Validating satellite imagery products of woody thickening using aerial photograph interpretation: methods and preliminary results

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Abstract

The increase in woody plant density in grasslands and the conversion of open woodlands into shrublands (i.e. woody thickening) is a phenomenon that has been increasingly reported in the past decade and is particularly common across arid and semi-arid regions of Australia. The goal of this project was to investigate the trends in woody vegetation cover change across western NSW to inform assessments of carbon potential, landscape productivity and habitat change. Landsatimagery from January 1988 to December 2012 (25 years), was used to develop models of linear trend in persistent green cover over time ('trend product'). The trend product is expected to represent the woody, rather than herbaceous, component of vegetation change. Aerial photograph interpretation (API) was used to validate the use of the persistent green index as a measure of woody cover change. Further investigations aim to determine whether the nature of the relationship between the API results and the trend product change according to land system/landscape position, or any other discernible factors. The methodology presents an advanced and novel development in the use of remote sensing for natural resource management.

Introduction

The increase in woody plant density in grasslands and the conversion of open woodlands into shrublands (i.e. woody thickening) is a phenomenon that has been increasingly reported in the past decade and is particularly common across arid and semi-arid regions (Eldridge *et al.*, 2011). While woody thickening may reduce biomass available for domestic livestock grazing, there are some significant benefits for carbon sequestration (Burrows *et al.*, 1998; Shackleton & Gambiza, 2008). Effects of woody thickening on biodiversity are diverse, with species and ecosystem-specific responses to increased woody cover widely reported (Ayres *et al.*, 2001; Maestre, 2004). The causes of woody thickening are generally attributed to changes in grazing intensity, fire regimes and climate, (Bond & Midgley, 2000), though reports are highly variable and interactions are not well understood. Grazing can enhance woody plant growth by directly reducing competition from perennial grasses, as well as through reduced fuel loads thereby suppressing fire and favouring the shrub component of a community (Burrows *et al.*, 1998; Strand *et al.*, 2014). However, of the occurrence of woody thickening across a range of land-use histories from heavily disturbed by fire and grazing to un-grazed and rarely burnt, suggests an influence of climatic factors, for example temperature, rainfall and atmospheric CO_2 (Heisler *et al.*, 2003; Bond & Midgley, 2012).

Aims and Objectives

The primary goal of this project was to enable the spatial documentation of the extent of change in woody vegetation cover across western NSW to inform assessments of carbon potential, landscape productivity and habitat change. The first phase involved developing a trend product from Landsat imagery. All available Landsat-5 TM and Landsat-7 ETM+ imagery, from January 1988 to December 2012, was used to model the linear increase over time in persistent green cover across the western division of NSW at a resolution of 30 meters.

