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Sustainable and Profitable Grazing Management in a Highly Variable Environment-Evidence and Insights from a Long Term Grazing Trial in Northern Australia

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Sustainable and profitable grazing management in a highly variable environment-evidence and insights from a long term grazing trial in northern Australia

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Key points : Rainfall variability is a major challenge to sustainable management in semi-arid rangelands . We present empirical evidence from a large , long-term grazing trial in northern Australia on the relative performance of constant heavy stocking , moderate stocking at long-term carrying capacity and variable stocking in coping with climate variability over a range of rainfall years . Moderate stocking gave good economic returns , maintained pasture condition and minimised soil loss and runoff . Heavy stocking was neither sustainable nor profitable in the long term . Variable stocking generally performed well but suffered economic loss and some decline in pasture condition in the transition from good to poor years . Importantly , our results show that sustainable and profitable management are compatible in semi-arid rangelands .

Key words : stocking rate , rainfall variability , economics , pasture condition , soil health , runoff

Introduction Rainfall and hence forage production in semi-arid rangelands vary sharply between years , with variability generally increasing as mean annual rainfall declines . Rainfall also varies spatially at a range of scales and this , together with underlying landscape heterogeneity leads to spatio-temporal dynamics in forage quality and availability (Ellis and Swift , 1988) . Traditionally , pastoralists have exploited this spatial variability to buffer temporal changes in feed supply through nomadism , transhumance or by simply utilising a range of landscapes or land types (Ellis and Swift , 1988) . With settled agriculture , landscape fragmentation and declining property size however , many of these traditional strategies are unfeasible and grazing management has to adapt accordingly if it is to be ecologically and economically sustainable .

A range of grazing strategies have been suggested to sustainably manage for rainfall variability e .g . (Danckwerts et al . , 1993) which may broadly be classified as follows . C*onservative* or *moderate* stocking , also termed the equilibrium approach (Vetter , 2005) , aims to utilise some safe amount of pasture to ensure sufficient forage in drier years and avoid overgrazing (or at least ensure it is relatively infrequent) to allow recovery in subsequent wetter , seasons . In Australia , recommendations for tropical and sub-tropical savannas are to utilise an average of 20-25 % of the available forage that can be expected to be produced in at least 70 % of rainfall years (McKeon et al . , 1990) .

In contrast , variable or flexible stocking , termed the non-equilibrium approach (Vetter , 2005) , involves matching stock numbers to forage supply to avoid overgrazing in dry years but take economic advantage of good rainfall years without damaging the resource . In highly seasonal environments like northern Australia , a logical time to adjust stock numbers is at the end of the wet season when the probability of further rainfall in the next 6 to 9 months is low (Ebersohn 1973 cited by (Orr et al . , 1993) . Variations of this approach may also involve the use of climate forecasting to inform stocking rate decisions in advance of any shifts in rainfall (McKeon et al . , 1993) .

A third approach involves resting a portion of a property each growing season , to buffer inter-annual variation in fodder supply and improve pasture composition (Danckwerts et al . , 1993) . Evidence suggests that wet season spelling may also buffer the effects of increased grazing pressure on land condition (Ash et al . , 2001) .

There has been considerable debate in the literature on the appropriateness of the equilibrium and non-equilibrium approaches for semi-arid rangelands (Vetter , 2005) . However , the distinction between these philosophies for the management of commercial grazing lands in northern Australia has not been a major issue with most recommended forms of adaptive management stressing elements of both e .g . (Watson et al . , 1996) . Of far greater concern is that adoption rates of grazing management practices that aim to manage sustainably in a variable climate have been relatively poor . Accordingly , many properties continue to suffer excessive grazing pressure , particularly in drier years , with resultant consequences for land condition , water quality and downstream systems like the Great Barrier Reef Lagoon (Furnas , 2003) . Reasons for this non-adoption are complex but a key reason is the belief that sustainable management is not economic and that heavier stocking rates maximise economic return (Lawrence et al . , 1994 ; O'Reagain et al . , 2003) .

