International Grassland Congress Proceedings

XXIV International Grassland Congress / XI International Rangeland Congress

A Systematic Review of Ecological and Production Outcomes under Rest-Grazing Systems

S. E. McDonald
Department of Primary Industries, Australia

R. Lawrence
University of New England, Australia

R. Rader
University of New England, Australia

A systematic review of ecological and production outcomes under rest-grazing systems

McDonald, S.E*., Lawrence, R [†]., Rader, R[†]
* NSW Department of Primary Industries, Trangie Agricultural Research Centre, Trangie, NSW, 2823, Australia; [†] University of New England, Armidale, NSW, 2351

Key words: grazing management; biodiversity; integration, land condition, livestock

Abstract
With increasing pressure on grazing lands throughout the world, there is a growing need to balance sustainable management of livestock to meet food production and environmental impacts. Grazing management practices that incorporate periods of planned rest between grazing events (RG) may achieve both ecological and production goals simultaneously. We conducted a systematic review of global literature that compared ecological and production outcomes of RG systems with either continuously grazed (CG) or ungrazed (UG) areas. In addition, we evaluated the extent to which ecological and livestock production outcomes have been assessed simultaneously in these studies and identified future research needs. A large proportion of the literature reported no difference (neutral response) between the different management systems. However, where differences did occur, the response of biodiversity, land condition and livestock production metrics was more often positive under RG than CG. When RG was compared to UG areas, differences were predominantly positive for plant biodiversity metrics, but negative for invertebrate biodiversity, ground cover and plant biomass. Only a small proportion of studies considered the effect of RG on both ecological and production outcomes simultaneously. An understanding of both ecological and production trade-offs associated with different grazing management strategies is essential to make informed decisions about best-management practices for joint production and ecological outcomes across the world's grazing lands.

Introduction
Globally, the livestock sector is recognised as a key driver of land-use change and degradation (MA 2005; Steinfeld *et al.* 2006) and increasing global population and demands for food production are placing greater pressure on grazing lands (Tilman *et al.* 2001; Foley *et al.* 2005; Steinfeld *et al.* 2006). Livestock grazing managed for both ecological and production goals can provide an opportunity to improve land condition and biodiversity conservation across large areas without sacrificing important socio-economic requirements (Papanastasis 2009; Metera *et al.* 2010). Several authors in recent decades have called for greater communication, collaboration and integration between animal production research and ecological research to bridge these disciplinary silos (Jackson and Piper 1989; Watkinson and Ormerod 2001; Dorrough *et al.* 2004; Vavra 2005; Fischer *et al.* 2006; Metera *et al.* 2010; Glamann *et al.* 2015). If we are to gain an understanding of the potential for dual ecological and production outcomes under different management strategies, it is essential to address this knowledge gap.

Grazing practices that incorporate periods of planned rest are commonly promoted to avoid environmental degradation and improve productivity (Norton 1998a; Teague *et al.* 2008) but considerable debate exists around the benefits, or otherwise, of these grazing management systems (Briske *et al.* 2008; Teague *et al.* 2013). Previous reviews have generally concluded that there is little difference in outcomes for animal production (i.e., weight gain, production per unit area, reproductive success) or rangeland sustainability (i.e., maintenance of biomass or ground cover) between contrasting management systems (Gammon 1978; O'Reagain and Turner 1992; Holechek *et al.* 2000; Briske *et al.* 2008; Hawkins et al. 2017; di Virgilio et al. 2019). Yet, recent meta analyses indicate that alternative grazing systems that incorporate periods of rest, compared with continuously grazed or ungrazed areas, have the potential to achieve multiple objectives (e.g. McDonald et al. (2019). Here, we examine how grazing systems that incorporate periods of rest from grazing (RG), compare with continuously grazed (CG) and ungrazed (UG) systems to determine the potential trade-offs between animal production, landscape condition and /or biodiversity. We also explore the extent to which research has considered both ecological and animal production effects of RG management simultaneously and identify research gaps and directions for future grazing management research.

Methods and Study Site
A systematic literature review was conducted using Scopus, returning articles from 1950 until November 2019. We searched for studies that compared RG systems with either CG or UG systems, and that examined the

effects on above-ground biotic or animal production variables. Title, keywords and abstracts were searched for the terms (graz*) AND (*divers* OR biomass OR "carrying capacity" OR "weight gain" OR conserv* OR richness OR product* or "ground cover" OR groundcover OR "bare ground") AND (various grazing system terms, McDonald et al. (2019)).

