Identifying Natural Revegetation of Mine Waste Using Compact Polarimetry

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Abstract

Mining waste poses a considerable threat to surrounding environments. Great effort must, therefore, be made to monitor and rehabilitate broad zones where mine tailings are deposited. This paper presents an approach to observe natural revegetation on a tailings deposition zone using C-band fully polarimetric Synthetic Aperture Radar (PolSAR). Since PolSAR acquisition generally consumes high energy, we evaluate the possibility of halving transmitted energy using compact polarimetry theorems. In this paper, three compact polarimetric techniques and two modes of reconstruction are studied to reconstruct PolSAR data and assessment is performed using Pauli decomposition. We conclude that compact polarimetry can be exploited to some extent. If PolSAR reconstruction is needed, this research demonstrates that the Polar State extrapolation generates a Covariance Matrix closely resembling the original PolSAR data. Natural forests are generally well recovered; however, it appears that reeds are slightly over estimated.

Key words: Compact polarimetry, mine waste, Pauli decomposition, reeds, revegetation.

1. Introduction

Despite its significant economic returns, mining arguably contributes to environmental degradation. This generally applies in countries, including Indonesia, where monitoring relies on conventional, in situ observation. Remoteness of mining sites makes regular monitoring expensive. To date, remote sensing data have been employed to monitor mining waste extension and its rehabilitation.

Some optical sensors have been favoured due to the abundance of datasets. Multi-spectral imageries such as Landsat have proved to be useful for monitoring an extending tailing zone (Paull et al. 2006). Shang (2005) also concluded that hyper-spectral sensors can be used to monitor tailings with some degree of accuracy. However, those sensors have a limitation in tropical regions where cloud and haze are persistent. In this case, Synthetic Aperture Radar (SAR) is paramount to provide data with less atmospheric attenuation.

Tailings have been successfully identified among other land cover classes using SAR (Trisasongko et al. 2007). However, of key importance is the detection of recovering vegetation as an aide in rehabilitation planning. Previously, Touzi et al. (2004) proved that C-band ERS datasets are useful, despite the limitation of single polarisation in the detection. Trisasongko et al. (2012) extended the result by using fully polarimetric SAR (PolSAR) data to observe naturally grown reeds in Papua, Indonesia. Nonetheless, implementing PolSAR mode for mapping purposes requires substantially
higher power for transmitting the signals than in single and dual polarised mode. Employing PolSAR mode often sacrifices swath coverage to conserve the energy. Especially in the case of PALSAR, this strategy results in incomplete coverage of PolSAR and leaves a substantial gap between tracks.

To overcome the problem, Souyris et al. (2005) have proposed a compact polarimetric π/4 mode where only one linear wave is submitted while receiving normally (vertical and horizontal). A similar ‘hybrid’ method was proposed by Raney (2007). Despite its advantages, however, compact polarimetry is yet to be evaluated in various environments.

This paper discusses an evaluation of compact polarimetry to identify small, naturally growing reeds along a tailings deposition zone. Specifically, the paper compares PolSAR and reconstructed PolSAR using different approaches, and assesses their ability to discriminate reeds from woody vegetation.

2. Methodology

The research was situated in Timika, Papua, Indonesia, where an extensive area of tailings has been deposited along the Ajkwa River. PolSAR data were taken by AirSAR during the 2000 PACRIM airborne campaign. Only C-band PolSAR data were employed in this paper since L- and P-band were found least suitable for the identification of reeds (Trisasongko et al. 2007). The data have a spatial resolution about 3 and 4 meters in azimuth and range direction, respectively.

AirSAR data provided in multi-look detected format were converted into a covariance matrix using PolSARPro 4.0. From the PolSAR data, compact polarimetric components were simulated to allow direct comparison of both datasets. The following transmission configurations were performed: linear 45 degrees, left and right circular. During the compact polarimetry simulation, kernel size was set to 7. In order to obtain reconstructed PolSAR, two commonly-employed approaches were tested: polar state extrapolation (PSE) and rotation/reflection symmetry (RRS). All datasets were then compared qualitatively by visualising Pauli components of each dataset. Discrimination of land cover was performed using Jeffries-Matusita distance, only on the dataset that was visually the most similar to original PolSAR data. The following land cover classes were considered: reeds, water, disturbed and intact forests.

3. Results and Discussion

The Pauli composite of Ajkwa site is presented in Figure 1. In this figure, water is shown in dark blue, due to specular reflection of its smooth surface in all possible polarisations. Vegetation is presented in bluish green showing a strong volume scattering mechanism. Forested areas in the eastern part of the East Levee are intact with minor deforestation. The western part of the West Levee, on the other hand, is dominated by agriculture and mixed gardens, and appeared

Figure 1. Pauli composite of original PolSAR data.
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Figure 2. Pauli composite of reconstructed PolSAR.

In this research, reconstruction of PolSAR data was utilised to explore the capability of compact polarimetry using PSE and RRS algorithms (Figure 2). It appears that PSE generally generates a better visualisation that closely resembles the original Pauli composite of PolSAR data. There have been moderate discrepancies, however, observed in both the original and reconstructed Pauli composite. Forest and water courses are generally well reconstructed. Reeds and disturbed forest are visually separable from other land cover classes to some extent. Ambiguity is evident in dead forest stands where a high degree of disturbance occurs. Nonetheless, reeds are slightly overestimated in compact polarimetric images compared to the original PolSAR data. There is no feasible explanation to this constraint at present; however, we suspect that this would be related to the extrapolation algorithm.

Figure 3 provides a quantitative comparison between two primary compact polarimetric methods. In general, water and reeds are aligned in a 1:1 line, indicating that agreement is achieved in both land cover classes. Hence, for the purpose of simple detection, both linear-45 and circular left were robust. Variation tends to be higher in woody vegetated lands. Intact forests are plotted around the 1:1 region, despite an increase in variation. The figure, in contrast, displays high variance in both datasets. This is possibly due to variation of disturbance observed in the field.
The Jeffries-Matusita distance suggests that compact polarimetry through linear-45 or circular-left signal transmission could be employed for mapping reeds with reasonably high accuracy. The data can substitute optical data in regions where atmospheric disturbance persists. However, considering the Faraday rotation phenomenon, circular signal transmission is likely to be implemented in spaceborne platforms since the polarisation is less attenuated by the Ionosphere (Rignot 2000).

**4. Conclusions**

We conclude that irrespective of the hybridisation method, reconstructing PolSAR data could be best achieved using PSE, preferably using linear 45 or left circular transmitted signals. Reeds are generally well identified and therefore suitable for mapping. They are well separated from open water surface as well as degraded forest. A lower separability level was found from intact forest, which indicates that both surface covers have similar signal interaction properties, possibly due to volume scattering.

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References