The paradigm of more cattle equal more money is difficult to challenge given the disparate experimental and anecdotal evidence available . The majority of previous grazing trials in northern Australia are of limited relevance to the management of extensive rangelands because they involved exotic legumes and/or grasses (Eyles et al . , 1985) . Although the benefits of light utilisation (stocking) rates and wet season spelling on native pasture have been demonstrated experimentally (McIvor and Gardner , 1995 ; Ash et al . , 2001) , there is virtually no work directly quantifying the relative impacts of different management strategies on economic performance .

Previous grazing trials have also usually been conducted on relatively small, (<30 ha) uniform areas e.g. (Gillard, 1979), although recent work has focussed on larger, commercial scale paddocks (Cowley et al., 2007). Data from small paddocks is of limited relevance to extensive areas where paddocks are often large (> 1000 ha) with widely spaced water points and frequently contain a diversity of soil and vegetation types. Under these conditions spatial variability may buffer or distort stocking rate effects on both animal production and land condition (Ash and Stafford-Smith, 1996). Indeed, management practices identified as sustainable in small uniform paddocks e.g. light stocking, may lead to significant degradation in large spatially variable paddocks, where grazing is not uniform and selective over-utilisation of preferred areas often occurs.

Biophysical and economic simulations exploring the relative performance of different strategies over multiple years and rainfall sequences have been conducted for northern Australia e.g. (McKeon et al., 2000). However, while these simulations are of great value for individual case studies e.g. (Buxton and Smith, 1996) or for exploring different management scenarios e.g. (Ash et al., 2000), they are only as sound as the underlying data. Moreover, simulation models generally lack the credibility and impact to initiate adoption of sustainable management by graziers (O'Reagain et al., 2003).

A significant number of graziers do of course manage their land in a sustainable and profitable manner through light (Landsberg et al., 1998) or variable stocking (Mann, 1993), wet season spelling (Purvis, 1986) or combinations of all three. However, such cases are often discounted by other managers due to real or assumed differences in circumstances such as rainfall, property size or debt level. Work from South Africa also indicates that some successful conservation farmers achieved their present economic status via off-farm investment or even through previous exploitation of their resources, rather than through good land management *per se* (Mentis et al., 1989).

Many of the recommended grazing strategies for managing rainfall variability in northern Australia have thus not been tested at a scale or in a manner directly relevant to graziers. In particular, there is little objective data on their long-term profitability and sustainability relative to existing systems such as constant heavy stocking. A further important issue is the lack of practical guidelines and management tools for the implementation of these strategies e.g. variable stocking, at a paddock or property level (O'Reagain et al., 2003). Accordingly, many managers persist with the more traditional strategies of heavier stocking, delayed destocking and a reliance on drought feeding to cope with low rainfall years.

In 1997, a large, long-term grazing trial was established in northern Australia to address these issues by quantifying the relative performance of different grazing strategies to cope with rainfall variability. Importantly, this was to be done in a manner and scale relevant to graziers on commercial properties to support extension processes to improve adoption of sustainable management practices by the grazing industry (O'Reagain and Bushell, 1999). In this paper, we briefly report some of the preliminary results from the first ten years of the project. While the results and insights presented are somewhat context dependent, we believe that they will assist in informing the wider debate on managing for rainfall variability in semi-arid environments.

Materials and methods The trial is located on Wambiana, near Charters Towers, Australia (20° 34' S, 146° 07' E) in an open *Eucalypt* savanna on relatively infertile soils. Experimental paddocks are *c*. 100 ha in size and contain similar proportions of 3 different soil-vegetation associations. Mean annual rainfall is 650 mm and is highly variable (C.V. = 40%). Precipitation is largely (70%) concentrated in the wet season between December and April. Stocking strategies being tested are: (i) constant *moderate stocking* (MSR), stocked at the long term carrying capacity (LTCC) of 8 ha/large stock unit (AE= 450 kg steer) to achieve the recommended safe average pasture utilisation rate of 20-25%, (ii) constant *heavy stocking* (HSR): run at twice LTCC (4 ha/AE) to achieve an average of 40-50% utilisation of pasture, and (iii) *variable stocking* (VAR)-stock numbers adjusted annually in May at the end of the wet season (range: 3-10 ha/AE) according to available pasture. A *Southern Oscillation Index-Variable* strategy and *Rotational wet season spelling* are also being tested but for present purposes will not be discussed further.

