

## **SAR DATA ANALYSIS FOR WAVE SPECTRUM, BATHYMETRIC, AND COASTAL INFORMATION**

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**KEY WORDS:** JERS-1 SAR, Fast Fourier Transform, TNO model, Classification

**ABSTRACT:** In this study, JERS-1 SAR data were examined and analyzed for extraction of coastal information, namely: (i) wave spectra, (ii) sea bottom topography, (iii) mangrove species classification, and (iv) mangrove forest biomass. The wave spectra were extracted using Fast Fourier Transform whilst, the TNO model were examined and analysed for the relationship between the backscatter and the sea bottom topography. The classification of SAR data to mangrove species level were performed using combined inparametric-parametric approach together with image segmentation technique. The allometric relationship between tree features and total weight were used as basis for modelling the biomass from SAR backscatter. The results of this study indicates that wave spectra can be extracted from JERS-1 SAR data, but it is rather restricted to certain sea condition to enable sea bottom topography be modelled from the backscatters. SAR data were found able to map mangrove at species level with an accuracy of 62 percent, and were also found as good estimator for biomass in the range 301-400 ton/ha with an overall 50 percent accuracy, at par with in-situ survey.

### **1. INTRODUCTION**

Over the past two decades, remote sensing techniques have found wide area of applications in natural resource management, environmental protections as well as in strategic planning. The data used for these applications include the all data captured ranging from visible to microwave region of the electromagnetic spectrum, acquired from various platforms at variable spectral, spatial and temporal resolutions depending on scale of information required. Active remote sensing systems that capture data in microwave spectral region is one of the recent development in remote sensing of which its potential has not been fully utilized despite its advantage that can acquire data in all weather conditions. Synthetic aperture radar (SAR) are sensors normally used in the active remote sensing system, and data captured widely known as SAR data. In operational satellite remote sensing systems, most SAR sensors captured data in C and L bands. This paper reports one of the studies carried out at UTM as part of contract research to NASDA, Japan in Global Rainforest Mapping using JERS-1 SAR data (Hashim et al, 1999). In fact this is one of its R&D works on method to extract related information for various applications at operational level (Mohd Ibrahim et al, 1997; 1999). The SAR data analysis for coastal information extraction is emphasized in this study. The utility of JERS-1 SAR data were examined and analyzed for (i) wave spectra, (ii) sea bottom topography, (iii) mangrove species classification, and (iv) mangrove forest biomass.

## 2. MATERIAL AND METHOD

### 2.1 Image data

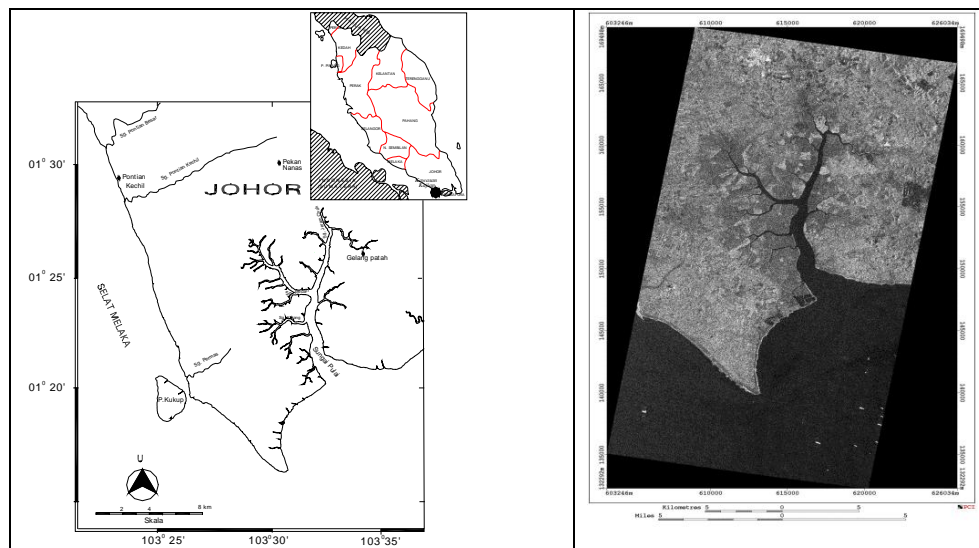
The JERS-1 (pre-processed at level 2.1 by NASDA) data was used in this study. This data have already been compensated for range correlation, azimuth correlation with range migration and geometric correction using MRSO (Malayan Rectified Skew Orthomorphic Projection). Specification of the data is tabulated in Table 1. The ancillary information used to support the study which includes the corresponding area topographic map (1:50,000 scale), related forestry records and documents, in-situ sea measurements were used as ground reference data.

