AIRSAR PACRIM : The Malaysian Experience

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Introduction

Microwave Remote Sensing (MRS) is necessary in Malaysia because the occurrence of persistent and extensive cloud covers in certain areas limits the use of optical remote sensing for earth resource observation. In addition MRS is sensitive to surface roughness and dielectric constant giving it an advantage over optical data in terrain analysis, oceanography, geology, crop growth monitoring and moisture stress analysis.

In efforts to acquire the relevant technology, Malaysia, under the coordination of the Malaysian Centre for Remote Sensing (MACRES), has participated actively in several international SAR missions. These include airborne SAR acquisition missions and application: Canadian STAR 1 (1990) and Globesar (1993); and United States of America AIRSAR PACRIM 1 (1996) as well as space SAR programmes: European Union ERS-1 (1993); Japanese JERS-1 (1993) and Canadian Radarsat (1999) Currently Malaysia is also participating in the ENVISAT-1 and ERS-2 and AIRSAR PACRIM 2 mission. To-date many Malaysian users are trained in the processing and interpretation of advanced SAR datasets accruing from relevant technology transfer from these missions. Apart from this Malaysia has also sent its researchers for training and on-job attachment in MRS in various centers of excellence which includes the European Space Agency, University of Texas at Arlington and University of California (Los Angeles)

MACRES has recently embarked on a systematic approach to develop programmes in efforts towards making MRS operational in Malaysia. This entails system and infrastructure development; application development; and human resource development.

This paper highlights the recent development in MRS in Malaysia with particular emphasis on our experience in the applications development under the AIRSAR PACRIM programmes.

System , Instrumentation and Infra-structure Development

MACRES and the Multi-Media University Malaysia (MMU) have developed a field quad polarimetric scatterometer system (Figure 1) for MRS application development and constructed an anechoic chamber (Figure 2) to facilitate radar cross-section measurement for fundamental and experimental research. Both these ground based systems will enable us to enhance our understanding of the physics of MRS through development of theoretical models on MRS-target interaction both in a field and a controlled laboratory environment, respectively

Figure 1a: The complete Scatterometer system

Figure 1b: Complete Mobile Scatterometer

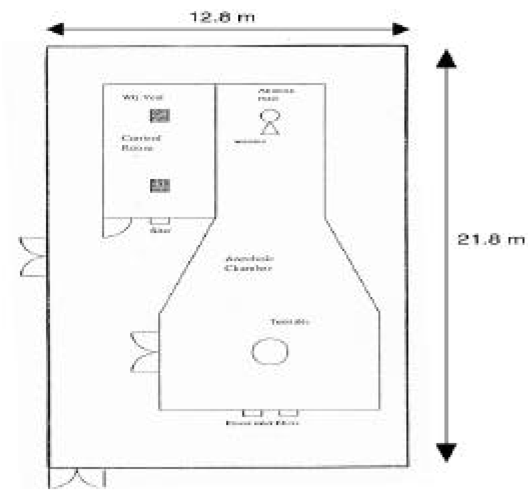


Figure 2a: Anechoic Chamber Floor Plan

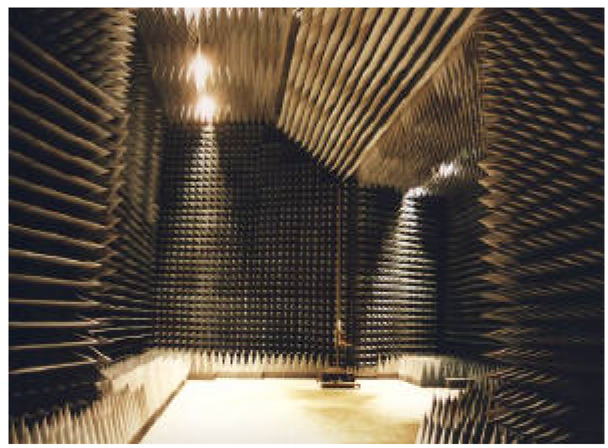


Figure 2b: Internal View of Anechoic Chamber

The scatterometer system consists of a truck with a hydraulic boom cum articulating jib that reaches a height of 26m; radar C-band scatterometer; and a data acquisition cabin facilitated with a signal processing system. The anechoic chamber is a 22m x 13m x 8m tapered-rectangular shape structure with a biostatic antenna system targeted to operate from 30 MHz to 18 GHz frequency..

Application Development

Under the Globesar Project, Ewe et al., 1995 studied on the potential of C band multi-polarized (VV,HV and HH) airborne SAR datasets for land cover classification using fractal analysis The fractal dimension images, which reflected surface roughness ,well characterized in SAR imagery, were computed using backscattered intensity values as heights. The HV polarized fractal image gave the best result in land cover visual and digital discrimination vis-à-vis the HH and VV images.

Loh et al., 1999 studied on radar interactions at different stages of paddy growth using Radarsat data (Standard Mode-7) acquired on four dates – 12/05/97 (planting stage), 5/06/97 (First tillering stage), 29/06/97 (Second tillering stage) and 23/07/97(Reproductive stage). The results showed that the radar coefficient (σ°) increased from planting to 2nd tillering stage due to increase in volumetric scattering. It however decreased fom the 2nd tillering stage to the reproductive stage despite increase in vegetative growth. This was attributed mainly to decrease in plant moisture content .

The nature of this SAR – paddy growth stage interaction allows the delineation of different growth stages of paddy using multi-date radar data. The composite radarsat image (Figure 3a) - 12/05/97, 5/06/97 and 29/06/99 depicted the two stages of paddy growth (vegetative - blue and reproductive – yellow). The discrimination of these two stages was clearer in the ratio image of 29/06 over 12/05 (Figure 3b), treated with the Kwan filter.

