PACRIM-2 Clear-fell Mapping Studies in New Zealand

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Introduction

New Zealand forestry companies are actively involved in research on radar techniques aimed at updating detailed forestry maps to account for continuous clear-felling and replanting. To date, these updates have been done as frequently as monthly based on aerial photography. This is often disrupted by unfavourable weather. Radar imaging techniques that could provide all-weather imagery of sufficient quality for map revision applications would therefore be ideal.

Unfortunately, the discrimination of even relatively simple classes, such as mature trees and clear-felled areas, is not easy at the pixel level. This is especially true when using single polarization C-band imagery, as is currently available from the commercial Radarsat-1 instrument. The relatively high level of speckle is the main cause of this difficulty. Although this can be mitigated by filtering, this is generally at the expense of reduced resolution. A second concern is that the C-band backscatter from clear-felled regions can vary significantly due to environmental conditions. In the past we have noted shifts of around 5.5dB for clear-fell in otherwise identical Radarsat-1 images taken only 7 weeks apart.

Future SAR instruments, such as Radarsat-2, will offer multiple polarizations. This should help solve the difficulties with classification accuracy. During the PACRIM-2 mission in August 2000, a 70-km strip of POLSAR imagery was acquired over the Kaingaroa Forest, New Zealand=s largest production forest. These data, along with information provided by Fletcher Challenge Forests (FCF), and information gathered at the time of the flight, allowed a more extensive analysis of these issues.

PACRIM-2 Study

The PACRIM-2 Kaingaroa study aimed to investigate the separability of mature trees from clear-felled areas, and the effect of moisture on the response from clear-felled areas. Unfortunately, when the mission was delayed into the southern hemisphere winter, generally damp soil ground conditions resulted. Despite irrigating several hectares of clear-fell using firefighting equipment, the moisture contrast with the surrounding areas was therefore slight and could not be observed in the imagery. However, the forest inventory GIS data provided by Fletcher Challenge Forests contains a host of information on each polygon, including planting dates, species, pruning and other treatment histories. This has allowed the AIRSAR imagery to be compared with the different ground cover types present in the forest.

The imagery was provided in compressed Stokes matrix format by NASA/JPL. Components such as HH, HV and VV can easily be synthesized from this information. Over 50 ground control points were identified in both image coordinates and map coordinates by using both topographic maps and, more usefully, the GIS coverage of the forestry road network provided by FCF. A digital elevation model of the area was constructed from 20-m contour data and used to ortho-rectify the radar imagery. The Lee polarimetric filter [1] was used to reduce the speckle noise in the data while preserving the polarization information. Finally the radiometry was corrected for variations in pixel size due to both the variation in look angle across the scene and local incident angle due to terrain.

Fig. 1 shows the ~40 km subset of data used in this study.