**Table 1** : Specification of JERS-1 SAR data employed in the study.

Sensor	JERS-1
Acquired date	Sept. 28, 1994
Pixel size / resolution	18 meter
Wavelength	23.5 cm
Polarization	HH

### 2.2 Study area.

In order to validate of SAR data in extracting information pertinent to classify mangrove at species level and to estimate the biomass, a study area which is located in the southwest of Johore, Malaysia (Figure 1). The study area covers approximately an area of 12.3 km x 18.0 km (centered at  $103^{\circ} 16'$  E lat. and  $1^{\circ} 13'$  N long.). In the past decade, this area although has been demarcated as reserve forest but lately has also been given way to conversion for land related development programs such as development of new port, aquaculture, charcoal-making industry as well as residential area for supporting the newly developed industries. The wave spectra analysis is carried out in the adjacent coastal area.



**Figure 1** : The study area Southwest Johore coastal water and corresponding JERS-1 SAR data of the area.

### **2.3 Field Data**

Ground truthings were carried out for two reasons: (a) verifying the classified SAR data for accuracy analysis, and (b) to make in-situ measurements for biomass estimation. For verification, survey random samples were identified in the field where the position and corresponding class were noted, which later used in contingency matrix for classification assessments. Global positioning system is used in recording the positions of samples collected. In the biomass estimation, measurement of mangrove tree samples at selected sites for consist of the tree basal area, dbh (diameter at breast height), biomass by parts and density of trees. For the wave spectra studies, the climate data published by both Malaysian and Singapore Meteorological Department were used to analysed the results, while the nautical chart of the area is used in examining bathymetric analysis.

### **2.4 Data Processing**

#### **2.4.1 Minimizing speckle**

Minimization of speckle effects in SAR data are commonly carried out using adaptive radar filters (Lopes et al, 1990). In this study, Lee-Sigma filter at window size 7x7 showed the best result over mangrove forest in both images. This selection was made based on the analysis of the mean vectors before and after filtering operation as well as the coefficient of variance (Paudyal and Aschbacher, 1993).

#### **2.4.2 Wave spectra analysis**

Wave spectra is extracted using 2- dimensional Fast Fourier Transform (2-DFFT), The image over sea region was subset (200 pixel x 200 pixel) and applied the 2-DFFT. Wave spectrums are derived from JERS-1 image have been demonstrated to provide wavelengths and directions.

#### **2.4.3 Bathymetry Model**

In this study, SAR bathymetry model implemented using TNO model. This model is based on the action balance equation, weak hydrodynamic interaction theory and Bragg scattering (Vogelzang,1989). In this work the radar backscattering cross section of the sea surface has been simulated and analyzed.

#### **2.4.4 Image Classification**

The extracted pixels within the mangrove boundary were classified using combined inparameteric-parametric approach with maximum likelihood classifier. In this approach, the spectral classes generated in the unsupervised approach are refined based on the existing forestry records and ancillary data. Once the samples from all available classes within the area are known, training areas and signature vectors of these classes were then generated before supervised maximum likelihood classification was performed. Apart from classification algorithm, image segmentation were also examined using region growing algorithm to segment the mangrove-non mangrove boundaries, and then sub-segment for smaller fragments of mangrove.

#### **2.4.5 Biomass Estimation**

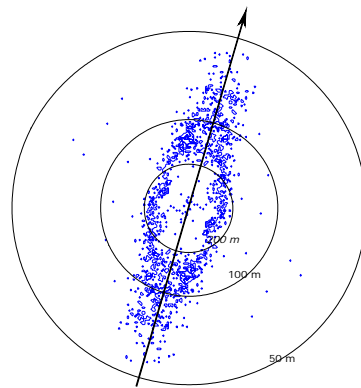
In this study, we focused on the estimation of mangrove biomass from radar backscattering of JERS-1 SAR data. Regression analysis of the sample biomass measured in the field with radar backscatter coefficient of JERS-1 SAR were

examined using stepwise regression approach. Based on the regression analysis, the parameters describing the relationship of mangrove biomass to radar backscatter were used to calculate the biomass of the entire area. The computed biomass was then compared with the recently surveyed biomass of the area by Forestry Department (1996).

