State-wide inter-annual changes to foliage projective cover: better products from higher resolution satellite imagery and improved processing methodologies

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Abstract – Landsat and SPOT5 imagery have been used to derive foliage projective cover (FPC) over the states of New South Wales (NSW) and Queensland (QLD). Year-to-year changes have been analysed based on satellite observations as far back as 1986. The products created provide stakeholders and decision makers with a solid information base relevant to vegetation management planning and compliance.

This study focuses on the continuing improvements that have lead to more refined FPC products. The original FPC products were based on medium resolution Landsat TM and ETM+ imagery (30m resolution), but since 2005 SPOT imagery with a resolution of 10m or 2.5m pan-merged has become available.

The signal recorded by the satellite detector is the radiation received at the top of the atmosphere at a specific viewing angle convolved with the optical filter function. But to reliably compute FPC we require the NADIR viewed reflectance on flat ground. Past image processing on ortho-rectified imagery included corrections for the optical filter function, cloud masking, and a practical atmospheric correction based on the 6S algorithm (Vermote, 1997). Recent improvements to the cloud masking are described in a separate presentation (Fisher 2011).

The improved atmospheric correction includes a new Bidirectional Reflectance Distribution Function (BRDF) module that accounts for topographic differences including slopes. As a result the scene-to-scene variability of the final FPC product has been reduced, while at the same time providing much finer detail.

Keywords: Land Cover, Technology, Mapping, Surveying, Vegetation

1. INTRODUCTION

There is increased interest in monitoring changes to land use globally with as much detail and accuracy as possible while keeping total costs in perspective. The NSW government is obliged by the Native Vegetation Act to monitor the extent of native vegetation over the State and take complaince action if required.

Since 2006, annual changes in woody vegetation has been mapped statewide using Landsat TM and ETM+ imagery. The methods used were developed for the Statewide Landcover and Trees Study[1] (SLATS) in Queensland and reports on woody vegetation change covering time periods from 1988–2009 have been published (DECCW 2009). The ability to detect woody vegetation change is influenced by the modest 30m resolution of the Landsat imagery, the type and pattern of vegetation on the ground as well as the observation geometry and ground topography (areas in shadow) and any presence of clouds. These factors combine to reduce the ability to detect woody vegetation change, in particular in landscapes such as open woodlands with scattered trees, grasslands, and highly modified areas.

The NSW Native Vegetation Monitoring Program was commenced in July 2007. This program provides annual monitoring based on high resolution satellite imagery for the whole state using summer image epochs. Existing methods that were established to map woody extent and monitor change in woody extent using Landsat imagery have been adapted to enable analysis of SPOT imagery.

This paper describes the methods that are being used for the analysis of woody vegetation change using SPOT 5 imagery and the results so far.

2.1 Data

SPOT 5 imagery has been acquired for 2007/08, 2008/09 and 2009/10 epochs. Imagery for 2004/05 was acquired through an earlier project and is also available for use. A single state-wide SPOT image coverage of NSW requires the acquisition of approximately 340 SPOT scenes. Reflectance images are available at 10m resolution and contain 4 spectral bands (XS1, XS2, XS3, SWIR). Further, there is a panchromatic product available, at the higher resolution of 2.5m.

Most of the images have been acquired during the dry season, which typically coincides with summer for most of the state. During this time confusion between crops and woody vegetation is minimised in the interpretation of the imagery. However, due to the time required for SPOT data acquisition over NSW, cloud cover and off nadir look angle limitations, there are some images that were not acquired at the optimum date. As a result some images either have some cloud cover or were acquired when there was green herbaceous cover, which makes it more difficult to separate woody from non-woody vegetation. Ortho-rectification had been carried out by Geoimage.

