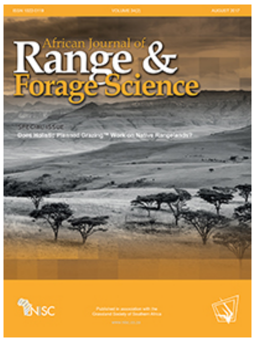

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Position Paper

A global assessment of Holistic Planned Grazing™ compared with season-long, continuous grazing: meta-analysis findings[§]

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It has been claimed that Holistic Planned Grazing™ (HPG), a type of rotational grazing, can increase productivity in rangelands and reverse climate change while doubling the stocking rate, mainly through the impact of densely bunched animals on primary production. Previous reviews have found similar or greater plant and animal production in continuous (season-long) compared with rotational grazing. Here season-long continuous grazing is compared with HPG alone to explore the evidence for animal impact. Three quantitative meta-analysis models were used to assess data sets from literature between 1972 and 2016. Weighted mean differences (effect sizes) between HPG and continuous grazing showed that there was no difference in plant basal cover, plant biomass and animal gain responses ($p > 0.05$). Thus, from the balance of studies, if animal impact is occurring during HPG, it has no effect on production. As interesting as the overall result is the significant between-study heterogeneity assessed using Cochran's Q ($p = 0.007$ to <0.0001). Studies with positive effect sizes tended to have higher precipitation ($p < 0.05$), suggesting that only some rangelands have the resources to support HPG. Furthermore, there is scope for investigating the impact of HPG on socio-ecological aspects of rangelands, such as management.

Keywords: animal density, aridity index, biodiversity, Holistic Planned Grazing™, rotational grazing

Online supplementary material: Supplementary information for this article is available at http://dx.doi.org/10.2989/10220119.2017.1358213

Introduction

Native rangelands are under increasing pressure globally and it is vital to manage commercial livestock production in a way that is both economical and ecologically sound. It has been claimed that Holistic Planned Grazing™ (HPG) can increase productivity on rangelands and reverse climate change while doubling the stocking rate (animal units [AU] per area on a given amount of land over a certain time period), primarily through the impact of densely packed animals on primary production (Savory 1983; Savory and Butterfield 1998; Butterfield et al. 2006). Previous reviews assessing the efficacy of rotational grazing (including HPG) are comprehensive (Briske et al. 2008, 2011) and conclude that 87% of studies showed equal or greater plant production with continuous (season-long) compared to rotational grazing. There are no quantitative comparisons between season-long grazing and HPG. Season-long continuous grazing refers to the utilisation of an area for part or all the growing season, with subsequent rest or deferment. In contrast, continuous grazing in the communal rangelands of South Africa commonly refers to year-round grazing, and is well known to result in severe loss of plant basal cover (Harrison and Shackleton 1999). Management of grazing approaches may be adaptive or prescriptive or, in the latter case, completely unplanned.

Holistic Planned Grazing is a type of time-controlled, rotational grazing that utilises an adaptive versus prescriptive management called Holistic Management™ (HM), which is a framework for decision-making (Butterfield et al. 2006). Synonyms for HM include the Savory approach and Holistic Resource Management. In HM, a holistic goal-setting process is used to define the desired quality of life, form of production and future resource base for a land owner. These goals will usually include rangeland improvement using 'existing tools' of technology, fire, rest and organisms, and the 'new tools' of less-selective grazing and animal impact (Savory 1978, 1983; Savory and Butterfield 1988; Butterfield et al. 2006). Once the goal is set, adaptive management concerns the time-controlled movement of animals, much like any other adaptive management model for livestock (Tainton et al. 2013). Initially, animal movement is planned based on an estimate of resource availability. Depending on the actual forage off-take, plant regrowth and

[§] This position paper is part of a special issue entitled 'Does Holistic Planned Grazing™ Work on Native Rangelands?'

animal condition, subsequent grazing plans are adapted to vary the time animals spend in an area and the time interval before returning to that area (e.g. Heitschmidt et al. 1982; Kothmann 1984; Tiedeman 1986). A farm may be delineated into multiple grazing areas using fenced camps, or shepherds may use natural landscape features to define grazing areas (Savory 2013b).

These camps or grazing areas play a vital role in defining a fundamental claim of HPG, namely that overgrazing is the result of leaving animals to graze for too long and returning them to an area too soon, rather than the actual number of animals per unit area (Savory 1983). Thus, given the case where the management model is adaptive, HPG can be distinguished from continuous grazing (season-long) by the existence of multiple camps enforcing short-duration, high-intensity grazing with long return times to allow vegetation regrowth and reproduction. The regular movement of livestock at high densities in HPG is thought to mimic natural herd migrations and bunching due to predators, resulting in trampling of the soil and less selective grazing (Savory 1983; Sacks et al. 2014). This is called animal impact or, where especially dense bunching of animals occurs, herd effect. The number of camps in HPG varies widely depending on the desired density of animals but tends to be higher (eight to 20 or more) than, for example, the commonly used four-camp rotational grazing approach in South Africa (Tainton et al. 2013). If adaptive management is used, there is little to distinguish HPG from other rotational, high-density, time-controlled grazing approaches such as short-duration high-intensity grazing, intensive rotational grazing, cell grazing, and strip grazing.