### 3. RESULTS

#### 3.1 Wave spectra

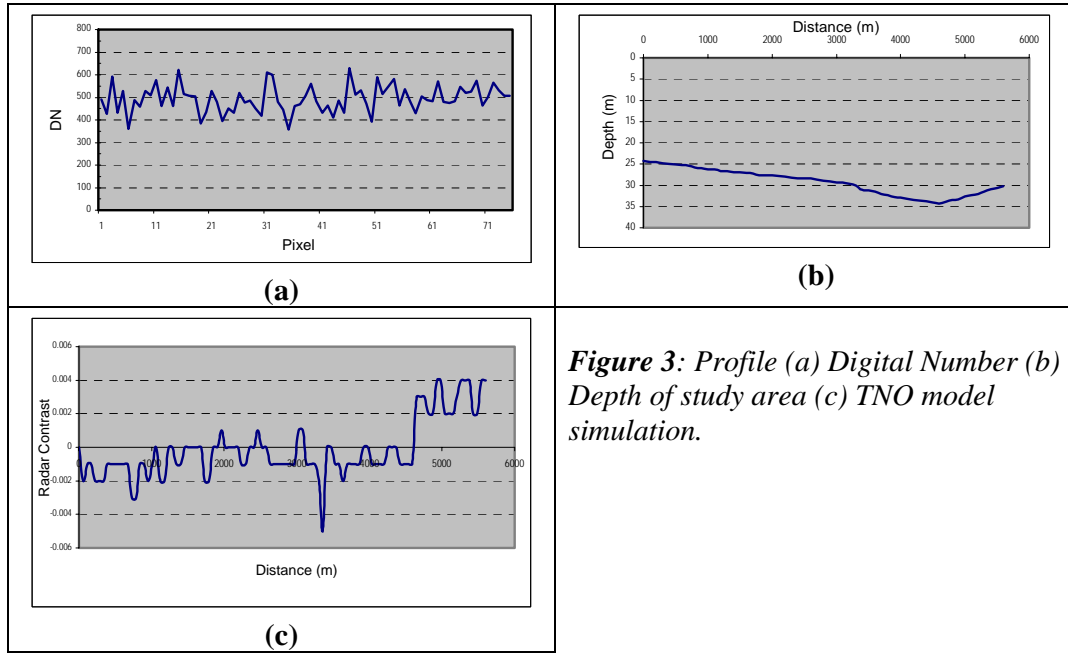
The penetration depth of microwave radiation in sea water is less than a centimetre and since the dielectric properties of the sea surface are relatively uniform, backscatter from the sea is dominated by surface scatter and hence sea's state can be inferred from. Calm seas cause specular backscatter, reflecting away from radar antenna ; while rough seas produce higher backscatter (Alpers; 1992). The signature of wave information is shown in Figure 2 derived using 2-D fast Fourier Transform. Circle and arrow represent ocean wavelength and direction respectively. The spectra sets derived show that the wavelength concentration is at 120m in northeast direction.



*Figure 2: Wave spectra derived from single frame of SAR image.*

#### 3.2 Bathymetry analysis

The understanding of the radar imaging mechanism of underwater bottom topography has been improved since the first attempt by Alpers and Hennings in 1984. The results are shown in Figure 3(a), 3(b) and 3(c). The contrast profiles produced by the model were compared to profiles extracted from JERS-1 image. Imaging of bathymetry in shallow water seas depends on the presence of a (tidal) flow at the time of imaging, as well as the wind speed having an intermediate value (not extremely low or high). The results obtained in this study indicated that the model examined is not valid to the relatively calm sea condition at the test site, suggested that new bathymetric model for sheltered sea with rather smoothen sea-surface need to be developed. Works on the later is now in progress at UTM.



**Figure 3:** Profile (a) Digital Number (b) Depth of study area (c) TNO model simulation.

### 3.3 Image Classification

Inparametric-parametric approach with maximum likelihood classifier was performed on JERS-1 (Figure 4). Seven classes can be defined from JERS-1 where dominant species is *Rhizophora sp* and it covers it 45.2 % of JERS-1. The overall classification result indicates that JERS-1 for mangrove species was found at 62 %, and therefore, suggested that further development in pre-classification operation need to fully addressed.

### 3.4 Biomass Estimation

The stepwise regression analysis indicated that mangrove biomass in JERS-1 SAR can reasonably be estimated by:

$$\text{Log (B)} = 0.0894\sigma^{\circ} + 3.4841 \quad (1)$$

where

B is the total biomass in ton/ha.,

$\sigma^{\circ}$  is the radar backscatter coefficient derived using  $20 \log (\text{DN}) - 68.5$ , and

DN is the digital number recorded from image.