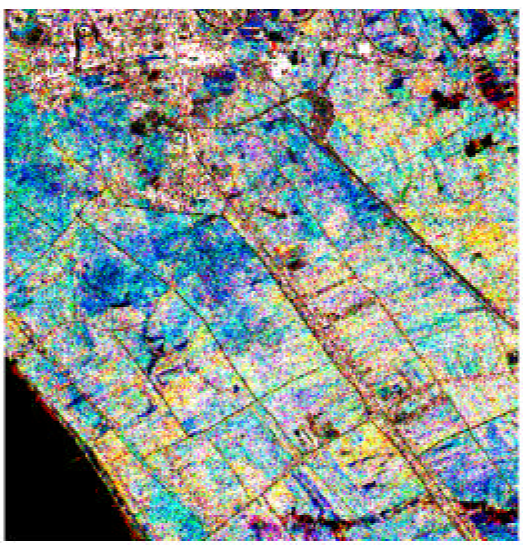


Figure 3a: Blue : Vegetative Stage and Yellow : Reproductive Stage

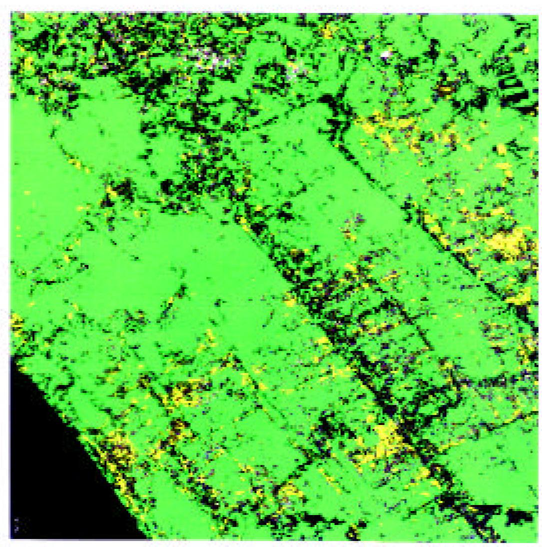


Figure 3b : Ratio Image

Vegetative Reproductive on Rice

Saiful et al. (2000) have further developed a predictive model for paddy estimation in Malaysia using Radarsat data : Yield (ton/ha) = 6.930 + 0.385 σ° where σ° values are computed at 90 days after seeding. The model has a regression coefficient R^2 of 0.894

MACRES under the EC-ASEAN –ERS-1 program worked on backscatter signatures characterization of major land cover types using Cvv SAR data (Loh et al., 1995) Oil palm, rubber and forest have similar SAR responses making visual differentiation among these cover types difficult in a SAR image. A difference of 3 dBs is required for visual separation among cover types. For instance Banana and built – up features of dB of –3.9 and –1.6 respectively are easily distinguishable from oil palm, rubber or forest with dB of –7.8, -7.7 and –7.0 respectively.

Rosenqvist et al., 1995 studied on the phenological characteristics of rubber and oil palm using ERS-1 (Cvv) and JERS-1 (Lhh) data. Both rubber and oil palm gave positive correlations between the L-band backscatters and tree heights, having a dynamic range of about 5 dB and the signal saturating at 12m height and 10m heights respectively. The major scattering mechanism is ground, trunk and branches interaction.

Cvv data shows no correlation between tree height and backscatter for rubber while for oil palm the correlation is clear with a dynamic range of some 3 dB, saturating at about 8m. The insensitivity of the C band on rubber even at a young stage was due to the leguminous ground covers with leaves of about similar size to those of rubber. The large leaves and trunks of the oil palm canopy structure contributed to the return signals at various stages of growth.

It is concluded that L and C bands complement each other for monitoring growth stages of oil palm and rubber. C is suitable for differentiation between the two crops as it saturates at different levels while L is useful for monitoring growth given its clear correlation between plant height and the return signals.

AIRSAR PACRIM Experience

Malaysia's participation in the AIRSAR PACRIM 1 mission (1993-1996) was coordinated by MACRES. Data were acquired over seven sites in 1993, four in Peninsular Malaysia and three in East Malaysia. Twelve projects were implemented by eight Malaysian agencies involved in PACRIM 1 using TOPSAR data. The projects covered Coastal Zone Information Extraction, Wave Spectra Study, Peat Soil Characterization, Geology, and Land Cover Discrimination. Results of these projects are highlighted below.

Coastal Zone Information Extraction

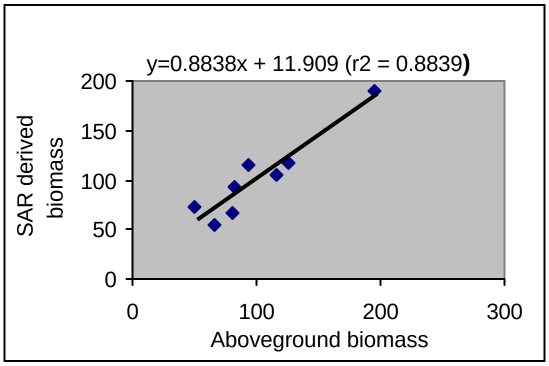
This project was carried out in the Trengganu Coastal Zone (Mazlan et al., 1999). Digitally using the combined unsupervised - supervised classification approach TOPSAR data provided high accuracy in delineating paddy (97%), built-up (84%), grassland (80%) and forest (70%) along the coast. Other coastal land covers – rubber, coconut, scrubs, and mixed horticulture are poorly differentiated.

