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# Classification of Australian forest communities using aerial photography, CASI and HyMap data

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**Abstract**

Within Australia, the discrimination and mapping of forest communities has traditionally been undertaken at the stand scale using stereo aerial photography. Focusing on mixed species forests in central south-east Queensland, this paper outlines an approach for the generation of tree species maps at the tree crown/cluster level using 1 m spatial resolution Compact Airborne Spectrographic Imager (CASI; 445.8 nm–837.7 nm wavelength) and the use of these to generate stand-level assessments of community composition. Following automated delineation of tree crowns/crown clusters, spectral reflectance from pixels representing maxima or mean-lit averages of channel reflectance or band ratios were extracted for a range of species including *Acacia, Angophora*, *Callitris* and *Eucalyptus*. Based on stepwise discriminant analysis, classification accuracies of dominant species were greatest (87% and 76% for training and testing datasets; $n=398$) when the mean-lit spectra associated with a ratio of the reflectance ($\rho$) at 742 nm ($\rho_{742}$) and 714 nm ($\rho_{714}$) were used. The integration of 2.6 m HyMap (446.1 nm–2477.8 nm) spectra increased the accuracy of classification for some species, largely because of the inclusion of shortwave infrared wavebands. Similar increases in accuracy were achieved when classifications of field spectra resampled to CASI and HyMap wavebands were compared. The discriminant functions were applied subsequently to classify crowns within each image and produce maps of tree species distributions which were equivalent or better than those generated through aerial photograph interpretation. The research provides a new approach to tree species mapping, although some *a priori* knowledge of the occurrence of broad species groups is required. The tree maps have application to biodiversity assessment in Australian forests.


*Keywords:* Forest species; Classification; Discriminant analysis; Aerial photography; Hyperspectral; Australia; Subtropical forest

## 1. Introduction

Within Australia and elsewhere, aerial photographs have been, and continue to be, utilized to delineate forest stands and attribute the resulting vector polygons with information on the tree species contained (Gong et al., 2001; Tickle et al., 2006). This process requires skilled aerial photograph interpreters with knowledge of the forested ecosystems observed and is demanding of time and resources. Furthermore, the datasets generated, although spatially relevant to the area of the mapped polygon, do not provide a detailed and permanent record of the distributions and species type of individual or clusters of trees.

In recent years, the availability and affordability of fine spatial resolution digital remote sensing data, together with the advent of Global Positioning Systems (GPS) and Inertial Navigation Systems (INS), has opened up opportunities for more automated characterization and mapping of forests at the tree level. Alongside this development has been the progressive advancement of algorithms that allow individual tree crowns or clusters of crowns to be delineated (e.g., Gougean, 1995; Culvenor et al., 1998; Culvenor, 2002) for purposes of retrieving structure, biomass and/or species type. Hyperspectral data have been of particular utility as observations in the visible (~400 −700 nm), the red edge (~700–800 nm), near infrared

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(NIR; ~800–1200 nm) and shortwave infrared (SWIR; 1200–2500 nm) wavelengths regions have allowed the spectral characteristics of tree species to be captured and differences between these identified (Xiao et al., 2004). However, linking delineated crowns with the spectral information they contain (such that tree species can be mapped) has yet to be widely demonstrated and difficulties have arisen largely because of the similarity in reflectance between some species (Cochrane, 2000).

For this reason, and focusing on forests in Queensland, Australia, the primary objective of this research was to evaluate whether tree crowns/clusters delineated within 1 m spatial resolution Compact Airborne Spectrographic Imager (CASI-2; Bunting and Lucas, 2006) could be discriminated to species and to acceptable levels of accuracy. More specifically, the study aimed to establish whether:

a) Spectra from selected points of areas within delineated tree crowns or clusters provided better separation of common tree species.
b) The inclusion of SWIR data (as provided by HyMap data) could provide better discrimination compared to when visible and NIR data were used alone.
c) Maps of tree crowns and community descriptions could be generated that were at least equivalent to those produced through interpretation of stereo aerial photography.