2.2 Methods

Pre-processing

The raw (Dimap) SPOT imagery and rectified products from Geoimage are loaded on the DECCW Linux computing cluster. An open source computing environment using Python[2], GDAL[3] and SciPy[4] is used for image analysis. Images are imported using a script that renames these files according to a standard file naming convention. During the load, PostgreSQL database tables containing scene footprints and processing metadata are

[1] http://www.derm.qld.gov.au/slats

[2] http://www.python.org/

[3] http://www.gdal.org/

[4] http://www.scipy.org/

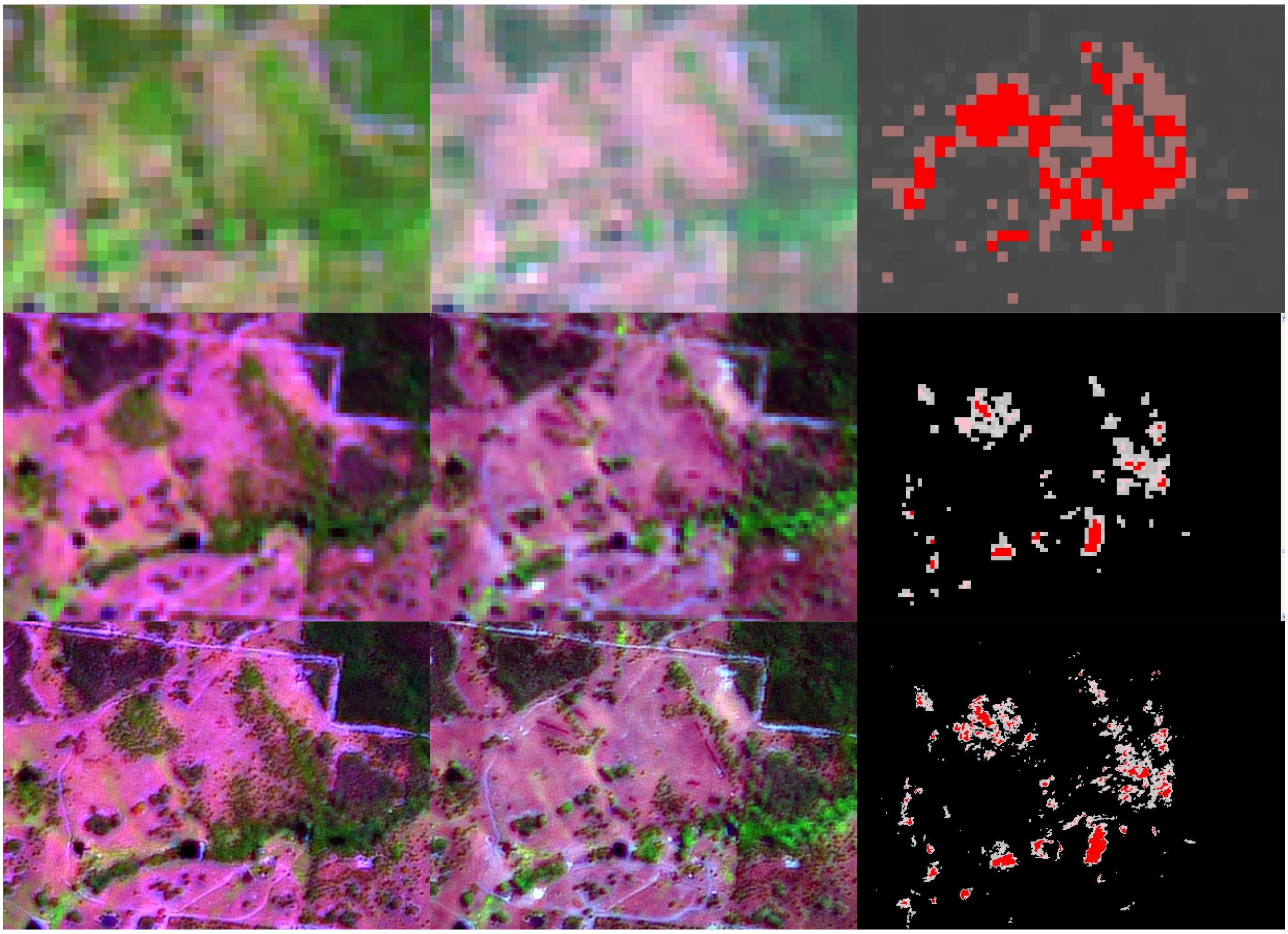

Figure 1: Annual change of woody vegetation using different satellite products. From left to right: a) atmospherically corrected images taken 2007-11-12.b) atmospherically corrected images taken 2009-01-17 and 2009-02-06 c) Differences between a) and b) in terms of deduced foliage projective cover. Red areas indicate high probabilities of removal of woody vegetation. From top to bottom: 1) Landsat products with 30m resolution, 2) SPOT5 products at 10m resolution. 3) SPOT5 pan-sharpened product at 2.5m resolution.

populated. Much of the software used has been developed through the Joint Remote Sensing Research Program [5](JRSRP).

