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ESTIMATION OF BIOPHYSICAL PROPERTIES OF UPLAND SITKA SPRUCE (*PICEA SITCHENSIS*) PLANTATIONS.

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1. INTRODUCTION.

It is widely accepted that estimates of forest above-ground biomass are required as inputs to forest ecosystem models (Kasischke and Christensen, 1990), and that SAR data have the potential to provide such information (e.g. Kasischke *et al.*, 1991; LeToan *et al.*, 1992). This study describes relationships between polarimetric radar backscatter and key biophysical properties of a coniferous plantation in upland central Wales, U.K. Over the test site topography was relatively complex and was expected to influence the amount of radar backscatter.

2. TEST SITE AND DATA

As part of the NASA MAC Europe (Curran and Plummer, 1992) the JPL AIRSAR was flown over the Tywi forest, in central Wales, U.K. This is an area of coniferous forest plantations, consisting of Sitka spruce (*Picea sitchensis*), Lodgepole pine (*Pinus contorta var. latofoliar*) and Japanese larch (*Larix kaempfei*), surrounding the Llyn Brianne reservoir. It is an upland region characterized by variable topography of up to 500m above mean sea level with some valley slopes of 45° or more. For this study only areas of Sitka spruce were analyzed since this was the dominant species with the widest range of planting dates on a variety of slope/aspect orientations relative to the SAR. All the species are densely stocked with planting spacing typically 2 metres. The ground data comprised results of an intensive field survey for a limited number of stands; and for a much larger area, the planting date of forest compartments was known from stocking maps.

The AIRSAR images consisted of a slant range pixel resolution of 3.4m and incidence angle ranged from approximately 20° near-range to between 55° and 60° far-range. The Stokes matrix data were analyzed using POLTOOL, a polarimetric SAR data processing package. P-band data were subject to interference at all polarization combinations and were consequently not used in the analysis. This is a disappointing situation since some authors have found P-band data to be most sensitive to forest biomass (e.g. LeToan *et al.*, 1992).

2. BACKSCATTER RELATED TO STEM BIOMASS ESTIMATES

Estimates of key biophysical parameters were derived for forest stands within the Cefn Fannog plantation managed by the U.K. Forestry Commission. Data available from the Forestry Commission included surveys performed in 0.01ha plots at regular intervals in the area. From standard forestry mensuration data the average basal area, stem volume and stem biomass for each stand were derived. The average intensity of backscatter (amplitude) for a group of pixels corresponding to a forest stand was extracted from the AIRSAR imagery, synthesized into HH, HV and VV polarizations using POLTOOL.

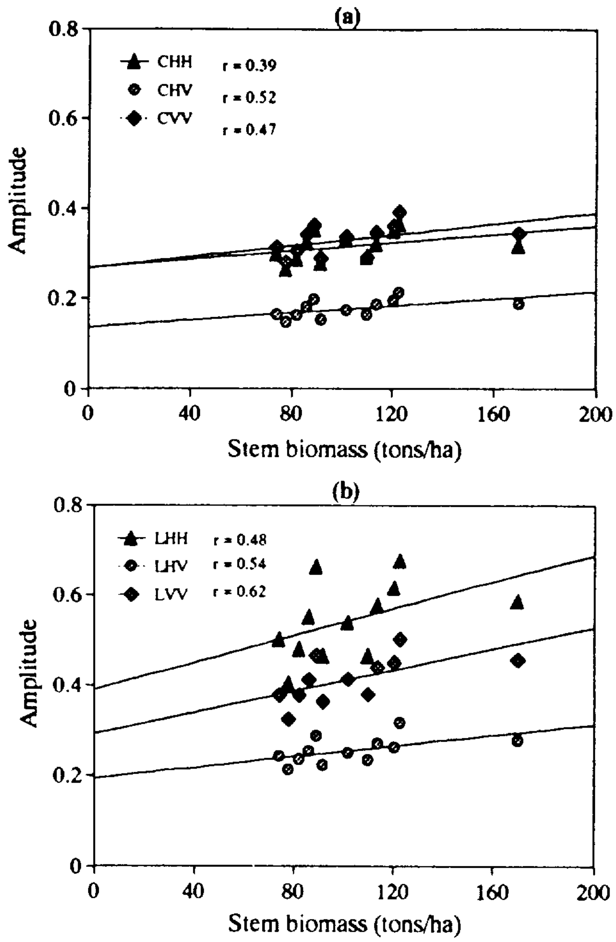

Figure 1. Plots of amplitude versus average stand biomass using data synthesized into HH, HV, and VV polarizations in (a) C-band, and (b) L-band.

Figure 1 shows plots of C-, and L-band backscatter versus stem biomass. The amount of C-band backscatter was lower than L-band. Luckmann and Baker (1993), using the same data set, attribute this to a lack of scatterers at the same size as C-band wavelengths. In Figure 1a the best-fit lines do not show any significant increasing relationships in any of the polarization combinations. This is to be expected if it is assumed that C-band scattering takes place in the upper levels of the canopy, since all the stands which were sampled had uniform canopy characteristics. The L-band plots (Figure 1b) show positive relationships. The highest correlation coefficient was derived for the VV polarization data (r=0.62, significant at the 95% level of confidence). Stronger relationships may have been obtained with the longer wavelength P-band data.