The claim that HPG will permit a doubling of the recommended stocking rate without a decrease in animal or plant production (Savory 1983) has been contradicted by much of the scientific (e.g. Hart et al. 1988; McCollum et al. 1999; Briske et al. 2008, 2011; Tainton et al. 2013) and popular literature (e.g. Hawkins 2016), but is supported by others (Teague et al. 2011, 2013, 2015). The claim that HPG can reverse climate change through the sequestration of carbon into complex, stable organocarbons and grass roots (Savory 2013a; Sacks et al. 2014) is also controversial. The idea that animals break the 'soil cap' with their hoofs, resulting in the incorporation of urine, dung, seeds and litter with subsequent increased microbial activity and carbon sequestration (Sacks et al. 2014), is yet to be thoroughly tested.

Considering the absence of a quantitative review, this study compares HPG (as a special case of rotational grazing) with season-long continuous grazing using data from the peer-reviewed literature over the last four decades. The inclusion of recent research in the last decade allowed a reassessment of the conclusions reached by Briske et al (2008). The meta-analysis methodology, which has been useful for ecological reviews previously (Osenberg et al. 1999), was used to assess how HPG and continuous grazing affect agricultural productivity, biodiversity and soils. Since the absolute number of camps, camp sizes and animal densities used in HPG in scientific trials varied considerably, these factors were considered as potential predictors besides the grazing approach.

Methodology

One of the main advantages of meta-analyses is that they allow between-study comparison by calculating a relative mean difference within studies. Data sets from peer-reviewed studies comparing the performance of HPG and continuous grazing (season-long, not year-round) at moderate set stocking rates were used in a meta-analysis. Moderate stocking rates were defined in the studies as those recommended for the area. The management systems were adaptive for both grazing approaches. Whether explicit or implicit in experimental trials, the 'set goal' was increased plant and/or animal production. The study was constrained to native (non-anthropogenic) rangelands, excluding successional grasslands and domesticated pastures. Although naturalised introduced species occurred in one of the studies (Badgery et al. 2017a, 2017b), the area represents the closest state to native rangeland available in the temperate zone of southern Australia with over 70% native species (W Badgery, New South Wales Department of Primary Industries, pers. comm., 2017). The use of relative mean differences and the standardization of datasets (moderate stocking rates, native rangelands, adaptive management) facilitated the combining of diverse studies to obtain a single effect size for HPG.

Steps in the meta-analysis

The meta-analysis comprised the following steps. (1) Search terms based on commonly used terminology to describe HPG were used to search several databases. The search terms were *Savory grazing method OR holistic planned grazing OR holistic resource management OR short duration grazing OR multi-paddock OR cell grazing OR mob grazing* using natural language on the Google Scholar and Academic Search Primer (EBSCO Host) search engines. Boolean operators were also used to search Science Direct using the same key words as above. Including search terms on ecology, biodiversity, soil health and farm economics did not yield further studies. Several studies were also obtained by 'snowballing', i.e. references within references including reviews. (2) Articles were selected based on abstracts and full-text content that compared HPG and season-long continuous grazing at set stocking rates, utilised moderate to moderate–heavy stocking rates and were peer-reviewed. (3) Studies that reported a positive, neutral or negative effect of HPG were downloaded into RefWorks®. (4) Means, variance and sample sizes was extracted from each study where several data sets were sometimes available per study (Supplementary Table S1). (5) The relative effect size of HPG was calculated as weighted mean differences using three meta-analysis models.

Meta-analysis models and software

The fixed-effects inverse variance (FE), random effects (RE) and quality effects (QE) models were used to determine the relative effect of HPG versus continuous grazing (MetaXL 5.3; Epigear International, Brisbane, Australia). The FE and RE models are well known in the literature, whereas the QE model is more recent (Doi and

Thalib 2008, 2009). All three models calculate a weighted mean difference (effect size; ES) at the $p = 0.05$ level as:

$$\text{Effect size} = \left(\frac{\bar{X}_t - \bar{X}_c}{\bar{X}_c} \times 100 \right)$$

where ($\bar{X}_t$) is the treatment mean and ($\bar{X}_c$) is the control mean. The three models differ in the way they assign weights and how they apply them (see Supplementary Table S2 for a comparison between models). The QE model assigns weights to studies depending on their quality. A quality index (Qi) was adapted from Doi and Thalib (2008, 2009) to be applicable to rangelands (Table 1). The input for all models was the study name, mean, standard deviation and sample size for the control (continuous grazing) and the treatment (HPG). The model outputs were the ES, Cochran's Q, p-value for Cochran's Q, and study weightings. A positive ES indicated a positive effect of HPG. The overall ES is the average of all studies and is considered statistically significant when the confidence interval does not contain the null. Results were expressed as forest plots where the null is indicated as the line of 'no effect'. The Cochran's Q indicates heterogeneity between studies.

Publication bias

Publication bias refers to the tendency of both authors and journals to select statistically significant studies for publication (Dickersin 1997). Funnel and Doi plots are routinely used to assess whether publication bias is present in meta-analyses. These are scatter plots of weighted mean difference of all studies versus an estimate of precision within each study. The precision estimate is usually study size or standard error for Funnel plots, or the Z-score for Doi plots, which is a derivation of standard error (Doi and Thalib 2009). In both Funnel and Doi plots we expect that weighted mean differences will occur as a spread around the overall ES, with more precise studies being closer to the overall ES and less precise studies further away, forming a symmetrical A-shaped plot. MetaXL uses the Luis–Furuya–Kanamori score (Z-score) to quantify asymmetry in Doi plots where a Z-score within ±1 indicates no asymmetry; a Z-score exceeding ±1 but within ±2 indicates minor asymmetry and a Z-score exceeding ±2 indicates major asymmetry. A criticism of both plots is that there are other reasons beside publication bias that can result in an asymmetrical plot, e.g. small study effects. For that reason, the distribution of studies within the Funnel plots was also assessed to see if there is a 'gap' around the area of non-significance (Higgins and Green 2011).