Atmospheric correction was performed on the SPOT imagery to retrieve estimates of surface reflectance. The radiative transfer modelling software, 6S (Vermote., 1997) was used. Details of the process have been described previously (Danaher 2010). The aerosol optical depth is one of the most sensitive and also difficult parameters to obtain. After testing many approaches (Gillingham,2011) it was decided to run with a constant AOD of 0.05 as in most cases the atmosphere in NSW is quite clear and all techniques for estimation of AOD from the image data were problematic. Table 1 lists the parameters required by 6S and the source of those parameters used for this study. The removal of cloud is an important step if automated processing is to be run on the data. We use the method implemented by (Fisher, 2011).

The methods for pan-sharpening are based on (Hahn, 2008 -- implementing formula 4, corresponding to Figure 1f). This method was chosen as it is efficient and does not distort the radiometric scaling of the imagery. Cubic convolution is used for re-sampling the low resolution image based on the high resolution image.

SPOT 5 / Landsat FPC cross-calibration approach

The metric of vegetation cover used in many Australian vegetation classification frameworks is Foliage Projective Cover (FPC). FPC is the percentage of ground area covered by the vertical projection of foliage. Regression approaches and other statistical techniques (Armston, 2009) have been used to predict FPC from Landsat imagery and these Landsat FPC data are then used for mapping vegetation extent and monitoring woody vegetation change. This can only be successful if the imagery has been radiometrically corrected to remove systematic spatial and temporal differences.

Details of the data processing and cross-calibration approach are described in (Danaher 2010). However, a BRDF correction has now been implemented which reduces the variability from image to image with different viewing geometries. Sun and view angles are standardised after the Ross-Thick-Li-Sparse (RTLS) model is used to adjust reflectance to a standard incidence angle of 45 degrees and a nadir view angle. The reflectance from the surface-leaving radiance and direct and diffuse irradiance are calculated. It includes modelling of diffuse reflectance as a function of direct reflectance and view angle (exitance).

Vegetation change mapping

The method used to map change in woody vegetation using Landsat imagery was developed in the SLATS program and is described by Scarth *et al*. (2008) and (Danaher 2010). Calibration data, collected from an analysis of previous

