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Improving ground cover and landscape function in a semi-arid rangeland through alternative grazing management

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ABSTRACT

The development and adoption of sustainable grazing strategies is important to improve the functionality and productivity of agricultural landscapes. Alternative grazing systems incorporating periods of planned rest may achieve this compared to continuous grazing systems, but the evidence is conflicting. Using paired paddock contrasts, soil characteristics, ground cover and landscape function (i.e. soil stability, nutrient cycling, infiltration and landscape organisation indices) were compared between alternative grazing management (incorporating periods of rest), traditional (continuous) grazing, and areas managed for conservation (ungrazed by commercial livestock but grazed by native and feral herbivores) on contrasting soil types in semi-arid rangelands. Relationships between the response variables and understorey floristic biodiversity measures were also explored. Total ground cover was greater under conservation management than grazing, and was greater under alternative grazing than traditional grazing management. Indices of landscape function, including stability, nutrient cycling, patch area and landscape organisation were significantly greater, and interpatch length significantly shorter, under conservation compared to traditional grazing management. Alternative grazing management had intermediate values of landscape function which did not differ significantly to traditional grazing or conservation treatments. Ground cover and floristic biodiversity measures were often positively correlated, but there was no clear relationship between most landscape function and plant biodiversity indices. Landscape function may be important in detecting changes in rangelands that remain undetected by floristic diversity measures. Alternative grazing strategies incorporating planned rest have the potential to improve ground cover with the associated benefits of improved productivity and landscape function compared to continuous grazing regimes.

1. Introduction

Overgrazing is a major cause of rangeland degradation throughout the world (Schönbach et al., 2010; Deng et al., 2014; Eldridge et al., 2016; Pulido et al., 2018). Livestock grazing has been associated with reduced ground cover of vegetative material and biological crusts and changes in soil structure and chemical composition, (Graetz and Tongway, 1986; Greenwood and McKenzie, 2001; Tongway et al., 2003; Eldridge et al., 2013; Deng et al., 2014). Overgrazing or poor grazing management has also been associated with a decline in landscape function (Freudenberger et al., 1997; McIntyre and Tongway, 2005; Eldridge et al., 2016). Landscape function refers to the capacity of landscapes to capture, retain and utilise resources (Tongway and Ludwig, 1997b). Dysfunctional landscapes lose excessive amounts of resources (such as water and nutrients), resulting in lower production and negative feedback effects, further reducing landscape function (Tongway and Ludwig, 1997b). Areas that accumulate resources are referred to as patches, and areas that shed resources are referred to as interpatches (Tongway and Hindley, 2004a). Maintenance of ground cover and landscape function in arid and semi-arid rangelands has been linked to land productivity and conservation of biodiversity (Freudenberger et al., 1997; Eldridge et al., 2016), hence there is both an economic and ecological incentive for landholders to conserve resources and maintain long-term sustainability (Dorrough et al., 2004; Hacker et al., 2010). While the removal of livestock from degraded systems can reverse degradation in some cases (Drewry, 2006; Castellano and Valone, 2007), the development and adoption of more sustainable grazing strategies is important to prevent degradation and improve both the productivity and biodiversity of agricultural landscapes (Papanastasis, 2009; Orr et al., 2017). Rotational grazing

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systems incorporating periods of planned rest can achieve this compared to continuous grazing (Teague and Dowhower, 2003). Resting pasture allows plants and soil to recover between grazing events, and smaller paddock sizes can result in the more even distribution of grazing pressure. This can reduce the negative effects of patch grazing, such as reduced infiltration and production, and increased bare ground, runoff and erosion (Teague and Dowhower, 2003; Norton et al., 2013).

Several recent studies of grazing management systems that incorporate rest from livestock grazing have reported positive effects on landscape function, ground cover and soil characteristics such as carbon and nitrogen content and bulk density (Teague et al., 2011; Read et al., 2016; Sanjari et al., 2016; Waters et al., 2017). However, evidence of the value of rotational compared to continuous grazing is equivocal (Briske et al., 2008, 2011; Hawkins, 2017), and some studies have found no difference in soil, ground cover or landscape function between the two (Hall et al., 2014). These contrasting findings may be a result of differences in grazing regimes, grazing intensities, class of livestock, vegetation communities, soil type, seasonal conditions and scale of study, all of which affect the ecological responses to grazing (Teague et al., 2008, 2013; Metera et al., 2010; Tóth et al., 2018). In addition, rangeland research has not tended to integrate the biophysical and social aspects associated with complex adaptive systems (Briske et al., 2011). Little research has focused on the effects of alternative grazing management (incorporating periods of planned rest) on soil, ground cover and landscape function, in different soil types in semi-arid areas or compared the impacts of alternative grazing management with traditional (continuous) grazing or areas managed for conservation. In addition, few studies have compared soil, ground cover and landscape function variables across contrasting soil types.