For shallow bathymetry information extraction, it was found that the sea bottom profile derived from TOPSAR data did not correspond well with the hydrographic chart. off the coast of Trengganu, Malaysia.

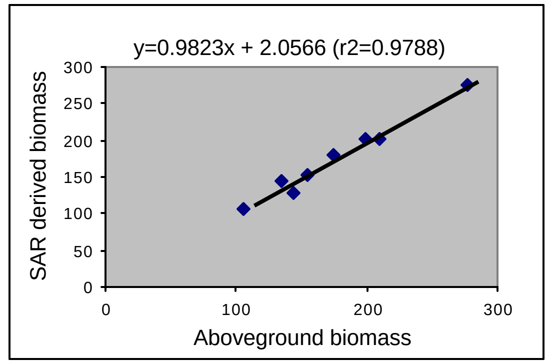
Figure 4 shows good correlation between SAR (TOPSAR-L) derived biomass and above ground biomass. The SAR derived biomass is computed based on the model adopted by Beaudoin et al. (1994) :

$$\mathrm{Log}\ 10\ (W) = a0 + a1(\sigma°\ HV) + a2(\sigma°HV)^2 + b1(\sigma°HH) + b2(\sigma°HH)^2 + c1(\sigma°HH-\sigma°VV) + c2\ (\sigma°HH-\sigma°VV) \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

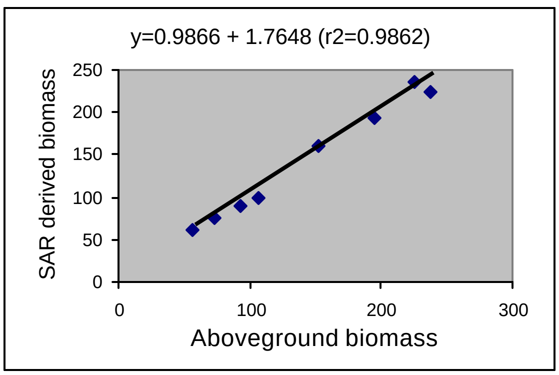
where a,b,c are the coefficients of different parts of the tree; $\sigma°$ is the radar backscatter coefficient.



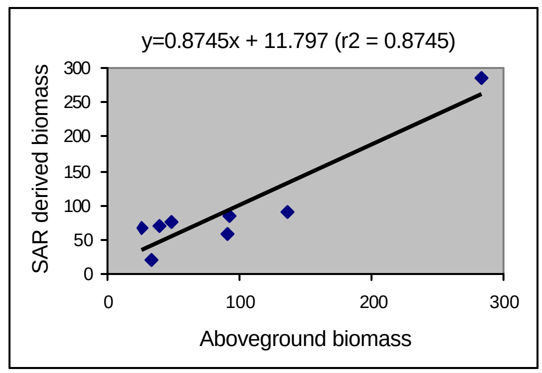
Rubber



Coconut



Mangrove



Forest

Figure 4: Relationship Between Aboveground Biomass and SAR Derived Biomass for

Wave Spectra Study

Shattri et al.(2001) extracted wave spectra information from TOPSAR data using the fast fourier transformation technique as appeared in Figure 5a, showing wavelength ranging from 20 - 170 m in the north-east direction. Based on the quasi-linear transformation (2) , incorporating sampled field data and the SAR spectra, the model wave spectra (5b) of a particular site and its representative spectra density (5c) were simulated:

$$S(Q) = H(Kx,Kc)S(L)S(K) \ldots\ldots\ldots\ldots(2)$$

where S(Q) is the quasi linear function, H the wave height, Kx the wave number in azimuth direction, Kc is the cut-off wave number , S(L) is real wave spectra and S(K) is the SAR wave spectra.