5 http://www.gpem.uq.edu.au/jrsrp

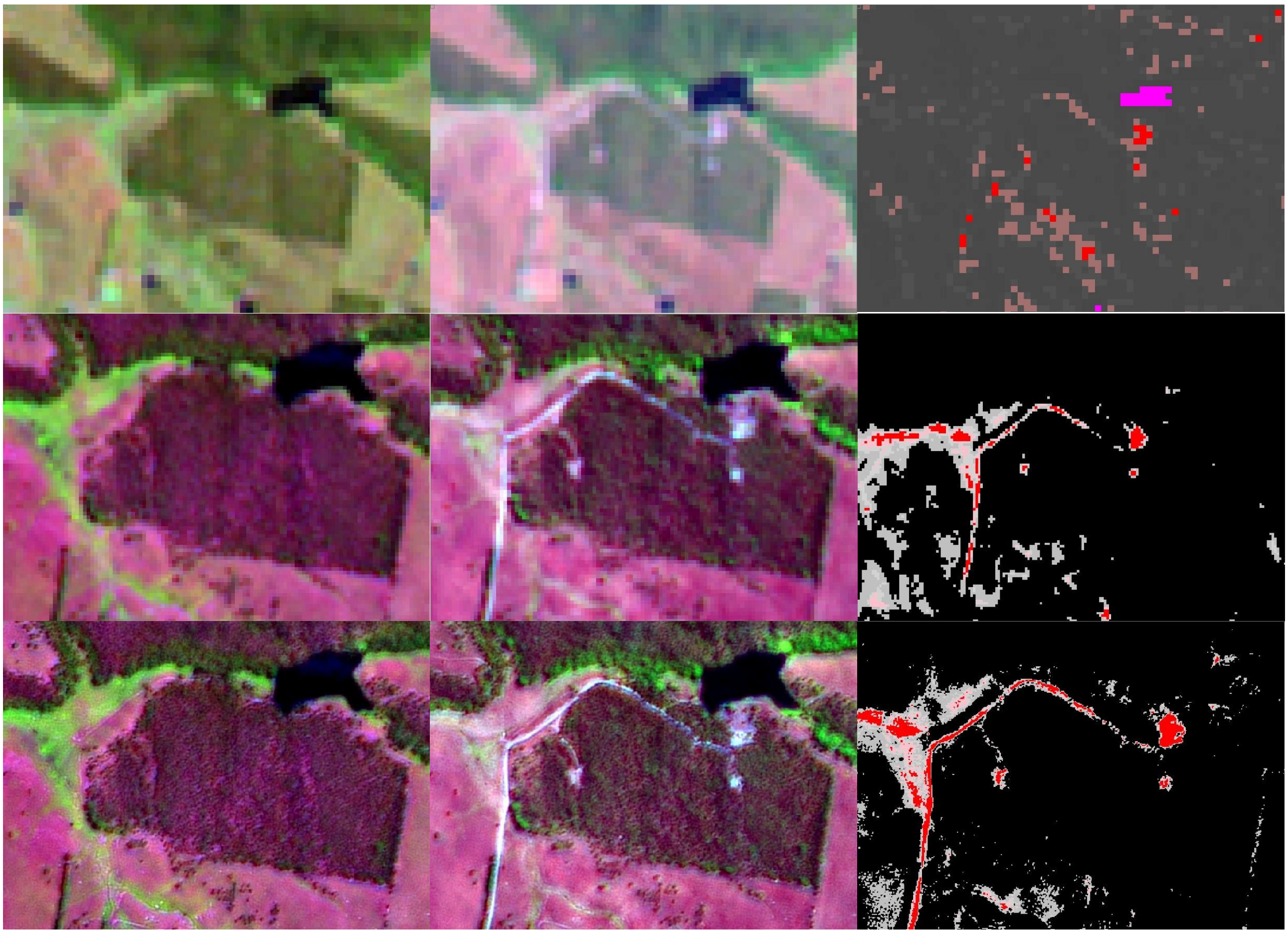

Figure 2: Annual change of woody vegetation using different satellite products. From left to right: a) atmospherically corrected images taken 2007-11-12.b) atmospherically corrected images taken 2009-01-17 and 2009-02-06 c) Differences between a) and b) in terms of deduced foliage projective cover. Red areas indicate high probabilities of removal of woody vegetation. From top to bottom: 1) Landsat products with 30m resolution, 2) SPOT5 products at 10m resolution. 3) SPOT5 pan-sharpened product at 2.5m resolution. The highest resolution is superior, in particular where there are thin linear structures, such as road clearings.

operator-interpreted and field checked woody change data sets from previous years, were used to develop the spectral and temporal change indices.The final classifier sits within the SLATS operational processing framework and is run automatically across the state. However, in order to use this classifier in an operational reporting environment, three levels of classification at the 2%, 5% and 15% omission level are produced which are then further interpreted, edited and field checked by an operator.

Thresholding of the woody change index is done on a scene by scene basis or multi-scene block, where the image dates are the same. Four possible change class thresholds are set to assist in the visual interpretation of the change images. This thresholding task is being done by two experienced image analysts to ensure consistency in the approach. Visual editing is used to check the output of the classifier, and further improve the accuracy of the final product.

With the availability of a BRDF correction we expect to derive statewide or regional change indices as opposed to the scene-by-scene approach used thus far. However, we have not processed a sufficient number of scenes yet to decide whether this will be successful. The increase in resolution may also help as discussed below.

3 Results and Discussion

The FPC cross calibration approach was applied to 627 SPOT images acquired during the 2008–2009 period. For each scene the SPOT FPC was validated against the Landsat FPC product using a minimum of 1100 points and an average of 44000 per run. The average slope, intercept and RSME were 0.66, 6.7 and 4.5 respectively.

Tests have been made on a few selected scenes to apply the BRDF correction and to use pan-sharpened higher resolution imagery. Examples that compare SPOT and Landsat imagery at different resolution are illustrated in Figures 1 and 2. It is evident from the illustrations that the higher resolution provides more detail and a more accurate determination of change occurring. At 2.5m resolution individual trees can be identified (Figure 1) and image blurring has an almost negligible effect on the derived product. Narrow linear changes, such as along fences or roads, can also be detected much more accurately at 2.5m resolution and are poorly, if at all, detectable at 30m resolution (Figure 2). However, computing time and data storage require significantly higher resources, but may be justified through the better quality of the products. The 2.5m resolution imagery also requires excellent rectification (better than 1m) to analyse changes over time.