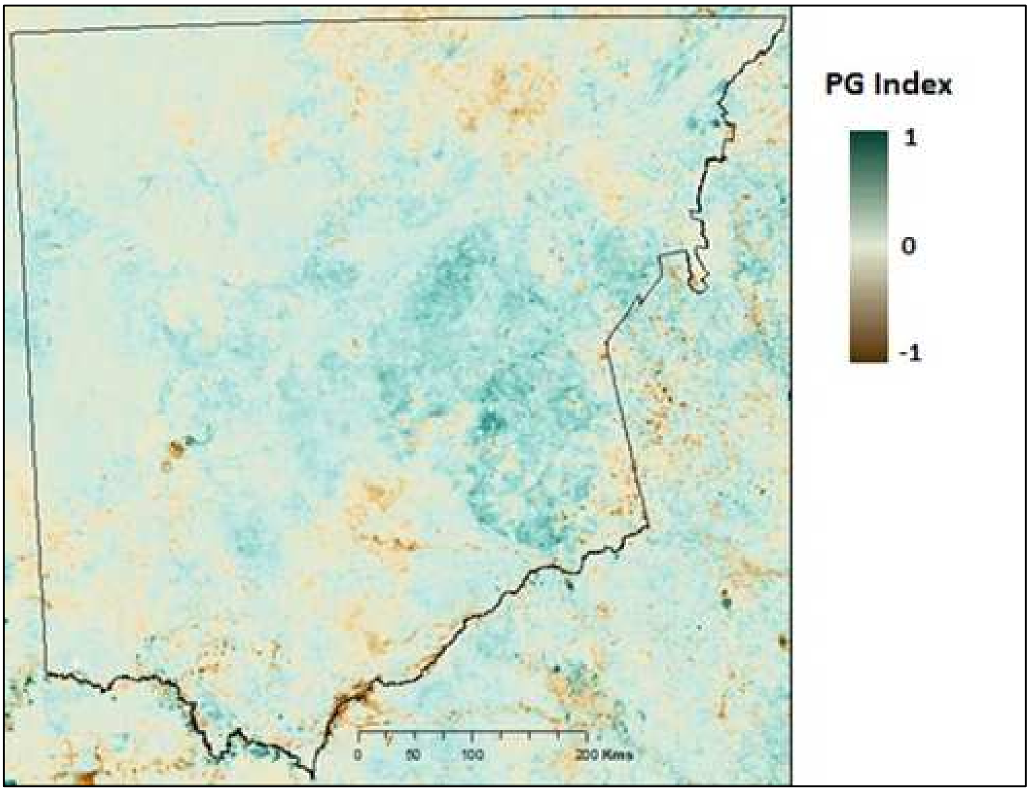

Figure 1. Landsat trend product, modelling linear trend in persistent green (PG) cover in the NSW Western Local Land Services boundary. The trend index ranges from -1, decreasing, to 1, increasing. 0 indicates no changing trend.

The second phase is currently in progress and aims to validate the modelled trend using aerial photograph interpretation (API) by determining whether a change detected in the trend product appears as a change (positive or negative) in the aerial photographs, and vice versa. A further aim of the study will be to examine drivers of woody thickening through statistical analyses of effects and interactions of variables such as fire and grazing histories, temperature and rainfall, vegetation community composition and range types.

Validation using aerial photograph interpretation

Aerial photograph interpretation was used to measure woody cover at exact locations across multiple years to measure the proportion of change in woody cover over time (increase or decrease). Digitally scanned aerial photos covering selected locations were orthorectified and processed for 3d viewing using Stereo Analyst in ArcGIS. For each set of overlapping images (i.e. across multiple years), sites were selected by placing 10 by 10 grids of cells (5m radius). The gridded sites were selected based on having a relatively uniform photo-pattern over at least 50ha (Fensham *et al.*, 2002) and provided a sample of the range of Landsat trend product values representative of the area. Each cell within a site was assigned as either ground, shrub or tree, depending on the majority of cover for the cell, to give an estimate of percent cover for each site. The API results will then be compared to the underlying Landsat trend product value at each site.

