Are we there yet? Tracking state and change in Australia's rangelands

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Abstract

Objectively monitoring trend in the state of Australia's grazed rangelands has proven elusive because of their extensive area and considerable spatial and temporal variability. National archives of fractional vegetation cover derived from satellite data now mean that this problem is more tractable. Through the Australian Collaborative Rangelands Information System, we developed and tested a dynamic reference cover method that objectively separates grazing effects on ground cover from that due to inter-annual variation in rainfall. The method is based on the persistence of ground cover in years of lower rainfall. An indicator of rangeland state for Landsat TM pixels is produced by subtracting automatically calculated reference cover from actual ground cover and then spatially averaging these deficits across a paddock, pastoral lease or larger reporting region as required. Change in the mean cover deficit between sequences of dry years reliably indicates change due to grazing.

We have used the method to report state and change in approximately half of the Queensland rangelands between 1988 and 2005 (recent paper in The Rangeland Journal) and all of the NSW rangelands between 1992 and 2013 (results not yet published). In progressing towards a national capacity to track the state of Australia's grazed rangelands objectively, based on ground-cover dynamics, we will run a more contemporary and complete analysis for the Queensland rangelands and include the NT to generate results that complement those currently available for NSW. This enlarged analysis is possible with the availability of suitably calibrated and validated Landsat-derived fractional vegetation cover through the NT Government's formal association with the Joint Remote Sensing Research Program. Change in cover-deficit values between dry years at pixel to paddock resolution may also provide useful information for land managers and their advisors as web-based technologies for information delivery develop.

Introduction

Rangeland scientists have sought to objectively and comprehensively report change in the state of Australia's pastoral estate for close to 30 years. Well established ground-based monitoring programs such as the Western Australian Rangeland Monitoring System (WARMS) provide robust regional-scale information about changes in landscape function and perennial vegetation components that are critical for sustained pastoral production (e.g. Watson et al. 2007 and Novelly et al. 2008). WARMS, in particular, also provides plausible inferences as to whether inter-annual variation in rainfall or past grazing is the most probable cause of site-level change. Acknowledging the valuable information that ground-based monitoring has generated about the pastoral estate, most systems are costly to operate, rely on often tenuous spatial extrapolation to indicate change beyond fixed sites and monitoring may be missing parts of the landscape where more rapid and insidious change is occurring (Pringle et al. 2006).

Remote sensing-based methods have claimed to address the limitations of ground-based monitoring by analysing the archived, multi-temporal and spatially extensive data acquired by satellites. However, until recently, analysts faced considerable overheads in assembling suitably calibrated imagery that reliably indicated change in ground cover across extensive and diverse landscapes. Calibrated fractional cover products derived from Landsat TM imagery (30m pixel size, extending back to 1987) and MODIS (500m pixels, since 2000) now exist for Australia (Guerschman et al. in press). These products allow the fraction of bare soil (conversely, ground cover) to be tracked by land type within paddocks using VegMachine (Terry Beutel, this conference) or complementary tools within the developing NRM Spatial Hub (Mike Digby and colleagues, this conference). Despite this progress, the challenge of using these data to efficiently and definitively separate grazing effects on ground cover from that due to inter-annual variation in rainfall has, until recently, remained.

The Dynamic Reference Cover Method

We have developed, tested and applied an automated procedure for determining the state of grazed rangelands based on the persistence of ground cover in the driest (i.e. drought) years. Higher levels of ground cover at such times is likely due to more benign grazing management that maintains the cover of perennial herbage species. Our approach is ecologically sensible because it directly relates to landscape function principles (Ludwig et al. 1997) and, in practical terms, indicates the extent to which soil is protected against erosion in dry times.

The Dynamic Reference Cover Method (DRCM) uses the averaged ground cover of reference-pixel locations in a suitably dry year to calculate an expected level of cover for the central (i.e. focal) pixel in a window of specified size that is moved across and down the image. Reference pixel locations are defined by the 90-95th percentile of temporal minimum ground cover. The difference between actual and expected cover (cover deficit, ΔGC) provides a seasonally-adjusted measure of grazing impact on the pixel area. Change in ΔGC between successive dry years, ΔΔGC, indicates the effectiveness of grazing management over time. Both statistics are spatially averaged across groups of pixels to give $\overline{\Delta GC}$ and $\overline{\Delta\Delta GC}$. These statistics indicate state and change, respectively, of management areas such as paddocks and the property.

The ability of DRCM to reliably track change in the state of grazed rangeland was tested at scales between small research paddocks and commercial beef properties (results reported in Bastin et al. 2012). We subsequently used the method to report state and change in approximately 640,000 km^2 of Queensland's rangelands between 1988 and 2005 (Bastin et al. 2014).

Beyond Queensland

The NSW Office of Environment and Heritage has adapted the DRCM software to analyse the dynamics of bare-soil (as a component of fractional cover) in the NSW rangelands. State and change at the spatial resolution of sub-bioregions is yet to be reported in the peer-reviewed literature but indicative results, to 2006, are shown in Fig. 1. Comparative published results are also shown for Queensland sub-bioregions (i.e. Fig. 4 in Bastin et al. 2014). The NSW analysis also allowed for a more contemporary assessment based on 2013 being sufficiently dry to apply the DRCM (2013 results not reported here).