These wave information extracted are useful in predicting shoreline change

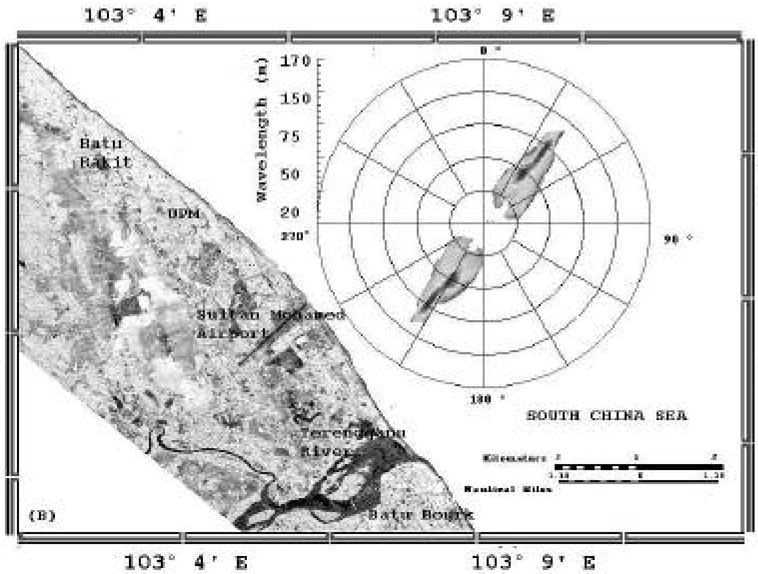


Figure 5a : SAR Wave Spectra

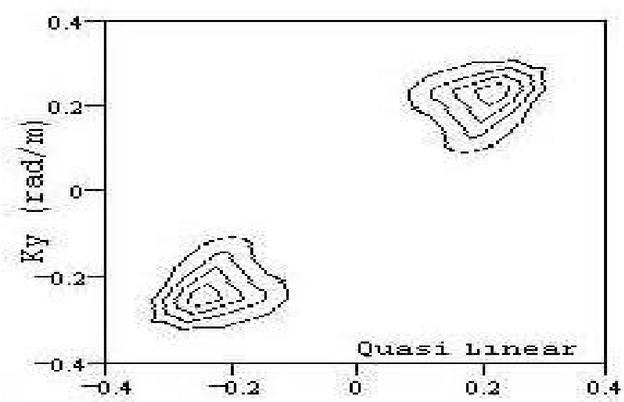


Figure 5b: Model Wave

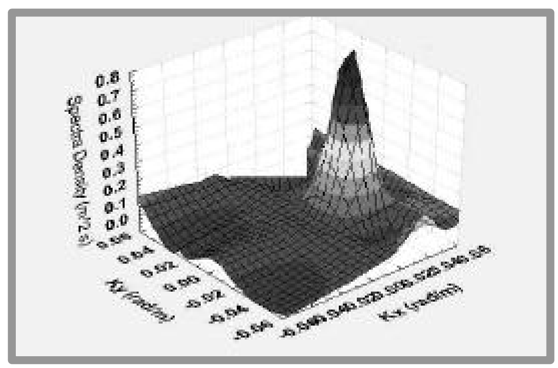


Figure 5c: Spectra Density

Peat Soil Characterization

Mazlan et al.,(2001) computed several regression models for peat soil characterization. The model for determining peat soil decomposition level using TOPSAR data is given in equation (3) with $R^2 = 0.88$ and the result is shown in Figure 6a:

$$\text{Bulk Density} = .6849 - (-.0202\sigma^\circ Lhh - (-.0484\sigma^\circ Lvv) + .0561\sigma^\circ Lhv - (-.0448\sigma^\circ Phh) + .0662\sigma^\circ Pvv - (-.0740\sigma^\circ Phv) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The regression model adopted for determining the ground water depth of peat soil is given in equation 4 with $R^2 = 0.89$ and the result is shown in Figure 6b

$$DWT = 1.969 + .003\sigma°Lhh + .045\sigma°Lvv + .056\sigma°Lhv + .035\sigma°Phh + .006\sigma°Pvv + .017\sigma°Phv \ldots\ldots (4)$$

The best fit relationship between σ° and soil moisture was also determined (Equation 5) with R^2 = 0.76 and the peat soil moisture map is given in Figure 6c :

$$Moisture = 0.610\sigma°Lhh + 45.99 \ldots\ldots (5)$$

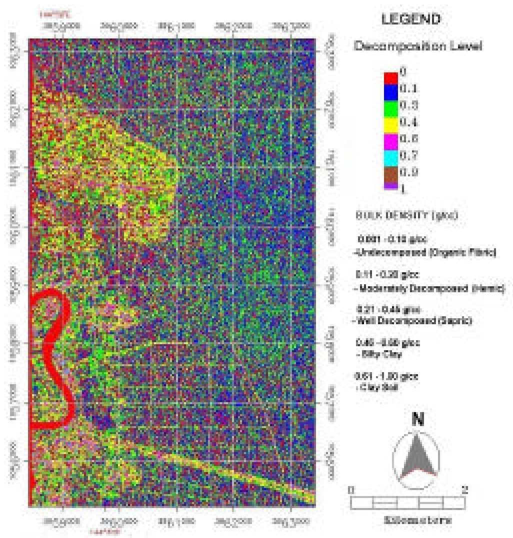


Figure 6a: Peat Type Derived from TOPSAR Data

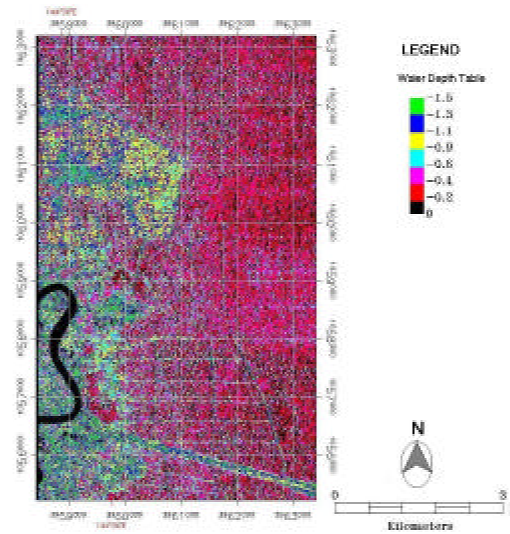


Fig 6b: Depth of Water Table in Peat Derived from TOPSAR Data

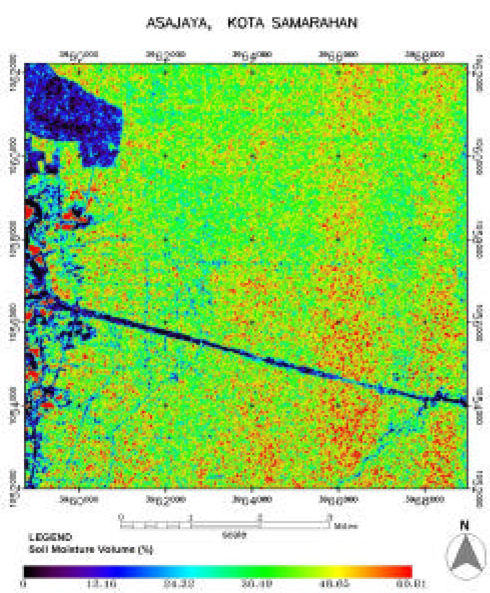


Figure 6c: Soil Moisture Map Derived from TOPSAR Data (L-HH)

Geological Information Extraction

Lai (2001) studied on structural geology information extraction using TOPSAR data. Lineaments information were accumulated visually from SAR composites (C,L and P) as well as 3D shadow relief models with varying sun azimuth directions generated the Cvv DEM (Figure 7a). Figure 7b and 7c depict the accumulated lineaments and the structural geology map.

