Detecting a fire-sensitive species in a fire-prone landscape: object-based rule-set driven approaches.

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Abstract – The Northern Cypress Pine, *Callitris intratropica* (fam: Cupressaceae) is a fire sensitive conifer that exists in a range of environments across the tropical savanna landscapes of Australia's Northern Territory. Its susceptibility to intense fires means that populations are vulnerable under late season high intensity burning regimes, limiting the range to areas that are protected from such fires. The presence or absence of *C. intratropica* is seen as an indicator of the fire regime within a landscape. Methods of detecting individuals and stands of the species from high resolution remotely sensed imagery will assist in assessing the distribution of the species within the landscape. The work here describes two object-based methods: one region growing and the other a thresholding technique, for detecting stands and individuals of the species from high spatial resolution multispectral satellite imagery from within Eucalypt dominant savanna. The region growing algorithm identifies 'seed objects' within trees based on maximum Normalised Difference Vegetation Index (NDVI) values and then grows these objects to encompass the tree crowns. The threshold segmentation technique creates objects of woody cover in the savanna using a NDVI threshold. *C. intratropica* is then differentiated from other woody cover using thresholds based on the near infrared and red bands of the data. Detected crowns and stands are then compared against recorded field and manually delineated observations. Based on the reference data, accuracies for both methods is over 70% showing the potential for mapping the species across a wider area.

Keywords: *Callitris intratropica*, tropical savanna, object-based image analysis.

1. INTRODUCTION

The relatively recent availability of high spatial resolution (<5m pixels) imagery and the development of object-based image analysis (OBIA) techniques have enhanced the potential for locating and mapping distributions of individual plant species (Bunting and Lucas 2006; Erikson 2004; Tiede *et al.* 2005). High spatial resolution data provides a minimum analysis unit that enables the delineation of individual trees and clusters (Gougeon and Leckie 2006; Leckie *et al.* 2005), while OBIA creates algorithms that facilitate the development of semi-automated processes for the extraction these features (Bunting and Lucas 2006; Tiede *et al.* 2007).

The northern cypress, *Callitris intratropica* (Cuppressaceae) is a long-lived (>200 years) conifer that is widespread across northern Australia (Hammer 1981). Dendrochronological studies indicate a strong correlation between growth rates and climate with potential for describing temporal variation in monsoonal activity in northern Australia (Baker *et al.* 2008).

C. intratropica is fire-sensitive and an obligate seeder (Russell-Smith 2006). Mature trees can survive moderate fires while seedlings cannot survive any fire (Bowman and Panton 1993). Distribution is relictual (Bowman and Panton 1993; Prior *et al.* 2007), and affected by contemporary fire regimes (Bowman and Panton 1993; Bowman *et al.* 2001; Price and Bowman 1994; Russell-Smith 2006). Widespread reduction in populations and the fragmentation of distributions may be attributed to the cessation or minimisation of traditional Aboriginal land management practices whereby fire regimes shifted from low intensity, patchy burning to widespread high intensity wildfires. (Bowman and Panton 1993; Bowman *et al.* 2001). The distribution of *C. intratropica* has contracted to areas that are less fire-affected such as rainforest margins, rocky outcrops and drainage lines (Bowman *et al.* 2001; Russell-Smith 2006).

As *C. intratropica* is fire-sensitive, it is an important indicator for measuring and monitoring land management change for a region. Thus robust techniques for the identification of stands and individuals of the species are needed. This paper describes two processes (in the initial stages of development) for the extraction and identification of *C. intratropica* crowns in tropical savanna from high spatial resolution multispectral imagery using object-based image analysis. Results of both approaches are then compared against reference data.

2. METHOD

2.1 Study area

The study area is located in the Florence Creek region of Litchfield National Park, in the northwest of the Northern Territory of Australia (
Figure 1). The area covers approximately 1373 ha. The region's climate is characteristic of monsoonal wet/dry tropics; consisting of a long warm dry season (May – September) with little to no rainfall, with over 75% of the annual rainfall (1500 mm) occurring in the hotter period between November and March. The study area is mostly plateau surface consisting of a layer of pervious sandstone overlying harder impervious sandstone intersected by few drainage lines. At the northern end of the area drainage lines intersect with the plateau edge and water exits from the pervious layer above a secondary plateau surface. At this edge a number associated springs and waterfalls occur. Vegetation within the study area is a matrix of open forest and savanna woodland with a *Eucalyptus* spp. (mostly *E. tetradonta* and *E. miniata*) dominated canopy and annual grass (*Sarga* spp.) understorey (Griffiths *et al.* 1997). Within this matrix, patches of monsoonal rainforest and *Melaleuca* spp. forest are located near permanent water and along creek lines, while in seasonally inundated sections grassland and sedgelands exist (Lynch and Manning 1988).

