CSIRO PUBLISHING
www.publish.csiro.au/journals/trj *The Rangeland Journal*, 2009, **31**, 143–150

Wet season resting – economic insights from scenario modelling

N. D. MacLeod[A,D], *B. S. Nelson*[B], *J. G. McIvor*[A] *and J. P. Corfield*[C]

[A]CSIRO Sustainable Ecosystems, QBP Blg, 306 Carmody Rd, St Lucia, Qld 4067, Australia.
[B]Queensland Department of Primary Industries and Fisheries, Charters Towers, Qld 4820, Australia.
[C]CSIRO Sustainable Ecosystems, Private Mail Bag, PO Aitkenvale, Qld 4814, Australia.
[D]Corresponding author. Email: Neil.Macleod@csiro.au

Abstract. Pasture degradation, particularly that attributable to overgrazing, is a significant problem across the northern Australian rangelands. Although grazing studies have identified the scope for wet season resting strategies to be used to rehabilitate degraded pastures, the economic outcome of these strategies has not been extensively demonstrated. An exploratory study of the prospective economic value of wet season resting is presented using an economic simulation model of a 28 000 ha beef enterprise located in the Charters Towers region of north-eastern Australia to explore seven hypothetical scenarios centred on the projected performance of a wet season resting strategy. A series of 20-year simulations for a range of pasture recovery profiles, stocking capacity, animal productivity responses, beef prices and agistment options are compared with a baseline scenario of taking no action. Estimates of the net present value of the 20-year difference in total enterprise gross margins between the various resting options and the 'do nothing' option identify that wet season resting can offer a positive economic return for the range of scenarios examined, although this is contingent on the assumptions that are made concerning the trajectories of change in carrying capacity and animal productivity. Some implications for management and policy making to support the practical implementation of wet season resting strategies are discussed.

Additional keywords: economics, rangelands.

Introduction

Pasture degradation and declining land condition, especially that attributed to overgrazing, are significant and long-recognised problems across the northern Australian rangelands (e.g. Tothill and Gillies 1993; Ash *et al*. 1997). In the face of predicted but uncertain climate change characterised by more extreme climatic events, including longer and hotter droughts and intense rainfall events, the scope for further degradation of range pasture condition necessarily remains high. Such degradation influences the capacity of rangeland pastures to grow and support the existing beef industry, but also is of general community concern through impacts beyond the immediate boundary of individual pastoral holdings (e.g. dust and sediment flows into water bodies). Efforts to contain such problems are more likely to be pursued with vigour by private landholders where practical remedies are available and the bottom line of their uptake is positive. Where hard empirical data is lacking, there remains scope for economic modelling to offer insights into the potential feasibility of various rehabilitation options. One such example, centred on wet season resting of degraded pastures, is presented in this paper.

Deleterious changes in rangeland pasture condition typically include reductions in the proportion of desirable perennial tussock grasses, increases in annual grasses and forbs, and increases in the amount of bare ground. These changes have been described in the ABCD land condition rating scale promoted by the Queensland Department of Primary Industries and Fisheries (QDPIF); where 'A' represents land in very good condition and 'D' is land in very poor condition, with 'B' and 'C' conditions representing intermediate states (Chilcott *et al*. 2003). As land condition declines from A through to D, there are typically substantial reductions in herbage production (McIvor *et al*. 1995), although the quality of the available forage may initially improve with an increasing proportion of forbs and other annual pasture species in the available sward (e.g. Hacker and Tunbridge 1991; Ash *et al*. 1995). The impact of these pasture condition changes on carrying capacity and animal productivity (e.g. mortality, reproduction rates, liveweight gain) are not clearly defined, as few long-term grazing experiments have been conducted that specifically addressed that question without the compounding effects of stocking rates, use of fire, species augmentation and other management manipulations. Where pasture quality changes were found to be positively related to individual levels of animal productivity this was largely observed at low stocking rates with both pasture production and animal gains collapsing with increasing stocking rates and declining annual rainfall (e.g. Ash *et al*. 1995). Therefore, as land and pasture condition deteriorates, particularly through the suboptimal C and D states, it remains highly likely that a substantial and consistent decline in both forage quantity and quality will be associated with a decline in carrying capacity and animal production.