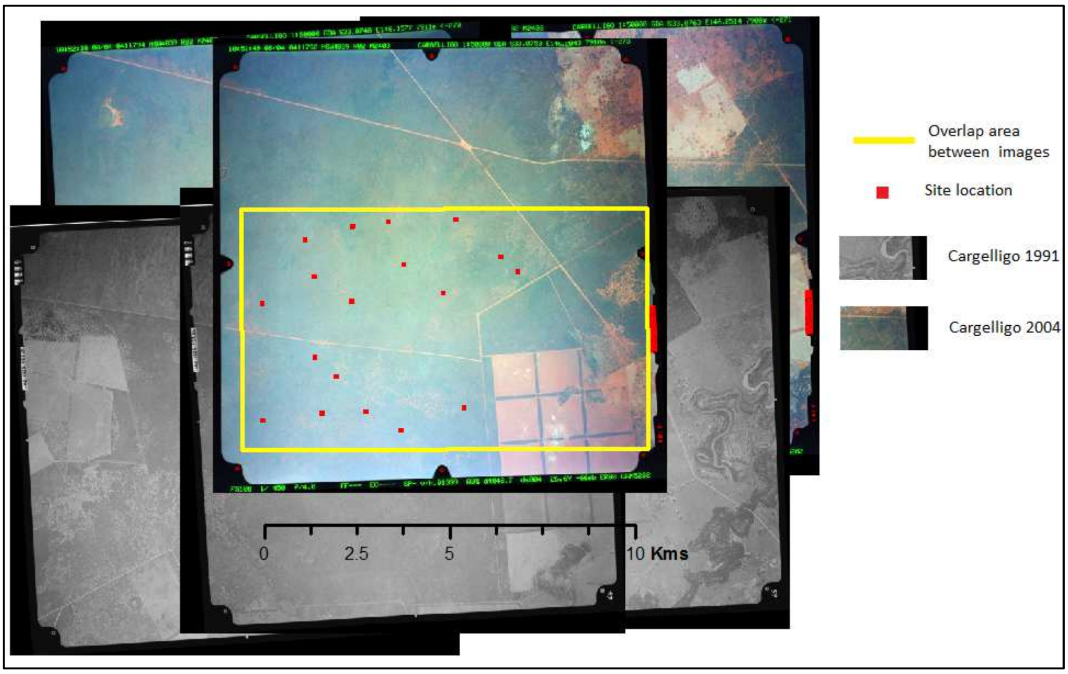

Figure 2. Example of site locations between overlapping imagery from multiple years.

Preliminary findings and progress

Methodological issues have been refined and tested through the initial stages of data collection. Image resolution of the digital scans of aerial photos influences API capability. Resolution of 1200dpi is considered a minimum requirement for this study. A total of 800 sites have been selected across rainfall (Low <250mm/yr, Medium 250-400mm/yr and High >400mm/yr) and range type categories (Mulga, Bimblebox-pine, Downs Country, Mallee, Belah). The balance of sampling design was limited by availability of images and the occurrence of rainfall/range type combinations (e.g. Downs Country does not occur at high rainfall). Height classification between shrubs and trees (e.g. shrub<3m<tree) is difficult to measure with API. For example, distinguishing tree from shrub cover within stands of Mulga, *Acacia aneura,* is more difficult than in saltbush plains with scattered emergent trees. As such, different range types are expected to influence the ability to distinguish between tree and shrub cover as drivers of change in woody cover detected in the Landsat trend.

A total of 214 sites have so far been analysed for change in ground, shrub and tree cover. Preliminary results indicate the API scores of increase in woody cover are positively correlated with the Landsat trend values (Figures 3 and 4). Generalised linear regression analysis of the effect of a change in combined shrub and tree cover determined through API on the Landsat persistent green trend values indicates a significant positive relationship ($P<0.0001$). The assumptions of normality were met, as determined by the Shapiro-Wilks test on the residuals of the model ($W=0.9946$, p-value = 0.6404).