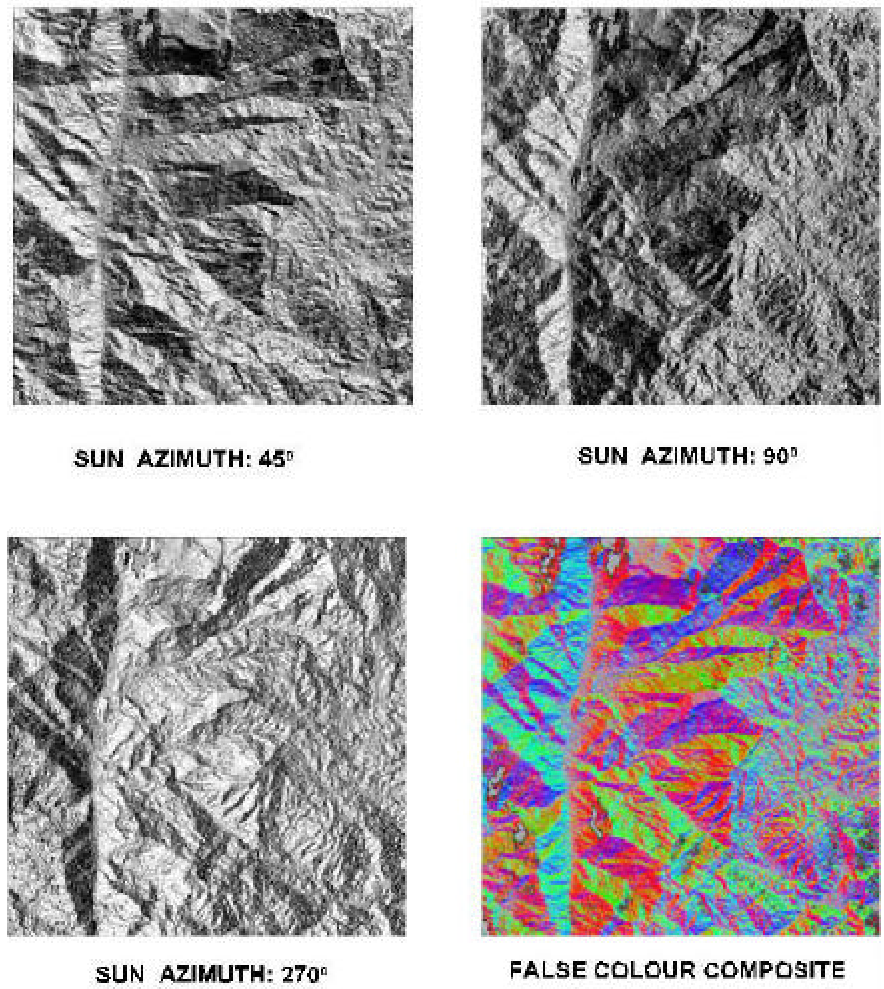


Figure 7a: AIRSAR DEM Shaded Relief Models, Cameron Highlands

Lithology information extraction from TOPSAR (C,L and P) data was conducted by Freddy et al.(2001). Three lithology types could be extracted (Figure 8)– Riverine alluvium, Neogene Peripheral Basin (Folded sanstone beddings mainly); and the Folded Rajang Formation (Mainly massive sandstones).

