Comparative performance of ALOS PALSAR polarization bands and its combination with ALOS AVNIR-2 data for land cover classification

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Abstract. Microwave Remote Sensing data have been widely used for land cover classification in our environment. In this study, ALOS PALSAR polarization bands were used to identify land cover features in three study areas in Malaysia. The study area consists of Penang, Perak and Kedah. The aims of this research are to investigate the performance of ALOS PALSAR datasets which are assessed independently and combination of these data with ALOS AVNIR-2 for land cover classification. Standard supervised classification method Maximum Likelihood Classifier (MLC) was applied. Various land cover classes were identified and assessed using the Transformed Divergence (TD) separability measures. The PALSAR data training areas were chosen based on the information obtained from ALOS AVNIR-2 datasets. The original data gave very poor results in identifying land cover classes due to the presence of immense speckle. The extraction and use of mean texture measures was found to be very advantageous when evaluating the separability among the different land covers. Hence, mean texture was capable to provide higher classification accuracies as compared to the original radar. The highest overall accuracy was achieved by combining the radar mean texture with ALOS AVNIR-2 data. This study proved that the land cover of Penang, Perak, and Kedah can be mapped accurately using combination of optical and radar data.

1. Introduction
Satellite based remote sensing has made considerable progress over the last three decades. Through research and development it has proven its usefulness for economic planning, resource management, environmental studies, restoration projects and disaster preparedness. It has become a powerful tool for the assessment of land use and land cover in terms of localisation, quantification, change detection, vegetation, and crop health assessment. It has also become important for monitoring the occurrences of catastrophic events such as fires, storms, droughts, floods, and pest outbreaks [1]. Over the past few decades, manual and computer-assisted image interpretation techniques were applied to optical Landsat MSS, Landsat TM, SPOT and ALOS imagery to classify land cover [2]. The manual interpretation was also aided with color infrared visual analysis. The availability of the spaceborne Synthetic Aperture Radar (SAR) data, which is considered in this study, has provided the scope for mapping crops even in the wet season where cloudy conditions are common [3]. The possibility of all weather, day-and-night operation, and the ability to penetrate through clouds and other features, gives SAR some advantages over the optical systems [4]. The purpose of this study was to evaluate and improved multisensor data sets of spaceborne radar for the delineation of land cover areas in Malaysia. Initial analyses were conducted to determine methods to improve the classification accuracy from radar. These methods included speckle reduction, texture measures, and various combinations of these techniques. Combination of SAR and optical images can take advantage of the

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complementary nature of these data, and could potentially enhance the classification accuracy [5-6]. The best radar manipulations were merged with ALOS AVNIR-2 data through simple layer additions.

2. Study Area
A number of study areas have been chosen which are located in northern peninsular Malaysia. These study areas include eastern part of Penang Island and Butterworth, northern part of Perak and southern part of Kedah are shown in Figure 1.

![Figure 1. Location of the study area](image)

2.1 Penang
Penang is the second smallest and one of the thirteen states of Peninsular Malaysia. The study area is located in the eastern part of Penang Island and a portion of mainland called Butterworth. The geographical extent of the study area is between 578153.554mN and 612053.554mN and between 644065.806mE and 658690.806mE (Figure 1), which covers an area of approximately 510 km² (15 km x 34 km). The ALOS PALSAR image for Penang was acquired on 14 April 2009 (Figure 2a), and the ALOS AVNIR-2 imagery on 15 December 2009. The satellite images for Penang were acquired at different dates. However, this would not bring any impact factor for land cover since both images were acquired in the same season. The seven classes identified for Penang are water, residential, urban, oil palm, paddy, bare land and forest.

While the island has an amazingly constant temperature, Penang’s tropical location subjects to annual monsoons. The average temperature varies between 27 °C to 30°C throughout the year [7]. The mean daily humidity varies between 60.9% and 96.8%. The two rainy seasons are southwest monsoons from April to October and north-east monsoons from October to February with annual rainfall averages 2670mm [8].

2.2 Perak
The state of Perak is Peninsular Malaysia’s second largest at 21,000 km² wide [9], making up 6.4 percent of total land banks in Malaysia. The second study area is located in northern part of Perak. The area extends approximately from 534456.281mN to 581056.281mN and 649752.028mE to 668202.028mE, which covers an area of approximately 893 km² (19 km x 47 km) (Figure 1).
ALOS PALSAR imagery (Figure 2b) was acquired during the hot and dry season on 14 April 2009 and the ALOS AVNIR-2 image was acquired on 30th July, 2009. The ALOS AVNIR-2 images were acquired during the rainy season. However, this difference in seasonality should not be an impacting factor, as most of the land covers/uses identified for this study site are not affected by seasonality. The Perak's states climate is tropical monsoon, with offers bright sunny days and cool night’s whole year through. Temperature is fairly constant, varies from 23°C to 33°C, with humidity normally above than 82.3%. Annual rainfall measures at 3,218 mm [10].

2.3 Kedah
Kedah which sits up high in the northwest corner of Peninsular Malaysia is a fairly small state covering an area of 9,425 km² and its highest peak is Gunung Jerai, at 1200 meter above sea level. The final study area is located in southern part of Kedah, Malaysia (Figure 1). The area extends approximately from 593223.562mN to 639986.062mN and 662661.965mE to 677974.465mE, which covers an area of approximately 705 km² (15 km x 47 km). The ALOS PALSAR imagery (Figure 2c) was acquired during the hot and dry season on 14 April 2009 and the ALOS AVNIR-2 image was acquired on 30th July, 2009.