This decline in pasture productivity has led to interest in means of improving land condition. Perennial tussock grasses are the

 10.1071/RJ08043 1036-9872/09/010143

major component of many pastures but are sensitive to heavy grazing, particularly during the early wet season (Hodgkinson *et al*. 1989; Mott *et al*. 1992; Ash and McIvor 1998). Resting of pastures from grazing in the wet season has been suggested as a strategy to avoid deleterious impacts of defoliation at this time and was tested in small grazed plots in the Ecograze project (Ash *et al*. 2001) centred on three sites in the Charters Towers region of Queensland, north-eastern Australia – Hillgrove/Eumara Springs, Cardigan, and Lakeview/Allen Hills. This research showed that either low utilisation (25%) or moderate utilisation (50%) of pasture biomass combined with resting for 8–10 weeks at the start of the growing season could maintain land in good condition or restore land that was already in poor condition. There was good recovery, even in years of below-average rainfall. A later study examining wet season resting and controlled utilisation under commercial conditions at Virginia Park, also near Charters Towers (Post *et al*. 2006), also showed there were improvements in land condition although they were smaller than those obtained in the Ecograze plots on a similar soil type at Cardigan (Corfield and Nelson 2008).

The preceding grazing studies have shown that wet season resting, when systematically applied and supported with conservative pasture utilisation, has considerable promise for restoring degraded rangeland pastures and enhancing their potential for supporting higher levels of cattle production. The potential for improved pasture productivity was clearly demonstrated in the field trials, but there were no specific measures taken of animal production. Some positive financial implications also have been advanced for wet season resting strategies (Ash *et al*. 2001; Post *et al*. 2006), but the economic response was not able to be explored in detail.

There are no comprehensive empirical studies available of the economic outcomes for northern beef enterprises that have implemented successful wet season resting strategies, particularly for periods long enough to gauge the ultimate success. There is, however, considerable interest on the part of individual landholders and natural resource management (NRM) groups in further exploring wet season resting as a land management option. To provide some preliminary guidance to the question of economic feasibility, we apply insights from the Ecograze and Virginia Park studies to a herd economic simulation model to explore the scope for wet season resting to provide economic benefits for northern beef enterprises. Projected economic outcomes based on comparisons of total enterprise gross margins over 20 years with or without a paddock resting program, and some implications for wet season resting management are discussed.

Materials and methods

The evaluation of wet season resting practices is based on economic modelling of seven scenarios built around different projections of pasture carrying capacity and animal production response over a 20-year period from the time of initiation of a resting strategy. The analysis is based on a hypothetical beef enterprise of 28 000 ha that is located in the Charters Towers Goldfields region of north-eastern Australia. The geographic context lies within the Burdekin River catchment and corresponds to the location of the original pasture studies. The scale of operation approximates a median sized beef enterprise in the region (MacLeod *et al*. 2004).

The longer-term 'safe' carrying capacity of the pastures for the model enterprise is based on 25% utilisation of average annual pasture growth which equates to ~11 ha per adult equivalent (AE)[1] if all of the pastures were in B (fair) land condition, using the ABCD land condition rating scale (Chilcott *et al*. 2003). This gives a total carrying capacity of 2500AE for the model enterprise under that condition. As a result of previous land management practices, 50% of the breeder paddocks are assumed to presently be in C/C+ (poor) land condition and the remaining 50% of the breeder paddocks are assumed to be in B land condition. Profitability is assessed using the net present value (NPV) of the cumulative net change to total enterprise gross margins (TGM) for each 20-year simulation. We acknowledge the general limitations of using partial budgets based on gross margin comparisons to address questions of changing practices on enterprise level benefits and costs (e.g. Makeham and Malcolm 1992). Nevertheless, for this analysis it is unlikely that the nature and scale of the herd management activities and production system would change sufficiently as a result of wet season resting to alter the overhead costs structure of the enterprise.

A 10-year restoration strategy is employed for the whole property. This strategy utilises a four paddock rotation sequence comprising three degraded breeder paddocks and a spare paddock that is drawn from the remaining steer paddocks on the property to accommodate the breeders from the rested paddock each wet season (Fig. 1). To support a relatively fast recovery process for the three breeder paddocks (i.e. recovery within 10 years), the recommended strategy of giving each of the targeted paddocks an initial sequence of annual whole of wet season resting in years 1 and 2, repeated in years 4 and 5 with an ongoing sequence of 1 season of resting and 2 seasons of grazing (Fig. 1) was used. It is unlikely to be possible to introduce each of the three paddocks into this sequence initially, as this requires two extra paddocks from years 2 to 7. To retain the displaced stock elsewhere on the property would significantly raise the grazing pressure in the remaining paddocks. Hence, when a spare paddock is unavailable to take breeders displaced from a rested paddock, 100 steers that would normally occupy that paddock are agisted elsewhere for 180 days and sold off-property. The importance of this assumption to the projected economic outcomes is formally considered as part of the analysis.

This particular resting regime represents an accelerated recovery attempt to test the scope for economic returns from wet season resting strategies under quite challenging conditions. In practice, a more conservative resting regime (e.g. 1 year rest and 2 grazing without agistment) may be effective, but would presumably take longer to effect a recovery in paddock land condition and consequent carrying capacity. In the absence of contrary empirical data, changes in carrying capacity of the treated pastures are assumed to follow a trajectory that is based on projected relative differences between the estimated 'safe'

[1]One adult equivalent represents the approximate annual feed demand of a 455 kg steer.