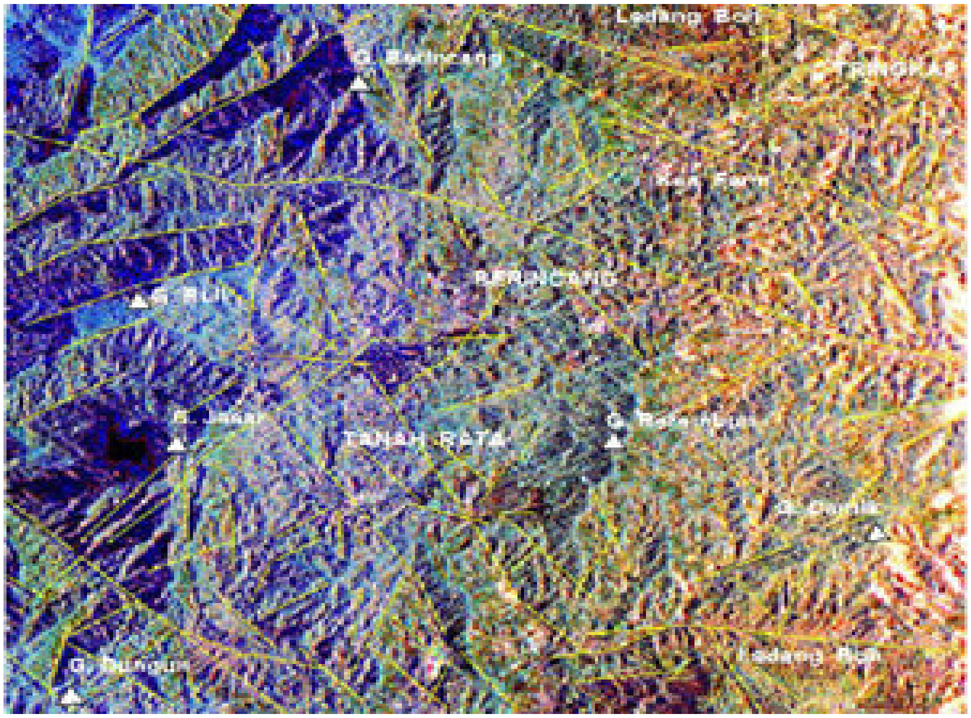


Figure 7b: Fracture Lineaments of the Cameron Highlands Area

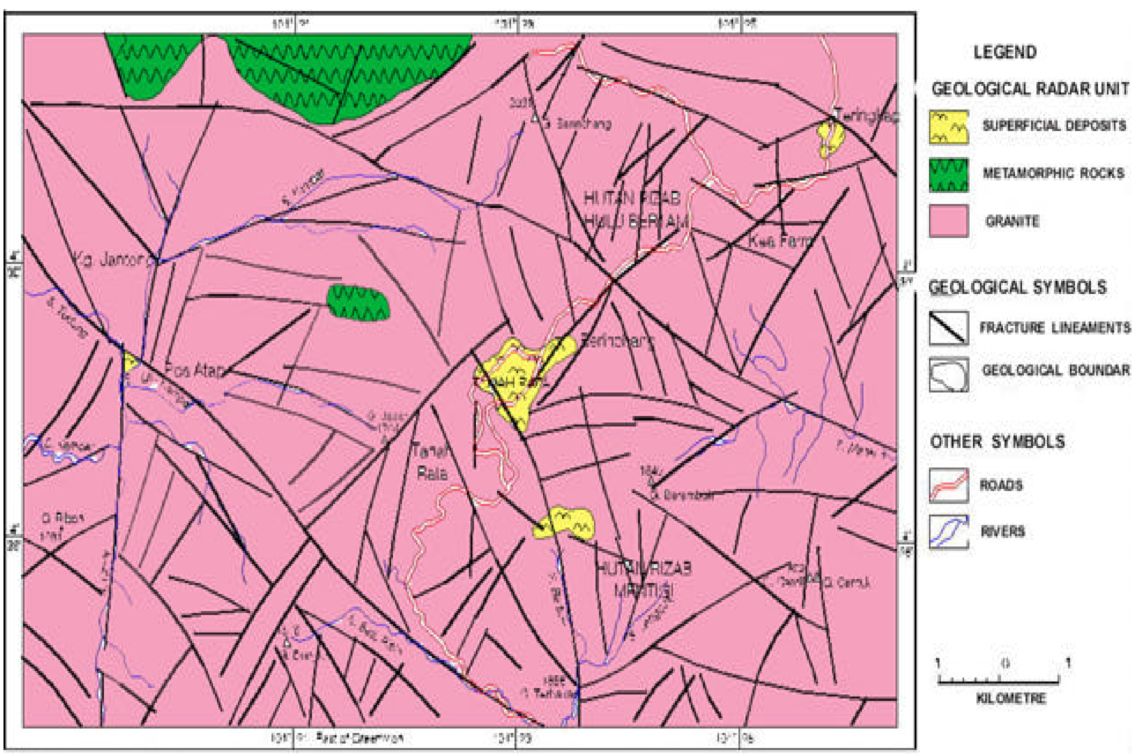


Figure 7c: Photo-geology Map of Cameron Highlands

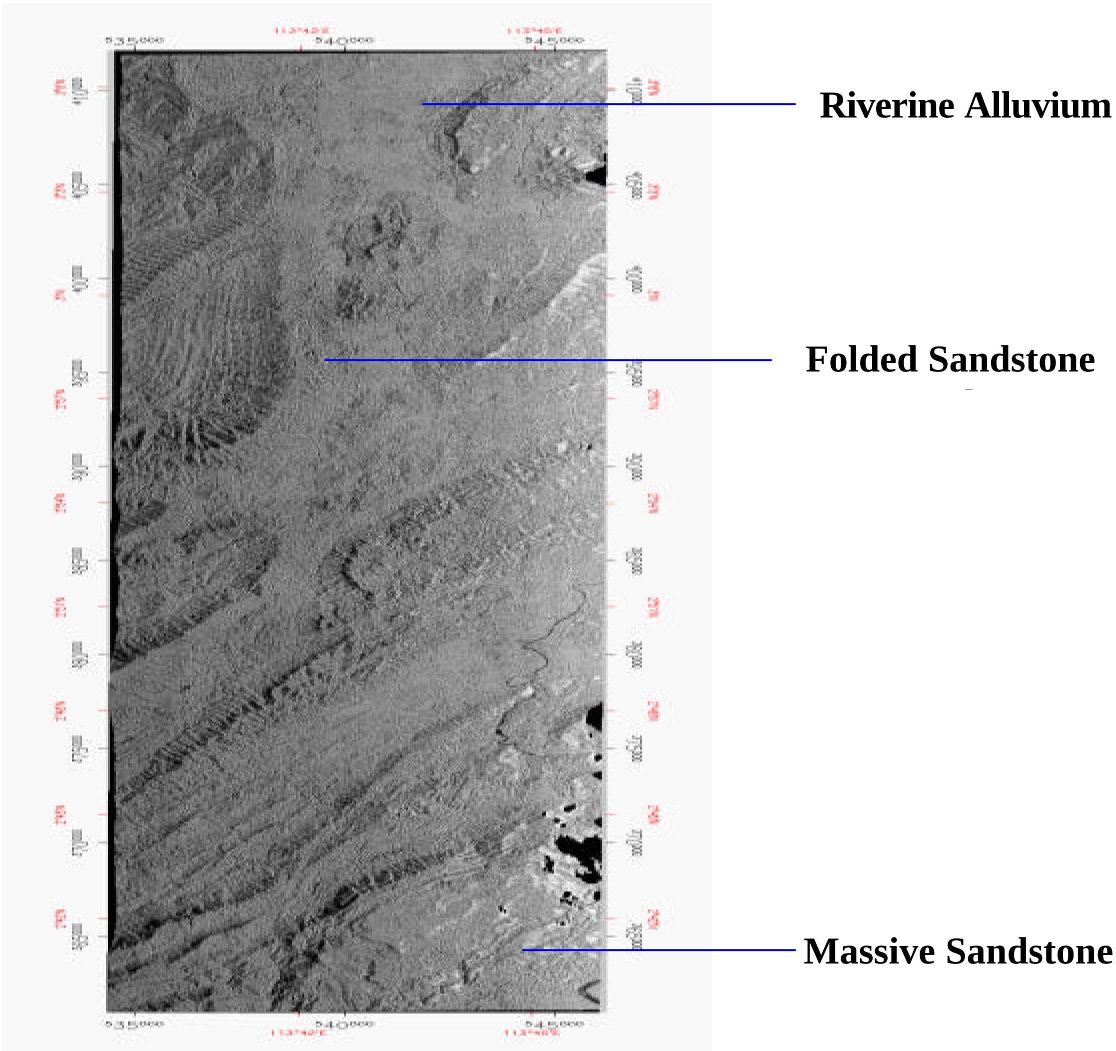


Figure 8: The Cvv Polarization Image of the Tubau area

Land Cover Discrimination

Noh et al.(1999) and Laili et al.(1999) studied on SAR backscattering characterization and polarization signatures of common cover types using TOPSAR data. Polarization signatures and radar backscattering coefficients of L and P frequencies were studied but C band data was not available for comparison. Lvv shows the best discrimination among the cover types (Figure 9). Figure 10 gives the polarization signature plots of the various cover types, which are distinguishable by shape or pedestal height. For instance, forest and rubber have almost similar shapes but differ in their pedestal heights

With the experience gained by Malaysian investigators in PACRIM 1, the country was all geared up to participate in PACRIM 2 in 1999. Both AIRSAR and MASTER data were acquired over 11 sites in Malaysia on September 19-21, 2000. The MASTER data were processed and delivered to MACRES while the AIRSAR dat are expected to be delivered by June 2002. Nineteen applications development projects, involving 10 research institutions, were planned fro PACRIM 2. These projects cover vegetation analysis; soil characterization in steepland; highlands development, agriculture plantation management, urban planning, mineral exploration; coral reef characterization; coastal biophysical characterization and hazard monitoring; hill forest resource mapping; wetlands characterization; biodiversity study; and marine study.