We compiled all studies that reported either RG–CG contrasts, or RG–UG contrasts. For each study, we recorded the geographical region in which the study was undertaken (Europe, Asia, Middle East, Africa, North America, South America and Australia/New Zealand), climatic zone (tropical, arid/semi-arid, temperate, cold) based on the Koppen–Geiger Climate Classification, and all above-ground biotic and animal production response variables reported for each study comparing RG–CG and RG–UG. For each response variable, the effect of RG relative to CG and UG treatments was recorded as either significantly greater (positive, $P \leq 0.05$), significantly lower (negative), or no difference (neutral). Species composition was recorded as either a difference or no difference in composition between the grazing systems. When opposing or inconsistent trends were present across multiple contrasts it was denoted as neutral. From this information, we calculated the proportion of studies conducted in different regions and climate zones, and the proportion of RG–CG and RG–UG comparisons reporting a positive, negative or neutral response for each variable. Studies that reported on both biodiversity and animal production variables in the same paper were classified as 'integrated'. We also considered the proportion of studies that reported on both animal production variables and additional landscape condition variables such as ground cover, biomass and plant species composition.

Overall, variables were grouped into 50 categories relating to different biodiversity (e.g., richness, diversity, evenness, abundance), livestock production (e.g., livestock weight gain, production per ha, pasture quality or products such as milk, meat and wool), and landscape condition metrics (e.g., ground cover, biomass, pasture height, plant composition). This review focuses on those variables that had been reported in at least 10 studies.

Results

Rest-grazing versus continuous grazing

In total, 280 studies comparing RG and CG systems were included in this review. Most studies were undertaken in North America (40%), followed by Australia/New Zealand (29%). A little more than half of the research (52% of studies) was conducted in temperate regions. Most of the remaining research was evenly split between arid (24%) and cold climates (22%). Very little comparative RG research had been conducted in the tropics (2%).

The most commonly reported response variables in studies comparing RG and CG were biomass (114 studies), plant composition (107), livestock weight gain (105), ground cover (54), animal production per area (47) and plant species richness (41). Few studies reported on mammal, reptile or bird biodiversity metrics, or functional diversity.

A large proportion of studies comparing biodiversity, land condition or production variables reported no difference or no consistent difference between RG and CG systems (Table 1). However, where differences were observed, more studies reported positive than negative responses under RG management. The exception was livestock weight gain, where 34% of studies reported a negative response under RG systems. While there was most often no difference in plant diversity metrics, the majority of studies (74%) reported a difference in plant composition between the two grazing treatments.

Rest-grazing versus ungrazed

109 studies compared RG with UG areas. The majority of these studies were in arid or semi-arid environments (45% of studies), followed by temperate (30%) and cold (24%) climates. Again, very few (1%) studies have been undertaken in tropical environments. Most research has been undertaken in North America (42% of studies), followed by Asia (18%) and Europe (16%).

While again a large proportion of studies did not report a significant difference in response variables between management systems, where differences occurred for the plant biodiversity variables, they were more often positive under RG than UG (Table 1). In contrast, invertebrate richness, bird abundance, ground cover and biomass were more frequently negative than positive under RG. In addition, 75% of studies reported a difference in composition between RG and UG areas.

Integration of biodiversity and livestock production research

The majority (51%) of research comparing RG and CG reported on animal production related variables, while 32% reported the response of biodiversity variables. Only eight studies (<1%) examined both biodiversity and livestock production variables simultaneously. However, a greater proportion of studies (33%) examined livestock production variables alongside land condition variables.

Table 1. Trends in response variables (percent of total papers) in studies that compared rest-grazing (RG) with continuous grazing (CG) and in studies that compared rest-grazing to ungrazed (UG) areas. For each contrast the number of studies is shown in parentheses beside the parentheses (n) Only response variables with total number of studies for the RG–CG contrast ≥10 are included in the table.