The study was motivated by the requirement to obtain detailed species information at the tree level to assist interpretation of moderate (>5–30 m spatial resolution) remote sensing datasets, including Landsat-derived Foliage Projected Cover (FPC; Armston et al., 2004) and airborne/spaceborne Synthetic Aperture Radar (SAR; Lucas et al., 2006a), to enhance descriptions of floristic diversity and ecosystem dynamics across the landscape such that the impacts of natural (e.g., drought) and anthropogenic (e.g., land use) change on the long term sustainability of forests could be better understood (Lucas et al., 2006b; Bunting and Lucas, 2006), and to refine existing estimates of carbon stocks and allocation (to the leaves, branches, trunks and roots) at a range of scales for purposes of greenhouse gas accounting (Lucas et al., 2006c; in press).

## 2. Background

### 2.1. Tree species discrimination

With advances in fine spatial resolution (herein defined as ≤5 m) hyperspectral imaging from airborne sensors, the potential to discriminate tree species has increased considerably compared to when only coarser (>5 m) spatial resolution multispectral sensors were available. Nevertheless, discrimination of tree species from image spectra remains complicated, partly because many are obscured by crowns in the overstorey, the reflectance of many species is similar, and there is often as much spectral variability within crowns of the same species as between crowns of different species.

Variation in the reflectance within species occurs largely because of canopy shadowing and differences in light absorption and scattering across the wavelength regions. At the leaf scale, variability is associated with differences in leaf age, mechanical damage and the presence of various biotic stressors including ephiphylls, fungi, lichens, algae, bacteria and insects that can influence leaf pigment content (Stone et al., 2001), induce necrosis (Roberts et al., 1998; Stone et al., 2005) or modify leaf structure (Guyot et al., 1989). The reflectance contribution from the underlying soil surface and non-photosynthetic components (bark and wood) is also variable (Coops et al., 2003) and becomes more influential on the overall reflectance as the openness of the crown increases. Shadowing is similarly dependent on the overall structure of the canopy and particularly the presence of within-crown gaps and the size and proximity of adjacent, overstorey or understorey trees (Asner and Heidebrecht, 2002; Leckie et al., 2005). In multi-layered canopies with variable crown sizes, such variability results in differing illumination conditions which complicates interpretation of imagery. Within-species variation is also complicated by differences in tree health (Treitz and Howarth 1999; Sampson et al., 2001).

Variation in reflectance between species is largely a function of differences in leaf properties (dimensions, internal structure, pigment types and amounts) but also in the nature of the surface (e.g., presence of waxy cuticles or hairs), the orientation of leaves and the overall architecture of the crowns (Lucas et al., 2002; Galvao et al., 2005). Instrument noise may also compromise the extraction of the true reflectance spectra from surfaces (Coops et al., 2004).

A number of studies have achieved success with the discrimination and/or mapping of tree species, although many have focused on forests of the northern hemisphere which are of relatively simple structure and contain only a few species. For example, Holmgren and Persson (2004) used NIR images to discriminate coniferous from deciduous species, although the use of LiDAR data was considered necessary for separating Scots Pine (*Pinus sylvestris* L.) from Norway Spruce (*Picea abies* L. Karst). Leckie et al. (2005) discriminated and mapped Western Hemlock (*Tsuga heterophylla*), Amabilis Fir (balsam; *Abies amabilis*) and Western Red Cedar (*Thuja plicata*) within old growth forest by applying an object-orientated maximum-likelihood classification to hyperspectral CASI data acquired on two dates. Other studies have discriminated forest types using masking (Xiao et al., 2004) and stratification techniques (Ustin and Xiao, 2001). Discrimination from image spectra has also been attempted in more complex tropical environments (Lucas et al., 2004a; Zhang et al., 2006) and some success has been achieved using field spectra (Cochrane, 2000; Wilson and Ustin, 2004).

In Australian forests, Coops et al. (2004) suggested that CASI-2 bands could be used to discriminate a range of forest species but noted difficulties in separating different *Eucalyptus* and also rainforest (non-*Eucalyptus*) species. The difficulty in discrimination of *Eucalyptus* species was attributed to the complexity of the forests associated with disturbance (both natural and anthropogenic) at the stand level and structural variability at the crown level. In particular, mature evergreen *Eucalyptus* species tend to have sparse crowns with pendulous leaves