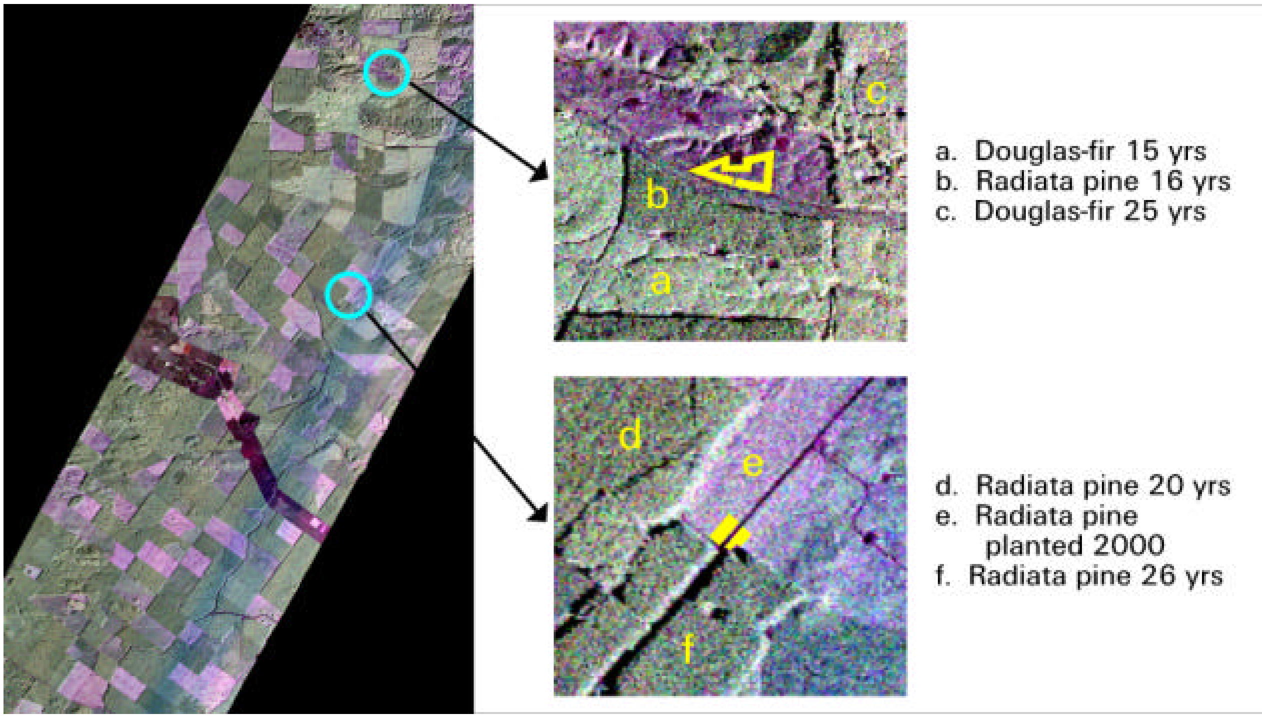


Fig. 1. C-band substrip ~40 km long over Kaingaroa Forest (blue=hh, green=hv, red=vv). Two irrigated sites (another part of the PACRIM study) are shown in detail as yellow.

Polarimetric Results.

Visually, significant differences between mature forest and clear-felled areas are obvious. The clear-felled areas (and young trees) are apparent in

Fig. 1 as purple. Older trees show up as various shades of green, while the strip of farmland through the middle of the image is much darker. In fact, visually it is easy to distinguish different species. Douglas-fir stands are a lighter tone of green and clearly distinguishable from Radiata pine despite a wide range of ages.

Polygons within the subregion (

Fig. 1) were analysed and statistics drawn from those that were >10 ha, contained bare ground or Radiata pine (the dominant species planted in Kaingaroa Forest) and were reasonably compact in shape. Those criteria were used to mitigate both misregistration problems and boundary effects due to the way the analysis package (Erdas Imagine) defines pixel membership of a polygon.

Age Characteristics of C-band Response

Fig. 3 shows the polygon average sigma-nought corrected response against the age of the Radiata pine stands. The C_{HH} component shares many of the characteristics we have noted previously in Radarsat-1 imagery – a decrease in backscatter over the first 8 or so years. Previously we have noted that the effect of elevated backscatter in younger or clear-felled stands is variable and can almost disappear in some (presumably wetter) conditions. Surprisingly, the C_{HV} component appears less sensitive to ground cover, whereas it was the strongest distinguishing feature in a study of the Karioi Forest done as part of PACRIM-96 [2].