Variable	RG – CG			RG – UG		
	Negative (%)	Positive (%)	Neutral (%)	Negative (%)	Positive (%)	Neutral (%)
Plant richness	12 (5)	39 (16)	49 (20)	13 (4)	40 (12)	47 (14)
Plant evenness	0 (0)	40 (4)	60 (6)	0 (0)	36 (4)	64 (7)
Plant diversity	8 (2)	50 (13)	42 (11)	18 (4)	23 (5)	59 (13)
Bird abundance	17 (2)	33 (4)	50 (6)	50 (3)	0 (0)	50 (3)
Invertebrate abundance	20 (3)	47 (7)	33 (5)	30 (3)	30 (3)	40 (4)
Invertebrate richness	0 (0)	90 (9)	10 (1)	29 (2)	14 (1)	57 (4)
Total ground cover	4 (2)	59 (32)	37 (20)	31 (8)	12 (3)	58 (15)
Plant density/abundance	23 (3)	31 (4)	46 (6)	50 (2)	0 (0)	50 (2)
Sward height	0 (0)	63 (10)	38 (6)	67 (4)	0 (0)	33 (2)
Biomass	7 (8)	49 (56)	44 (50)	41 (16)	21 (8)	38 (15)
Specific plant species for livestock production	10 (2)	52 (11)	38 (21)	NA	NA	NA
Pasture quality	13 (4)	33 (10)	53 (16)	NA	NA	NA
Livestock weight gain	34 (36)	17 (18)	49 (51)	NA	NA	NA
Livestock production per area	17 (8)	49 (23)	34 (47)	NA	NA	NA
Other livestock products (milk, wool, meat)	10 (3)	32 (10)	58 (18)	NA	NA	NA
Livestock health	9 (2)	27 (6)	14 (64)	NA	NA	NA

Discussion

Consistent with previous reviews (O'Reagain and Turner 1992; Holechek *et al.* 2000; Briske *et al.* 2008, di Virgilio et al. 2019), a large proportion of studies found no difference, or no consistent difference in biodiversity, land condition or livestock production variables between RG and CG or UG areas. This is in agreeance with previous conclusions that stocking rate is a greater driver of grazing impacts than grazing system (O' Reagan and Turner 1992, Ash and Stafford Smith 1996). Despite this finding, significant differences between grazing systems were reported in many studies. This, combined with the fact that positive benefits of RG systems are widely promoted, highlights a need to better understand what is driving these differences and how positive effects can be achieved. Analysis by McDonald et al. (2019) indicated the relative length of rest and graze events can influence response of some variables, with benefits generally observed with increasing amount of rest relative to graze time. Di Virgilio et al. (2019) also examined a number of potential explanatory factors, including livestock type, rangeland type, rainfall, grazing intensity, paddock size and study duration, however few consistent effects were identified.

Where differences were found between RG and CG, these were predominantly positive under RG for all biodiversity, land condition and production variables, except livestock weight gain. This indicates potential benefits of certain RG systems, and further research into how these benefits can be achieved is warranted. When compared with UG areas, RG had a predominantly positive effect on most plant biodiversity variables, but not invertebrate richness and bird abundance. However, land condition variables (plant density, sward height, biomass and ground cover) were lower under RG than UG. While to some extent this is to be expected under grazing, it indicates that despite the benefits of RG systems in comparison to CG management, greater attention is needed on how to further reduce the impact of grazing on land condition. Most studies reported a difference in species composition between RG areas and CG or UG systems, highlighting the importance of investigating changes in composition that may not otherwise be detected using traditional measures of richness and diversity.

An understanding of the ecological and economic (production) trade-offs associated with different grazing management strategies is necessary to make informed decisions about best-management practices (Metera *et al.* 2010). While over half of studies examined livestock production variables, less than 1% of the total studies included in this review examined livestock production in conjunction with biodiversity variables. This highlights the need to improve communication and collaboration between ecological and agricultural production researchers in order to achieve ecological and animal production outcomes simultaneously in grazing lands, a goal that will become increasingly important as demand for food production increased biodiversity declines continue.

In conclusion, this review shows potential for RG systems to achieve greater biodiversity, land condition and production outcomes, and further research is needed to better understand how these can be attained. Most studies that have examined periods of planned rest are concentrated in North America, Australia/New Zealand, Europe and Asia. Comparatively, little research has been undertaken in South America or Africa and tropical environments. Greater research effort needs to be directed toward the impacts of grazing management systems on fauna, and on biodiversity metrics in conjunction with animal production outcomes.

Acknowledgements

We would like to thank Dr Warwick Badgery and Dr Yohannes Alemseged for their review and comments on earlier versions of this manuscript.