Predictor factors

The influence of factors that potentially predict the outcome of any HPG study, e.g. abiotic variables (mean annual precipitation [MAP] and the global aridity index [AI]), and variations between trials (duration, animal density [camp number] and camp size) on the effect sizes was tested using multiple regression (Statistica 13, StatSoft Inc., Tulsa, OK, USA). Various other management differences between trials likely also impact the efficacy of HPG (e.g. residual dry matter targets and herbage allowances per head) but not all of this information could be extracted for all studies.

Table 1: Quality scoring system used in the quality effects (QE) model of the meta-analysis. Questions and scores are adapted from epidemiology (Doi and Thalib 2008) to be relevant to rangeland science

Question	Score
Did the experimental layout use randomisation or another appropriate sampling strategy?	0 = No or not reported 1 = In part 2 = Yes
Were the groups being compared comparable at the baseline?	0 = No or not reported 0.5 = In part 1 = Yes
Was the outcome of interest already present at the start of the study?	0 = Yes 2 = No
Was the trial conducted over an adequate time period to allow differences to emerge (≥5 years)	0 = 1–2 years 0.5 = 3–5 years 1 = 6–10 or more years
Was the analysis clearly reported and appropriate?	0 = No 0.5 = In part 1 = Yes
Were protocol deviations or losses during the study acceptable (<20%)	0 = No or not reported 0.5 = In part 1 = Yes

$$\text{Quality index (Qi)} = \frac{\text{sum of scores}}{8}$$

The AI is a modelled measure of MAP in relation to the mean annual potential evapotranspiration (MAE) using the Hargreaves method (Hargreaves et al. 1985) and was obtained from the CGIAR-CSI Global-Aridity and Global-PET Database (http://www.cgiar-csi.org; Zomer et al. 2007, 2008). The AI values from the geodatabase were point sampled at the study site locations and multiplied by 0.0001 to retrieve the values in the correct units (Supplementary Table S1). The AI scale, which is recognised by the Food and Agriculture Organization of the United Nations as well as the United Nations Environment Programme, was used in preference to the Savory Brittleness (SB) scale as the latter is subjective with no formula for its calculation. To roughly compare the scales, very arid environments score low on the AI scale (<0.05) and high on the SB scale (10), whereas humid environments score high on the AI scale (>1) and low on the SB scale (1).

Results

The literature search returned studies that compared HPG with continuous grazing spanning the years 1972 to 2016, comprising 75 data sets across five countries (Argentina, Australia, Canada, USA and Zimbabwe) and two major biomes (Temperate or Tropical Grasslands; Savannas and Shrublands; Olson et al. 2001).

Agricultural production

The meta-analysis showed that there was no significant effect of HPG on plant basal cover compared with continuous grazing (Figure 1, Table 2). There was significant between-study variation ($p < 0.001$, Cochran's Q; Table 2) but only two data sets from high and medium

