Progress Report
Assessment of *Eucalyptus Wandoo* (Wandoo) and other tree canopy decline using Landsat Trend Analysis

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Progress Report

Landsat Thematic Mapper (TM) has previously been used in forestry applications in assessing timber resources and gross changes in forest cover. In this project we used Landsat TM data to examine changes in *Eucalyptus wandoo* canopy cover between 1988 and 2005. Data were manipulated using *Vegmachine* (CSIRO) software to provide spatial models of canopy change within the Helena River catchment and Talbot Block, Dryandra Woodland Reserve, Julimar Conservation Park and Drummond Nature Reserve. Validation of the technique was based on *A Priori* selection of ground-truth sites using the spatial models to predict points of canopy loss, canopy increase and no change. On ground assessments of these selected points were then made to determine the accuracy of the spatial model.

Based on the wandoo vegetation community data available within the Department of Environment and Conservation, areas of decline and increase in wandoo canopy are smaller than the areas of stable canopy. Proportions (percentage area) of increasing wandoo canopy in the period 1988 to 2005 range from 4% at Julimar Conservation park to 23% at Dryandra Woodland Reserve. Proportions of decreasing canopy in the period 1988 to 2005 in wandoo vegetation range from 17% at Helena and Julimar to 18% at Dryandra. Stable (no change) proportions range from 59% at Dryandra to 79% at Julimar.

Trend analysis using *Vegmachine* does indicate that canopy loss or decline in wandoo has occurred at a number of locations. The procedure also identified that canopy increases also have occurred. In some of these 'canopy increase' sites it would appear that wandoo crowns are re-establishing from epicormic growth. However, over most of the areas (60 – 70%), the canopy appears to be stable.

A Priori selection of trends indicate the technique was correct in predicting a recently declined, an increasing or stable tree canopy (regardless of which *Eucalyptus* or *Corymbia* species) in 60 to 70% of occasions. Reasons identified for failure to correctly predict an event were:

- Incorrect delineation of vegetation communities, or insufficient mapping data defining vegetation communities. For example, significant declines in canopy are apparent at Drummond Nature Reserve. Vegetation data indicated this change was likely to be a decline in wandoo canopy. On-ground assessments determined that gross canopy decline had occurred but that Marri was the species affected. Wandoo canopy in this reserve is healthy.
- Incorrect record or mapping of fire events. If not mapped, fire scars are assumed to be a decline. This occurred at one site in Julimar.
- Boundaries between vegetation communities. Incorrect predictions of canopy loss occurred at several sites in Dryandra at boundaries between mallet plantation and natural vegetation, and also at one boundary between an *E. accedens* and *E. wandoo* community.

Gross changes to canopy are accurately identified using this technique. However, predictions of changes that are related to particular tree species rely on accurate delineation of vegetation communities within the survey areas.

A full report for this ***project is currently under review***. Presentations that outline the methodology for on-ground assessments of canopy changes and the use of *Vegmachine* have been made to meetings of the Wandoo Recovery Group and the Drummond Natural Diversity Recovery Catchment field days.

Extracts of the full report**,** including several draft spatial images are presented below.

INTRODUCTION

Tree deaths and declines are worldwide phenomena, and linking causal agents to decline events are problematic. In some instances, such a sudden oak death (SOD) caused by *Phytophthora ramorum* and chestnut blight (*Cryphonectria parasitica*), identifiable pathogens causing the death of trees could be isolated (Gilbert 2002; Rizzo *et al*. 2002). However, the interaction between host, pathogen, environment and the complexity of multiple-abiotic causes makes it unlikely that attributing a single factor to a tree decline event is possible. Indeed, expression of the diseases caused by pathogens, even when well understood, often requires the favourable interaction between pathogen, host and environment. For example, in modelling landscape-scale spread of SOD in the western United States, expression of the disease was highly clumped, and models clearly showed that forest edges (that promoted high-light requiring understorey host species) predicted disease expression (Holdenrieder *et al.* 2004). In this case fragmentation of oak forests has provided an important role in dispersing and progressing the disease (Holdenrieder *et al.* 2004). The spatial component was the key to understanding the characteristics of deaths across the landscape.