Animal production is measured using Brahman-cross steers, supplemented with wet-season phosphorous and dry season urea. Molasses and urea drought feeding was provided in extreme circumstances. Accumulated cash surplus (ACS) was calculated from annual gross margins (GM) i.e. the value of beef produced minus variable and interest (10%) costs. Pasture total standing dry matter (TSDM) and species contribution to yield are assessed annually in May. Species data is grouped into 5 functional groups i.e. 3-P and 2-P (palatable, productive and/or perennial) grasses, wiregrasses (*Aristida* and *Eriachne* spp.), annual grasses and other. 3-P tussock densities are derived from tussock counts in 0 25 m^2 quadrats measured in May 2007. Pasture utilisation rates were calculated retrospectively using the GRASP model (McKeon et al., 1990) calibrated for the site. Runoff and soil loss are measured in a 1 ha bounded catchment using San-Dimas flumes (O'Reagain et al., 2005).

Results and discussion General Rainfall was initially above average but declined sharply in later years with the period from 2001 to 2006 being within or close to the lowest 20% of rainfall years (Figure 1). Pasture TSDM consequently changed profoundly from a high of *c*. 4500-5000 kg/ha in 1999 to average only 500 kg/ha in 2007. Differences in TSDM between grazing strategies were most pronounced in later years, with the HSR being virtually devoid of forage in the dry season of some years. Stocking rates in the VAR were set very high in the early wetter years (*c*. 4 ha/AE) but were halved in 2002 due to poor yields, and then progressively reduced as available pasture declined (Figure 1a). In the HSR, drought feeding was needed in 3 consecutive dry-seasons to sustain animals, but stocking rates were eventually cut by 30% in May 2005 due to continued forage shortages (TSDM < 400 kg/ha). Pasture utilisation rates were thus initially low (< 20%) but increased sharply in 2002 as rainfall declined, particularly in the VAR (64%) which was very heavily stocked due to previous good seasons (Figure 1a). As stocking rates were subsequently reduced in the VAR, utilisation rates dropped sharply to slightly below that in the MSR. Pasture utilisation rates in the HSR in contrast, remained high due to continued heavy stocking.

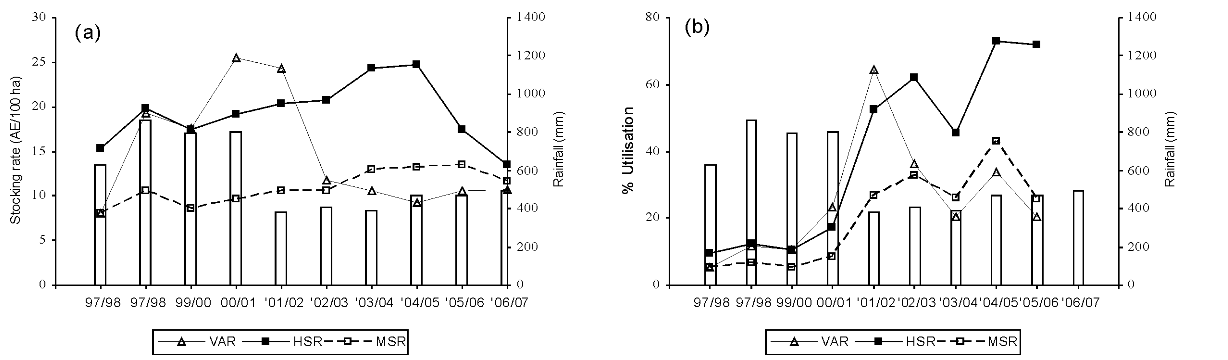

Figure 1 *Annual rainfall and (a) stocking rate (expressed as AEs per 100 ha) and (b) calculated annual pasture utilisation rate (%) for moderate, heavy and variable stocking over 10 years at the Wambiana grazing trial. See text for treatment abbreviations. NB: No pasture utilisation estimates were available for 2006/07.*

Animal production Individual animal live weight gain (LWG) varied between years (range: 30-180 kg/year/animal) depending upon rainfall and treatment. Over 10 years, average LWG was highest in the MSR (mean: 115 kg) followed by the VAR (mean: 108 kg), but considerably lower in the HSR (mean: 87 kg). Lighter stocked steers finished heavier, taller and in better condition and received a significant price premium (AU $0.10-0 20/kg) at the meatworks, particularly in drier years.