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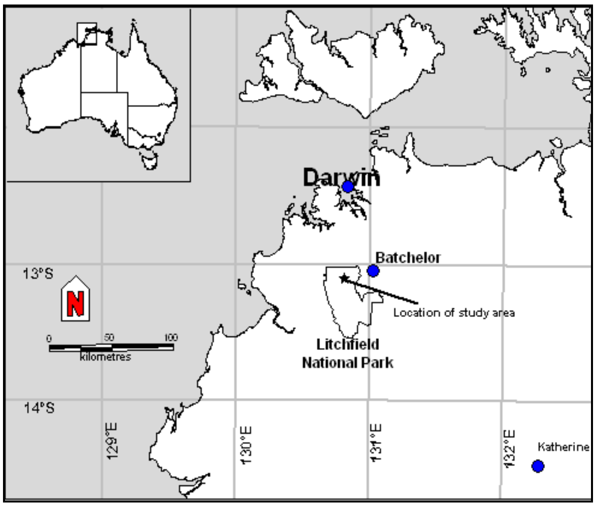

Figure 1. Location of the study site

2.2 Data and Pre-processing

The primary dataset for this project was a DigitalGlobe QuickBird image (

Figure 2). The time of capture was 11.09 am (local time) on 28 August 2004. The panchromatic and multispectral bands were utilised. Ground resolution of this imagery is 0.6 (panchromatic) and 2.4 (multispectral) metres at nadir. Off-nadir angle for the scene is 8.9 degrees. Data were adjusted to top-of-atmosphere reflectance values (Krause 2005) and the image was geometrically corrected to a previously geo-referenced aerial orthophoto of the area with an accuracy error of less than 0.5 pixels. An additional derivative 'decorrelation stretch' data set was also created (Gillespie *et al.* 1986) with the third layer DS3 being included in the analysis due to its potential for differentiation between Eucalypt and non-Eucalypt dominant communities.

2.3 Analysis

Two object-based approaches were used to extract tree crowns from the imagery. Both processes involved two levels of segmentation and classification. The first broader level (level 2) of segmentation identified areas of Eucalypt dominant vegetation while the second finer segmentation (level 1) is used to identify and classify tree crowns.

The first segmentation step in both approaches created objects that provide broad land cover classes to separate Eucalypt or savanna vegetation from closed forest riparian, grassland and flood plain vegetation. The segmentation at this level was undertaken using the multiresolution segmentation algorithm within the eCognition Developer V8 software application. This region growing segmentation algorithm that partitions images into objects based on several homogeneity criteria (Benz *et al.* 2004). For this level of segmentation, only the multispectral layers were considered and Table 1 shows the details of the parameters for segmentation and figure 2b displays the resultant objects.

At the broad segmentation level (Level 2) objects were classified based on a threshold of the DS3 layer. Objects representing riparian forest and grassland (with a mean DS3 value equal to or less than 0.435) were classified as non-Eucalypt dominant communities and excluded or masked out from further segmentation and analysis. Objects possessing a mean DS3 value greater than 0.435 represent Eucalypt dominant vegetation communities and were thus included in the finer level (Level 1) segmentation and extraction processes. The finer level segmentation processes created the objects representing tree crowns and clusters.