Forest ecologists recognise that together with anthropogenic factors (such as land clearing), the interplay between environment, herbivores and pathogens can help explain the community characteristics and functionality of forested ecosystems (Holdenrieder *et al*. 2004; Davis et al. 1994). It is a dynamic view of forests and one that accepts the role of disturbance in developing spatial and temporal heterogeneity. This is a conceptual model for the development of forest communities, but it is a model that requires an understanding of the distribution of both species and events at a landscape-scale. Managing unwelcome environmental events when they occur, such a tree decline or mass deaths, also requires a clear understanding of the spatial and temporal distribution of the event. Obtaining spatial data, in the form of topographic maps, aerial photography (including high resolution) and remotely sensed information, is now almost routine in managing natural ecosystems, including assessments of tree declines and large-scale deaths.

Landscape-scale assessments using remote sensing

In recent years remote sensing has been applied to the assessments of vegetation structure and condition for natural resource management over wide areas of southeastern Australia. For example, Catling *et al*. (2001), Coops and Catling (2000; 2004), and Gibson *et al*. (2004) describe procedures for the use of Multispectral Airborne Videography that allow the interpretation of fauna habitat in forests, damplands and heathlands in New South Wales and Victoria. The drawback of these techniques is cost. The data are often available at very fine scale (as low as 1 metre pixels) and acquisition of high-resolution multi-spectral and hyper-spectral data, and manipulation of the spatial data are both very expensive (Stone and Haywood 2006).

An alternative approach uses satellite remote sensed imagery. Landsat Thematic Mapper (TM) imagery has been used to map forest inventory and change in East Timor (Bouma and Kobryn 2002); the Philippines (Baynes 2004), and in Australia in Queensland (Bruce and Hilbert 2006), New South Wales and Victoria (Lee *et al.* 2002). In Western Australia, Landsat TM has been successfully used to map forest cover in the Kimberley (Behn *et al.* 2001) and in the Midwest, Murchison and Goldfields Regions (Behn *et al.* 2003).

Standard Landsat TM analysis provides a spatial distribution of landscape-scale data, although mapping temporal change has been more difficult to achieve. However, recent software developments undertaken by the CSIRO (*VegMachine*) has provided The Department of Environment and Conservation (DEC) with the opportunity to assess vegetation cover changes at landscape-scales by allowing trend analysis of Landsat TM data for the period 1988 – 2005. *VegMachine* was developed to provide a landscape-scale monitoring tool for the pastoral industry in the Northern Territory rangelands (Karfs et al 2004). The procedure involves three stages of analysis and interpretation. Firstly, the trend in vegetation at single point reference sites is examined by interpreting the reflectance of two band-widths that relate directly to vegetation cover. The changes observed over time are related to actual events that have occurred at the reference points. For example, the occurrence of fire is clearly visible in these trend analyses. Once on-ground data that describes the strata where vegetation decline has occurred is gathered, interpolation models are developed that extrapolate the point-based spectral data across the entire landscape that is being assessed. An image showing the spatial distribution of decline (and recovery) can then be produced. The final stage involves ground truth assessment of the vegetation cover change images.

This current project aimed to assess this approach to map the epicentres of wandoo (*Eucalyptus wandoo*) decline in three regions of the southwest. These are:

Helena Valley Catchment and Talbot Brook
Julimar Conservation Park (and Drummond Nature Reserve)
Dryandra Woodland Reserve

Methodology – Data collection and analysis

The best available aerial photography covering each of the study sites was obtained from CALM Geographic Information Services section. The dates of the photography for each site were varied, from 1999 to 2001.