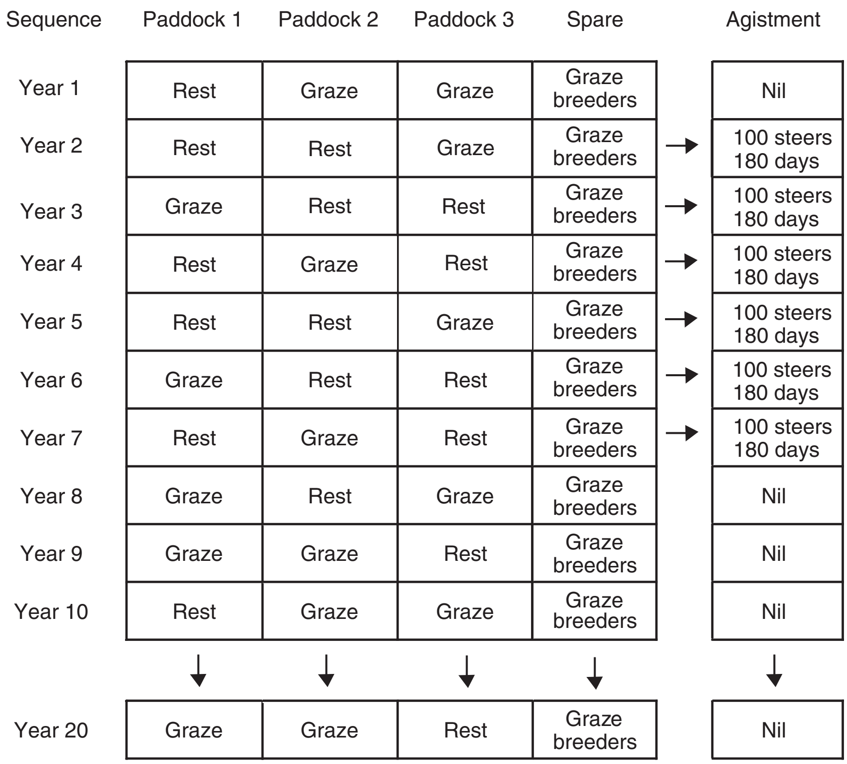

Fig. 1. Schematic representation of the four paddock rotational wet season resting system used for scenario analysis.

carrying capacity for land condition class A and other land condition classes (i.e. B, C and D) using condition discount factors suggested for the Burdekin region (Chilcott *et al*. 2003). In this case, the discount factors against A land condition (baseline = 100%) for B, C and D land condition are, respectively, 80, 55 and 20%. Intermediate carrying capacity values between different land condition states are projected by weighted extrapolation according to the recovery or degradation profiles that are specified in each of the seven scenarios that are considered in this paper (details below). Animal and herd productivity levels that are relevant to each of the land condition states are projected to follow the same trajectory as that for changes in carrying capacity. The limitations of extrapolation of carrying capacity and animal productivity changes are clearly recognised. Accordingly, the potential economic impact of changing the projected timing and levels of recovery in these critical parameters is the specific basis of the seven different recovery and degradation scenarios around which the model simulations are conducted.

A herd economic model that has been previously used to evaluate the economic implications of grazing trials and an array of rangeland management practices (MacLeod and McIvor 2008) was populated using input and output data for the region (e.g. Fordyce *et al*. 2001; Smith *et al*. 2001; MacLeod *et al*. 2004) and the considered judgement of beef research and extension staff from QDPIF and CSIRO Sustainable Ecosystems working within the region. The main parameter values used for the model are presented in Table 1. Economic performance is assessed using a comparative enterprise budgeting technique (Makeham and Malcolm 1992) and is based on comparing the TGM calculated for a given resting scenario with the TGM for an alternative 'do nothing' scenario that involves no change to existing grazing management. The annual differences for each of the 20 years of the simulation period are aggregated and converted to a NPV using standard discounting procedures (e.g. Chisholm and Dillon 1971)[2]. A real discount rate of 10% has been used to estimate the NPV for each resting scenario, this rate being consistent with the cost of commercial credit for rural investment projects at the time of writing.

The TGM for each run of the model enterprise is calculated as:

$$\text{TGM} = \text{gross animal revenue} - (\text{livestock purchases} + \text{direct husbandry} + \text{marketing costs} + \text{feed costs}) \quad (1)$$

where,

$$\text{gross animal revenue} = \text{total kilograms of sale animals} \times \text{price per kilogram} + \text{sales of surplus and cull animals} \quad (2)$$

The TGM is converted to a gross margin per hectare (GM/ha) by dividing by total land area (28 000 ha). However, for the

[2]The present value PV of a future sum FV_n is an amount that, if invested at an interest rate i for a period of n, would grow to FV_n, represented by the formula $PV = FV_n/(1 + i)^n$, and the interest rate i is referred to as the 'discount rate'. Net present value (NPV) is the sum of annual PV values over a time horizon 1 to n years.

