9. Grazing management in rangeland grassland systems in South and East Australia

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1. Related practices

Grazing management (rotational grazing)

2. Description of the case study

Rotational grazing (i.e. a system where livestock are moved to portions of the pasture (called paddocks) while the other portions rest) has become widely applied across South and East Australia, mostly in the state of New South Wales (NSW). This is replacing traditional forms of grazing such as continuous grazing because of its potential to enhance SOC densities/stocks in grasslands, and conserve ecosystem sustainability, as well as promote production outcomes (McDonald *et al.*, 2019). Controlling animal stocking, intensity and duration can result in a more favourable environment for plant growth, and organic matter allocation to soil by improving soil hydraulic conductivity and infiltration through reducing the bulk density and compaction (Orgill *et al.*, 2018).

Overall, rotational grazing is considered as an effective carbon management strategy with additional benefits and is regarded as a contributor to the protection of the natural environment improving resilience to the impacts of climate change (Conant *et al.*, 2017). In Australia, this form of grazing management has been used in combination with others such as partial exclusion fencing to reduce native and feral animal populations (Waters *et al.*, 2017). Despite the general benefits of this grazing management strategy, its potential for carbon sequestration can vary across soil types, locations, and environmental factors (Orgill *et al.*, 2017; Sanderman *et al.*, 2015).

3. Context of the case study

In Australia, more than 75 percent of the total surface is defined as rangelands that extend across low rainfall and variable climatic zones including arid, semi-arid, and some seasonally high rainfall areas. Rangelands contribute significantly to Australia's economy (National Land and Water Resources Audit, 2001). These areas occupy a broad range of vegetation types from tropical woodlands to shrublands, grasslands and saltbush. Soils in these areas, with low nutrient contents and varying deficiencies of nitrogen and phosphorus and trace elements, are typically Vertisols and Durasols. Overall, soils in Australian rangelands are typically lower in contents of SOC compared with other areas (e.g. the United States of America), because of contrasting differences in soil type and climate (Badgery *et al.*, 2017). Mean annual rainfall ranges typically between 300 and 800 mm and mean annual maximum temperatures can be in the range of 20-23°C and the minimum temperatures between 6 and 10.5 ° C (Chan *et al.*, 2010).

Arid and semi-arid tropical areas in Australia are used for extensive cattle grazing. In the intermediate rainfall areas such as most of the Eastern and Southern Australia (which extends from southeastern Queensland through New South Wales, northern Victoria and southern South Australia), grazing management is often used to maintain pastures in an optimal composition and productive state, and to adjust the quality and quantity of forage required for grazing animals (Badgery *et al.*, 2017). Nevertheless, the appropriate intensity and management of grazing is still questioned and depends on several factors (Orgill *et al.*, 2017). Rotational grazing is now broadly considered as an effective and sustainable grazing management practice in Australian grasslands (Orgill *et al.*, 2018; Sanderman *et al.*, 2015), sometimes in combination with other approaches, e.g. improved pasture, fertilization, exclusion or use of native grasses (McDonald *et al.*, 2019).

4. Possibility of scaling up

Rangeland management through rotational grazing is applied in several areas worldwide but there are different benefits and constraints for adopting this practice that are specific to each country or region. In the United States of America, many grassland ecosystems are threatened by long-term overgrazing, increasingly frequent and severe drought, and land use change (Teague, 2018). The most common form of grazing management on rangeland and pasture in the Great Plains of the United States of America has been continuous year-round stocking. This management has had several negative consequences including reduced productivity and decreased soil carbon. Recent studies propose rotational grazing in these areas as an effective method for increasing efficiency in forage utilization and promoting soils C sequestration as a carbon mitigation option (Wang *et al.*, 2015).

In other areas such as China, livestock grazing is the dominant form of grassland use. To meet food demands and economic development, intense forms of grazing such as continuous grazing have been the most frequently applied. Because of increased degradation in grasslands, policies regulating grazing were implemented at the end of the 90's and some farms have since then established grazing management practices such as seasonal or rotational grazing (Dong *et al.*, 2020). Other areas with large potential for broad implementation of sustainable grazing management are Europe where moderate grazing can contribute to maintaining protected plant communities and at the same time reducing fuel loads and wildfire hazard (Silva *et al.*, 2019). Also, in Eastern Africa, where 75 percent of the surface is dominated by managed grassland systems, there is a yet untapped potential for C sequestration with managed grazing (Tessema *et al.*, 2020).

5. Impact on soil organic carbon stocks

There is a large variation in the results of the impacts of grazing on SOC densities/stocks, generally as a consequence of the interactions between climate, edaphic factors including initial SOC levels, and management variability (Orgill *et al.*, 2017; Waters *et al.*, 2017; Table 35). However, lower sequestration rates were reported on average for Australia (0.09 C/ha/yr) compared to other regions like Africa (0.21 tC/ha/yr) or South America (0.69 tC/ha/yr) following rotational grazing management practices.