Aerial photography and Arc View (3.2) was used to determine different areas of homogeneous vegetation densities, according to dot grid templates (Figure 2), to locate prospective field sites.

Field Sites

Each of the five study sites had a unique number of field sites depending on size, topography, vegetation and access. Enough field sites were chosen at each study site to give an accurate representation of ground information in order to calibrate the satellite imagery with ground measurements. In total there were 92 field sites (ground-truthed reference points) across the five study areas.

Measurements

Crown Cover

Crown cover is a measure of the ground area within the vertical projection of the periphery of crowns in an area, assuming that tree crowns are opaque (Behn *et al* 2003). Using the same method as in the Goldfor Project (Behn *et al* 2003) the Crown Cover for the prospective field sites was estimated on aerial photographs using dot grid templates (Figure 2). The template assumes an open opaque crown. To convert the crown cover to projected foliage cover (which is what the satellite imagery responds to), ground measurements in the field sites were used to establish the degree of actual crown density (Behn *et al* 2003). Crown cover was also estimated in the field to double check desktop measurements and account for any change or error in aerial photography.

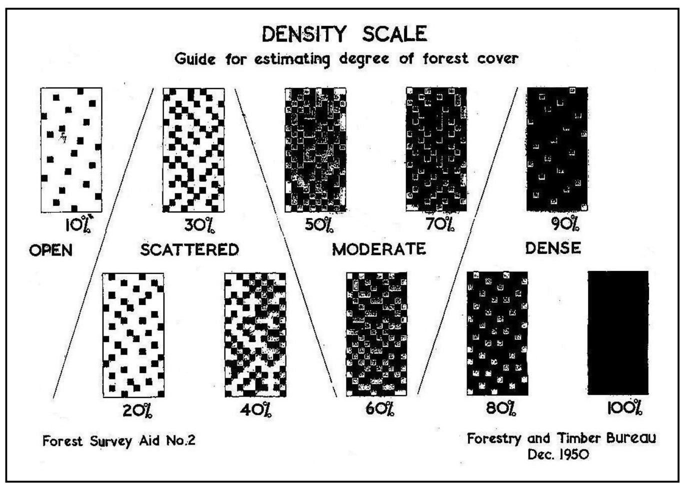

Figure 2: Crown density template (Forestry and Timber Bureau 1950)

For example, Figure 3 demonstrates a field site at Dryandra Woodland Reserve, chosen as it represents an area of homogeneous vegetation cover. Using the density template (Figure 2) this site was estimated at 30% forest cover.

Figure 3. Field site at Dryandra demonstrating homogeneous vegetation cover at 30% crown density.

Crown Density

Crown density is a measure of the ground area within the outline of a tree crown that is occupied by leaves. Crown density was estimated by standing under a tree crown and visually comparing the density of leaves within the crown outline with that in the photographic standards of 'crown type' provided by Walker and Hopkins (1990) Up to seven representative crowns were assessed at each field site, with each estimate taken from a random spot under different individual trees. The crown density for the field site was then taken as an average of all the estimates for that site (Behn *et al* 2003).

Projected Foliage Cover (PFC)

PFC is the percentage of the field site occupied by the vertical projection of foliage. PFC is the product of crown cover and crown density (Behn *et al* 2003). Using the crown cover and density estimates, a PFC value was determined for a number of reference points in each field site.

30 % Crown Cover X 75% Crown Density = 22.5% PFC

Figure 4. Projected foliage cover (PFC) is determined using the values of crown cover and crown density,

Other field site attributes
Photos were taken at each field site and a record of dominant flora species for each of canopy, understorey and groundcover were noted, as well as evidence of disturbance (past logging, dieback, fire) and individual tree decline.

Trend Analysis of Landsat TM Image

Regression
To determine the relationship between on-ground measurements and the Landsat imagery, a regression equation of the mean spectral information from the cover index image was determined as a function of the on-ground values of PFC at the ground-truthed reference points. The regression value is then applied to the cover index image to relate the image reflectance to the predicted PFC.