Table 1. Selected parameters for Goldfields property model

Parameter	Land condition B	Land condition C+/C	Land condition C–/D+
Property area (ha)	28 000	same	same
Carrying capacity (AE)	2500	1800	900
Breeders (AE)	1400	1000	500
Av. Breeder mortality (%)	3	4	5
Branding rate – 1st calving (%)	50	45	35
Branding rate – 2nd calving (%)	55	50	45
Branding rate – 3rd calving (%)	70	65	60
Selling prices ($kg/liveweight basis)			
Steers – export Ox ($)	1.85	1.75	1.65
Steers – weaners/stores ($)	1.90	1.80	1.75
Cows – domestic ($)	1.70	1.60	1.50
Cows – heifers ($)	1.80	1.70	1.60
Weaning weights – steers/heifers (kg/hd)	150	130	120
Sale weights (kg/liveweight basis)			
Steers	320	270	250
Heifers	280	260	240
Culled breeders	500	470	450
Supplements			
Ration 1 – M8U			
Days fed – weaners	90	90	0
Days fed – breeders	120	120	210
Days fed – heifers	180	180	0
Cost ($/head/day)			
Weaners	0.15	same	same
Breeders	0.30	same	same
Heifers	0.23	same	same
Ration 2 – M3UP			
Days fed – weaners	120	120	210
Days fed – heifers	0	0	180
Cost ($/head/day)			
Weaners	0.16	0.16	0.16
Heifers	0	0	0.64
Dry licks (200 g/day)			
Days fed – steers	120	120	210
Cost ($/head/day) – steers	8.40	8.40	14.70

present analysis this particular efficiency ratio adds limited additional insight to the TGM estimate as to whether the resting option is a more efficient use of invested resources. That is, if the NPV of the TGM differences is positive the scenario is economic. Values for GM/ha are presented in the result tables for readers' interest but are not discussed in any detail.

The model enterprise is assumed in the first year of each simulation to be carrying 1000 breeding cows in six paddocks and to turn off 18–24 month old steers for sale into local markets.

The principal drivers of the profitability of investments in rangeland pasture rehabilitation options are the absolute increase in the carrying capacity of recovered pastures, the rate at which the recovery is achieved, and subsequent gains in productivity per animal carried (MacLeod and Johnston 1990). The rate of recovery of rested pastures will also be strongly influenced by growing conditions (McIvor 2001).

To provide an indication of the sensitivity of the model outputs to variations in these drivers, the analysis is initially based on a comparison of four scenarios that involve different carrying capacity recovery profiles and concurrent changes in animal productivity. The results of economic modelling exercises are naturally susceptible to changes in the assumptions that are made concerning the key agronomic and economic parameters (e.g. as contained in Table 1) and sensitivity testing of the key model parameters is desirable for robust analysis. Such testing is usually conducted by varying one or more parameters through a range of values (e.g. ±5–20%) for a single simulation scenario and examining the impact of these changing values on the main performance indicators (e.g. TGM, net profit). For the present exercise, where the model is necessarily operating beyond the boundaries of empirical response data sourced from actual experimental trials, we believe that sensitivity testing is best achieved by exploring the impact of a range of critical scenarios that capture the essence of the main drivers underpinning the likely economic performance of the particular management option under review. Examining further variations in individual model parameter values within the context of an individual scenario is likely to offer limited additional insights to economic performance at the cost of considerable additional complexity.

The return on investments in pasture rehabilitation will also be directly influenced by the value of the livestock that are carried on the treated pastures and any opportunity costs that are associated with removal of livestock from the pastures during the rehabilitation period (MacLeod and Johnston 1990). To examine the sensitivity of the model outputs to these factors an additional two scenarios are included to consider the impact of a reduction in cattle prices and avoiding the need to agist any stock that are displaced from the treatment paddocks. The six wet season resting scenarios are compared with a 7th 'do nothing' scenario that assumes that no wet season resting and conservative pasture utilisation strategy is implemented. There are two variants of the 'do nothing' scenario – the first assumes that the targeted pastures will degrade no further and pasture condition and animal productivity will remain at the present level, and the second assumes that the pastures continue to decline over the first 10 years from C+/C (poor) land condition to C–/D+ (very poor) land condition. All seven scenarios assume that paddocks are stocked each year according to available end of growing season dry matter (25% utilisation), reflected in the carrying capacities outlined in Table 1.

All scenarios are based on the four paddock rotational resting sequence (Fig. 1) with the three targeted breeder paddocks all in C+/C (poor) land condition, and the spare paddock in B (fair) land condition. In all scenarios after the recovery is complete the pastures remain in B (fair) condition for the remainder of the 20-year period.

