Land Cover Classification Using ALOS Imagery For Penang, Malaysia

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Abstract. This paper presents the potential of integrating optical and radar remote sensing data to improve automatic land cover mapping. The analysis involved standard image processing, and consists of spectral signature extraction and application of a statistical decision rule to identify land cover categories. A maximum likelihood classifier is utilized to determine different land cover categories. Ground reference data from sites throughout the study area are collected for training and validation. The land cover information was extracted from the digital data using PCI Geomatica 10.3.2 software package. The variations in classification accuracy due to a number of radar imaging processing techniques are studied. The relationship between the processing window and the land classification is also investigated. The classification accuracies from the optical and radar feature combinations are studied. Our research finds that fusion of radar and optical significantly improved classification accuracies. This study indicates that the land cover/use can be mapped accurately by using this approach.

1. Introduction

Land cover classification based on remotely sensed data has attracted great attention since the launch of Landsat MSS, Landsat TM, and SPOT imagery [1-5]. The availability based on remote sensing data applicable for global, regional and local environment monitoring has greatly increased over recent years. Although optical sensors have been successfully and heavily used for land cover classification throughout the world’s humid tropical biomass, cloud cover still presents a challenge to continuous observation. With the launch of new spaceborne radar systems, including ALOS PALSAR, RADARSAT-2 and TerraSAR-X, may prove beneficial to the collection of current and reliable land surface information which is especially valuable when optical sensor data are not available due to cloud cover. [6-9]. Radar data are often acquired at one wavelength with different polarization options. How to effectively use the spatial information inherent to the radar data to generate new images becomes an important research topic. Combination data from multiple sensors, i.e., Landsat and radar has proved to be an exceptionally efficient technique in reducing the overall ambiguity in the datasets. Previous studies have suggested an increase in the overall classification values by combining multiple datasets together. The combination of SAR data and optical images gives significantly higher classification accuracy than using a single type of data [10]. The objective of this study was to examine and improve upon the classification accuracy of specific land cover categories by utilizing these portions of the electromagnetic spectrum at a study site located in Penang Island, Malaysia. Initial analyses were conducted to determine methods to improve the classification accuracy from radar. These methods included spatial filtering, texture measure and sensor combination. Standard Supervised classification technique of maximum likelihood (ML) decision rule was applied [11]. The monitoring task can be accomplished by supervised classification techniques, which have proven to be effective categorization tools [12-13]. Post-classification of accuracy assessment also was carried out in this study.

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2. Study Area
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).

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

3. Methodology
In this study, we used the ALOS PALSAR Quad polarization Level 1.5 Products with HH, HV, VH and VV polarizations options (ground range, unsigned 16-bit integer number, 12.5m pixel spacing). The ALOS PALSAR imagery (Figure 2a) was acquired on 14 April 2009. The radar image quality was carefully examined. ASF MapReady 2.3 program 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. After the terrain correction applied, a terrain corrected geocoded image was produced. Figure 2b shows the raw ALOS AVNIR-2 satellite image acquired on 15 December 2009 was used for the selection of training areas and validation the land covers type. The speckle in a radar image is often a problem. Speckle should be reduced before the radar image is used for further quantitative analysis. Finally, the Frost filter with a window size of 9 x 9 pixels was selected for this study. The speckle-reduced radar images were directly used for landcover classification. Meanwhile, textural images were developed from the raw radar images by using different texture measures and various window sizes. Maximum likelihood classifier was used to conduct land cover classification. The classification results were evaluated with the error matrix method and the best scenario was further analyzed with different classification algorithms. Spectral signatures were extracted for the seven land covers type namely water, urban, forest, oil palm, bare land, paddy and residential. Sample plots for different land cover types, were collected in the study area during field visitation. The sample plots were used to create representative Region of Interest (ROI) polygons. A total of 500 sample plots were collected, including 250 ROIs for use as training sample plots during image classification and the rest 250 ROIs for use as test sample plots for accuracy assessment. The accuracy from this study was determined from the overall classification accuracy and kappa coefficient.
4. Data analysis and result

Classification accuracies for the original radar data have been summarized in Table 1. The overall classification accuracy when all four radar bands are combined is 72.0% and Kappa coefficient 0.595. The frost filtered images gave significantly better results than the original radar images. While all four bands were combined, overall accuracy and kappa coefficient has increased from 72.0% to 79.2% and 0.595 to 0.705 respectively. The use of filter was a slightly improvement over the moderate results achieved with the original radar data but still not adequate for accurate land cover classification. Mean texture yielded the best separability results, and hence it was selected for the next step of classification. In particular it was the 11 x 11 mean textures that showed the most improvement over the original and Frost filtered radar. Table 1 show the classification accuracies and kappa coefficient for the four stacked bands. A detailed discussion on the different texture measures (Mean Euclidean Distance, variances, Skewness, median, and Kurtosis) and window sizes is beyond the scope of this paper, and hence the results have not been summarized. All four ALOS AVNIR-2 bands were stacked with the all four Mean radar texture quad polarization bands (HH, HV, VH, and VV). Table 2 summarizes the classification accuracies for the two datasets. The overall classification accuracies and kappa coefficient for combinations of radar texture with ALOS AVNIR-2 are 97.0% and 0.981. In term of producer accuracy, all classes were greater than 80%. The user accuracy for all classes also exceeds 80%. This implies that combinations of radar texture with ALOS AVNIR-2 have greatly improved the overall consistency and reliability of the classification. A classified image of the radar texture with ALOS AVNIR-2 has shown Figure 3.

**Table 1.** The Overall Classification accuracies and Kappa Coefficient.

| Method                        | Overall Accuracy (%) | Kappa Coefficient |
|-------------------------------|----------------------|-------------------|
| Original Radar                | 72.0                 | 0.595             |
| Frost Filtered Radar          | 79.2                 | 0.705             |
| Mean Texture Radar (11 X 11)  | 80.0                 | 0.713             |
| Sensor Combination            | 97.0                 | 0.981             |
Table 2 Classification accuracies radar texture with ALOS AVNIR-2, Penang.

| Land cover/uses | combination of Radar texture with ALOS AVNIR-2 | User's Accuracy |
|----------------|-----------------------------------------------|-----------------|
| Water          | Water 280 Bare land 1 Forest 0 Oil palm 1 Paddy 0 Residential 0 Urban 0 | 99.3            |
| Bare land      | 1 23 0 1 2 0 1 1 | 85.2            |
| Forest         | 0 0 30 1 0 1 1 1 | 90.9            |
| Oil palm       | 0 0 0 8 0 0 0 0 | 100.0           |
| Paddy          | 0 1 0 0 39 0 0 0 | 97.5            |
| Residential    | 0 0 0 0 21 0 0 0 | 100.0           |
| Urban          | 1 0 0 0 0 3 8 4 | 95.5            |
| Producer’s Accuracy | 99.3 92.0 100.0 80.0 92.9 84.0 97.7 |                 |

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 results of this study show that ALOS-PALSAR data was incapable of accurately delineating all Seven of the land cover types of this area. Speckle filtering improved considerable improvement over the poor results achieved with the unfiltered, original radar data. The extraction and use of Mean texture measures was found to be very advantageous. The study areas for Penang greatly improved classification accuracies while using ALOS AVNIR-2 combined with radar.

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