LWG per hectare (LWG/ha) also varied sharply (range: 12-48 kg/ha) between years due to rainfall and, in the VAR, changes in stocking rate (Figure 1a). Average LWG/ha was highest in the HSR (mean: 21 kg/ha), followed by the VAR (mean: 19 kg/ha) but lowest in the MSR (mean: 14 kg/ha). Differences between the HSR and MSR narrowed in later years and by (2005/06) were relatively minor (20 vs. 18 kg/ha) and, by 2006/07, had been reversed (1 vs. 5 kg/ha), suggesting a decline in the production potential of the former treatment.

Economic performance The heavily stocked VAR and HSR strategies made rapid initial gains in accumulated cash surplus (ACS) due to relatively high gross margins (GM) in the earlier wetter years (Figure 2b). However, ACS in the HSR dropped sharply in drier years post-2000/01 due to negative GMs arising from drought feeding costs, interest on livestock capital and reduced product value. In the MSR in contrast, ACS increased consistently across all years due to low costs and a higher product value. In the VAR, the initial gain was eroded by losses from reduced LWG and the forced sale of poor condition cattle with the transition to dry years in 2001/02. However, in contrast to the HSR, the rapid reduction in VAR stocking rates allowed ACS to recover in subsequent years. After 10 years, ACS was consequently highest in the MSR and VAR but lowest in the HSR: for a property size of 20 000 ha, this equates to a gross income advantage over the HSR of about AU $1.6 million.

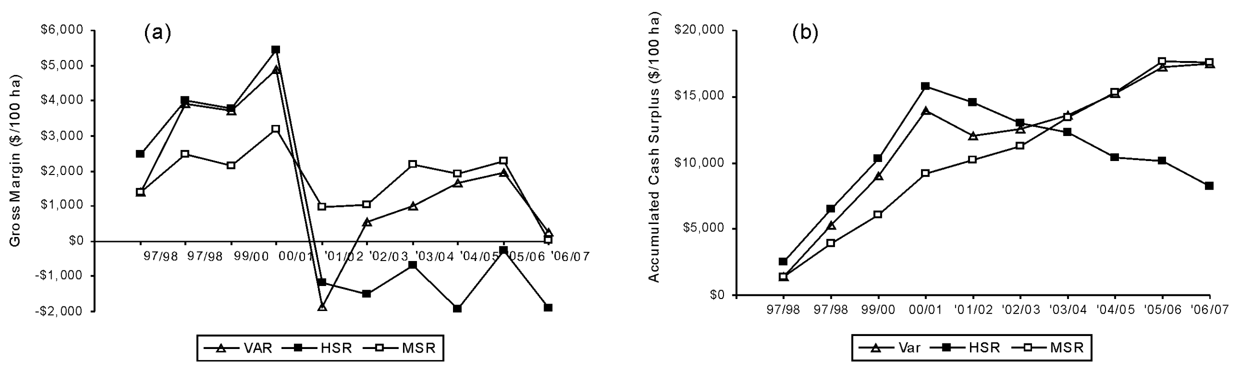

Figure 2 *(a) Gross margin (expressed per 100 ha) and (b) accumulated cash surplus for moderate, heavy and variable stocking strategies over 10 years. NB: interest on livestock capital calculated at 10%, AU $0.20 price premium for animal condition. See text for treatment abbreviations.*

Pasture composition After ten years , pasture TSDM was far greater in the MSR and VAR than in the HSR strategy . Total 3-P (palatable , productive , perennial) grass yield was also 8 to 10 fold greater in the former strategies . In terms of pasture condition , 3-P tussock density was 3 to 4 fold greater in the VAR and MSR than in the HSR . The slightly greater 3-P density in the MSR than in the VAR reflects the high utilisation rates inflicted on the VAR immediately preceding and leading into the dry years (Figure 1) .