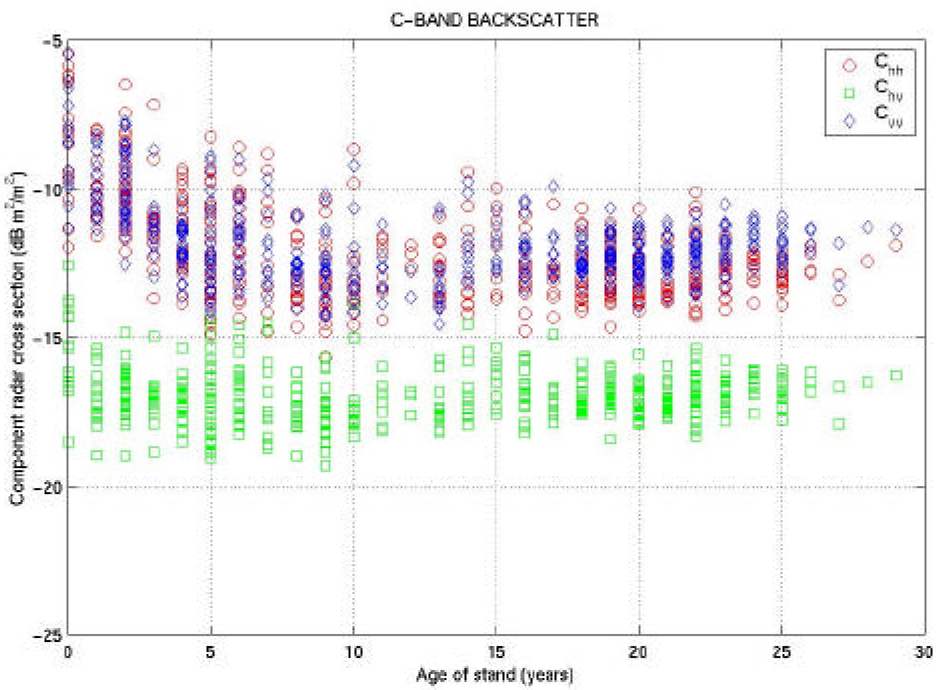
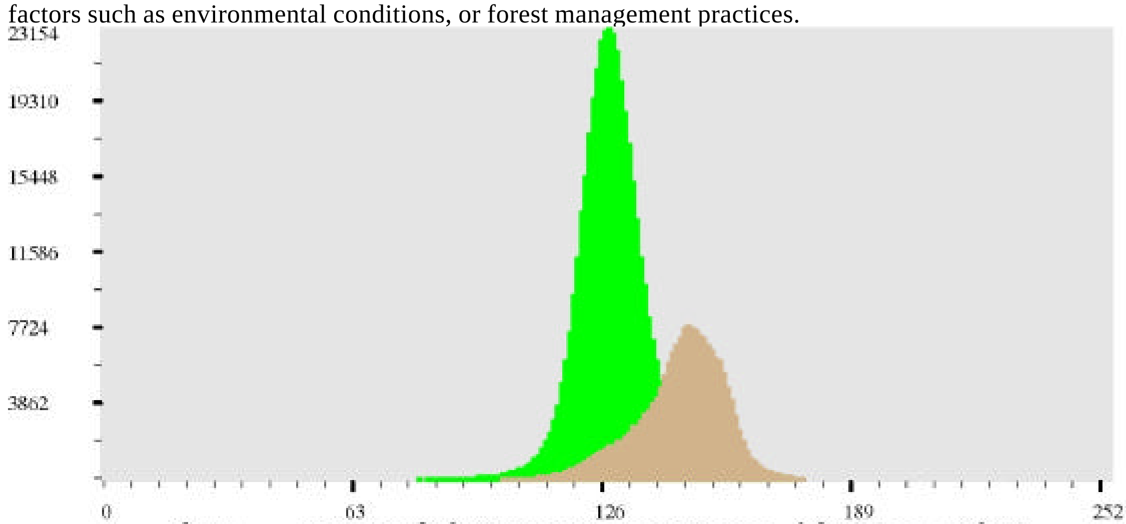


