ALOS PALSAR for Characterizing Wooded Savannas in Northern Australia

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Abstract

The research sought to establish the potential of the ALOS PALSAR, either singularly or in combination with optical data, for retrieving the biomass and structure of wooded savannas typical to northern Australia. This paper provides an overview of the results obtained, first using airborne remote sensing data acquired near Injune in Queensland, and focusing on the retrieval of biomass and the mapping of woody regrowth, dead standing timber and forest structural types. The transferability of several approaches developed using airborne SAR to ALOS PALSAR and other datasets is outlined.

Keywords: Forests, structure, biomass, SAR, optical, Australia

1. INTRODUCTION

Within Australia, information on forest biomass and the distribution of structural types is required to support national scale assessment and monitoring of carbon stocks and indicate biodiversity values. In the knowledge that the ALOS PALSAR was to be launched, a major airborne campaign was conducted near Injune in central east Queensland (Figure 1) in 2000 with a view of establishing the potential of this sensor for retrieving biomass and mapping forest structural types, including those associated with native vegetation, but also regeneration. The following sections provide an overview of the airborne campaign and major research outcomes and then establish the utility of ALOS PALSAR for characterising and mapping wooded savannas.

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Figure 1. The Injune Study Area in central east Queensland, Australia

2. THE INJUNE LANDSCAPE COLLABORATIVE PROJECT

2.1 Acquisition of remote sensing datasets

The Injune datasets were acquired over the 40 x 60 km area between July and September 2000 and included fully polarimetric AIRSAR data. Aerial photography, airborne LiDAR and hyperspectral data were also acquired for 10 x 15 500 x 150 m primary sampling units (PSUs) located ~ 4 km apart in the north-south and east-west directions [1]. Each block was subdivided into 30 50 x 50 m plots, giving a total of 4500 secondary sampling units (SSUs) for the study area. Field data, including plot-based inventories of forests and biomass (through destructive harvesting), were obtained for 34 of the SSUs to support the interpretation of the airborne datasets.

2.2. Derived data sets and SAR backscatter modelling

From these finer spatial resolution data, key datasets that were derived have included:

a) Estimates of total above ground biomass generated by a stepwise regression between above ground biomass and both the number of LiDAR returns at different height levels and also LiDAR-derived crown cover [2].

b) Maps of individual tree crowns/clusters of crowns generated from both LiDAR and hyperspectral data, with each crown/cluster differentiated to species type and associated with an estimate of height [3, 4]

c) Maps of leaf, branch, trunk and total biomass generated by integrating tree size and species information [5].

The airborne datasets have been derived with reference to ground data and have been used subsequently to support the retrieval of forest structure and biomass from AIRSAR data. Furthermore, these data together with those collected in the field (e.g., measures of leaf and branch size, vegetation moisture content), have also been used to parameterize and develop a range of microwave simulation models [6, 7, 8], thereby allowing increased understanding of the interaction of microwaves of different frequency and polarization with the different plant components (e.g., leaves, branches, trunks) and growth forms (e.g., excurrent, decurrent and regrowth).

2.3 Main outcomes

Analysis of the field and fine spatial resolution datasets in conjunction with the AIRSAR data has established the following:

a) The retrieval of biomass from SAR data is dependent upon the frequency, polarization and also incidence angle of the radar, with best retrieval obtained using L-band HV data acquired at higher (generally > 35^o) incidence angles. The saturation level in this channel is typically around 80 Mg ha^{-1} [2].

b) Differential interaction of microwaves with different forest components occurs. In particular, and in wooded savannas, L-band microwaves at HH and HV polarisation were shown to interact primarily with the trunks and larger branches respectively [6; based on simulation modelling]. Information on the leaf and small branches can be obtained using C-band HV data, and a close correspondence with Landsat-derived Foliage Projected Cover (FPC; [9]) is observed.

c) In areas of woody regrowth, L-band HH returns do not become significant until stands of trees exceed about 2.5 m in height when their stem size is sufficient to evoke a response [9]. A lag in the increase in L-band HV returns is also evident suggesting that the structural development of regrowth (particularly that dominated by *Acacia* species) might be traced using a combination of these data. Furthermore, as woody regrowth supports a high FPC but a low L-band return in the early stages of growth, mapping using airborne data can be achieved by simply integrating these data within a rule-based classification.