3. BACKSCATTER RELATED TO STAND AGE.

Over large areas it is logistically impossible to carry out intensive field surveys in order to derive biomass estimates. However, accurate Forestry Commission stock maps exist for the whole of the Tywi forest containing information regarding the planting dates of forest stands. Stand age was used as a surrogate for biomass and only unthinned stands

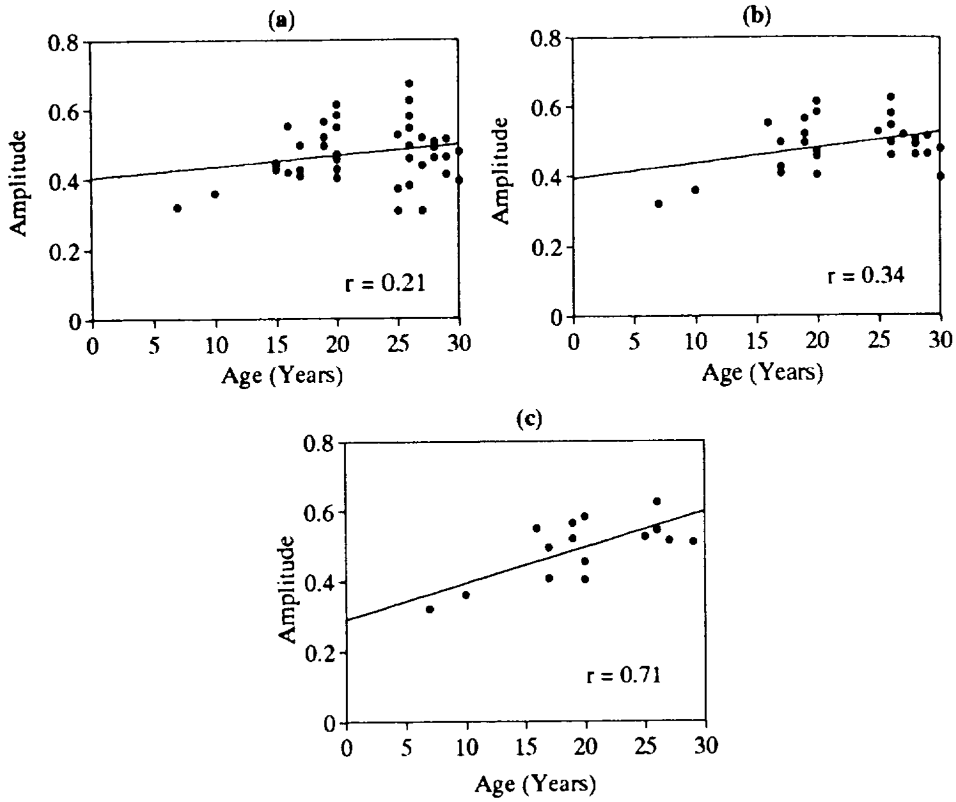

Figure 2. Plots of L-band HH amplitude versus stand age for (a) all stands; (b) stands on steep slopes facing away from the SAR removed; (c) stands on level ground removed.

were considered in the analysis ensuring, as far as possible, uniform canopy structure and density of boles.

Figure 2a shows a plot of L-band HH polarization backscatter versus stand age. There was a general increase in backscatter until the age of 25 years. There was then significant variability in backscatter illustrated by a weak negative relationship. However, it was to be expected that as trees reach maturity that the amount of backscatter will increase at a slower rate until a saturation point is reached (Groom *et al.*, 1992). It was expected that topographic variations will influence the amount of backscatter . In order to reduce the effect of abnormally low backscatter, all stands at an aspect of between 90° and 180° relative to the SAR look direction and with slope angles greater than 5° were eliminated (Figure 2b), i.e. stands on steep slopes facing away from the sensor were excluded from the analysis. Some of the variability disappeared and the correlation rose to r=0.34.

Much of the variability that still existed was found to be the backscatter from those stands that were situated on flat ground (slope angles typically less than 1°). These stands were located in a basin surrounding a natural lake. Productivity of Sitka spruce stands is related to soil water content, which varies as a function of slope angle (Coutts and Philipson, 1978). Stands situated on well drained slopes tend to have higher growth rates and hence more biomass compared to stands of a similar age in areas of poorly drained soils. Therefore topography indirectly determined the amount of biomass production. When stands situated on slope angles of less than 1° were eliminated from the data set the resulting relationship (Figure 2c) resembled those derived by previous authors from forests in different environments, and the r-value again increased (r=0.71). Therefore in this instance, age is not a good surrogate for biomass unless other environmental information is taken into account.

4. CONCLUSION.

This study has shown preliminary results of analysis of radar backscatter in a dense spruce forest plantation in an upland environment, although these conclusions need to be validated with larger data sets. It was found that:

1. A significant relationship exists between L-band VV backscatter and stem biomass estimates derived from intensive field survey.
2. Topographic variation influences the amount of backscatter directly as a result of viewing geometry and indirectly as a determinant of biomass production. This latter point limits the use of age as a surrogate for biomass.

5. ACKNOWLEDGEMENTS.

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