 inches), tree age, stand age, habitat type, growth rate of co-dominant tree, and the presence of vines, snags, and cavities. The forest stand types that are used in this study include 89 acres of Acidic Cover (black birch, tulip popular, eastern hemlock), 59 acres of High-Elevation Red Oak (red oak, maples, Allegheny serviceberry), 163 acres of Montane Oak-Hickory (white oak, pignut hickory, maples), 126 acres of Northern Hardwood (yellow birch, American beech, yellow buckeye), 84 acres of Chestnut-Oak (chestnut-oak, scarlet oak, maples), and 183 acres of Rich Cove (tulip popular, mountain silver bell, white basswood, white ash). Other land-cover classes within the Preserve include golf course, pasture and residential.

2.2 RADARSAT-2 Data

RADARSAT-2 is an active sensor using the microwave portion of the electromagnetic spectrum; it is complimentary to optical data and can be acquired in almost all-weather conditions. The all-weather capability is beneficial to planning field data collection of natural vegetation, which changes throughout the growing season and from year to year. The data was acquired in an ascending orbit on September 4, 2008 at 19:33 (GMT). The incident angle range at scene center is 38.51° with an accuracy of +/- 2°. This image was acquired with Fine spatial resolution (12 m range x 8 m azimuth), C-band (5.4 cm wavelength) and is processed at 32-bit radiometric resolution. The temporal resolution for RADARSAT-2 data is 24 days, and a second image of this site was acquired on December 9, 2008 during leaf-off conditions (not used in this paper). RADARSAT-2 data contains a single file, which has both complex, and georeferenced data; in comparison to ALOS data which contains separate files for complex data and georeferenced data. The data acquired is quad-polarization (HH-HV-VH-VV), which allows for both multi-polarization and polarimetric analyses.

Stratifying areas with east- and west-facing slopes was done to account for the relationship between the radar data and topographic affects on target backscatter. Topography was also accounted for during *in situ* data collection to account for aspect differences. Elevation information extracted from 2001 LIDAR data [7] was used to create an east and west aspects map within the study site. Aspects were classified as east-facing when values were between 45° and 135° and classified as west-facing when values were between 225° and 315°. The east and west aspects were exported as separate raster files, then converted to polygons which were then used to clip the FSI forest stand layer to generate a forest stands on east- and west-facing slopes map.

2.3 Radar Analysis

The RADARSAT-2 data was imported into POLSAR Pro 4.0 and polarimetric analysis done using the full resolution complex data extracted using the T3 coherency matrix. Complex data preserves calibration integrity of the data but does not contain georeferenced information. Polarimetric analysis was completed in a batch process by filtering the data (7 x 7 Lee filter), generating decomposition images (e.g., entropy (H), dominant scattering (σ), and secondary scattering (anisotropy)), and classifying the H and σ images using the Wishart unsupervised algorithm. The entropy (H) image represents the randomness of the scattering mechanism (e.g., low, medium, high) and the alpha (σ) image represents the dominant scattering mechanism (e.g., surface reflectance, volume scattering, multiple scattering). The unsupervised classified map was imported into ArcGIS and georeferenced; georeferencing could only be done on the entire scene since the deciduous study site area had no acceptable ground control points. The next step was to create a sub-image of Balsam Mountain Preserve and to perform an overlay analysis with forest stand data on east and west facing slopes. Overlay analysis results were then exported in tabular form for interpretation in Excel and SPSS.

For the multi-polarization analysis, the georeferenced RADARSAT-2 data was processed in POLSAR Pro 4.0 using the full resolution GEOTIFF data based on the Sinclair scattering matrix. Multi-polarization classification was completed on a sub-image of the Balsam Mountain Preserve using Wishart supervised classification of HH-HV-VV data. Wishart supervised classification algorithm uses the calibration sites to group the remaining image pixels based on Wishart distribution; this distribution is a generalization of multiple dimensions of chi squared distribution for non parametric data [9]. Residential, golf course and three of the largest stand types (by area) were used in the supervised classification. The classes used were limited because stand types had to have sufficient number of pixels (10n to 100n) for statistical analysis [5] and POLSAR Pro has a limit of twenty classes for supervised classification. The forest stand types had separate calibration sites for east and west facing slopes. The classified map was then imported into ArcGIS to assess accuracy compared to the FSI forest stand map.

3. DISCUSSION

The results of the unsupervised classification using H and σ showed that High-Elevation Red Oak (east and west slopes) and Northern Hardwood (west) forest stands are unique compared to other stands due to high surface reflectance (99% and 100% respectively) and low entropy values. These stands are even-age, have closed canopies and little variation (s <2.3 cm) in the canopy characteristics. The remaining stands did not have unique scattering and entropy values but did show unique dominant scattering characteristics when entropy was aggregated into one class.

Acidic Cove and Montane Oak Hickory stands were the only forests that had similar proportions of dominant scattering mechanisms on east- and west-facing slopes. Acidic Cove stands were dominated by multiple scattering (40%) while Montane Oak Hickory was dominated by surface reflectance (43%). The dominant multiple scattering mechanism within Acid Coves is is associated with open canopy, different age classes, or a dense understory while the dominant scattering mechanism of surface reflectance relates to partially closed canopy, mostly even aged stands of the Montane Oak Hickory forests.

The Chestnut Oak and Rich Cove forest stands had even distribution of scattering mechanisms on the west facing slopes but tended to be dominated by surface reflectance on the east-facing slopes. Chestnut-Oak forest stands typify dominant scattering mechanisms expected due to topography; surface reflectance on east slopes that face away from the sensor and more volume and multiple scattering on west facing slopes that face the sensor.

The supervised classification of deciduous forest using HH-HV-VV did not discriminate deciduous forest stand types in the study area. This was because of species similarities in different forest stand types as designated by FSI (e.g., tulip popular in Acidic Cove and Rich Cove stands; maples in High-Elevation Red Oak, Montane Oak-Hickory and Chestnut-Oak stands) as well as the aspect differences. The similarities in species types within stands increased the overlap in calibration statistics, which reduces the ability of the classification algorithm to find unique stand types. Forest stand differentiation was not possible but the forest class was discriminated from the other land-use land-cover classes (e.g., golf course, horse pasture, residential).

4. CONCLUSION

The goal of this project was to explore the use of polarimetric RADARSAT-2 data for the differentiation of forest stands. This work includes the use of both Wishart supervised (HH-HV-VV) and unsupervised (H and σ) classifications. The duplication of species within the different forest stands resulted in very low classification accuracy of forest stands using the multi-polarization data and Wishart supervised classification. The polarimetric analysis using H and σ images shows promise for discriminating forest stand types such as Northern Hardwood and High- Elevation Red Oak forest stands using both the entropy and dominant scattering mechanisms. Several of the other forest stands had distinct proportions of dominant scattering, which were consistent on both east and slopes. The remainder of the stands had consistent dominant scattering on east and west slopes but the proportions differed based on aspect. Analysis continues using classified H and σ image with the next stage to model the stand types based on the proportion of each of the scattering mechanisms [3] [8].

5. REFERENCES

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