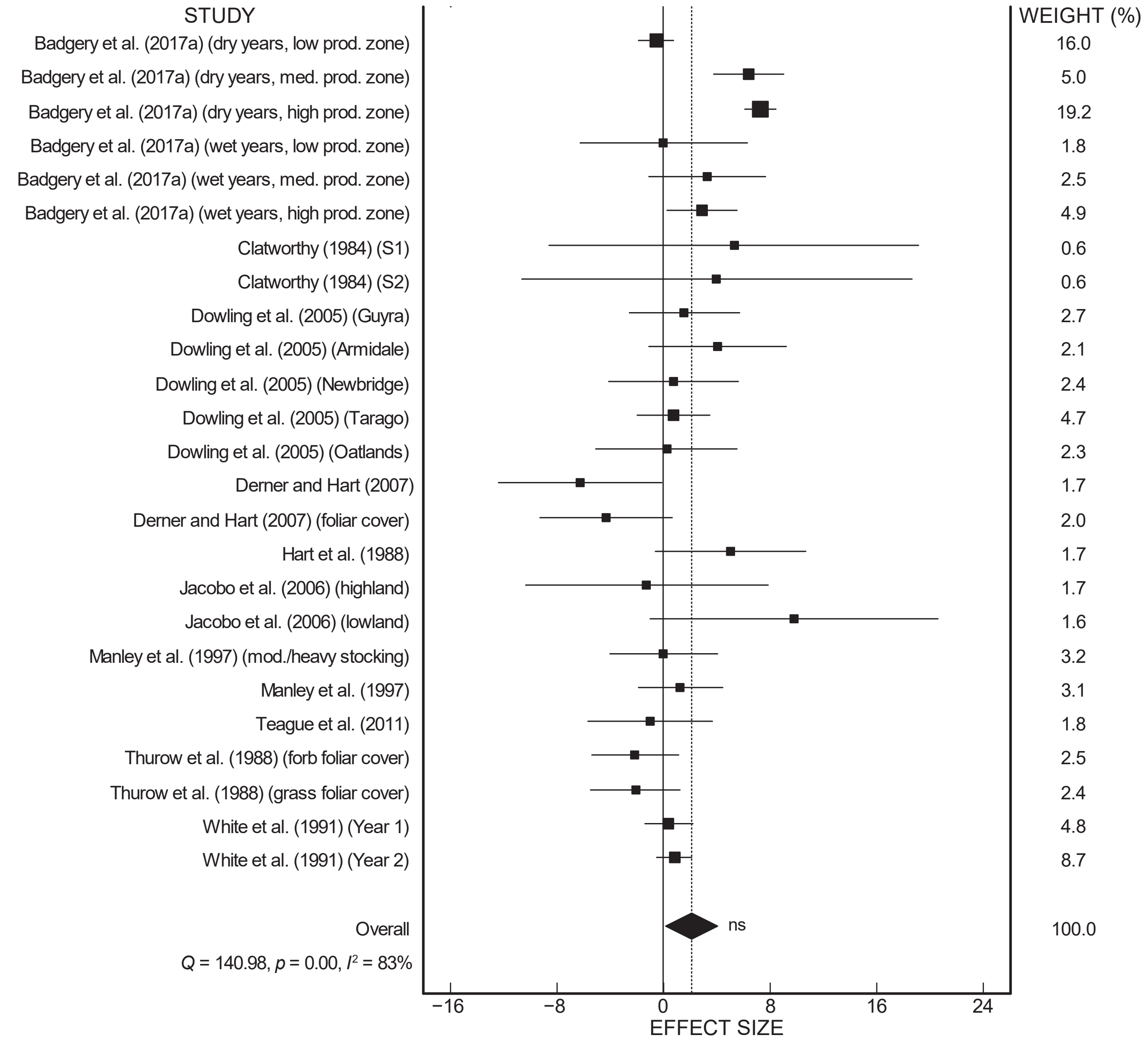

Figure 1: Forest plot of plant basal cover (%) comparing Holistic Planned Grazing™ (HPG) with season-long continuous grazing using the effect size (or weighted mean difference) method and quality effects model. Individual data sets are named according to the studies from which they were sourced. The effect size from each study is indicated by the mean (■) and 95% confidence intervals (horizontal lines through means). The overall effect size from all studies is indicated by a dashed vertical line and a diamond (♦). The solid vertical line is the 'line of no effect' or null effect. All studies with negative treatment effect sizes are on the left side of the line of no effect, and those with positive effect sizes appear on the right side. The overall effect size is significant at the $p = 0.05$ level when the width of the diamond (indicating 95% confidence intervals) does not cross the line of no effect. The letters (s.) or (ns.) adjacent to the overall effect size also indicate significance or non-significance, respectively. *P*-values refer to the significance level of the heterogeneity index, where $p < 0.05$ indicates significant heterogeneity (Cochran's *Q*) between studies. The I^2 statistic also describes the variation across studies as a percentage heterogeneity. The weight that each study contributed to the overall effect size was based on a quality score system and appears on the right of the plot

production zones under sheep production had higher cover with HPG (see Badgery et al. 2017a in Figure 1). The effect of HPG on plant standing biomass was also neutral (Figure 2, Table 2). The high publication bias scores (*Z*-score ≥ 2 from Table 2, and a lack of data around the null effect in Funnel plots) mean that we must interpret these data with caution. Between-study heterogeneity was high ($p < 0.0001$). Considering individual studies (Figure 2), it is obvious that the source of the heterogeneity is the difference between Teague et al. (2010, 2011) and other studies and if the latter are removed the data are no longer asymmetrical ($Z = 0.54$). Biomass here refers to green and brown (dead) standing biomass with only Badgery et al. (2017a) quantifying green and dead biomass separately. Animal gain or animal production (kg ha^{-1}) was neutrally affected by HPG compared with continuous grazing

Table 2: Effect size (ES), lowest and highest confidence intervals (LCI and HCI) and heterogeneity index (Cochran's Q with the p-value for Q in brackets) for plant basal cover, plant biomass, animal gain and animal average daily gain when comparing Holistic Planned Grazing™ with season-long continuous grazing. Results from the quality effects (QE), random effects (RE) and inverse variance fixed effects (FE) meta-analysis models are shown. The quality index (Qi) indicates the extent to which the QE model has reduced the confidence intervals by accounting for systematic errors within studies (see Table 1 for scoring criteria). Z-scores less than 1 indicate no asymmetry whereas scores above 2 indicate major asymmetry and publication bias. The significance or non-significance of the effect size at the $p < 0.05$ level is indicated as s. or ns., respectively, based on the null value or 'line of no effect' within forest plots

Effect	Model	ES	LCI	HCI	Cochran's Q (*p*-value)	Data sets (*n*)	Qi (%)	Publication bias (*Z*-score)	Significance (ES)
Plant basal cover (%)	QE	2.1	0.15	4.10	141	25	26	0.05	ns
	RE	1.2	−0.34	2.77	(<0.001)		/	0.05	ns
	FE	0.3	−0.42	1.11			/	0.49	ns
Plant biomass (kg ha^{-1})	QE	28.2	−99	156	221	29	14	3.36	ns
	RE	128.6	42	215	(<0.0001)		/	3.36	ns
	FE	−2.8	−24	18			/	3.36	ns
Animal gain (kg ha^{-1})	QE	5.8	−31.9	43.4	599	8	43	0.38	ns
	RE	9.6	−15.4	34.6	(<0.0001)		/	0.38	ns
	FE	7.4	5.9	8.8			/	0.38	s
Average daily gain (kg head^{-1} d^{-1})	QE	−0.01	−0.058	0.035	30	15	24	−0.05	ns
	RE	−0.02	−0.055	0.021	(0.007)		/	−0.05	ns
	FE	−0.02	−0.037	0.002			/	−0.05	ns

according to the QE and RE models (Figure 3, Table 2). The FE model found HPG to have a positive effect on animal gain compared with continuous grazing (Table 2). The result for animal average daily gain (kg head^{-1} d^{-1}) was much clearer, with all three models showing a neutral effect of HPG (Figure 4, Table 2) with no asymmetry in the data (Z-score < 2). Most of the livestock in studies were cattle, except for Badgery et al. (2017b) who studied sheep. Animal gain and average daily gain analysis also showed high between-study heterogeneity ($p < 0.0001$ and $p = 0.007$, respectively).