d) L-band data might provide an optimal radar-based approach to the empirical estimation of biomass in woody savannas as the lower frequency P-band microwaves were observed not to interact with all components of the woody biomass and hence were not sensitive to the entire mass. This was in contrast to L-band where interaction with these components did occur. Little increase in backscatter was observed above 80 Mg ha^{-1} for both L and P-band and these observations differ from those typical for more closed canopy forests where the saturation level is generally higher at P-band (e.g., 150 Mg ha^{-1}) compared to L-band.

e) Areas of dead standing timber could be mapped as these exhibited a high L-band return at all frequencies and polarizations but a low FPC, which reflected the absence of leaves/small branches in the canopy (Figure 2).

f) The integration of data acquired at different frequencies and polarizations with optical data can increase opportunities for discriminating and mapping forest structural types because of sensitivity to different components of the forest volume.

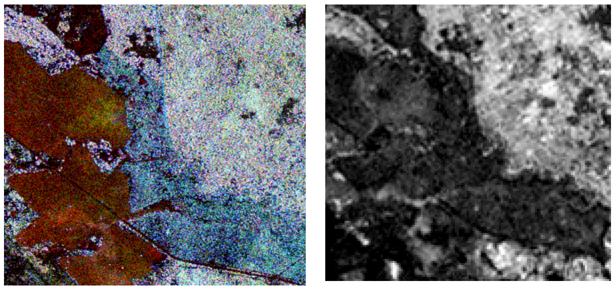

Figure 2. Areas of dead standing timber(in blue) observed using) L-band SAR (left) and Landsat-derived FPC (right).

The analysis of the airborne and field datasets at Injune provided considerable insight into the potential of the ALOS PALSAR for forest characterization and mapping. To fully investigate this potential using the ALOS PALSAR data themselves, a number of acquisitions at various polarizations and incidence angles were requested over Injune and the following section provides an overview of preliminary results associated with analysis of these data.

3. ALOS PALSAR FOR FOREST CHARACTERISATION AND MAPPING

3.1 Biomass retrieval

As observed using the airborne datasets, saturation of L-band backscatter was observed at about 75 – 80 Mg ha^{-1}, with considerable scatter observed as a function of the structural complexity of the forests, particularly towards the saturation point. These observations highlighted the potential of the data for estimating biomass below the saturation level and also the viability of using the ALOS PALSAR data acquired at 34^o viewing angle. The study also re-emphasized the requirement for developing methods that overcome the saturation problem and this is the subject of ongoing research.

3.2 Woody regrowth mapping

Through integration of ALOS PALSAR and Landsat-derived FPC, maps showing woody regrowth extent were generated using a rule-based classification. Furthermore, different regrowth stages could be mapped (Figure 3). Some confusion between the older stages of regrowth and shrubs occurring within the forest area (in gaps) was evident, which suggested the potential of integrating these data for retrieving information on the structure of 'intact' forest. Comparisons of regrowth maps generated using JERS-1 SAR and Landsat-derived FPC from 1995 and ALOS PALSAR/FPC data from 2007 indicated substantial increases in the extent of regrowth on previously cleared land and highlighted the potential of combining historical datasets for quantifying changes in the extent of regeneration over time.