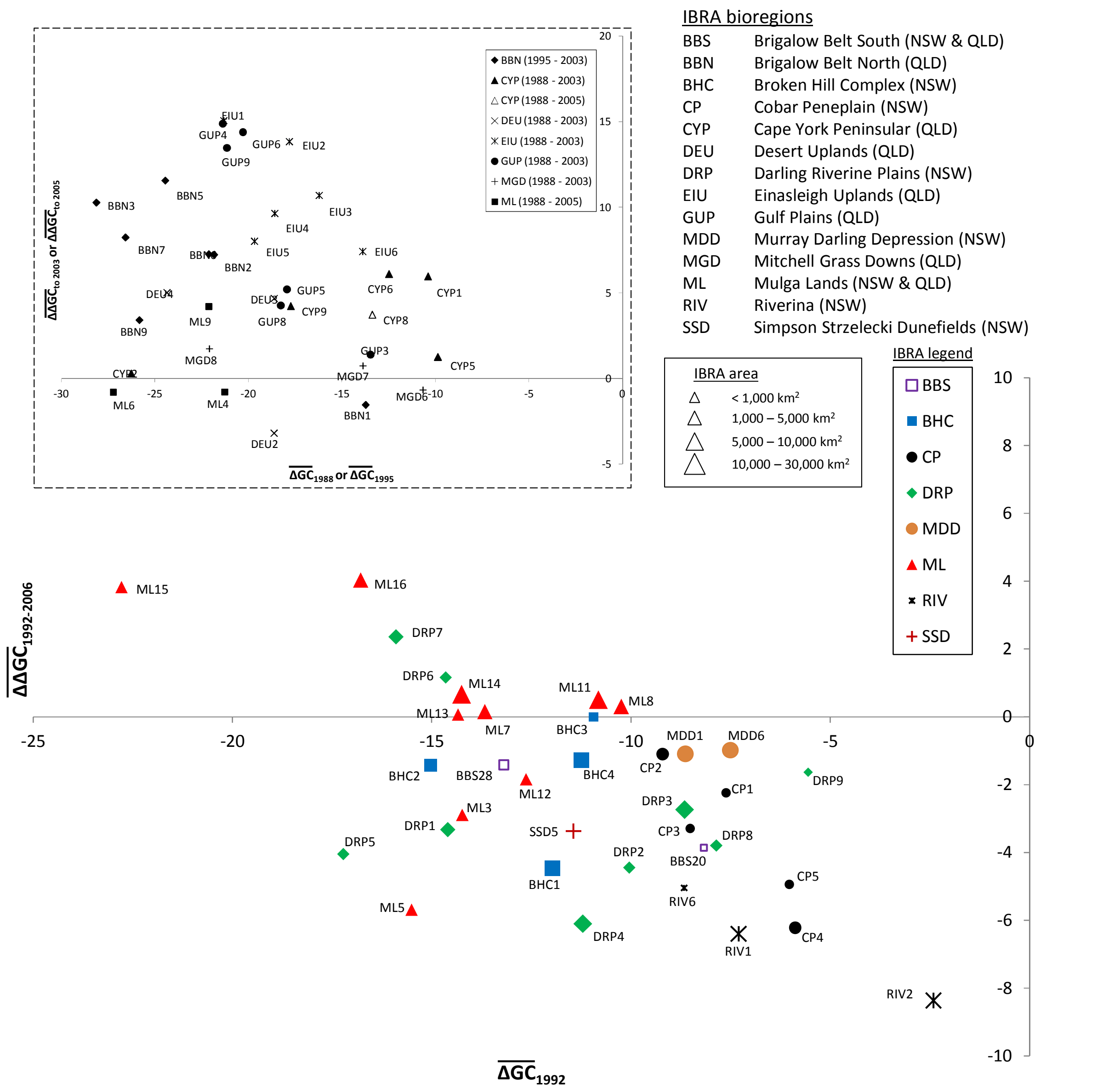

Figure 1. Mean cover deficit ($\overline{\Delta GC}$) in 1992 and its change ($\overline{\Delta\Delta GC}$) to 2006 for grazed, non-cleared parts of NSW rangeland sub-IBRAs. Symbol size indicates the ranked area of each sub-IBRA (see legend). The insert (top left) shows corresponding results for Queensland rangeland sub-IBRAs (Fig. 4 in Bastin et al. 2014). IBRAs (v6.1) are listed in the top right of the figure. IBRA: Interim Biogeographic Regionalisation of Australia.

We will shortly include the NT pastoral estate and remaining parts of rangeland Queensland in a spatially more complete and temporally recent analysis of grazing impact to complement the results available for NSW. This expanded reporting requires:

1. Identifying suitably dry years for analysis based on the variable rainfall characteristics across the large region. Fig. 2a provides a guide to the potentially suitable analysis area based on decile rainfall for the period April 2012 to March 2013. In reality though we may use a combination of (i) ≤ decile 3 wet-season (November-April) rainfall for northern Australia receiving monsoonal rainfall, (ii) a rolling 18-month rainfall anomaly for the more arid rangelands with aseasonal rainfall and (iii) as yet, unspecified criteria elsewhere.
2. Excluding areas of agricultural land use (including horticulture) from DRCM analysis. These areas, located mainly on the eastern margin of the rangelands, are unsuitable for identifying valid reference-pixel locations to estimate cover deficit due to grazing.