Table 35. Carbon stock changes at 0-30 cm depth in different study locations in New South Wales (NSW), Australia

Location	Climate zone	Soil type	Baseline C stock (tC/ha)	Additional C storage (tC/ha/yr)	Duration (Years)	More information	Reference
South Eastern NSW	Warm Temperate Dry	Lixisol	29.5	1.46	4	Grazing and rest for 4-6 weeks	Orgill *et al.* (2018)
			32.9	0.78		Heavily grazed and then rested for 80-120 days	
South NSW		NA	39.2	0.41	5-10	Rotationally grazed; pair-site approach contrasted with continuous grazing	Chan *et al.* (2010)
Western NSW	Tropical Dry	Kandosols and Rudosols	21.62	1.04	8	Rotational grazing (rotational grazing + TGP fence); contrasted with continuous grazing.	Orgill *et al.* (2017)
		Kandosol	-	0.13			

6. Other benefits of the practice

6.1. Improvement of soil properties

Some of the additional benefits of rotational grazing are the reduction of and protection against soil erosion, enhancement of the aboveground diversity and productivity and increased microbial activity (Dong *et al.*, 2020). With this practice, plants are grazed in their vegetative state for relatively short periods, compared with continuous grazing, diminishing the tendency for preferred species to be grazed. Also, the rest periods allow perennials to replenish their root reserves and better tolerate dry periods, promoting both soil structure and land condition (Waters *et al.*, 2017).

6.2 Minimization of threats to soil functions

Table 36. Soil threats

Soil threats	
Soil erosion	Larger groundcover promotes soil protection from erosion (Orgill *et al.*, 2017).
Nutrient imbalance and cycles	Through enhanced plant productivity, nutrient cycling, and diversity (Waters *et al.*, 2017).
Soil contamination / pollution	Reduction or replacement of mineral and fertilizers (Orgill *et al.*, 2018; Waters *et al.*, 2017).
Soil biodiversity loss	Enhanced plant diversity (McDonald *et al.*, 2019; Waters *et al.*, 2017).
Soil compaction	Reduced bulk density and compaction (Chan *et al.*, 2010; Orgill *et al.*, 2018).
Soil water management	Improved soil hydraulic conductivity and infiltration (Orgill *et al.*, 2018).

6.3 Increases in production (e.g. food/fuel/feed/timber)

Management of grazing through rotational or low-intensity grazing can affect both above and below-ground biomass production as well as ground cover. In Eastern and Southern Australia, there has been evidence that exclusion fencing (and thus reduction of grazing pressure) can result in higher perennial and litter ground cover (Waters *et al.*, 2017). Both perennial grasses and litter form are an important source of organic matter in Australian rangelands through food provision and shelter for organisms. In addition, trees can provide shading and shelter for livestock (Orgill *et al.*, 2017).

6.4 Mitigation of and adaptation to climate change

Predictions in Australian rangelands estimate indicate that continuous grazing combined with long-term patterns of drought can result in emissions of 730 to 1 470 Mt CO_2eq in any 5-year period (Hill *et al.*, 2006). More sustainable grazing land management practices could offer opportunities for reducing GHG emissions from rangelands and savannas in Australia. For example, in regions of South Australia, it has been reported that the recovery of chenopod shrubland by grazing management can recue GHG fluxes between 0.1 and 0.6 t CO_2eq/ha/yr (Henry, Butler and Wiedemann, 2015).

6.5 Socio-economic benefits

Other benefits of rotational grazing include even grazing pressure and reduced herbivore selectivity and selection of palatable species; enhanced flowering, growth and survival of plant species; improved pasture utilization and maintenance of pasture cover; higher perennial grass content; and increased herbage production and animal production (Badgery *et al.*, 2018; Sanderman *et al.*, 2015).

7. Potential drawbacks to the practice

Rotational grazing can increase the need for infrastructure and labour and may not be practical when plants are not growing, sheep and cattle are lambing and/or calving (Wang *et al.*, 2020). The reduced opportunity to selectively graze following a rotational grazing management approach can also lead to a decline in production due to livestock being forced to graze less nutritious plant species.

Several factors need to be considered when implementing rotational vs. continuous grazing management such as baseline SOC concentrations, topography, climate, vegetation, and soil types, as shown in previous studies that have reported a large variation in SOC sequestration as a consequence of these factors (Khalil *et al.*, 2007; Orgill *et al.*, 2017). Moreover, some mechanistic processes including primary productivity and species composition, allocation of nutrients between roots and shoot, stocking density, and modifications in the decomposition and carbon export through processes at landscape levels can also influence the effects of grazing activity on carbon cycling (Allen *et al.*, 2014). Grazing may also not influence nutrients like N and additional incorporation may need to be considered (Orgill *et al.*, 2017). Besides, the biomass remaining in the fields at the end of the grazing season determines the maximum stocking density allowed for a good pasture management. So, the stocking density must not exceed the grassland carrying capacity.

8. Potential barriers for adoption

Table 37. Potential barriers to adoption

<table>
<tr><th>Barrier</th><th>YES/NO</th><th></th></tr>
<tr><td>Social</td><td>Yes</td><td rowspan="2">Potential increased amount of labour required for management intensification; uncertainties in investment (e.g. fencing repairs; water points installation); potential decline in forage quality if pastures are not harvested in a timely manner.</td></tr>
<tr><td>Economic</td><td>Yes</td></tr>
<tr><td>Legal (Right to soil)</td><td>Yes</td><td>Lease agreement may be designed exclusively for conventional grazing.</td></tr>
</table>

Barrier	YES/NO	
Knowledge	Yes	Lack of information about the benefit of the practices
Natural resource	Yes	Weather/climate factors may be challenging, e.g. drought periods.

Source: Wang et al. (2020)

Photo

Photo 20. Northern tablelands of New South Wales (Eastern Australia) 2012

Foreground is grazed only by native macropods with main paddock lightly grazed by sheep.

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