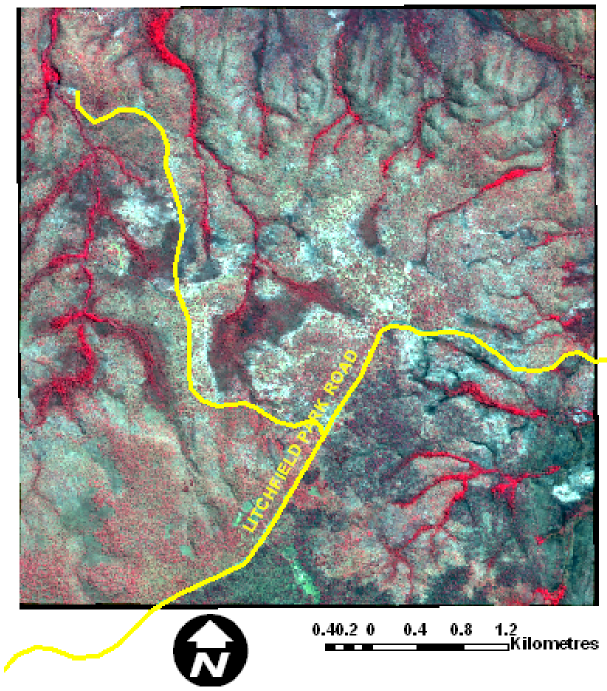

Figure 2. The QuickBird scene used in this study, RGB = bands 4, 3, 2.

Table 1: Parameters for the broad level (level 2) of segmentation.

Segmentation method	Scale parameter	Colour /Shape	Compactness / Smoothness
Multiresolution	200	0.4 / 0.6	0.8 / 0.2

2.4 Tree crown identification and extraction

2.4.1 Region growing method

The region growing method was applied to the Eucalypt dominant regions of the scene. The first step was a chessboard segmentation to create, at Level 1, square objects 2x2 panchromatic pixels in size. Next, the customisable arithmetic feature within eCognition Developer was used to create a NDVI feature and a rule set was developed to identify tree crowns follows five steps:

- Identifying local NDVI maxima;
- Growing the seed objects to tree crown objects;
- Splitting objects into crowns and clusters;
- Splitting clusters into crowns;
- Delineating *C. intratropica* crowns and clusters.

Seed objects that lie within tree crowns were created by identifying local maxima objects based on their mean NDVI value and a search distance of 10 panchromatic pixels. An iterative region growing algorithm 'grew' the seed objects engulfing adjoining objects to a NDVI threshold of 0.2. Following the region growing, smaller classified objects, less than $10m^2$, where classed as fragments or scraps and then merged to abutting larger objects. Those not abutting larger objects were identified as not being tree crowns (most likely understorey shrubs). Unclassified objects fully enclosed by crown objects were also classified as belonging to crowns and merged into the larger object.

Classified objects were then determined to be either individual crowns or clusters of crowns based on three shape-based criteria: area, length/width ratio, and shape index. Objects that were either greater than $180m^2$ in area, had a length/width ratio of 2:1 or a SI greater than 1.3 were considered clusters and not crowns. Clusters were re-segmented to objects 2 x 2 panchromatic pixels in size and local maxima were identified based on NDVI values with a shorter distance of 8 pixels. Further iterative region growing using the maxima as seeds was undertaken within the cluster objects to a threshold NDVI value of 0.225. A second iteration was then undertaken on objects less than $10m^2$ to a threshold of 0.2.

The canopy of *C. intratropica* trees are characteristically different spectrally to other trees within the savanna. A comparison of mean object layer values versus the dominant Eucalpyts, shows the spectral values are lower across all bands, most notably in the Red and NIR (
Figure 3). This distinct spectral signature was use to be extract objects representing *C. intratropica* crowns using class rules based on mean object layer values for Red and NIR. Tree crown objects were determined to be potentially *C. intratropica* if their mean Red and mean NIR values were less than 30 and 56 respectively.

2.4.2 Contrast threshold method
Within the threshold method, objects representing tree crowns and clusters were created using a threshold value to separate the crowns and clusters from surrounding understorey. All pixels above the defined NDVI threshold value were assigned as potential tree crown candidates and adjacent pixels merged in objects. Invariably with this method, trees with overlapping canopies are clustered together in objects. To attempt to split these clusters into individual crowns, a watershed transformation was conducted followed by a series of morphological erosion and dilation opening operations using disc structuring elements of certain diameters. Class rules using the distinctive spectral signatures for *C. intratropica* were then applied to extract those objects representing the target species from all tree crown objects.

2.5 Validation
The identified *C. intratropica* crowns and clusters from both methods were validated against a sample (64) of field-recorded and image-observed locations of trees and clusters. A handheld GPS (Global Positioning System) unit was used to obtain the coordinates of these features in the field. As no measure of accuracy was recorded the reference data was uploaded into a GIS and the locations further refined using the GPS location, and visual interpretation, identification and remarking of *C. intratropica* crowns using pan-sharpened QuickBird imagery over the study area.