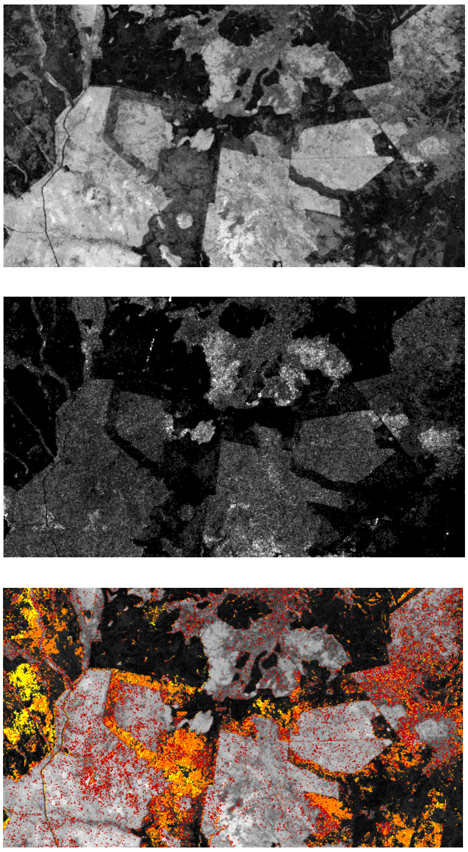

Figure 3. Landsat-derived FPC image (top), ALOS PALSAR L-band HH image (centre) and a map of regrowth extent and relative stage (bottom, yellow to red representing younger to older regrowth) derived through integration of these data.

3.3 Mapping of forest structural types

The integration of Landsat-derived FPC and reflectance data and L-band HH and HV data allows for enhanced mapping of forest structural types. For example, forest stands dominated by White Cypress Pine (*C. glaucophylla*) exhibited a higher FPC compared to *Eucalyptus* species with more open canopies. *C-glaucophylla* stands were further distinguished as they exhibited a higher L-band HH SAR backscatter because of strong double bounce interactions with the more vertically orientated stems. Forests dominated by poplar box (*E. populnea*) and silver-leaved ironbark (*E. melanaphloia*) could also be separated using near infrared and short-wave infrared reflectance whilst the combination of the L-band HH/HV and FPC data allowed for the discrimination of *Acacia*-dominated regrowth forests at different stages of growth. The classification (Figure 4; here based on airborne SAR) was trained using maps of tree species generated using 1 m hyperspectral data [10].

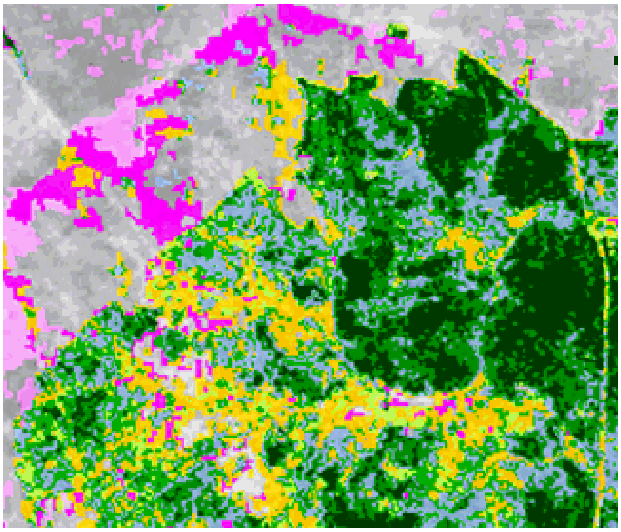

Figure 4. A rule-based classification of forest communities dominated primarily by E. populnea (orange), E. melanaphloia (blue), C. glaucophylla (dark green) with E. melanaphloia (light green) or E. populnea (yellow), and Acacia harpophylla (in the early (pink) and later (magenta) stages of regrowth).

More advanced approaches to classification using the ALOS PALSAR data are being implemented to establish the potential of integrating these with optical data for refining classifications of forest structural type and also species composition.

5. DISCUSSION AND CONCLUSIONS

The establishment of a long-term research site and comprehensive remote sensing and field dataset near Injune in central east Queensland has provided a unique opportunity to develop an understanding of the information content of L-band SAR data acquired over wooded savannas. The study highlighted the potential and limitations of ALOS PALSAR prior to the launch of the sensor but also provided the evidence to support the use of these data across the wider landscape once data came on stream. As a consequence, the utility of PALSAR for quantifying biomass but also mapping forest formations (e.g., woody regrowth, dead standing timber, species and structural types) is now well established in Queensland.

Further work is being conducted at other sites in Queensland to better establish whether algorithms and understanding developed at Injune can be applied elsewhere where vegetation types and the physical environment differ (e.g., in terms of soils, geology and topography). The outcomes of this research are being used to support the development of algorithms for regional characterisation, mapping and monitoring of forests in Queensland and subsequently across northern Australia.

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