The six recovery scenarios and the two alternative 'do nothing' scenarios are as follows:

Scenario 1 assumes that recovery (measured as breeder carrying capacity) is slow during the early years of resting. Stock numbers are not immediately increased for the initial 2 years of the resting strategy to promote recovery, are then increased by 33% of the full recovery level by 8 years, and then accelerated so that full recovery is achieved after 10 years (Fig. 2).

Scenario 2 is similar to Scenario 1 in all respects except that the recovery trajectory is more rapid, and after an initial lag of

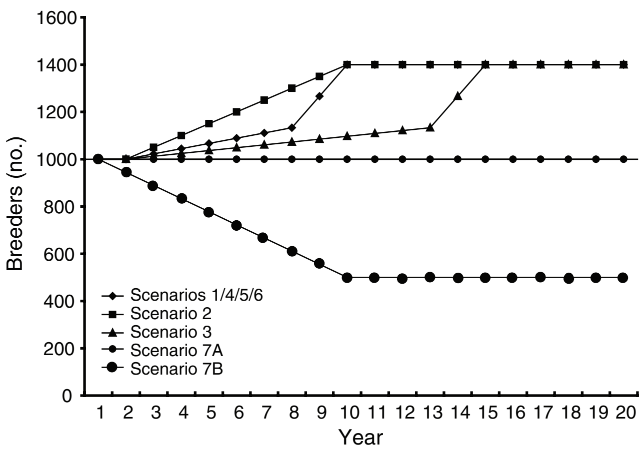

Fig. 2. Assumed trajectory for breeding cow numbers associated with modelling Scenarios 1 through to 7B.

nil change for 2 years follows a linear trajectory to year 10 (Fig. 2). Such a scenario might be consistent with a return to more favourable seasons than those that have generally prevailed in the region in recent years.

Scenario 3 assumes a slower rate of recovery of the targeted paddocks than used for Scenario 1, so that after nil change for 2 years the first 33% of recovery occurs over 13 years and the remainder in years 14 and 15 (Fig. 2).

Scenario 4 is identical to Scenario 1 in breeder carrying capacity and recovery rates, but assumes that the increasing stock numbers carried over the recovery period will, through higher utilisation of the available herbage resources, restrict per animal productivity gains which remain unchanged from the baseline values in each of the 20 years of the simulation period.

Scenario 5 is also identical to Scenario 1 in all respects except that the market price for all stock categories is reduced by 20%. This scenario, representing an extreme market deterioration, provides a guide to the sensitivity of the projected economic outcomes to a much less favourable beef price regime than has prevailed for the northern beef industry in recent seasons. The prospective impact of taking no action, as described in Scenarios 7A and 7B (below), is also altered with respect to beef prices for a consistent comparison with this case.

Scenario 6 assumes that stock displaced from the rested paddocks can be accommodated on other parts of the property during the resting period without placing excessive grazing pressure on those pastures. Therefore, this scenario is also identical to Scenario 1 in all respects except that there is no requirement for agistment of steers in any of the 20 years of the simulation period.

Scenario 7A ('do nothing' with no further productivity loss) assumes that the three degraded breeder paddocks have reached a floor in their prospective productivity loss, and will not decline any further in land condition, carrying capacity and animal performance. Breeder carrying capacity for the model enterprise remains at 1000 breeders from year 1 through to 20 of the simulation period.

Scenario 7B ('do nothing' with further productivity decline) assumes that the pastures are still over-utilised and will continue to decline in land condition to C–/D+ by year 10. Breeder carrying capacity for the enterprise declines from 1000 breeders in year 1 to 500 breeders by year 10 and remains at this rate to year 20. Per animal productivity values (Table 1) are projected to further decline below year 1 baseline values in years 2–10 in direct proportion to the assumed decline in breeder carrying capacity.

With the exception of Scenario 5, the projected value of the economic performance for each of the preceding six resting scenarios is the aggregated net difference between the economic returns for each of the scenarios and that of the alternative 'do nothing' scenarios (7A or 7B). The analysis of Scenario 5 necessarily also involves a modification to the beef prices used for the alternative 'do nothing' scenarios whereby the prices ($/kg liveweight) for each class of stock are also reduced by 20% in each year of the simulation period – identified as Scenarios 7A (20%) and 7B (20%).

In the first instance, the projected 20 year streams of TGM for the 6 resting scenarios are compared with Scenarios 7A and 7A (20%) as this comparison provides the stronger test of the merit of wet season resting – the baseline alternative remains unaltered and contributes nothing to the projected net benefit stream. The changes in TGM for the six resting scenarios are then compared with Scenarios 7B and 7B (20%), which should reveal a greater level of net benefit to the resting option as some of the annual benefit stream for each scenario will be comprised of opportunity gains derived from avoiding further baseline productivity losses.