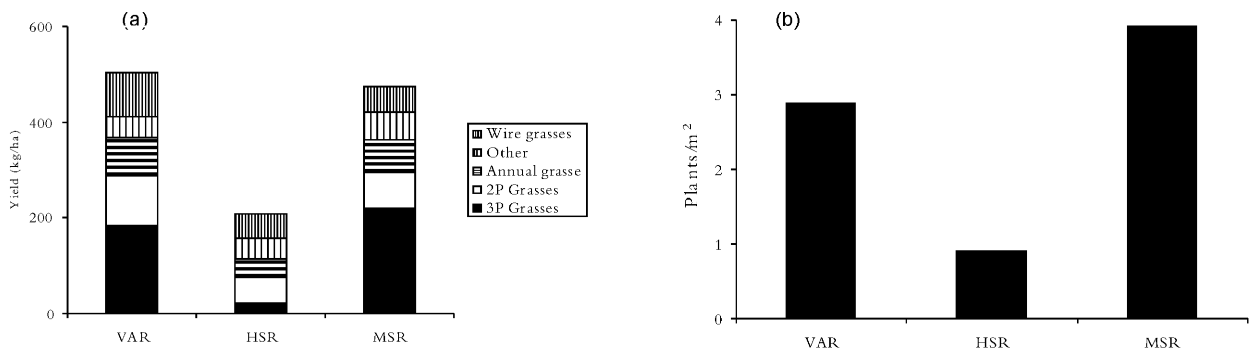

Figure 3 *(a) Contribution of different species groups to yield (b) and 3-P tussock density/m^2 in 2007 for moderate , heavy and variable stocking after 10 years at the Wambiana grazing trial . See text for details .*

Runoff and soil loss Initially , there were few differences in runoff between strategies due to high ground cover in early , high rainfall years . In later years however , the number and intensity of runoff events was markedly greater in the HSR compared to the MSR . This occurred particularly with early wet season storms in November and December , leading to increased sediment and nutrient loss . Overall , loss of nutrients , sediment and bedload increased with increasing long-term pasture utilisation rate {O'Reagain , 2008 #630} . The increased runoff was a direct consequence of the reduced soil macro-faunal activity and soil infiltration rates under heavy , constant stocking (Dawes-Gromadzki et al . , 2007) .

Discussion Data collected at the Wambiana trial over 10 years and a wide range of seasonal conditions , provide important evidence on the relative ability of the three stocking strategies to cope with rainfall variability . Constant heavy stocking at *c* . twice the long-term carrying capacity of the site , gave good economic and animal performance in the early high rainfall years and initially had no adverse affects upon land condition . However , the heavy stocking strategy suffered major economic loss with the advent of the drier years , and ultimately was far less profitable than either variable or moderate stocking . Heavy stocking combined with an inevitable sequence of low rainfall years led to a decline in land condition and carrying capacity , reduced soil health and increased the intensity and frequency of runoff events . In the longer term , the reduced rainfall use efficiency that is likely to occur with reduced infiltration will have obvious negative consequences for pasture and animal production .

In contrast , constant moderate stocking at long-term carrying capacity gave good individual animal production , minimised costs and importantly was profitable across a range of rainfall years . Moderate stocking also maintained pasture condition within acceptable limits , maintained soil health , and consequently had a reduced intensity and frequency of runoff events . Critically , it was profitable and sustainable over the ten years and showed no evidence of reduced carrying capacity . However , our observations are that the strategy would be improved by (a) inclusion of some form of wet season spelling (and possibly fire) to allow recovery of overgrazed patches or landtypes , (b) judicious adjustments of stocking rate to avoid overgrazing and loss of animal production in very dry years and possibly take some advantage of sequences of above average rainfall seasons .

Lastly , variable or flexible stocking showed some promise as a means of capitalising on good years and avoiding the losses caused by overstocking in low rainfall years . However , it clearly demonstrated the risks and adverse impacts associated with large changes in stocking rate between years . Variable stocking was profitable in most years but incurred significant losses in the transition from good to poor years and appeared to inflict significant and relatively long-lasting damage on pasture condition . Although the sharp downwards adjustment in stocking rate allowed margins to recover , it is significant that after ten years accumulated cash surpluses are nearly identical in the variable and moderate strategies . It is also noteworthy that pasture condition is still marginally poorer in the variable relative to the moderate strategy , despite 6 years of relatively light stocking rates in the former (Figure 1a) .