3. RESULTS AND DISCUSSION

Figure 4 shows the results of the level 1 segmentation and subsequent masking. Areas in grey are classified non-Eucalypt and not analysed.

3.1 Region growing approach
Using the region growing approach, 3424 objects were identified as potentially *C. intratropica*. Visual inspection shows good delineation of known individuals and clusters (Figure 5a). Further inspection shows trees in some areas were identified as *C. intratropica* when they were actually other canopy. For example, a number of small areas of monsoon and riparian forest were not masked out in the first classification. Some of these were included in the identified objects. In addition, some trees located on steep terrain and affected by shading were also detected.

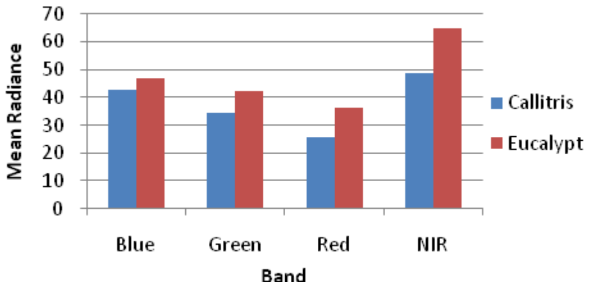

Figure 3. Mean radiance band values for objects representing *Callitris intratropica* compared to objects representing Eucalypts.

(b)

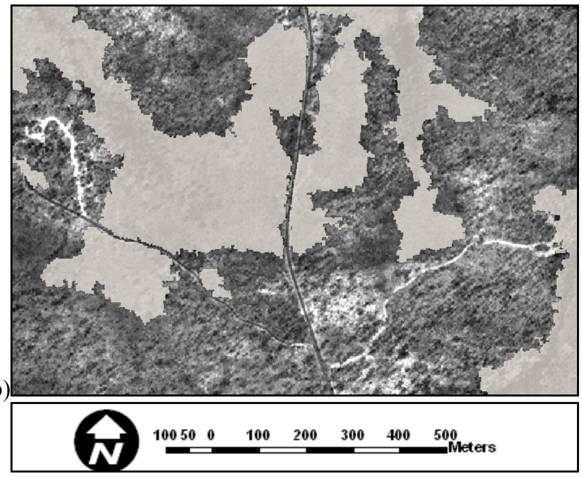

Figure 4. A portion of the study areas showing greyscale of the DS3 derivative band with areas of non-Eucalypt dominant vegetation communities masked out.

Table 2 shows crowns and clusters identified against reference data. Of the locations identified in the reference data, 65% were matched to extracted crowns. The locational accuracy of the reference data may have attributed some of the error.. Incorrect tree species identification would also contribute to the error.

3.2 Threshold approach
Using the threshold approach, 3398 objects were identified as potentially *C. intratropica*. Visual inspection again shows good delineation of known individuals and clusters (Figure 5b). As for the region growing approach, further inspection shows trees in some areas were identified as *C. intratropica* when they were actually other canopy and some trees located on steep terrain and affected by shading were also detected.

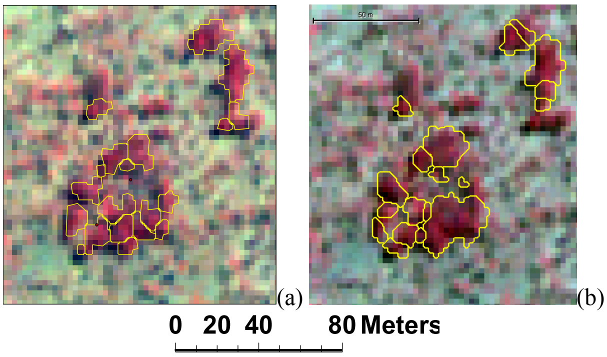

Figure 5. Sample of crowns extracted by the region growing method (a) and the contrast threshold method (b).

Table 2. Comaprison of the no. of *C. intratropica* crowns detected by the two methods against reference data.

	Region		Threshold	
	Reference	%	Reference	%
Extracted	42	65	45	70
Not extracted	22	35	19	30
Total	64	100	64	100

4. CONCLUSION

The two methods of tree crown delineation in tropical savannas described here are in the early stages of development. Both methods are able to identify and map a species of tree that is under threat from altered land management practices. Further work is required to better discriminate *C. intratropica* crowns, adjust the non-Eucalypt mask to better cover these areas, and apply the methods on a broader scale both spatially and temporally.

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