# Reporting change in landscape function using the Queensland ground cover index

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## Abstract

A ground cover index (GCI) derived from Landsat TM data is available for Queensland since 1986. It provides a potentially robust means for reporting change in landscape function to the Australian Collaborative Rangelands Information System (ACRIS). We report early progress in developing such an index based on the temporal behaviour of pixel GCI values. Pixels within paddocks in the Wambiana grazing trial were classified as notionally 'functional' or 'dysfunctional' based on a specified deviation in ground cover from their longer-term temporal mean. This produced distinct spatial patterning of 'dysfunctional' areas for some grazing treatments in drier years. The proportional area of this 'dysfunctional' class within paddocks and vegetation types was significantly correlated with estimated ground cover. Further methodological development will relate the currently developed temporal deviations in pixel GCI to that occurring in the surrounding neighbourhood. When a suitably robust method for indicating landscape function from GCI is available, we will increase the scale of analysis to sub-bioregions so as to report change in landscape function for Queensland's rangelands to ACRIS.

## Introduction

Landscape function describes the extent to which landscapes regulate (capture) rainwater and nutrients for plant growth (Ludwig *et al*. 1997a). It is typically monitored with ground-based measurement at hillslope scale but Ludwig *et al*. (2007b) have demonstrated how monitoring can be increased to the sub-catchment scale with their leakiness index. At a much larger scale, e.g. bioregion, the Australian Collaborative Rangeland Information System (ACRIS) has amalgamated site-level data to report change in landscape function for much of the pastoral rangelands (Bastin *et al*. 2008). Site data were used to indicate change for the areas surrounding, and represented by, sites but it was not possible to report change for the entire area of each region. Remote sensing provides spatially dense coverage, but to date we are not aware of a method for reporting regional change in landscape function using such data.

An annual Ground Cover Index (GCI) derived from Landsat TM data extending back to 1986 is now available for Queensland at 25-m pixel resolution (Scarth *et al*. 2006). Percentage ground cover is calculated for all pixels but typically analysed where foliage projected cover of woody species is less than 20%. Images are acquired in the mid to late dry season (July-September) when ephemeral herbage has largely disappeared and ground cover comprises more persistent species. For groups of pixels, the GCI potentially indicates landscape function. But what is the relationship between GCI and landscape function when the data are analysed at regional scale? For example, there are 76 sub-regions of the Interim Biogeographic Regionalisation for Australia (IBRA) in the Queensland rangelands with an area greater than 1,000 $km^2$ (with the largest being 68,870 $km^2$).

Our approach to deriving an index of landscape function from regional GCI data is developing. In this paper, we explore patterning in the temporal behaviour of pixel GCI values and relate an index derived from this spatial aggregation to available ground data and information about recent seasonal conditions.

## Methods

The temporal mean and standard deviation (SD) of pixel GCI values between 1988 and 2008 were calculated for the area surrounding, and including, paddocks within the Wambiana grazing trial (O'Reagain *et al*. 2008) south of Charters Towers. These ~100 ha paddocks provided diverse grazing treatments imposed over small adjacent areas and annual estimates of ground cover, stratified by vegetation type, against which to compare the remotely sensed data. Grazing treatments at the trial were initiated in December 1997.

$$\frac{X - \bar{X}_{temporal}}{\sigma_{temporal}} \sim N(0,1)$$

Assuming a normal distribution of ground cover values for each pixel, the deviation of any pixel time-value from the time-series mean (for that pixel) was normalised such that:

where $\bar{X}_{temporal}$ is the time-series mean and $\sigma_{temporal}$ is the time-series SD.

Pixel GCI values were included in the analysis where the annual foliage projected cover (FPC) of woody species was less than 15%.

Pixels with a GCI deviation of more than 1 SD below their temporal mean for any year were notionally assigned as 'dysfunctional' and those above -1 SD were considered 'functional'. We then examined the spatial patterning of these two classes through time for paddocks in the grazing trial. The combined area of 'functional' pixels as a proportion of paddock area with <15% FPC was used to calculate an interim index of landscape function. This index was correlated with ground cover estimated along fixed transects at the end of dry season in each of the Wambiana treatment paddocks.

## Results

There was distinct spatial aggregation of pixels with a deviation ≤-1 SD from their temporal mean (i.e. pixels notionally considered 'dysfunctional' for landscape function) in any year, example for 2006 (a drier year) shown in Fig. 1. Thus the proportional paddock area considered 'functional' decreased in drier years and was also related to grazing treatment (Fig. 2). The heavily stocked paddocks had greater concentrations of pixels considered dysfunctional (i.e. their temporal standard deviation of cover was below our notional threshold of landscape function). Additionally, in 2006 at least, there was considerable aggregation of 'dysfunctional' pixels in the two lightly stocked paddocks.