The natural land cover was tropical broad-leaf rainforest. Now, forest remains only in the upland areas. The lowland areas are covered by rice paddy and other oil palm, field crops, roads, streams, bare land, and urban. Kedah enjoy a warm equatorial climate the whole year, with a uniform temperature between 21°C to 32°C throughout the year. From January to April, dry and warm weather with consistently high humidity on the lowlands averaging from 82 to 86 % per annum. Kedah's average annual rainfall falls between 2,032 mm to 2540 mm with the wettest month from May to December [10].

3. Methodology
ALOS PALSAR datasets were acquired from Japan Aerospace Exploration Agency (JAXA) are converted from the original format to the GeoTiff product which compatible with most of the remote sensing software. ASF MapReady 2.3 was used to convert the original format to 32-bit floating point GeoTiff files. A 30 meter resolution GDEM of the image in the same geometric projection was used to perform the terrain correction. The terrain correction process alters the data in the SAR image, attempting to correct for the side-looking geometry of SAR. After the terrain correction applied, a terrain corrected geocoded image was produced. The information for geocoding was extracted from
the metadata. Sigma nought radiometry in the scaled decibels (dB) was chosen as the output results. The images were projected to Universal Transverse Mercator projection with UTM 47 N E012 WGS84 Ellipsoid. All images were accurately georeferenced at 12.5 meter pixel size using the nearest neighbor method. ALOS AVNIR-2 satellite image was rectified using second order polynomial coordinates transformations to relate certain coordinate system using two-dimensional (2D) ground control points in the georeferenced datasets to their equivalent row and column position in the ALOS AVNIR-2 scenes. After applying the necessary data processing techniques, further process was carried out to obtain certain information. In order to achieve the objectives, image enhancement methods such as transform divergence, speckle filtering, texture analysis, layer stacking, and data combination were performed. Standard supervise classification technique Maximum Likelihood Classifier was used [8]. Training site was chosen based on the stable points. The stable area as refer to ALOS AVNIR-2 satellite image used to assist the training area selection process. In the accuracy assessment step, randomly 1000 sample points were chosen throughout the image. Thus, the accuracy report can be generated for the specific classification image after the random samples have been collected. Two methods of accuracy assessments were tested in this study, the overall classification accuracy and kappa coefficients [11].

4. Data Analysis And Results
Prior to undertaking the analysis and subsetting the data, it is useful to view the statistical values for the data. Backscattering coefficient for the Regions of Interest (ROIs) where extracted from the Sigma Nought corrected PALSAR images. Visual interpretation and radar backscattering coefficient value were used to categorize the land cover classes. Different types of land cover and soil surface conditions will produce different backscattering coefficient. All three study areas had average separability for the various classes in the original radar datasets. The separability for a few land covers in all three study sites was quite low, i.e., below 1,500. These were classes which had similar DN values (spectral signatures) resulting in poor separability. MLC were applied with different combinations of polarization to the original radar, radar filtered, and radar texture and sensor combination. The classification accuracies with Overall Accuracy (OA) and the Kappa Coefficient of agreement for original radar, Frost filtered, Mean radar texture, radar combination and sensor combination are tabulated in table 1.

| Method                 | Penang OA  | Penang Kappa | Perak OA | Perak Kappa | Kedah OA  | Kedah Kappa |
|------------------------|------------|--------------|----------|-------------|------------|-------------|
| Original radar         | 72.1       | 0.595        | 73.4     | 0.641       | 67.8       | 0.526       |
| Frost Filtered radar   | 79.2       | 0.705        | 80.7     | 0.737       | 68.6       | 0.531       |
| Mean Radar Texture     | 80.3       | 0.713        | 82.3     | 0.761       | 75.6       | 0.625       |
| Radar Combination      | 81.4       | 0.721        | 83.1     | 0.782       | 80.6       | 0.729       |
| Sensor Combination     | 97.1       | 0.981        | 92.6     | 0.898       | 92.2       | 0.871       |

The frost filtered images gave significantly better results than the original radar images but still not adequate for accurate land cover classification. The use of texture on all radar images proved to be an excellent procedure for increasing the separability among classes. Class pairs which were inseparable in the original radar dataset showed major improvements when texture was applied. Based on the Table 1, it can be concluded that mean texture would have an important role in improving the classification accuracies. The use of texture is viable option for land cover classification in this study. Combination of separate radar images was found to increase the accuracy over that of a single image alone. The combinations that included a speckle filtered, as well as a texture image were showed an impressive improvement in the classification accuracies. Based on the results for these study sites it can be concluded that combination sensor is an excellent technique for increasing classification accuracies. Another advantage of combining different datasets is the fact that it helps reduce any inconsistency during classification. The highest overall accuracy was achieved with a merger that
included the best individual mean texture image and four reflectance bands of the ALOS AVNIR-2 data. Figure 3 show the classified images of the best classification results of radar texture with ALOS AVNIR-2.

Figure 3 Classified map of radar texture with ALOS AVNIR-2 data [color Code: Green=Paddy, Blue=Water, Pink=Residential, Yellow=Bare Land, Dark Green=Forest, Brown=Oil Palm, and Red=Urban]

5. Conclusion
The research in these three study areas was analyzed using the same methodology which proved to be extremely valuable as it helped exclude discrepancies in the results and made it easier to compare results across all three study areas. The goal of this study was to explore the possibilities that this recently available quad polarization radar data offers and its effectiveness in classifying land cover/use in diverse regions around the world. The results from this study can potentially be extended to other sites to improve classification accuracies by fusing different sensor technologies.

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