While the models were in general agreement, the QE model was an improvement on the other models because it quantified systematic errors within studies (see Table 1 for criteria and Supplementary Table S1 for scores) and weighted them accordingly, resulting in a reduction (24–43%) of confidence intervals (Table 2).

Factors predicting effect size

The sites ranged from arid to humid (AI values of c. 0.16 to 1.3, respectively; Supplementary Table S1) but only MAP and not AI influenced effect size (data for AI not shown). The effect size of HPG on plant basal cover increased with increasing animal density and MAP ($p = 0.009$ and $p = 0.030$, Figure 5a and b, respectively, after multiple regression). Animal density and MAP did not affect the effect sizes for plant biomass, animal gain or average daily gain ($p > 0.05$, data not shown). Neither camp size (0.75 to 350 ha) nor trial duration (2 to 13 years) impacted on effect size for plant or animal production ($p > 0.05$, data not shown).

Plant utilisation, soil and biodiversity

The relative effect of HPG on soil and plant or animal biodiversity was addressed by too few studies to include in a meta-analysis. Only one study (Hart et al. 1993a) measured plant utilisation and they found no difference between continuous grazing and HPG. Holistic Planned Grazing decreased (Teague et al. 2011), increased (McCalla et al. 1984; Booker et al. 2013) or had no effect (Sanjari et al. 2008) on soil compaction (measured as soil bulk density). Two of the three studies on soil infiltration found no effect of HPG relative to continuous grazing. Although one study found no increase in soil microbial biomass under HPG (Nisha et al. 2010), another found that HPG resulted in increased soil decomposer activity (Teague et al. 2011). The controversial claims around increased carbon sequestration under HPG have been disputed by most existing peer-reviewed studies (Teague et al. 2011; McSherry and Richie 2013 [C_3 grasses]; Badini et al. 2007; Sanjari et al. 2008), whereas one study reported increased soil carbon sequestration (McSherry and Ritchie 2013). Interestingly, this study reported that carbon sequestration was higher in C_4 but not C_3-dominated grasslands. Two studies found that HPG favoured the growth of annuals and early successional perennials and exotic plant species (Gillen et al. 1998; Loeser et al. 2007). Several studies found convincing evidence that HPG (or any intensive grazing activity) decreases nesting activity of passerine birds (Nash et al. 2004; Little et al. 2013, 2015a, 2015b), and decreases songbird diversity and abundance (Ranellucci et al. 2012).

Discussion

This analysis provides quantitative support for earlier reviews that compared season-long continuous and rotational grazing (e.g. Briske et al. 2008, 2011). More specifically, the review compares season-long continuous grazing with Holistic Planned Grazing to test whether HPG results in an animal impact on primary or secondary production. While Briske et al. (2008) found continuous grazing results in similar or greater production compared with rotational grazing in general, this meta-analysis found that HPG and season-long grazing resulted in comparable primary and secondary production. Thus, if animal impact