The computed biomass using the relationship is shown in equation (1) Figure 5. These computed biomass is then compared with biomass derived using most recent record of tree-age of the area compiled during fieldwork on 1998. Using random generation of more than 100 samples, the overall average accuracy of computed biomass in the seven tonnage categories is found only at 50 %. This, however is at par with most biomass estimation using in-situ surveys carried out in normal practice. The spatial distribution of the biomass categories in this study demonstrated its main advantage that it is not able reported in the conventional biomass surveys.

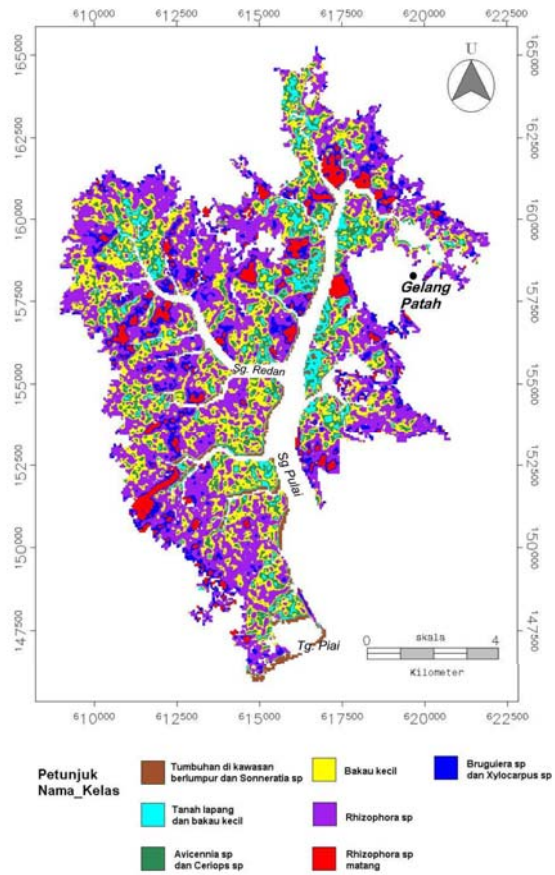


Figure 4: Mangrove species classified using JERS-1 SAR. data

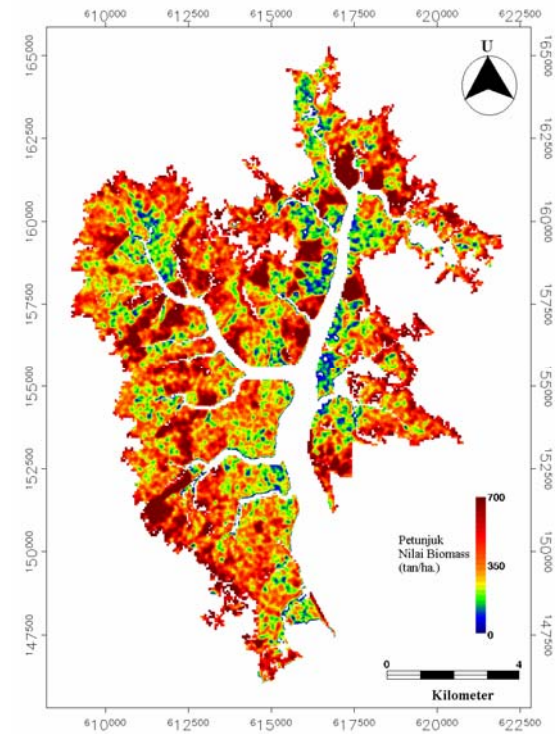


Figure 5: Biomass estimated derived from JERS-1 SAR

#### 4. SUMMARY

In this study, JERS-1 SAR data were examined and analyzed for extraction of coastal information, namely : (i) wave spectra, (ii) sea bottom topography, (iii) mangrove species classification, and (iv) mangrove forest biomass. The results of this study indicates that wave spectra can be extracted from JERS-1 SAR data, but it is rather restricted to certain sea condition to enable sea bottom topography be modeled from the backscatters. SAR data were found able to map mangrove at species level with an accuracy of 62 percent, and were also found as good estimator for biomass in the range 301-400 ton/ha with an overall 50 percent accuracy, at par with in-situ survey. Further works to understand the interaction of backscatter to targets of interest as demonstrated in this study is one of UTM on-going effort to extract information from SAR data at operational level.

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