A “Matchstick Model” of Microwave Backscatter from a Forest: A change of regime.

M. Brolly[(1)], I. H. Woodhouse[(1)]
[(1)] School of Geosciences (Geography), University of Edinburgh, EH8 9XP,SCOTLAND, UK,
M.Brolly@sms.ed.ac.uk

1. INTRODUCTION

This paper is concerned with a study of the use of SAR radiative transfer modelling software [1] parameterised in conjunction with macroecological forest structure scaling. Because the majority of biomass is contained within the stems of trees within forests, up to as much as 90% (Cannell, 1982), it is proposed that the canopy can be disregarded as a biomass contributor in terms of SAR backscatter returns in order to simplify, while at the same time increase the accuracy of forest backscatter interpretation. Here we regard the stems as “matchsticks” consisting of constant radius, constant density, and most importantly for radar studies, constant microwave dielectric properties. Furthermore by considering only the larger and more massive constituents of the forest a more precise correlation of biomass with the modelled backscatter from P and VHF Band SAR can be obtained. This study concentrates on the interpretation of “saturation” observed using VHF and P-Band SAR as a result of this “Matchstick” style parameterisation.

2. METHODOLOGY

Using backscatter data produced from a radiative transfer model, the effects of the scattering of SAR when interacting with forest stands consisting of solely vertical stems, or “matchsticks” is considered. With SAR frequencies of both 50MHz (VHF) and 429MHz (P Band) used, comparative radar interaction data sets have been produced. Through variations of macroecological forest parameters which affect the make up of a forest such as, proportionality of radius to height, radius to volume, and number densities, certain characteristics can be identified to influence the correlation of biomass density with the backscatter. The data sets produced not only allow a comparison of the scattering of SAR signals of different wavelengths but also of how interactions with solely stems can reveal novel clues as to the source of the backscatter saturation phenomenon of forests. The investigations move away from the established theory that attenuation and extinction effects are the major contributor to this behaviour and instead remove the volume scattering aspect of a forest, the canopy, a move which would be expected to also eliminate the saturation behaviour.

The scaling properties of the modelled forests are largely based on the relationship:

$$l \propto r^{2/3a}$$

This relationship is used in both [2] and [3], with the selection of values used in this particular work verified from field studies and literature reviews such as those of [4]. Concentration is paid to the effects that variations in scaling, thinning and number densities of trees have on the resulting saturation curves, with additional information regarding these parameters believed to exist within the shape of the curve. This investigation reduces the forest complexities to effectively four scenarios. 1) Absence of thinning with continual increase in forest total basal area; 2) Moderate thinning with reduced rate of increase in forest total basal area; 3) Large thinning rate resulting in constant basal area; 4) Negative thinning causing an increase in number of stems and subsequently forest total basal area. Analysis of these scenarios and their resulting backscatter reveals significant links between radius, basal area and backscatter through dissection of the scattering processes that take place.

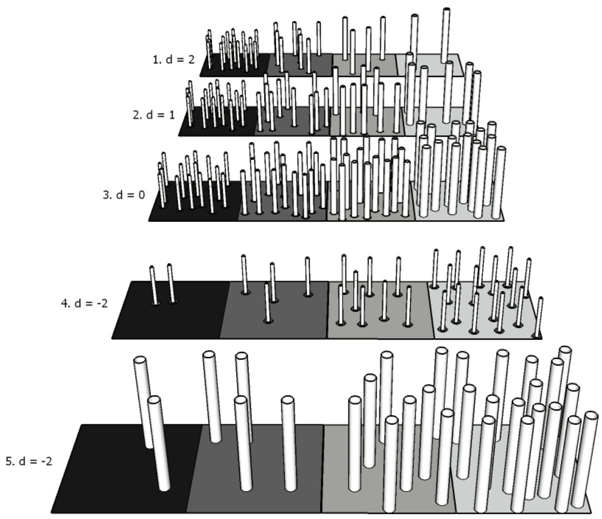

Figure 1. Example of thinning processes and their effect on basal area in relation to a thinning parameter, d.

Close examination of the scattering regimes of Rayleigh, Mie and Optical, in conjunction with the parameter values, specifically radii, provide explanations as to the backscatter behaviour. The proportionality equations for backscatter, given below, are simplified versions of those used in [5] with the attenuation effects considered in this case as constants. This therefore allows simple relationships between backscatter, radii, and number density to be established and explored.

$$\sigma_{Optical} \propto N_k A_k$$

$$\sigma_{Rayleigh} \propto N_k v_k^2.$$

As a result of these simplifications total basal area within a stand is then believed to play an important part in shaping a forest SAR saturation curve.