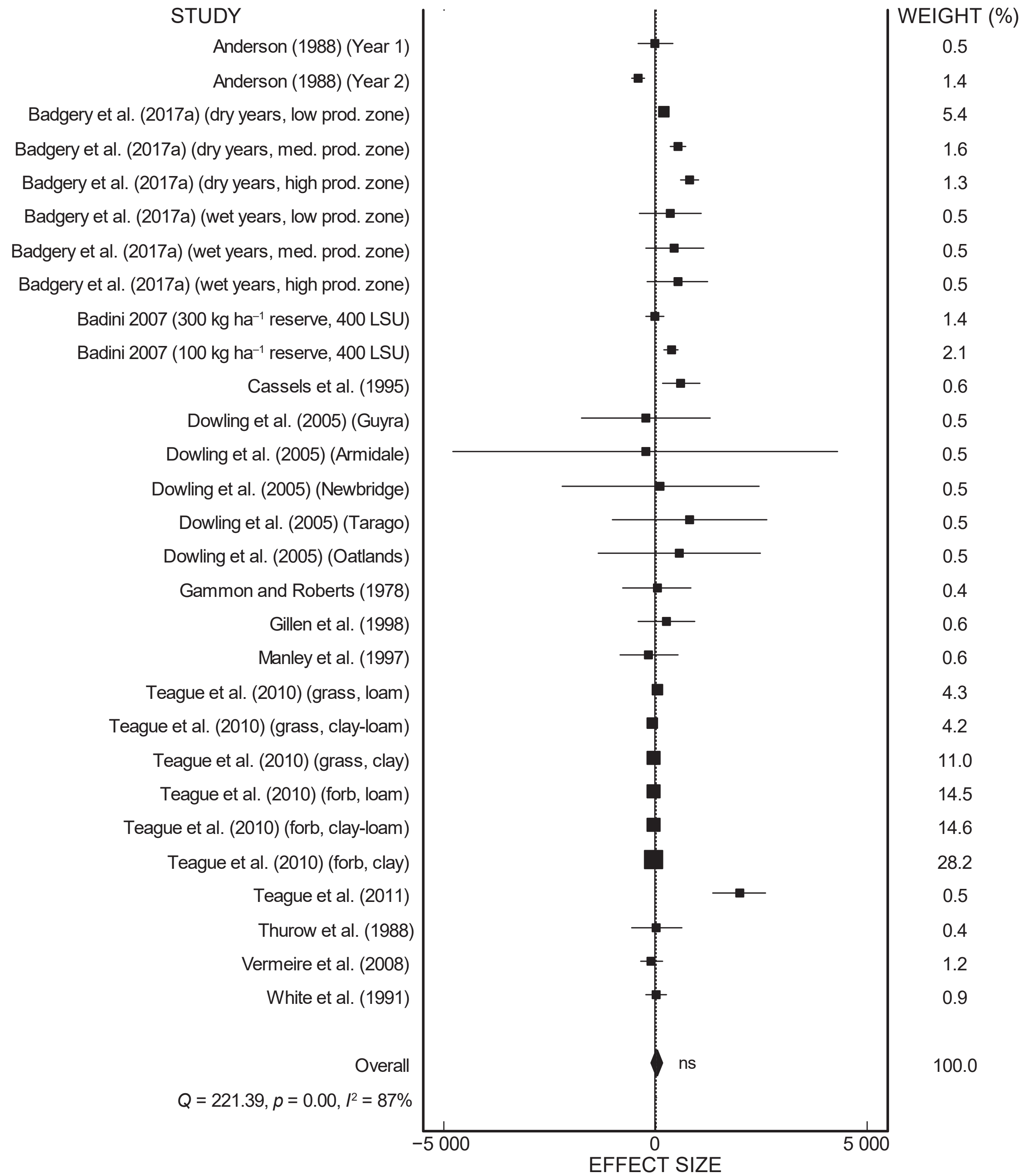

Figure 2: Forest plot of plant biomass (kg ha^{-1}) comparing Holistic Planned Grazing™ with season-long continuous grazing using the effect size method and quality effects model. The plot can be interpreted as explained in Figure 1

(trampling) and less selective grazing is occurring during HPG, it has no effect on production compared with season-long continuous grazing at the same stocking rate. It is still possible that animal impact occurs at some critical level of animal density because this study shows a slight, positive relationship between effect size for plant basal cover and animal densities. Given that the animal densities recorded did not exceed c. 12 AU ha^{-1}, there is scope to test the effect of a larger range of densities.

As noted by many studies reviewed here, stocking rate and grazing pressure (animal unit days per unit forage available) are more important than any grazing system in determining the balance between plant and livestock production (e.g. van Poollen and Lacey 1979; Skovlin 1987; Ralphs et al. 1990; Willms et al. 1990; Gillen et al. 1998; Briske et al. 2008; Derner et al. 2008; Briske et al. 2011). Productivity per animal is known to decrease with increasing stocking rate, whereas secondary productivity per unit area will increase until scarcity of forage reduces nutrient intake by livestock, i.e. the grazing pressure limits productivity. Wildlife biodiversity and abundance (birds, amphibians and mammals) also decrease with

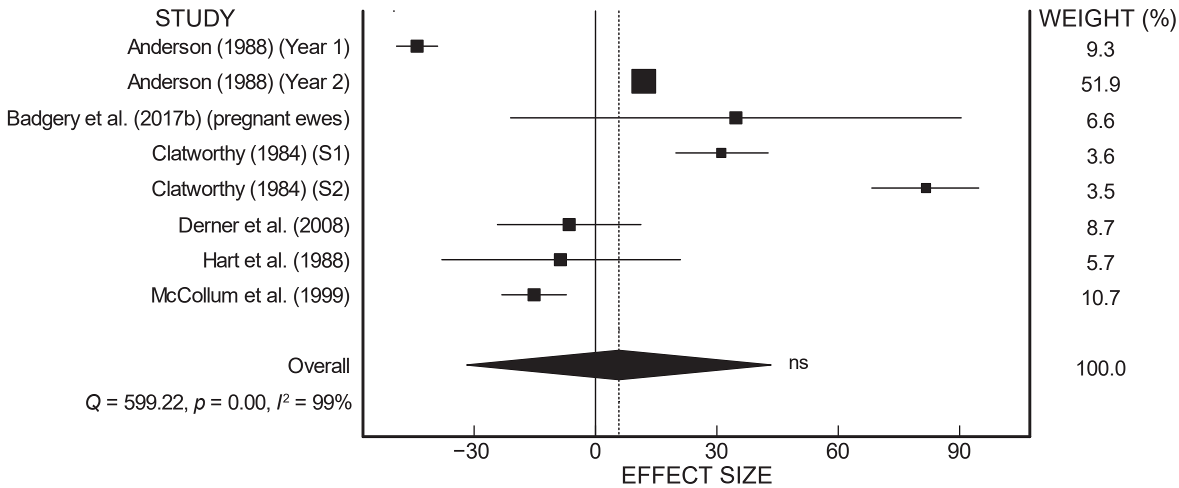

Figure 3: Forest plot of animal gain (kg ha^{-1}) comparing Holistic Planned Grazing™ with season-long continuous grazing using the effect size method and quality effects model. The plot can be interpreted as explained in Figure 1

