NSW Vegetation Monitoring using Satellite Imagery

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Introduction:
The NSW government has committed in the state plan to monitor the extent and condition of native vegetation. In order to achieve this goal, state-wide routine monitoring must be undertaken. In addition to the ability to monitor current vegetation distribution, analysis of historic vegetation distribution aids in the identification of trends and location of large variations in vegetation through time.

The NSW Department of Environment Climate Change and Water has been monitoring vegetation state-wide through the use of Landsat imagery on an annual basis since 2006. Historic analysis has been performed on a biannual NSW Landsat coverage from 1998 to 2006.

In addition, high resolution satellite imagery from the SPOT5 satellite has been used on an annual state-wide basis since 2008 to increase the precision of the analysis.

Landsat pre-processing:
Accurate detection and quantification of vegetation change over time and space requires removal of the confounding effects of geometric distortion; radiometric variability; illumination geometry; and cloud, shadow and water contamination from imagery. These pre-processed Landsat TM and ETM data form the basis of all derived image products.

The Landsat imagery is acquired from Geoscience Australia as Level 5 processed data and rectified to the SPOT 2004/05 image base developed by Geoimage. Development of the SPOT 2004/05 rectified image base is described by Peters (1). The pre-orbit radiometric calibration is used for ETM+ images; the onboard calibration is removed from TM images and an improved time-dependant vicarious calibration (2) is applied. Images are converted to top-of-atmosphere (TOA) reflectance and a three-parameter empirical model (3) applied to further reduce variation due to illumination geometry and bi-directional reflectance distribution function (BRDF).

Images are acquired in the dry season to minimize cloud cover, and maximize the spectral contrast between perennial vegetation and senescing annual grasses, however many Landsat images acquired contain some cloud contamination. Reflectance values are affected by cloud and cloud shadow, topographic shadow, and surface water. The Landsat images are masked using automated and semi-automated Landsat-derived masks for cloud, shadow (4) and water

(5). Areas of deep topographic shadow are masked by simulating illumination at the time of image acquisition using a ray tracing method with the SRTM DEM.

An optional topographic correction can be applied to the radiometrically corrected imagery. This correction is based on the WAK model (6).

Landsat vegetation extent and FPC:

The metric of vegetation cover adopted in many Australian vegetation classification frameworks is Foliage Projective Cover (FPC). Operational mapping of overstorey FPC requires an efficient and automated method due to the large volume of Landsat data that require processing and interpretation. Regression approaches (17) and other statistical techniques (8) have been used to predict FPC from Landsat imagery.

A multi-temporal rule based approach has been used to map the woody extent and FPC (9).The woody extent and FPC product uses a time series of Landsat images to calculate the best possible prediction of FPC for each pixel within a scene, for a specified time period e.g. 1988–2008.

The FPC products have been validated in Queensland using independent site measurements and airborne LIDAR data (8). It is planned to validate the NSW woody extent mapping using "desktop" validation sites taken from high resolution SPOT imagery. The FPC is currently being validated using sites measured in the field.

Landsat vegetation change mapping:

The difficulties in consistently and reliably detecting woody change across a wide range of vegetation types over a large geographical area required the development of a change method that combined both the spectral changes from scene to scene and the historical variability in foliage cover. This combination of change detection methodologies was based on combining a modified form of image differencing with a time series model using the FPC time series to detect true change. The method used to map change in woody vegetation was developed in the SLATS program and is described by Scarth et al. (7).

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 checked by an operator. This manual interpretation stage is used to check the output of the classifier, and further improve the accuracy of the final product before it is used to produce the annual SLATS woody change figures and reports.

A sample of the change data is checked through a QA process (16) to ensure a high level of consistency between operators. The analysis and interpretation of the woody change is done on a scene by scene basis. The results are combined to form statewide data sets which are used in a GIS environment to calculate rates of vegetation change, taking into account the different acquisition dates for each Landsat scene.

SPOT 5 pre-processing:

The calibration coefficients provided with the SPOT imagery is applied to the data to convert the data to radiance. Preliminary validation was performed to confirm that the SPOT calibration was correct and being correctly applied to the imagery.

An atmospheric correction is applied to the SPOT imagery using the 6S code (10). The inputs to this process are based on interpolated meteorological data and climatology data. The Aerosol Optical Depth (AOD) is one of the most sensitive and difficult to obtain parameters. After testing many approaches (11) 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 were problematic.

Removal of cloud is an important step if automated processing is to be run on the data. A cloud masking method has been developed and being applied (12,13). Further refinement of the method is also being done through a Joint Remote Sensing Research Program (JRSRP) project.

SPOT vegetation extent and FPC:
As the current radiometric correction for SPOT imagery is only an atmospheric correction and doesn't include correction for BRDF effects, significant scene to scene differences exist in some cases. Hence, it was not possible to develop a general FPC model that could be applied statewide to the SPOT imagery. To overcome this problem a cross calibration approach (14) combining atmospherically corrected SPOT 5 imagery and the existing calibrated Landsat woody extent and FPC product is being used to generate SPOT FPC products.

The cross calibration method (14) has been implemented in Pymodeller and is being run to provide FPC data for change mapping. It has been run on the 10m resolution SPOT imagery and in future will be tested on the 2.5m pan-merged products. The development of a multi-temporal SPOT woody extent and FPC product, using an approach similar to that used in the Landsat product will be investigated.

SPOT woody vegetation change mapping:
While it is planned to map vegetation change at the highest possible resolution that SPOT imagery allows, initially only the multi-spectral (10m) SPOT data is being used. A pre-processing method to enable pan-merging of the imagery in a way that is compatible with the radiometric correction method is being tested. This will allow analysis at a 2.5m pixel image resolution across the state.

As the radiometric correction applied to the SPOT imagery is only an interim correction at this stage and does not remote BRDF effects, it was not possible to develop a change mapping method that included automated thresholding of the change index, as is done with Landsat. Thresholding of the woody change index is done manually 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 visual interpretation of the change images.

Similar to Landsat, visual editing is used to check the output of the classifier, and further improve the accuracy of the final product (15). Polygons used in this editing process (Imagine AOI's) are being kept to enable the re-coding to be repeated with 2.5m change data when available, and are used in the QA stage.

Conclusion:
The NSW Department of Environment Climate Change and Water uses a variety of satellite imagery to monitor vegetation on an annual basis. Historic and trend information has been captured for the period 1988 to 2010. The vegetation monitoring programme has provided systematic and precise information as to the change in woody vegetation throughout continental NSW to better inform natural resource management in NSW.

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