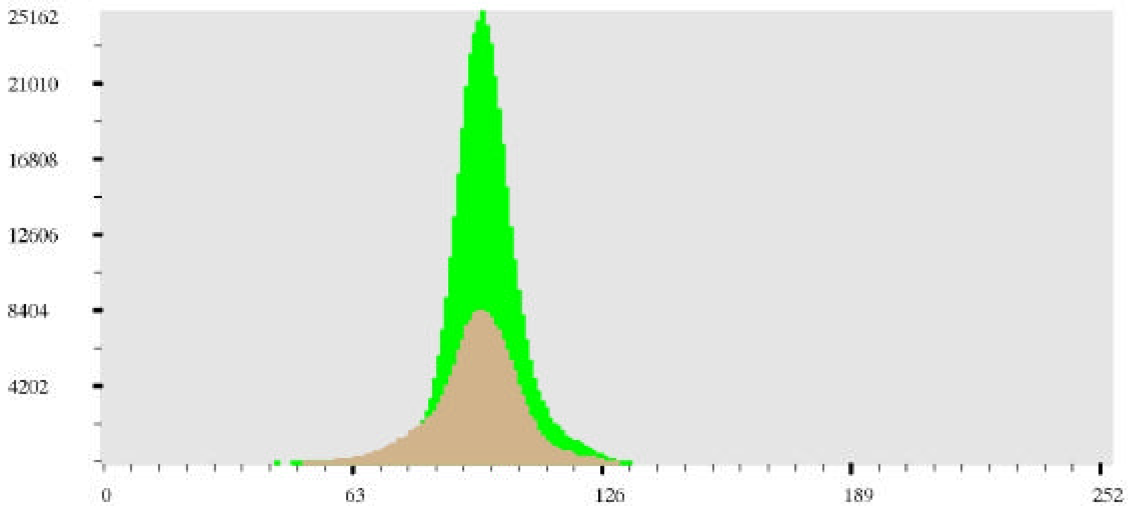
Fig. 3. Average C-band backscatter of polygons against age of trees in the stand.

Mature / Clear-fell Separability

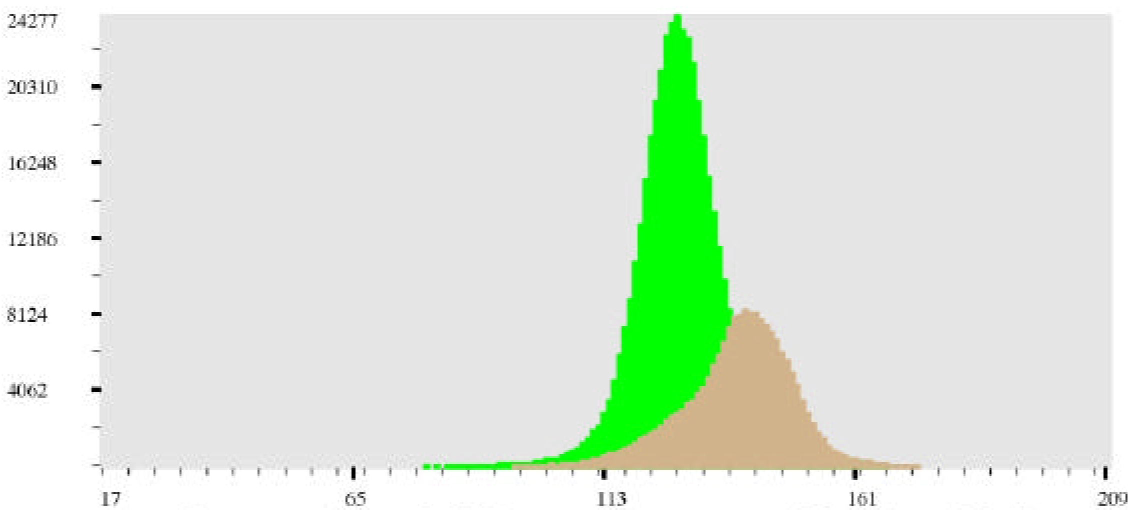
If stands 1 year old or clear-felled are defined as bare ground and those greater than 20 years are defined as mature, then a comparison of the pixel statistics can be made. When component data only, i.e. C_{HH}, C_{HV} and C_{VV}, is used, this study indicates that the HH component provides the most separability (see the histograms in Fig. 4). As noted above this contrasts with our previous Karioi study where the HV component dominated, and may indicate that there is significant sensitivity to factors such as environmental conditions, or forest management practices.