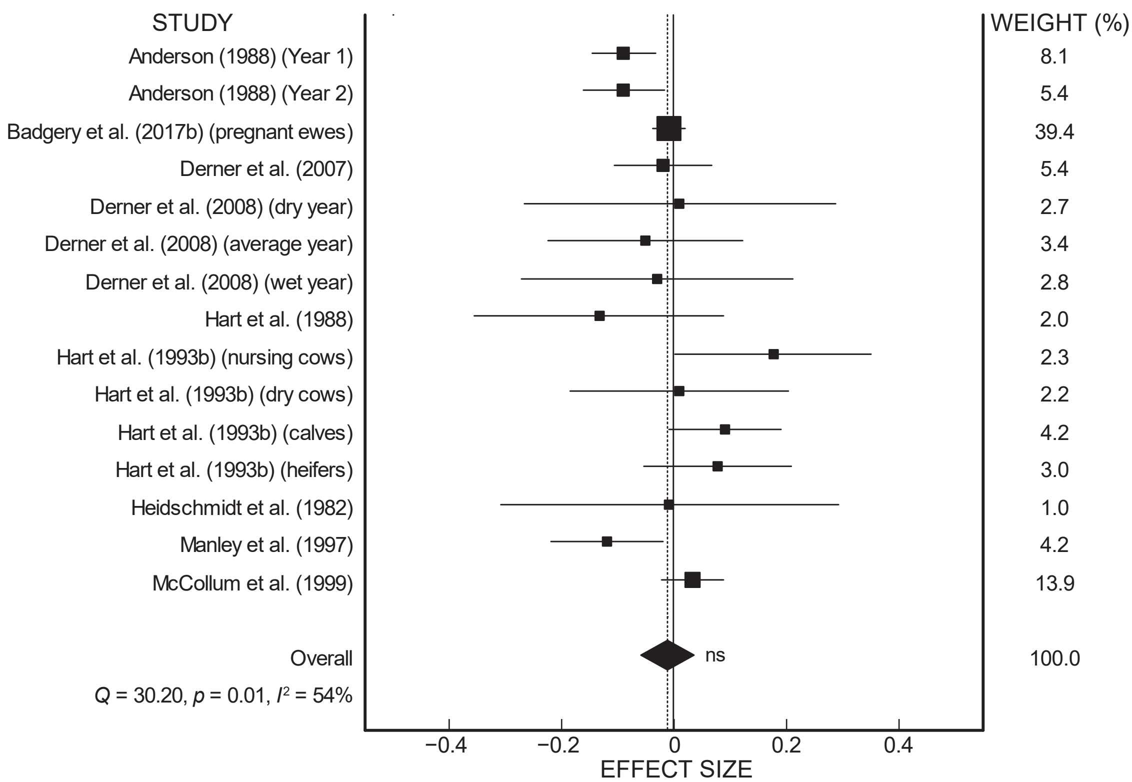

Figure 4: Forest plot of animal average daily gain (kg head^{-1} d^{-1}) comparing Holistic Planned Grazing™ with season-long continuous grazing using the effect size method and quality effects model. The plot can be interpreted as explained in Figure 1

increased stocking rates (Bock and Bock 1999; Briske et al. 2011; Carter et al. 2014). This review showed that HPG practiced at moderate stocking rates does not have a benefit for production. Thus, it seems particularly risky to assume that production will improve with a doubling of the recommended stocking rate under HPG.

Despite the lack of evidence for any benefit of HPG for production, the approach remains widely advocated. Is it possible that scientific studies have missed some of the ecological and social conditions under which HPG is beneficial? This study revealed that there was an overall neutral effect of HPG compared with continuous grazing but also that there was significant between-study heterogeneity. Studies with positive effect sizes tended to have higher MAP, indicating that HPG is more suited to areas with moderate to high rainfall. Rangelands with variable, arid or semi-arid climates tend to be in a non-equilibrium state where stochastic factors and climatic variability

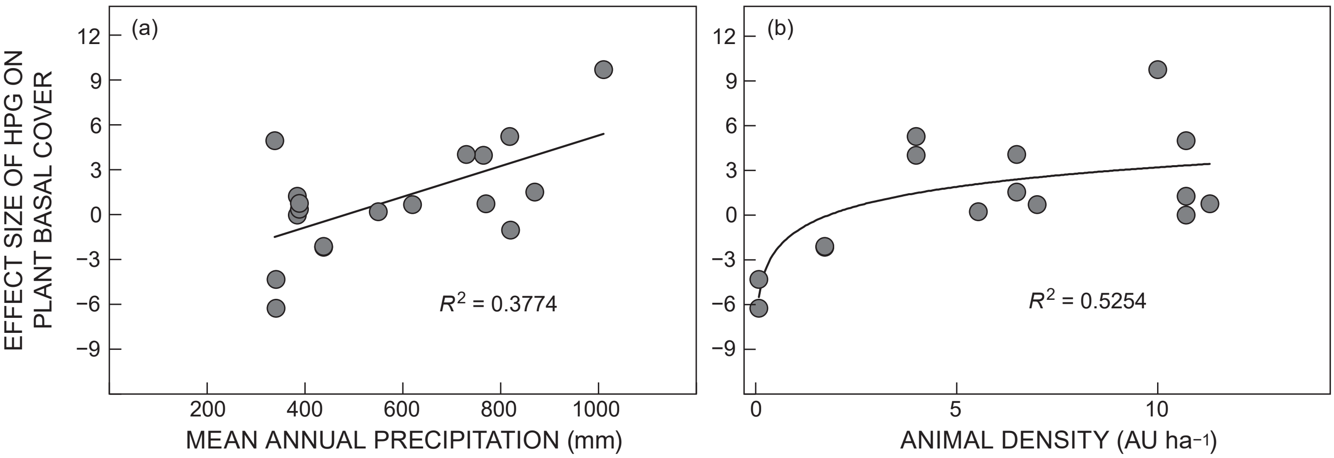

Figure 5: Impact of (a) mean annual rainfall and (b) animal density in animal units per hectare (AU ha^{-1}) on the effect size of Holistic Planned Grazing™ (HPG) when applied to plant basal cover. Linear and logarithmic trend lines as well as R^2 values are shown for the relationships in (a) and (b), respectively