Results

The estimates of the cumulative TGM, NPV of the difference in the respective TGM estimates and GM/ha values between the wet season resting Scenarios 1–6 and alternative 'do nothing' Scenarios 7A and 7B, and 7A (20%) and 7B (20%) for each 20-year simulation are presented in Table 2.

TGM Scenarios 1 to 6 cf. Scenario 7A, 7A (20%)

The TGM for the 28 000 ha Goldfields property is estimated to be $171 352* at the start of each simulation run for all Scenarios other than Scenarios 5 and 7A (20%) which reduced to $116 417 due to the assumption of lower beef prices.

Scenario 1 – Despite the assumed need to agist steers to accommodate the four paddock rotational resting strategy, the NPV of the net annual difference in TGM for the 20-year simulation is positive ($552 016) at the assumed 10% discount rate indicating that the option is economic. The cumulative TGM ($5 675 584) for the 20 year simulation period is 66% higher than for the 'do nothing' option (Scenario 7A, $3 427 037).

Scenario 2 – The more rapid trajectory of recovery for the rested pastures under this scenario (Fig. 2) is reflected in the higher cumulative TGM estimate ($6 021 774) for the simulation period (Table 2). The NPV of the net annual difference in TGM for the 20 year simulation is positive ($725 971), and is an increase of

*All values are in Australian dollars.

Table 2. Total enterprise gross margins (TGM, cumulative), net present value (NPV, TGM difference) and NPV(GM/ha difference) for the 20-year simulation run for (a) baseline performance is constant, and (b) baseline performance is deteriorating

	Scenario no.							
	1 $	2 $	3 $	4 $	5 $	6 $	7A, B[A] $	7A, B (20%)[B] $
	Baseline performance constant							
	TGM Scenarios 1 to 6 cf. Scenario 7A, 7A (20%)							
Cumulative TGM	5 675 584	6 021 774	4 822 190	4 133 846	3 973 805	5 935 721	3 427 037	2 328 346
NPV (TGM difference)	552 016[C]	725 971[C]	230 253[C]	105 828[C]	368 132[D]	711 694[C]	N/A	N/A
NPV (GM/ha difference)	19.29	25.93	8.22	3.78	13.15	25.42	N/A	N/A
	Baseline performance deteriorating							
	TGM Scenarios 1 to 6 cf. Scenario 7B, 7B (20%)							
Cumulative TGM	5 675 584	6 021 774	4 822 190	4 133 846	3 973 805	5 935 721	947 838	356 685
NPV (TGM difference)	1 373 746[E]	1 559 7014[E]	1 063 984[E]	779 829[E]	1 032 895[F]	1 545 424[E]	N/A	N/A
NPV (GM/ha difference)	49.06	55.70	38.00	27.85	36.89	55.19	N/A	N/A

[A]'Do nothing' Scenario with nil changes to per animal productivity. [B]'Do nothing' Scenario with beef prices 20% less than Scenario 7A, B. [C]Difference between Scenario in column and Scenario 7A. [D]Difference between Scenario in column and Scenario 7A (20%). [E]Difference between Scenario in column and Scenario 7B. [F]Difference between Scenario in column and Scenario 7B (20%).

almost 31% over the corresponding estimate for Scenario 1 ($552 016).

Scenario 3 – The 50% increase in assumed time to effect a full recovery of potential land condition back to land condition B, necessarily reduces the cumulative TGM estimate (Table 2). Although the projected reduction in NPV of net annual returns for the enterprise is substantial (58%), NPV remains positive ($230 253) indicating that the option would still be economic.

Scenario 4 – When the respective carrying capacity changes associated with the pasture resting option is not accompanied by gains in per animal productivity, the cumulative TGM estimate is much reduced (28%) relative to Scenario 1 (Table 2). Nevertheless, the NPV of the net annual difference in TGM for the 20-year simulation has declined by ~80% relative to Scenario 1 ($105 828 cf. $552 016), but it remains positive and the option is still economic. Under these circumstances the economic outcome is simply based on diverging herd numbers.

Scenario 5 – A central driver for an economic return to rangeland rehabilitation investments is the market price of the livestock grazing them. The impact of a 20% reduction in the price of cattle is to reduce the cumulative TGM estimates for both the resting option and 'do nothing option' Scenario 7A (20%) (Table 2). For example, the starting year TGM estimate of $116 417 for both Scenarios 5 and 7A (20%) is 32% less than that of Scenarios 1 and 7A ($171 352). Despite this significant decline in annual returns for beef production the investment in the resting option is still projected to yield a positive NPV ($368 132) over the 20-year period.