3. Analysing fractional bare-soil images from suitably dry years (e.g. Fig. 2b) with the DRCM software to determine pixel-level cover deficit (ΔGC). Change in cover deficit between dry years (ΔΔGC), $\overline{\Delta\mathrm{GC}}$ and $\overline{\Delta\Delta\mathrm{GC}}$ for sub-bioregions are subsequently calculated.

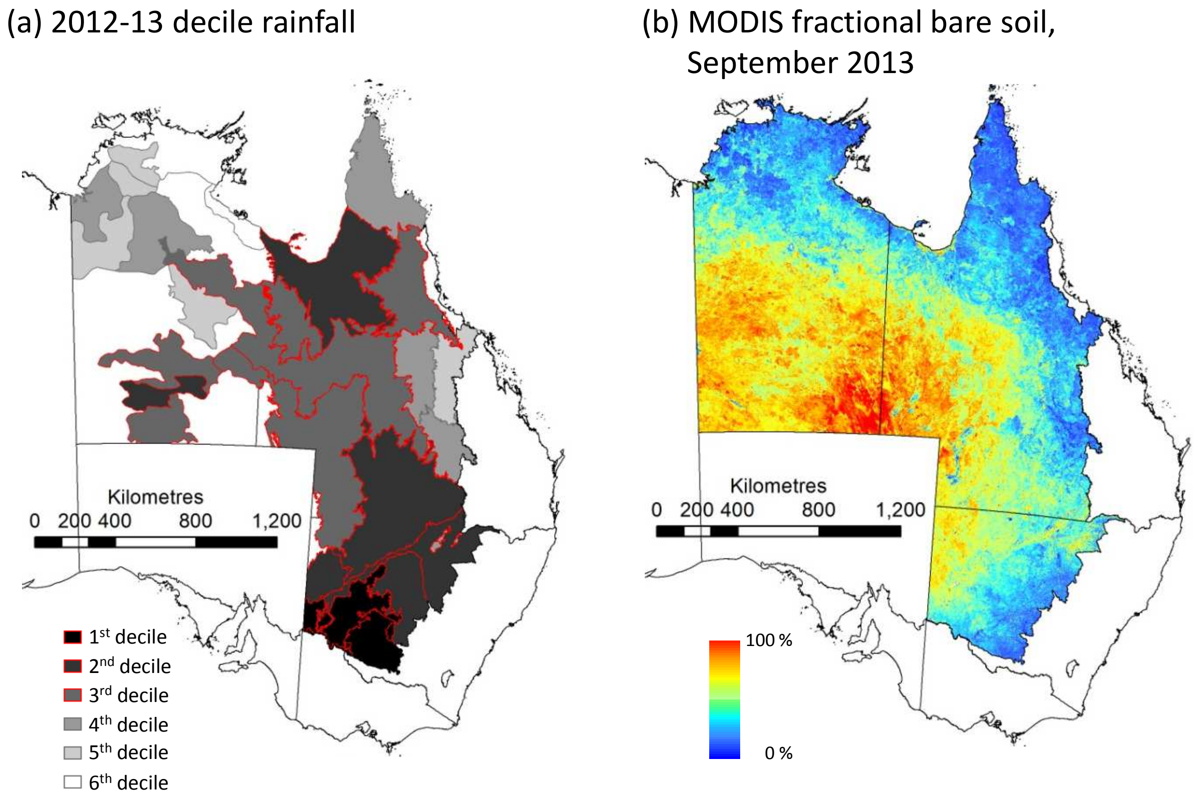

Figure 2. (a) For pastoral bioregions, spatially-averaged annual rainfall (between April 2012 and March 2013) ranked against the long-term (1890-2013) record as a decile. Bioregions outlined in red had ≤ decile 3 rainfall, one criterion of suitably dry conditions for DRCM analysis. (b) The percentage of bare soil for the NSW, Queensland and NT rangelands derived from MODIS 500m imagery.

DRCM: an example of innovation in the rangelands

Developing and applying the Dynamic Reference Cover Method has demonstrated both innovation and collaboration. Innovative features include a novel, largely automated procedure for separating seasonal and grazing effects on ground cover that utilises the extensive and multi-temporal coverage of Landsat TM imagery. The method is based on the ecological principle of persistence or stability of perennial herbage and uses the rangeland tradition of reference or benchmark areas to indicate the state of each focal pixel as an analysis window is moved across and down each image.

Progress to date has built on the coordination and leadership achieved through both the Australian Collaborative Rangeland Information System (ACRIS, Bastin et al. 2009) and the Joint Remote Sensing Research Program (Dan Tindall, this conference and http://www.gpem.uq.edu.au/jrsrp, accessed 7 January 2015).

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