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CHARACTERIZATION OF WETLAND, FOREST, AND AGRICULTURAL ECOSYSTEMS IN BELIZE WITH AIRBORNE RADAR (AIRSAR)

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1. Introduction

The Shuttle Imaging Radar-C/X-SAR Experiment includes the study of wetland dynamics in the seasonal tropics. In preparation for these wetland studies, we analyzed airborne P, L, and C band radar (AIRSAR) data of Belize, Guatemala, and Mexico acquired by NASA and JPL in March 1990. The first phase of our study focuses on AIRSAR data from the Gallon Jug test site in northwestern Belize, for which ground data were also collected during the three days prior to the overflight. One of the main objectives of the Gallon Jug study is to develop a method for characterizing wetland vegetation types and their flooding status with multifrequency polarimetric radar data.

2. Methods of AIRSAR Analysis

We converted the four look AIRSAR data acquired from JPL in the compressed Stokes matrix format into five re-scaled 8-bit rasters for each frequency (Table 1). The image was rectified to ground range. The HH and VV rasters were corrected for scene and sensor effects caused by changes in look angle across track. This was accomplished by compiling backscatter means for three sets of 7 sample polygons of homogeneous upland forest distributed across track, and then performing a regression analysis to determine the angular dependency of HH and VV. The regression equation was then applied to correct the image for variable look angles. Next, we filtered each raster with two iterations of a 3 x 3 modal filter to reduce the effects of speckle. Since we were primarily interested in characterizing vegetation types, we transformed the AIRSAR parameters from each band into four indices that reflect aspects of the vegetation (Table 1). These indices (except for the biomass index) have the added benefit of being mostly independent of terrain slope, thus allowing for better measures of vegetation characteristics. The canopy structure index provides a measure of the dominance of vertical structures such as stems or trunks. The volume scattering index provides a measure of volume scattering, which can be related to canopy thickness. The biomass index reflects the relative amount of woody compared to leafy biomass in forests and therefore has higher values for deciduous than for evergreen forests due to absorption by green leaves, especially in L and P band. The biomass index for herbaceous types more closely reflects total above ground biomass. The interaction type or phase angle difference index measures the importance of single bounce or volume scattering relative to double bounce interactions. The possible 360 degrees of phase shift have been scaled in a monotonic fashion so that interactions containing appreciable amounts of double bounce have lower values. It is important to note that these indices must be interpreted with caution, especially in comparisons between ecosystem types with very different structure.

The final step was a clustering analysis. Clustering was first run on a pixel by pixel basis for the four indices from P, L, and C band using the Isoclass algorithm with 45 classes. A second clustering of the 45 classes, based on class means, was performed using the centroid method in the SAS statistical package.

3. Results

The cluster analysis identified 12 distinct land cover types in the Gallon Jug test site that were verified with field data: 1) pasture and cultivated lands, 2) water, 3-4) two types of marsh, 5) recently cut forest, 6) regrowth, 7) flooded swamp forest, 8) non-flooded swamp forest, 9) flooded swamp thicket, and 10-12) three types of upland forest. Examination of the indices for each of the 12 types helps clarify differences. The two marsh types represent low (C band BM=29) and high (C band BM=92) biomass marshes. The swamp forests have a high percentage of woody compared to leafy biomass (P band BM=63-72), especially when swamp forests are compared with upland forests (see below). Swamp forest flooding is indicated by the lower PD (P band PD=43) as compared with the non-flooded swamp forest (P band PD=62). The swamp thicket has less woody biomass (P band BM=33) than the swamp forests, and again flooding is indicated by the low PD (P band PD=45). The three forest types represent a gradient from semi-deciduous to semi-evergreen as indicated by decreasing woody biomass (P band BM = 46, 40, 27). This decrease in BM is mirrored by an increase in P and L band volume scattering (e.g. P band VS = 49, 50, 52), which may reflect an increase in canopy closure or thickness. The BM index for the agricultural ecosystems shows an increase from pasture/cultivation (e.g. P band BM=6) to regrowth (e.g. P band BM=14), although some of the dense forest regrowth was classified as forest. The recently cut forest has felled trees with no leaves, which give a very high woody biomass value (P band BM=85), a low volume scattering value (P band VS=40), and a low canopy structure index (P band CAN=40).

Table 1. AIRSAR parameters and indices used in analysis (compiled for P, L, and C band).

Initial parameters derived from Stokes matrix*

Backscatter amplitude parameters

HH VV $CS = \frac{HV+VH}{2}$ $LK = \frac{VV + HH}{2}$

Backscatter phase angle parameter

HH,VV phase angle difference = PD

AIRSAR indices

Canopy structure = CAN = $\frac{VV}{VV + HH}$

Volume scattering = VS = $\frac{CS}{CS + LK}$

Biomass = BM = LK

Interaction type = PD (HH,VV phase angle diff.) = PD converted to monotonic scale

*Derivation of these parameters is described in detail in J. F. Paris, Processing Airborne Imaging Radar (AIR) Data on a Microcomputer Workstation. Technical Report TR-89-04, Department of Geography, California State University, Fresno, 1989.