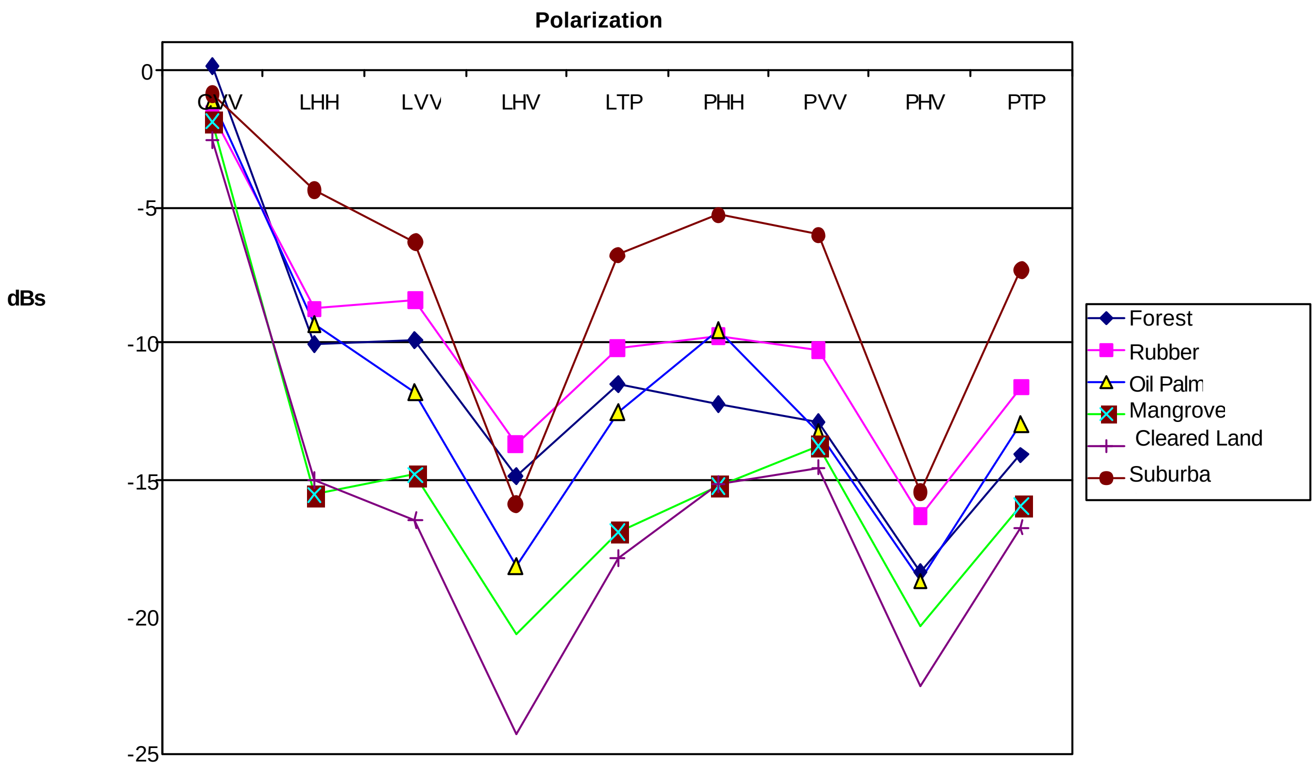


Figure 9: Radar Backscattering Coefficient of Land Cover Types

Conclusion

Malaysia has gained immense experience in the use of SAR data for application development through its participation in several international programmes. Participation in the AIRSAR PACRIM-1 has provided us useful insights in the full complement of state-of-the-art SAR polarimetric and interferometric applications in various fields. MACRES is grooming a team of researchers trained and skilled in microwave remote sensing. With the availability of the field scatterometer and anechoic chamber MACRES and other researcher in the country will be able to conduct fundamental research to better understand scattering properties of different targets and imaging mechanism of multi-frequency and multi-polarized radar data.

SAR sensor development for both airborne and space platforms has also been planned. Work on the C band imaging radar airborne sensor has started in 2001 and it is expected to be completed in 2002.

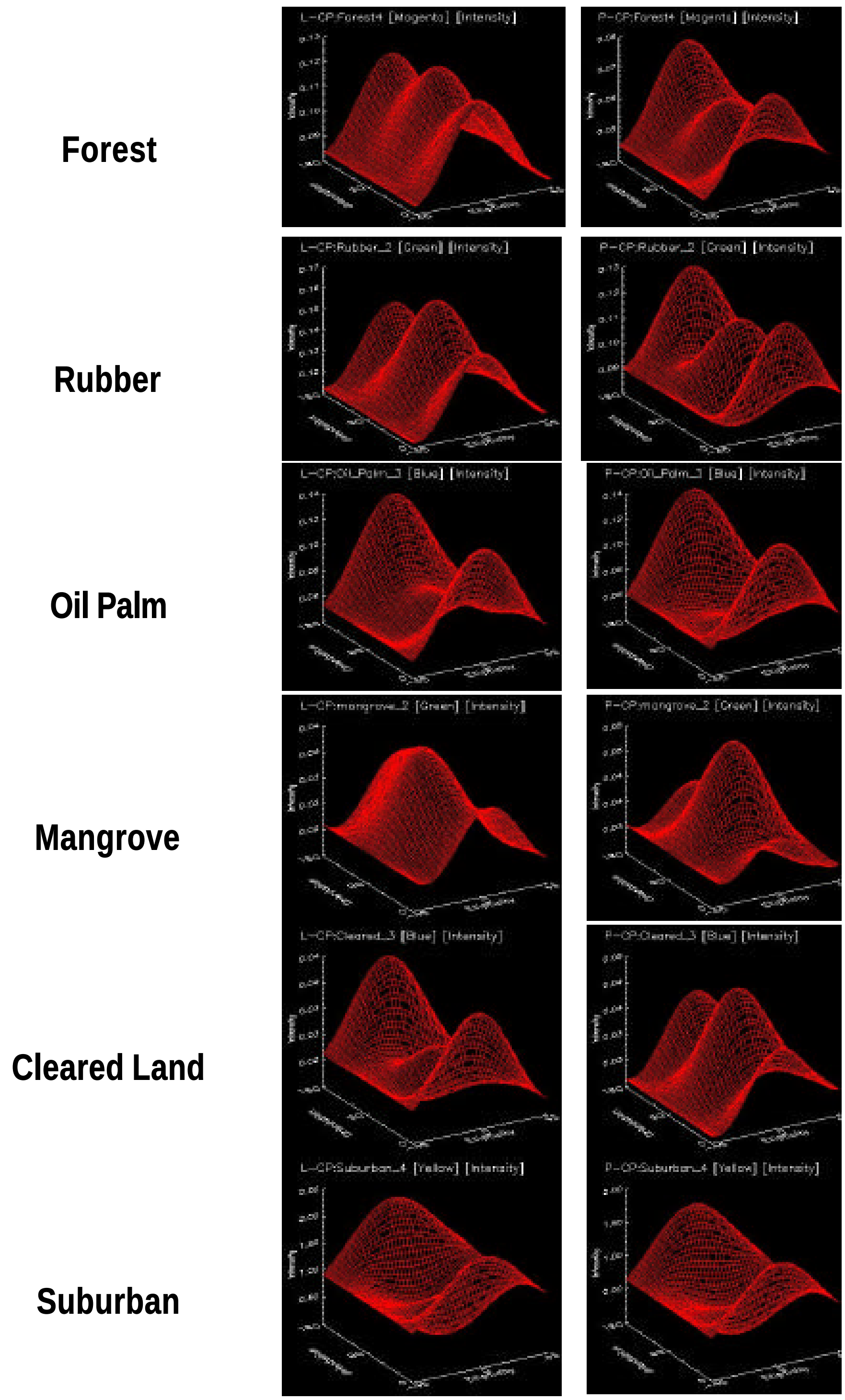


Figure 10: Polarization Signature of Major Cover Types at L and P Bands

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