References

Ash, A.J. & Stafford Smith, D. (1996) Evaluating stocking rate impacts in rangelands: animals don't practice what we preach. *The Rangeland Journal,* **18,** 216-243.

Briske, D.D., Derner, J.D., Brown, J.R., Fuhlendorf, S.D., Teague, W.R., Havstad, K.M., Gillen, R.L., Ash, A.J. & Willms, W.D. 2008. Rotational Grazing on Rangelands: Reconciliation of Perception and Experimental Evidence. *Rangeland Ecology & Management,* 61, 3-17.

di Virgilio, A., Lambertucci, S.A. & Morales, J.M. 2019. Sustainable grazing management in rangelands: Over a century searching for a silver bullet. *Agriculture, Ecosystems & Environment,* 283.

Dorrough, J., Yen, A., Turner, V., Clark, S., Crosthwaite, J. & Hirth, J. 2004. Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. *Australian journal of agricultural research,* 55, 279-295.

Fischer, J., Lindenmayer, D.B. & Manning, A.D. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. *Frontiers in Ecology and the Environment,* 4, 80-86.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C. & Gibbs, H.K. 2005. Global consequences of land use. *Science,* 309, 570-574.

Gammon, D.M. 1978. A review of experiments comparing systems of grazing management on natural pastures. *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa,* 13, 75-82.

Glamann, J., Hanspach, J., Abson, D.J., Collier, N. & Fischer, J. 2015. The intersection of food security and biodiversity conservation: a review. *Regional Environmental Change,* 17, 1303-1313.

Hawkins, H.-J. 2017. A global assessment of Holistic Planned Grazing™ compared with season-long, continuous grazing: meta-analysis findings. *African Journal of Range & Forage Science,* 34, 65-75.

Holechek, J.L., Gomes, H., Molinar, F., Galt, D. & Valdez, R. 2000. Short-duration grazing: the facts in 1999. *Rangelands,* 22, 18-22.

Jackson, W. & Piper, J. 1989. The necessary marriage between ecology and agriculture. *Ecology,* 70, 1591-1593.

MA. 2005. *Ecosystems and human well-being*. Millenium Ecosystem Assessment. Washington, DC: Island Press

McDonald, S.E., Lawrence, R., Kendall, L. & Rader, R. 2019. Ecological, biophysical and production effects of incorporating rest into grazing regimes: A global meta-analysis. *Journal of Applied Ecology,* 56, 2723-2731.

Metera, E., Sakowski, T., Słoniewski, K. & Romanowicz, B. 2010. Grazing as a tool to maintain biodiversity of grassland- a review. *Animal Science Papers and Reports,* 28, 315-334.

Norton, B. 1998. The McClymont Lecture: the application of grazing management to increase sustainable livestock production. *Animal production in Australia,* 22, 15-26.

O'Reagain, P. & Turner, J. 1992. An evaluation of the empirical basis for grazing management recommendations for rangeland in southern Africa. *Journal of the Grassland Society of southern Africa,* 9, 38-49.

Papanastasis, V.P. 2009. Restoration of Degraded Grazing Lands through Grazing Management: Can It Work? *Restoration Ecology,* 17, 441-445.

Steinfield, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & de Hann, C. 2006. Livestock's Long Shadow: environmental issues and options. LEAD and FAO, Rome, Italy.

Teague, R., Provenza, F., Kreuter, U., Steffens, T. & Barnes, M. 2013. Multi-paddock grazing on rangelands: why the perceptual dichotomy between research results and rancher experience? *Journal of Environmental Management* 128, 699-717.

Teague, R., Provenza, F., Norton, B., Steffens, T., Barnes, M., Kothmann, M. & Roath, R. 2008. Benefits of multi-paddock grazing management on rangelands: limitations of experimental grazing research and knowledge gaps. *Grasslands: ecology, management and restoration* (ed. H.G. Schroder), pp. 41-80. Nova Science Publishers, Hauppauge, NY, USA.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D. & Swackhamer, D. 2001. Forecasting agriculturally driven global environmental change. *Science,* 292, 281-284.

Vavra, M. 2005. Livestock grazing and wildlife: developing compatibilities. *Rangeland Ecology & Management,* 58, 128-134.

Watkinson, A.R. & Ormerod, S.J. 2001. Grasslands, grazing and biodiversity: editors' introduction. *Journal of Applied Ecology,* 38, 233-237.