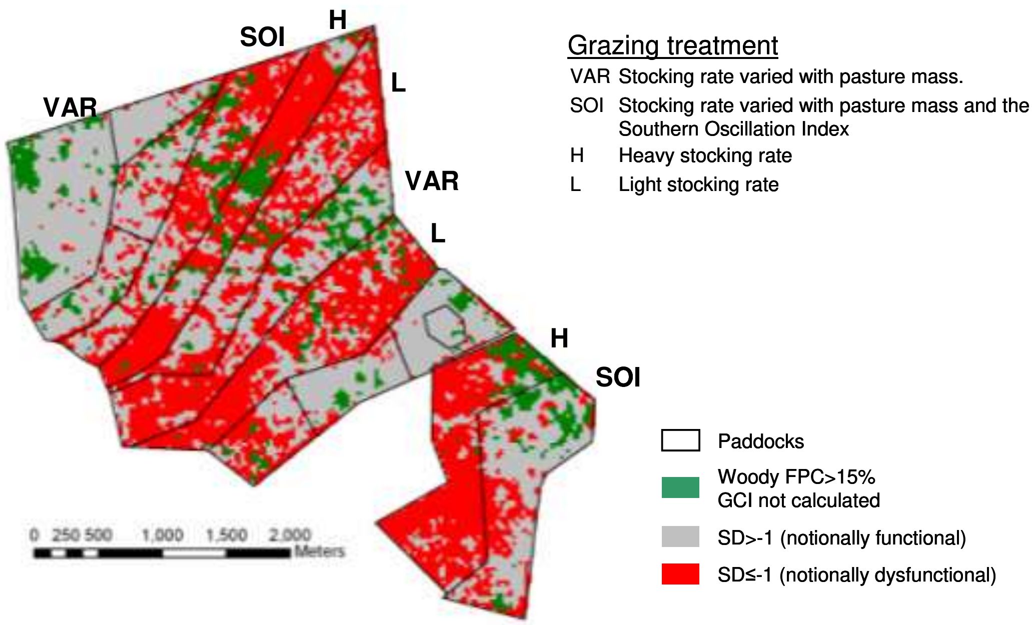


*Fig. 1. Areas within the Wambiana grazing trial notionally mapped as 'functional' and 'dysfunctional', based on standardised deviations of the 2006 GCI data from the longer-term temporal mean (1988-2008). GCI data were not analysed where woody FPC > 15%. The smaller paddocks without labelling are part of a spelling treatment and do not contribute to reported results. 2006 was a relatively dry year (see Fig. 2).*

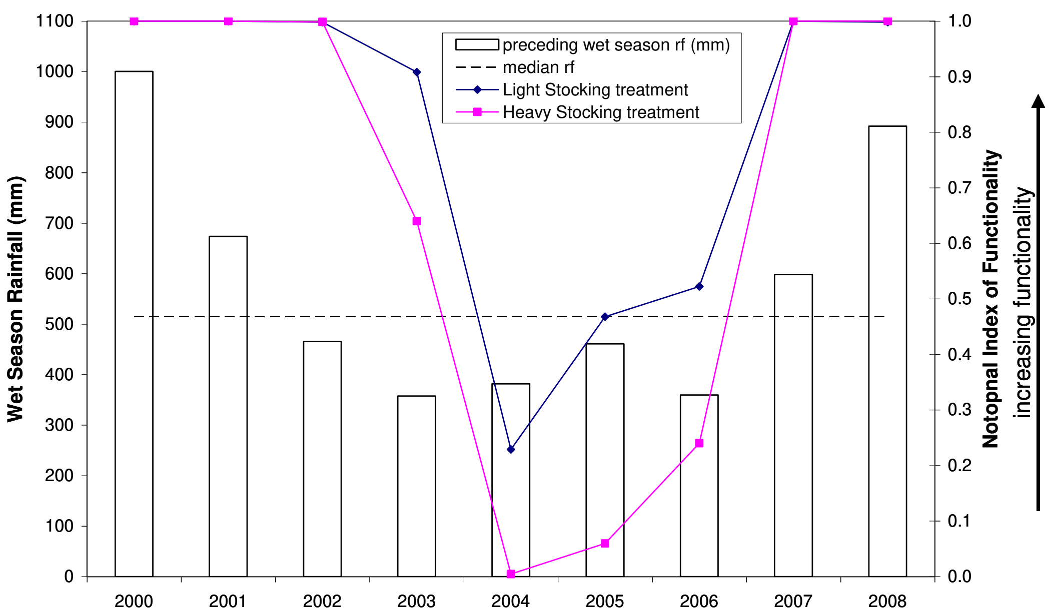


*Fig. 2. Time traces of a functionality index for light and heavy stocking treatments at Wambiana. Rainfall recorded at Charters Towers for the November-April period preceding the date of each ground cover image is also shown.*