CHH σ_0, where 0-255 spans the range -30dB to +10dB



CHV σ_0, where 0-255 spans the range -30dB to +10dB



CVV σ_0, where 0-255 spans the range -30dB to +10dB

Fig. 4. Component histograms of bare ground (brown) and mature Radiata pine (green).

If the log scale (dB) components are assumed to be reasonably Gaussian, then we can use a divergence measure to quantify the class separability.

Table 1. Divergence measure of mature forest and clear-fell classes for components (dB).

C_{HH}	C_{HV}	C_{VV}	Best pair (C_{HH}, C_{HV})	C_{HH}, C_{HV}, C_{VV}
8	1	5	9	7

Polarimetric Decomposition

An alternative approach is to use polarimetric decomposition models to derive a different set of indices. One advantage of this approach is that a physical meaning can more readily be attached to the indices derived. Following Cloude and Pottier [3] the Kaingaroa Forest data has been decomposed (see Table 2).

Table 2. Polarimetric Decomposition indices generated for the Kaingaroa study

Index	Interpretation	Range	Divergence
Entropy	Disorder	0=order 1=disorder	19
Anisotropy	Roughness	0=smooth 1=rough	1
M11	Total backscatter	ó$_0$ (dB)	1
Alpha 1	Dominant Scattering mode	0=single 45 =dipole 90 =double	1
Alpha 2	Secondary Scattering mode	0=single 45 =dipole 90 =double	0
Alpha 3	Tertiary Scattering mode	0=single 45 =dipole 90 =double	11

The divergence measure is inappropriate for some of these indices as they are not close to a Gaussian distribution in shape. However, the highest ranking pair of entropy and, to a lesser extent, anisotropy did appear to be reasonably Gaussian, as shown in the histograms of Fig. 5. Jointly, they gave a divergence measure of 22. This represents a significant improvement in separability over the C_{HH} and C_{HV} pair used earlier.