A Percentage Foliage Index (PFI) image is then created for each site from 1988 – 2005. This gives a 17-year historical sequence of imagery, and the changes over time can be summarised through a trend analysis.

RESULTS

1.1 Trend Analysis Maps – Entire study areas

A trend analysis map covering the entire area of the project study sites; Helena Catchment (Figure 5a), Julimar State Forest (Figure 6a) and Dryandra woodlands (Figure 7a) was produced.

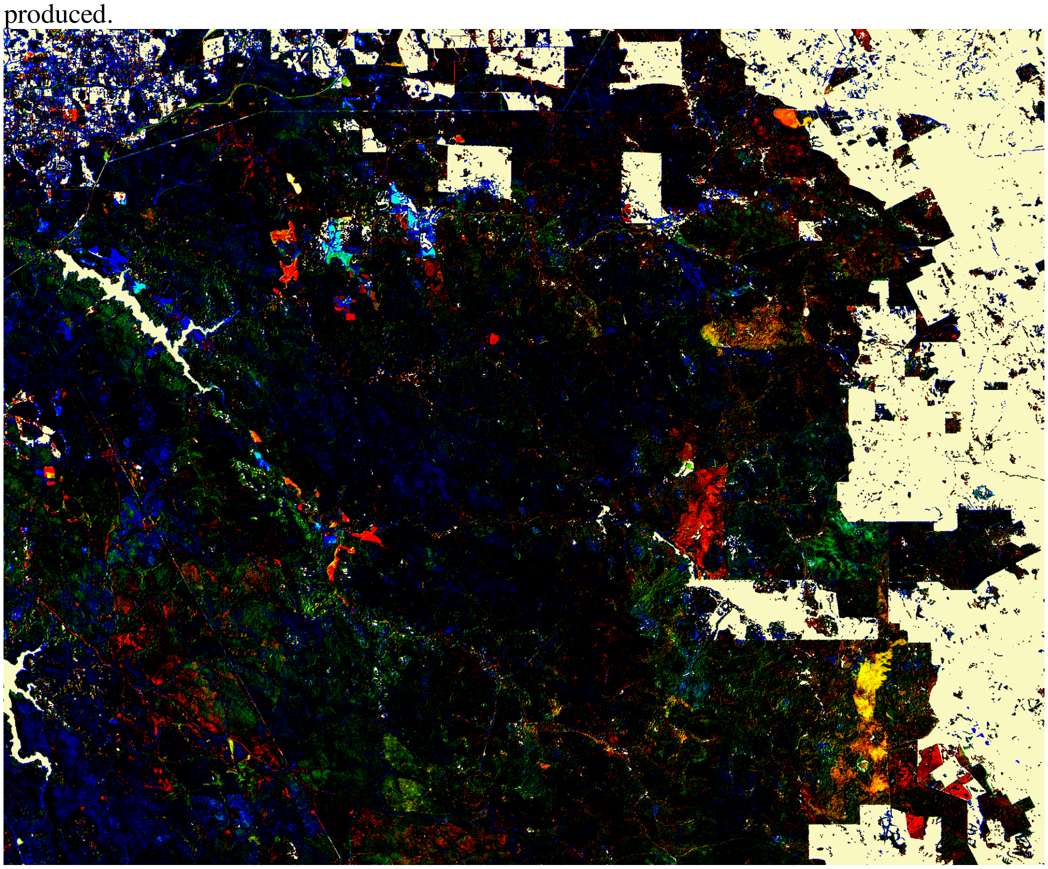

Figure 5a. Trend analysis map – Helena Catchment (entire area). Red indicates canopy loss or decline, blue indicates canopy gain and Black is stable. Causal agents of change can not be determined from this image alone.