may influence primary production more than management (e.g. Vetter 2005; Derner et al. 2008). Supporting this, Milchunas et al. (1988) and Cingolani et al. (2005) describe how the response of grassland community structure to grazing changes along gradients of moisture and evolutionary history. A simulation model by Beukes et al. (2002) found that arid rangelands with a rainfall of less than 250 mm did not benefit ecologically or economically from a multi-camp system and Carter et al. (2014) showed that bunchgrasses in arid areas are sustained by rest from livestock grazing. In addition, arid areas generally have relatively large scales of production, thus incorporating high climatic and spatial variability, making an intensive approach to management difficult. Thus, this review agrees with the conclusion of Briske et al. (2014) that the incorporation of HPG into policy is highly risky, but would add that this is especially so in arid environments.

Besides MAP, we know very little about how soil nutrients may limit intensive grazing approaches. Hempson et al. (2015) have attempted to disentangle the complex interactions between climate, nutrients and herbivory by reconstructing four distinct historical herbivory regimes for sub-Saharan Africa. Only one of these herbivory regimes or ‘herbivomes’ seems to have evolved the way Savory suggests. High nutrient areas with moderate rainfall were dominated by high ‘VALS’ (a variety and abundance of large herbivore species, including large migrating herds). The other herbivomes were either low-nutrient, high-rainfall areas that relied on fire and were dominated by bulk grazers, or were otherwise resource-limited, resulting in naturally low densities of herbivores.

Thus, if HPG is suited to high nutrient areas with moderate rainfall, its application in planted pastures may be more appropriate or at least less risky than on native rangelands. The HPG approach was originally developed for planted pasture systems (Voisin 1988) and Savory was inspired by this agriculturalist to extend the approach to natural rangelands. Planted pastures comprise domesticated, early successional plant species that have rapid growth strategies (high leaf nitrogen and specific leaf area). Early successional species would likely respond positively to soil disturbance and incorporation of animal dung into the soil by intensive hoof action (Laliberté et al. 2012). Indeed, annuals, early successional perennials (Gillen et al. 1998; Loeser et al. 2007) and exotic plant species (Loeser et al. 2007) increased under HPG. In addition, a review of the effects of HPG compared with continuous grazing in domesticated, planted pastures found that monocultures of forage grasses and grass–legume mixtures grown in high precipitation regions had greater plant production (c. 30%) and persistence of palatable species, although this did not increase livestock production in the majority (85%) of studies (Sollenberger et al. 2012).

The impact of HPG on plant utilisation, soil characteristics, biodiversity and global change are relatively less well researched compared with production. Based on the available evidence, the impact of HPG on soil characteristics appears to be similar to other types of rotational grazing and these are reviewed in detail elsewhere (Briske et al. 2008) as are claims that HPG could return atmospheric carbon to pre-industrial times (Briske et al. 2013; Carter et al. 2014). Intensive grazing approaches such as HPG may impact the complex above- and below-ground food webs in rangelands via a homogenisation of the vegetation structure and micro-topography needed by ground-nesting birds and other animals (Little et al. 2013; 2015a, 2015b; Ranellucci et al. 2012).

Several studies have found that organic matter digestibility was reduced in feaces of sheep on HPG (e.g. Badgery et al. 2017b) and this coincided with reduced weights per head of animal (Worthington 1984; Anderson 1988; Manley et al. 1997; Badgery et al. 2017b) and conception rates (Worthington 1984). These results suggest that a trade-off between forage quantity and quality occurs in HPG, possibly due to a more complete utilisation of the grass sward. High Performance Grazing, which also uses multiple camps, claims to avoid these problems by moving animals before depletion of the short, nitrogen-rich, leafy material (Skovlin 1987; Tainton et al. 2013). Barnes et al. (2008) suggest several ways that utilisation of forage can be improved without intensive grazing, namely distribution of watering points and supplementation, herding and selection of animals that occupy different feeding niches (e.g. browsers and grazers).

Besides ecological conditions, socio-ecological and socio-economic factors may determine the real or perceived benefits of HPG. It is obvious from the literature (e.g. de Villiers et al. 2014) and from communications with practitioners that HPG provides increased opportunities for decision-making, animal-handling and pre-empting of problems. Whether HPG camps are managed using herding or moveable fences, camps are commonly moved daily, which facilitates increased contact time between the land user, farm and animals. Besides contact time, the actual camps (in all rotational grazing approaches) allow the land user to manage for diverse goals such as production, conservation or restoration. As early as 1961, Heady suggested that specialised grazing approaches may be more useful for the restoration of deteriorated ranges rather than the maintenance of ranges in excellent condition. Camps also allow for the management of diverse vegetation types, patch burning regimes, livestock type, age or sex. Finally, de Villiers et al. (2014) found that farmers practicing Holistic Management™ had a higher social capital in that they participated more in groups, likely leading to increased learning and adaptive behaviour. Thus, the farm-level benefits besides production, i.e. socio-ecological aspects, should be included in future research on production rangelands.

Conclusions

From the evidence available, Holistic Planned Grazing does not improve production and thus does not warrant the additional inputs (infrastructure and labour) that the approach requires. However, few studies have considered the suitability of HPG across a gradient of nutrient and water availability, or across a range of animal densities. Together with potential socio-ecological benefits of HPG, this is where more research efforts should be placed.

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