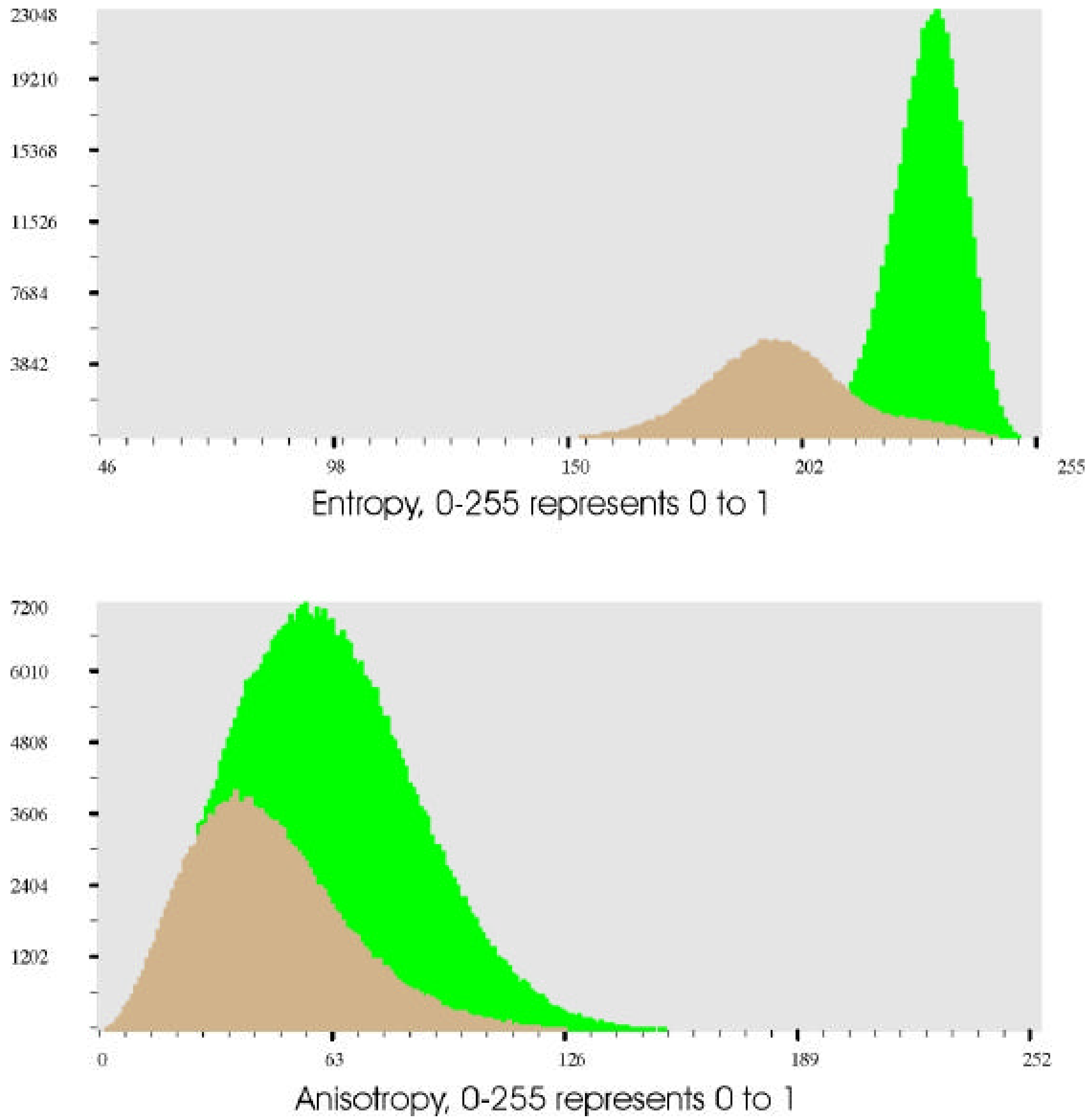


Fig. 5. Decomposition index histograms of bare ground (brown) and mature Radiata pine (green).

Interestingly, these physically interoperable indices provided less separability between the two major species of trees in the Kaingaroa Forest (Radiata pine and Douglas-fir) than the component imagery. This is due to the two species of trees being similar in the characteristics that the indices are attempting to model.

Conclusion

Fully polarimetric C-band radar imagery provides much more information on the target vegetation than single polarization imagery. Conventional discriminators of forest versus clear-fell, such as $C_{HH} - C_{HV}$ polarization difference from dual polarization radar systems (e.g. ENVISAT) do separate the two classes, but sometimes cannot separate the forest class from other bright targets in the scene. Modern radar decomposition approaches using full polarization SAR imagery (e.g. Radarsat-2), here calculating entropy, scattering mode and anisotropy, separate the bare ground and forest classes more effectively. However, this particular decomposition does not separate between forest species so well as polarization features. This result suggests that the best approach to classification of a C-band forestry scene into several forest species classes and bare ground is a two-step process – first, separate the combinedspecies forest classes from “other” classes using full polarization information radar decomposition, then second, separate between the two species in the forest using polarization features such as $C_{HH} - C_{HV}$ difference.

References

[1] Lee J.S., Grunes M.R., deGrandi G. **Polarimetric SAR filtering and its implication for classification;** *IEEE Trans. Geosci. Remote Sensing,* Vol 37(5), 1999, pp 2363-2373.

[2] Pairman D., McNeill S.J. **A Simulation of Radarsat-2 imagery from AIRSAR for a forestry application;** *Proc. Australasian Remote Sensing and Photogrammetry Conference,* Adelaide, Australia, August 2000.

[3] Cloude S.R., Pottier E. **An entropy based classification scheme for land applications of polarimetric SAR;** *IEEE Trans. Geosci. Remote Sensing,* Vol 35(1), 1997, pp 68-78.

[4] Pairman D., McNeill S.J., McNab D., Belliss S.E. **Exotic Forest Clear-fell Mapping from the New Zealand PACRIM-2 Mission;** *Proc. IGARSS’2001,* University of New South Wales, Sydney, Australia, 9-13 July 2001.