Scenario 6 – Each of the preceding cases has involved a requirement to agist some stock off the property for 6 years of the 20 year simulation period (Fig. 1). The costs associated with that agistment are not trivial and are a major source of the difference between the initial TGM estimates for resting Scenarios 1–5 and 'do nothing Scenarios 7A and 7A (20%). In the event that either seasonal conditions or the general condition of the remaining pastures allow all of the stock to be retained on the property, the projected economic returns to the resting option are considerably improved. The cumulative value of TGM is higher than that of Scenario 1 and the estimated NPV of the TGM net difference at $711 694 represents a 30% increase over Scenario 1.

TGM Scenarios 1 to 6 cf. Scenario 7B, 7B (20%)

In all cases, the Scenario comparisons with Scenarios 7B and 7B (20%) necessarily follow the same general pattern that was revealed when examining the various TGM estimates in the preceding subsection (Table 2). However, when the pastures are assumed to be over-utilised and still degrading under the alternative 'do nothing' strategies, the net benefit attributed to the wet season resting strategy is augmented by the prevention of further opportunity production losses; especially avoiding the need to supplementary feed large numbers of animals for increasing periods each year[3]. Moreover, the gain is not insignificant. For example, the NPV of the net TGM differences for Scenario 1 is ~150% higher ($1 373 746 cf. $552 016) when the 'do nothing' option (Scenario 7B) involves ongoing productivity losses. As before, the positive economic outcome holds in the face of assumed decreases in the price of cattle (Scenario 5) and is boosted considerably if displaced stock can be accommodated in other paddocks without further damage to pastures during the resting period (Scenario 6).

Discussion

The economic simulation discussed in this paper is based on only a single case study example and, in the absence of quantitative data drawn directly from wet season resting field experiments or station records, the projected carrying capacity and animal productivity data were necessarily heuristic. Although these

[3]For example, the annual supplementary feeding costs per breeder carried for Scenarios 1 and 7B were estimated to $77.86 and $147.69, respectively, by year 10 of the simulation period.

limitations are clearly acknowledged, there is considerable interest in both promoting the practice of wet season pasture resting by public land management agencies and NRM groups, and in adopting the practice by individual landholders. In the absence of detailed empirical data, the collection of which should be a high research priority, the present modelling exercise seeks to throw some exploratory light on the economic merit of wet season resting and the results are interpreted accordingly.

The projected results suggest that wet season resting with conservative pasture utilisation does offer potential economic advantages to a northern beef enterprise where land condition has declined, and even when the pastures are projected to show no further decline in productivity (Table 2). For the baseline resting scenario (Scenario 1) cumulative total gross margins are projected to increase by more than 65% over the alternative 'do nothing' case (Scenario 7A). Moreover, this projected profitability is supported by the NPV of the 20-year sequence of gross margin differences being positive (\$552 016). When the land condition of the affected pastures is still declining the economic gains from implementing remedial treatment are considerably higher (Table 2).

The analysis does suggest that employing the wet season resting option will necessarily involve some planning on the part of landholders to get the resting sequence for the affected paddocks into a workable rotation. For beef enterprises with limited paddock infrastructure, this will represent a significant challenge including potential sacrifices and risks involved in pursuing the rotational resting option. For the present modelling exercise, in order to make the four paddock rotational resting system work in a consistent sequence, it was necessary to agist 100 steers for 6 of the first 7 years, an option that many enterprises may find quite difficult to pursue. However, if seasons were favourable enough to allow these animals to be retained elsewhere on the property during the wet season, the profits are much better. Whether retaining the additional stock on-property in the wet season can be accommodated without further exacerbating degradation remains a serious issue and is something that would be usefully addressed as a policy priority for future NRM and leasehold management activities.

Although it is not shown in the summary result tables, it was projected to take 6 years before the annual TGM under wet season resting (Scenario 1) exceeded that of the 'do nothing' option Scenario 7A for which carrying capacity and the productivity of individual animals remain at their present level (Fig. 3). The spelling option would, however, be outperforming the alternative 'do nothing' option Scenario 7B within 3 years when animal productivity levels continue to deteriorate. Indeed, the alternative option of taking limited remedial action requires serious scrutiny, particularly if the pastures are likely to continue to degrade. For example, under the 'do nothing' strategy Scenario 7B, the annual TGM is estimated to decline from \$171 352 to only \$11 391 by year 10 of the simulation period (Fig. 3). When the overhead costs of running a 28 000 ha beef enterprise are considered, this would actually translate to an annual economic loss and insolvency were it to continue for an extended time. The situation would be less severe if per animal productivity levels do not decline in line with declining carrying capacity (Scenario 7A). However, if beef prices also declined significantly below their present levels – Scenario 7B (20%) – the longer term viability of the model enterprise would be seriously jeopardised.