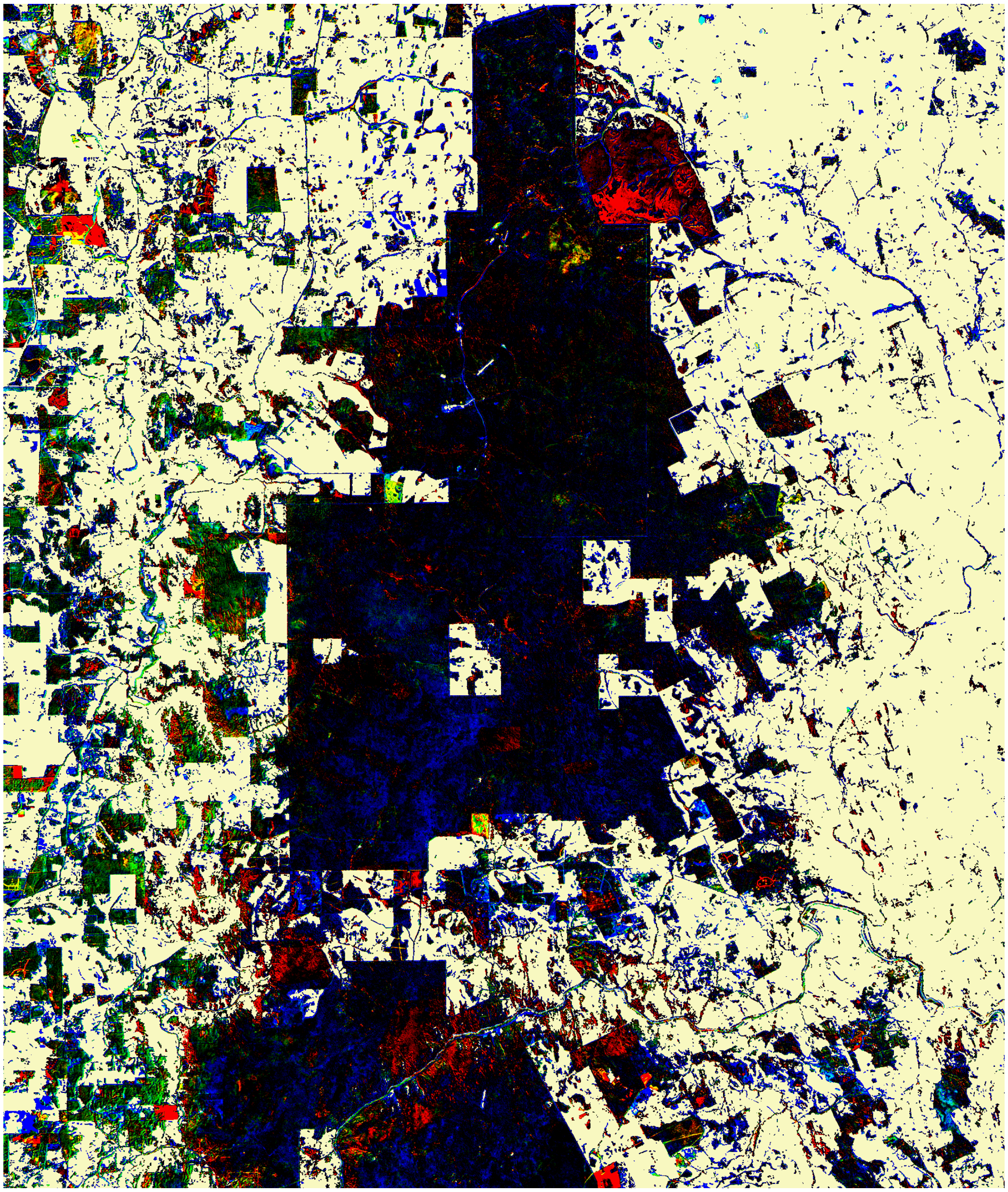

Figure 6a. Trend analysis map – Julimar State Forest (entire area)