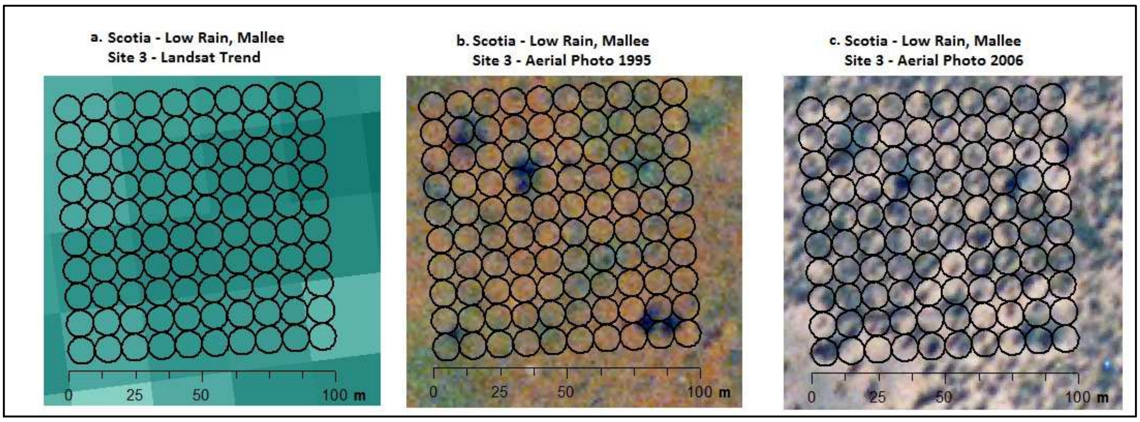

Figure 3. Example of a10x10 gridded site across Landsat trend and the aerial photos for 1995 and 2006.

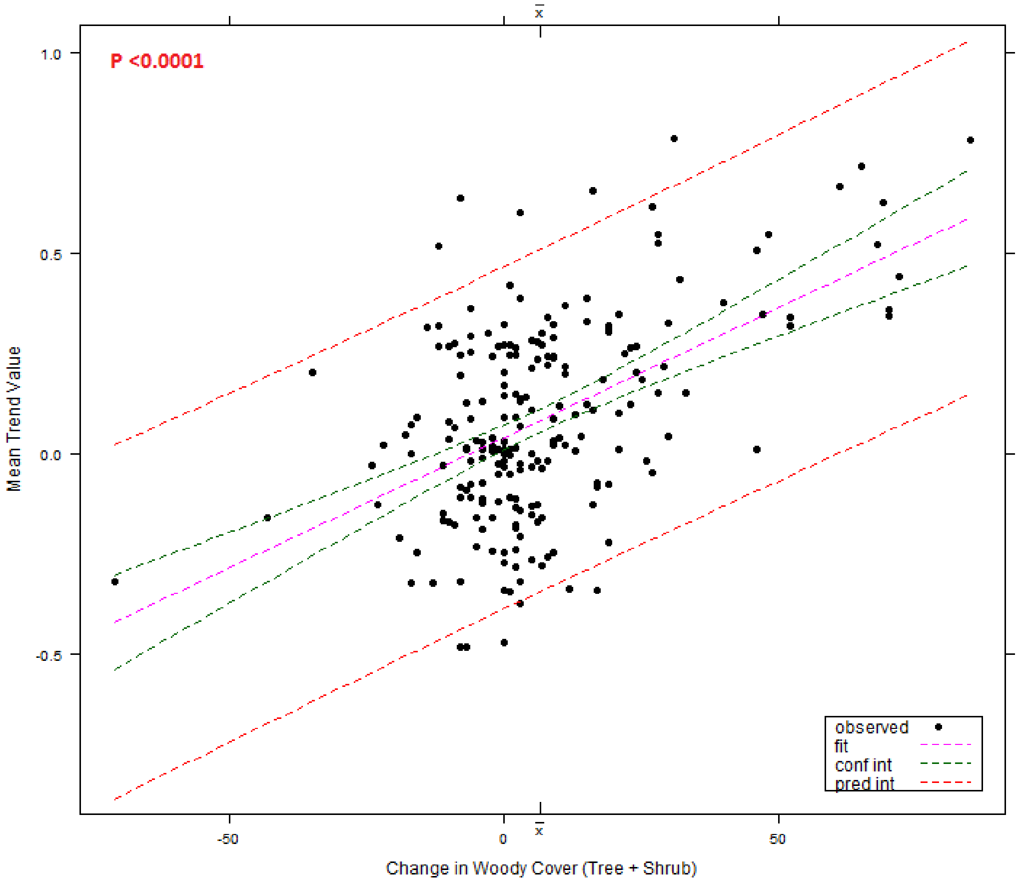

Figure 4. Generalised linear regression analysis of the effect of a change in combined shrub and tree cover determined through API on the Landsat persistent green trend values.

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