Variable stocking thus carries much higher risk in terms of land degradation and economic loss than moderate stocking at long-term carrying capacity . Recent modelling work tends to support this observation (Higgins et al . , 2007) . Even at very light stocking rates , a variable strategy would also still be vulnerable to area-selective grazing . Tight coupling of stocking rates with rainfall as advocated by some authors would also provide little opportunity for pastures to recover in good seasons , emphasising a need for some form of pasture spelling (Muller et al . , 2007) . Other practical issues associated with a variable or flexible strategy include (a) difficulties in estimating available forage in large extensive paddocks, (b) problems with calculating the appropriate stocking rate, (c) logistical problems of selling or buying large numbers of animals when required and (d) reconciling stocking rate changes with maintenance of a viable breeding herd e.g. (Foran and Stafford-Smith, 1991; O'Reagain et al., 2003).

We suggest that any form of variable or flexible stocking would be improved by (a) setting clear upper limits to stocking rate based on LTCC, (b) dampening fluctuations in stocking rate, particularly increases in stocking rate in good seasons, (c) inclusion of a second or third decision point to possibly adjust stock numbers downwards further if required during the year and (d), some form of wet season spelling to counter the effects of selective grazing and generally maintain pasture condition.

In summary, we advocate the application of constrained flexible stocking rates in line with seasonal variability within realistic limits determined by long-term carrying capacity. Changes in stock numbers should be based on firm decision rules based on set criteria e.g. the availability of forage at a fixed time in the year, and done in a strongly *risk-averse* manner with destocking more rapid than restocking. Evidence from other studies indicates that some form of wet season spelling is also critical to allow recovery or maintain pasture health {Ash, 2001 #187}.

In considering these findings, it is important to recognise the shortcomings of the underlying research. First, while 10 years is a long period in terms of project management, it is relatively short-term relative to many basic ecological processes e.g. species turnover. Second, the particular sequence of rainfall years encountered probably affected the performance of the different strategies tested. It is possible for example, that the variable strategy might have performed relatively poorly had a more disjointed sequence of wet and dry years occurred. Third, despite the size of the experimental paddocks and their relative heterogeneity, they are still relatively small compared to many commercial paddocks in northern Australia. Lastly, the work was done with steers and, as noted by Ash and Stafford Smith (1996), steer growth rates do not translate directly into reproductive performance in breeding animals. Nevertheless, while the present findings may not be directly replicated, we suggest that the general *principles* should still be relatively robust and should apply to breeding animals in larger commercial paddocks.

The present work is somewhat context dependent and largely relates to commercial cattle production in that the good economic performance of the more sustainable strategies was partly dependent upon the premium for animal condition received at slaughter. In other systems, this may not apply because either production is not particularly responsive to animal condition e.g. wool production, or because livestock provide other services (fuel, transport or social status) and animal condition is not particularly relevant. A key assumption in a commercial system is also that alternatives to investment in livestock exist i.e. the opportunity costs of investment in livestock are real. In the present study, drought feeding, although expensive was also relatively easy to supply which is not the case in many remote and/or subsistence communities. All of these factors would tend to discriminate against the performance of constant heavy stocking with its higher costs and lower product value. Irrespective of these points however, heavy stocking still reduced carrying capacity, with obvious implications for the sustainability and profitability of any system whether commercial or otherwise.

Conclusions Work conduced over the last ten years at the Wambiana site in northern Australia shows clear evidence of the profitability and relative sustainability of moderate-and to a lesser extent, variable stocking in a variable environment, relative to more common practices of sustained heavy stocking. The results need to be extrapolated upwards to the breeder and enterprise level and across a range of historical and possible rainfall scenarios but nevertheless provide key evidence to challenge the conventional wisdom that sustainability is not profitable and show that the maxim of more cattle equals more money is not necessarily true. We suggest a combination of constrained flexible stocking within limits set by long-term carrying capacity as well as the use of spelling for sustainable management of rainfall variability in semi-arid rangelands.

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