Figure 3 illustrates the effect that BRDF correction has by itself on the same 10m resolution SPOT imagery. Corrected

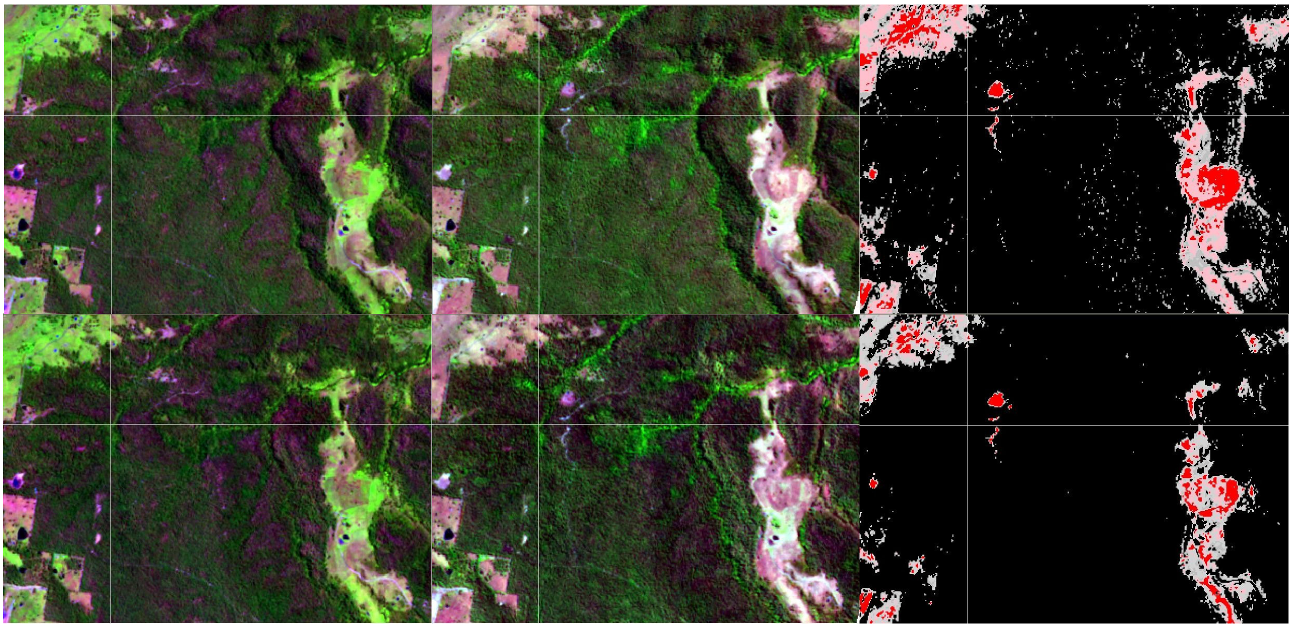

Figure 3: Annual change of woody vegetation using different satellite products. From left to right: a) atmospherically corrected images taken 2007-11-12.b) atmospherically corrected images taken 2009-01-17 and 2009-02-06 c) Differences between a) and b) in terms of deduced foliage projective cover. Red areas indicate high probabilities of removal of woody vegetation. From top to bottom: 1) SPOT5 products at 10m resolution **without** BRDF correction 2) SPOT5 products at 10m resolution with BRDF correction. The BRDF corrected woody change product (bottom right) is cleaner.

images appear flatter to the human eye. But also the derived woody change product (bottom right) is cleaner. There are fewer false positives from green herbaceous cover while the actual confirmed change (near the crosshair centre) represents about the same area. Scene-to-scene variability is also reduced (not illustrated).

Conclusions

High resolution imagery is superior to lower resolution imagery and provides the ability to monitor vegetation changes not visible in Landsat imagery. At 2.5m resolution individual trees are identified and provide greater detail for compliance cases. The use of BRDF corrections further improves the quality and reduces the area of false positives and noise and reduces the scene-to-scene variability. Application of the improved methods to state-wide products from past and present SPOT imagery is expected to provide more efficient processing and detect more detailed changes in native vegetation as demonstrated here for sample images.

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