3 CONCLUSIONS AND INITIAL RESULTS

Data extracted from Modelling this scenario have revealed that saturation will occur even for the single stem case where increasing the size of this stem through the radii associated with Rayleigh, Mie and Optical scattering will result in backscatter saturation behaviour as the biomass density is increased, regardless of extinction. At higher planting densities extinction affects the data but is not seen to be responsible for saturation. Consistent with this finding, a forest of solely vertical stems, approximately identical, will exhibit saturation behaviour at lower biomass density values when lower planting densities are used. This is due to the relationship of backscatter with radius of scatterers and in turn the basal area. The backscatter data deems the ground contribution to be negligible but considers the double bounce as a result of interactions between the stems and the ground. Furthermore, links between saturation and natural thinning phenomena are identified directly, establishing an explainable link between the scattering regime changes and the saturation curves.

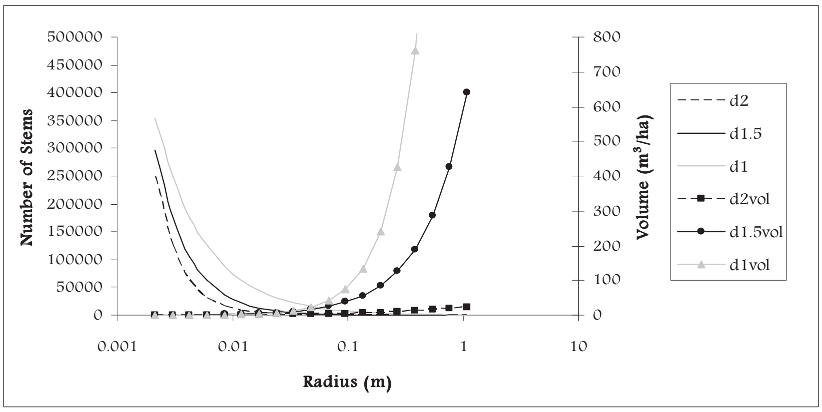

Figure 2. Relationships between number densities, radii and volume undertaking different thinning regimes.

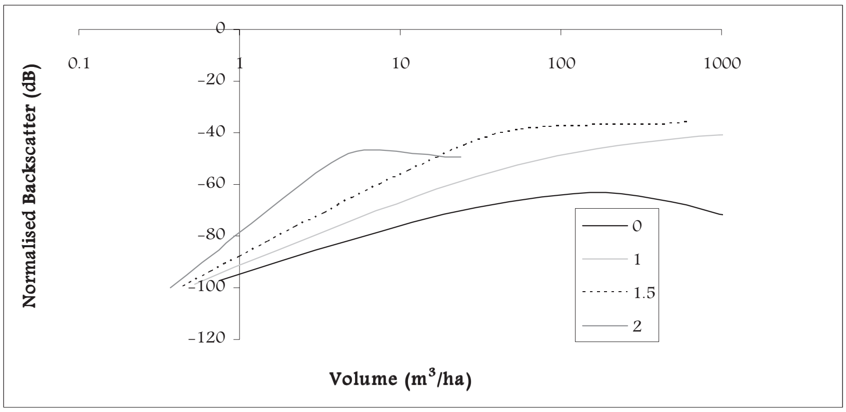

Figure 3. Varying effects on backscatter caused by thinning parameter variations which affect basal area.

Although concentration is particularly paid to Rayleigh and Optical scattering, Mie backscatter is also considered with backscatter oscillations effectively shown to average out when using both non vertical stems and random radius values about a mean, both independently and collectively. These findings would appear to reduce the backscattering scenario of forests to a two section problem involving Rayleigh scattering and Optical scattering. This serves to provide an explanation as to the origin of saturation, with its roots found in the definition of Optical scattering and its dependence on increasing basal area to increase backscatter.

4. REFERENCES

[1] Cannell, M.G.R, "World Forest Biomass and Primary Production Data", London: Academic Press.

[2] West G.B, Brown JH, Enquist BJ "A General Model for the Structure and Allometry of Plant Vascular Systems", Nature, vol. 400, pp 664-667, 1999

[3] Woodhouse I.H. "Predicting Backscatter-Biomass and Height-Biomass Trends using a Macroecolgy Model", IEEE Trans. GRS-44, pp 871-877, April 2006

[4] Zianis, D., and Mencuccini, M. "On simplifying allometric analyses of forest biomass," Forest Ecology and Management, vol 187, pp.311-332, 2004.

[5] Smith, G., and Ulanders, L.M.H., "Model relating VHF-Band backscatter to stem volume of coniferous boreal forest," IEEE Tans GRS-38, pp 728-740, 2000.