Ground cover is an indicator of plant and animal biodiversity in some ecosystems (Maestre and Cortina, 2004; McCosker et al., 2009; Ward and Kutt, 2009), and landscapes with greater functionality may exhibit greater plant biodiversity and biomass production (Ludwig et al., 2004). Greater biodiversity may contribute to improved multifunctionality of landscapes and ecosystem services provision, such as biomass and livestock production, and carbon and nutrient cycling (Maestre et al., 2012; Pasari et al., 2013; Tilman et al., 2014). While plant patches play a role in maintaining functioning landscapes though increasing nutrient cycling, microbial activity and soil moisture, or providing microsites to protect species from harsh climatic conditions and grazing herbivores (Callaway, 1995; Maestre, 2004), few studies have investigated the relationship between biodiversity and landscape function, particularly in semi-arid systems. In order to improve the environmental and socio-economic sustainability of commercial grazing enterprises, it is vital to address these knowledge gaps and understand the effects of different grazing management practices.

The semi-arid rangelands of south-eastern Australia have experienced considerable change and degradation (soil erosion, loss of biodiversity, encroachment by woody shrubs) as a result of overgrazing (Anon, 1901; Harrington et al., 1979; Stafford Smith et al., 2007). In recent years, adoption of alternative grazing management has increased in Australia (McCosker, 2000; ABS, 2013) and elsewhere (Teague et al., 2008; Savory and Butterfield, 2016). This study aimed to (1) determine the response of soil properties, ground cover and landscape function to different approaches to grazing management on contrasting soil types (sand versus clay); (2) compare soil properties, ground cover and landscape function on sand versus clay soils, and (3) examine the relationships between ground cover and landscape function variables with understorey floristic diversity measures. The results of this study may be used to inform grazing management to achieve improved ground cover and landscape function in semi-arid rangelands, and better understand the relationships with plant diversity.

2. Methods

2.1. Study region

Thirteen grazing management contrasts across six clusters of properties were selected in the Mulga Lands and Darling Riverine Plains bioregions in north-western New South Wales (NSW), Australia, on sandy-loam (‘sand’, $n = 6$) and heavy clay (‘clay’, $n = 7$) soils. Average annual rainfall ranged from approximately 400 mm in the east to 275 mm in the west of the study region. Three, six and twelve-month rainfall prior to this study varied between clusters and seasons (Table A.1). Three grazing management treatments were studied: (1) alternative grazing management (AGM) strategies where paddocks were frequently rested; (2) traditional grazing management (TGM) where paddocks were continuously grazed for most or all of the year; and (3) areas managed for conservation (CON) where domestic livestock had been removed. Each contrast compared at least two grazing treatments. Current grazing management regimes had been in place at each site for at least 5 years prior to surveys. AGM treatments did not comply with strict rest–graze times; rather, stocking rates and grazing regimes were managed adaptively in response to seasonal conditions and management constraints. Detailed information on grazing contrasts and site information is provided in Tables A.2–A.4. Stocking rate and dung count data for grazing treatments is provided in Table A.5.

2.2. Landscape function analysis

Landscape function analysis (LFA) was used to assess landscape function using soil surface indicators linked to physical, chemical and biological processes (Tongway and Hindley, 2004a). LFA is less vulnerable to short-term fluctuations in climatic and rainfall conditions than plant biomass, species diversity and composition, and therefore provides a reliable measure of longer term changes in landscape function (Tongway and Ludwig, 1997a). LFA was undertaken in autumn 2015, and followed the methods outlined in Tongway and Hindley (2004b). At each site, three 100 × 100-m plots were selected on similar soil types and vegetation communities to the adjacent site. Plots at each site were located on a single property under the same management within 1 km of each other and adjacent sites were located on different properties under differing management. A 100-m transect through the center of each plot was orientated with the direction of water flow. The length and width of patches and the length of interpatches was recorded along each transect. The dominant patch types on clay soils were litter (consisting predominantly of dead herbage and leaf material), perennial grasses (e.g. *Panicum* spp. and *Astrebla* spp.) and low shrubs (e.g. *Duma florulenta* and *Maireana* spp.). In sandy sites, patch types included shrubs and their beneath-canopy litter (e.g. *Eremophila* spp., *Dodonaea attenuata*, *Maireana* spp.), tree patches (e.g. *Eucalyptus populnea)*, areas of soil and litter accumulation around coarse woody debris, and tussocks and clumps of perennial grasses (e.g. *Eragrostis* spp.). Exposed bare soil was the dominant interpatch type recorded on both clay and sandy soils.

Eleven indicators of soil surface condition (Tongway and Hindley, 2004b) were assessed in at least three replicates of each patch and interpatch type along each transect (Table A.6). The suitability of these indicators has been verified in many studies (Holm et al., 2002; Tongway and Hindley, 2004a; Ludwig et al., 2005; McIntyre and Tongway, 2005; Maestre and Puche, 2009; Muñoz-Robles et al., 2011; Gaitán et al., 2018). Four indices were generated from the size and proportion of patches and interpatches, using the spreadsheet model in Tongway and Hindley (2004b): (1) total patch area (TPA, Σ[patch length × patch width]); (2) patch area index (PAI, total patch area ÷ [total length of transect × 10]); (3) landscape organisation index (LOI, total length of patches ÷ total transect length), and (4) average interpatch length (AIL, total interpatch length ÷ number of interpatches). Indices of soil stability, nutrient cycling and infiltration potential were