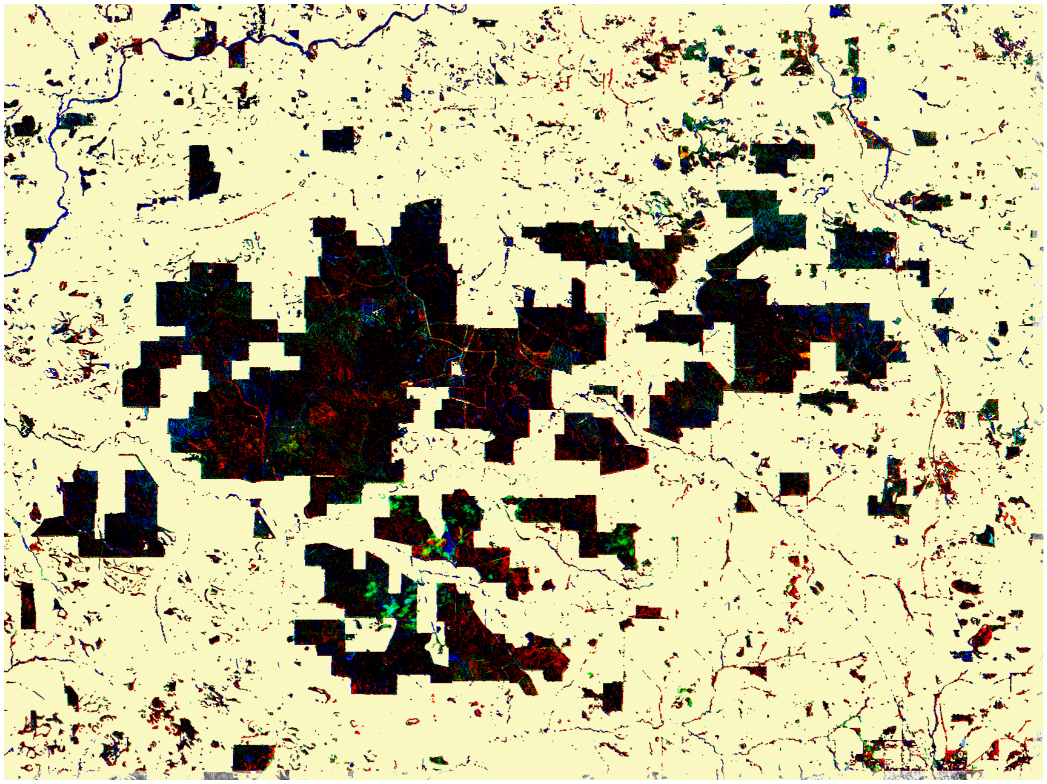

Figure 7a. Trend analysis map – Dryandra Woodland (entire area)

The proportion of declining, recovering and stable vegetation was assessed for the total area of each site, giving the following values. It should be noted that fie boundaries and other known causes of gross canopy change (such as clearing) were ignored in this analysis.

Site	% Increase	% Decline	% Stable
Helena Catchment	4	13	83
Julimar State Forest	8	13	79
Drummond Nature Reserve	4	30	66
Dryandra	14	10	76

Table 1. Proportions of vegetation change at each project study site

Trend Analysis Maps – Wandoo occurrence areas

A trend analysis map covering only the Wandoo occurrence area within each project study site; Helena Catchment (Figure 5b), Julimar State Forest (Figure 6b) and Dryandra woodlands (Figure 7b) was produced.

The proportion of declining, recovering and stable vegetation was assessed for each site, for the Wandoo occurrence area only, giving the following values:

Site	% Increase	% Decline	% Stable
Helena Catchment	11	17	72
Julimar State Forest	4	17	79
Dryandra	23	18	59

Table 2. Proportions of vegetation change within Wandoo occurrence areas only, at each project study site