Across all treatment paddocks, there was a significant Pearson correlation between ground cover estimated annually at the end of the dry season (2000 to 2008) and values of the interim index of landscape function (R=0.670, n=72, P<0.001). Correlations were stronger for the two heavily stocked paddocks (R>0.745) followed by the light stocking treatments (R ~ 0.66). There was also a vegetation type interaction: correlation was strongest for Ironbark country located generally in the southern part of paddocks (R=0.736) followed by the Box vegetation type in the northern part of paddocks (R=0.619). The correlation between the interim index and estimated ground cover for the Brigalow vegetation type (central area of paddocks) was considerably weaker although statistically significant (R=0.452, P<0.05).

## Discussion

The spatial arrangement of persistent ground cover is an important determinant of landscape function (Ludwig *et al*. 2007a). Although mid dry-season GCI does not exclusively discriminate persistent ground cover, it can usefully indicate landscape function because ephemeral species have often largely disappeared by this time. Pixel GCI values can be quite dynamic among years according to rainfall variability, fire effects and grazing management. Thus it can be difficult and quite subjective to ascribe when and where lower ground cover indicates reduced landscape function.

The statistical approach of standardising deviations in pixel GCI from their longer-term temporal mean and then focussing on larger negative deviations may provide some objectivity to this process. In an undisturbed landscape, characterised by perennial plants and ground cover commensurate with seasonal rainfall, the temporal deviations of GCI for individual pixels should not produce any distinct spatial pattern at any time. By definition, all pixels at some time will have GCI deviations ≤-1 SD from their temporal mean. Accordingly, the frequency of thresholded pixels (i.e. GCI ≤-1 SD) would be expected to increase in drier years and decrease in wetter years but lack any distinct spatial patterning at any time.

The strong spatial pattern in thresholded pixel GCI deviations at Wambiana (Fig. 1) reflects changes since 1997 (when the trial started) in ground cover related to current grazing treatments compared to their earlier temporal behaviour when all treatment paddocks were part of a larger commercial paddock. This is most apparent for the two heavily stocked paddocks where ground cover is now much lower in the mid to late dry season in most years. It is uncertain why the spatial differentiation of notionally functional and dysfunctional areas was so marked in the light-stocking treatments in 2006 and this requires further investigation.

Significant correlations between estimated ground cover and values of the interim index of landscape function validate the reliability of GCI in indicating ground cover more so than the performance of the index in indicating landscape function. The density of productive perennial and palatable (3P) grasses has been measured in treatment paddocks since 2006 and the data, although not reported here, show that while estimated ground cover in the lightly stocked paddocks was low in that year, 3P density remained relatively high. Both ground cover and 3P grass density were low in the heavily stocked paddocks. Ground cover has increased in both sets of paddocks with wetter years since 2006 but 3P grass density remains relatively low in the heavily stocked paddocks (Peter O'Reagain, unpublished data). Intuitively, the density of 3P grasses is a more reliable indicator of landscape function than ground cover, whether estimated directly or derived from remote sensing.

Thus further work is required to derive a suitably robust index of landscape function from GCI for the Wambiana treatment paddocks and, from there, scale this method up to the surrounding sub-bioregion and those of other bioregions in the Queensland rangelands. Our preliminary approach has explored the temporal behaviour of pixel GCI and shown, for Wambiana at least, there is distinct spatial patterning that appears related to grazing management. Our next step is to combine this temporal analysis with spatial analysis of large pixel neighbourhoods to search for relatively undisturbed areas in space and time. GCI values for these 'benchmark' pixels may serve as a reference against which to compare the temporal behaviour of the index for other areas in the neighbourhood. If this approach has validity, then we would seek to implement it at regional scale by simply moving the analysis neighbourhood across the entire region to be analysed.

If successful, the refined approach should provide an appropriate index of landscape functionality assigned on a per-pixel basis, albeit taking account of spatio-temporal GCI values from the much larger neighbourhood. The per-pixel assignment of functionality is expected to be scalable according to the stratification of interest. This would allow extrapolation of the index from the small trial paddocks to larger commercial paddocks to components of bioregions. Obviously, the interpretation of resultant landscape function at regional scale will be different to that for the research paddocks at Wambiana and we need to gain experience and confidence in making these cross-scale transitions and inferences.

Whatever the result, the range of treatments imposed in the Wambiana grazing trial and the resultant data for the herbage layer will be important for evaluating progress in developing this index.

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