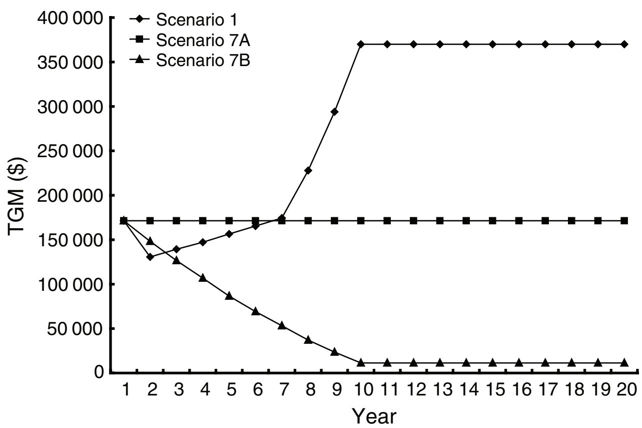

Fig. 3. Annual projections of total gross margin (TGM) for modelling Scenarios 1, 7A and 7B.

Under real-world rangeland conditions, things are not likely to always proceed as smoothly as simple computer simulations would imply. Recovery of land condition and carrying capacity in the degraded paddocks and improvements in animal performance may well take longer than projected for this exploratory modelling exercise. Reduced frequency of wet season resting in the rotation may reduce the immediate economic sacrifice, but would necessarily be traded off for a longer period to recovery in land condition. Climatic uncertainty and exposure to high supplementary feeding costs for degraded pastures, in particular, will have a large impact on the bottom line performance of northern beef enterprises (MacLeod *et al*. 2004). Although a large part of the rapid decline in projected TGM is caused by lower carrying capacity and poor animal performance, heavier reliance on dry season supplementation also directly contributes to this result. Escaping this penalty will become increasingly difficult if remedial action on grazing land degradation, such as pursuing wet season resting, is not undertaken. Operators of northern grazing enterprises who elect to pursue a 'do nothing' strategy may well be penalised in the future with an ongoing deterioration of both their land condition and enterprise economic performance.

The focus of this paper was essentially on exploring the prospective value of wet season resting and conservative pasture utilisation for a typical northern beef enterprise. Nevertheless, there are some general policy implications that may also be drawn from the present exercise. Foremost, the economic analysis is not empirically-based, although the management recommendations generally are, and is limited to examining some scenarios that are designed to capture the essence of the wet season resting practice. There is a clear need for further empirical support either from the conduct of formal trials or through the collection and analysis of detailed records – notably from 'pioneering' enterprises which may have taken up the practice.

The potential response trajectories for carrying capacity and animal performance under both the spelling strategies and cases where no management action is taken to address the incipient pasture degradation problem are of obvious interest. Although the ecovery trajectories are obviously important to the scale and timing of any economic response, the latter 'do nothing' trajectories are also important – noting that the duration of the break-even period is considerably extended for the scenario comparisons in which there is no further productivity decline (Scenario 7A) with 'nil action' than when there is an ongoing decline (Scenario 7B). As this is a potentially strong barrier to taking action, there may be scope for public support through incentives (e.g. through NRM grants or subsidies) to assist individual landholders to offset the cash flow loss in the initial years. In cases where temporary stock removal from the holding is required to implement a workable rotation plan, or seasonal conditions prevent the rotation from being adhered to, similar incentives to offset the cost might be warranted to reduce adoption costs.

Acknowledgments

The valuable contribution of QDPIF and CSIRO colleagues Geoffrey Fordyce, Felicity Hamlyn-Hill, Cam McDonald and Mick Stephens to the work covered in this manuscript is acknowledged. Two anonymous reviewers provided valuable constructive criticism and comments on an earlier version of this manuscript.

References

Ash, A., Corfield, J., and Ksiksi, T. (2001). 'The Ecograze Project – Developing Guidelines to Better Manage Grazing Country.' (CSIRO Sustainable Ecosystems: Townsville, Qld.)

Ash, A. J., and McIvor, J. G. (1998). How season of grazing and herbivore selectivity influence monsoon tall-grass communities of northern Australia. *Journal of Vegetation Science* **9**, 123–132. doi: 10.2307/3237230

Ash, A. J., McIvor, J. G., Corfield, J. P., and Winter, W. H. (1995). How land condition alters plant-animal relationships in Australia's tropical rangelands. *Agriculture, Ecosystems and Environment* **56**, 77–92.

Ash, A. J., McIvor, J. G., Mott, J. J., and Andrew, M. H. (1997). Building grass castles: integrating ecology and management of Australia's tropical tallgrass rangelands. *The Rangeland Journal* **19**, 123–144. doi: 10.1071/RJ9970123

Chilcott, C. R., McCallum, B. S., Quirk, M. F., and Paton, C. J. (2003) 'Grazing Land Management Education Package Workshop Notes – Burdekin.' (Meat and Livestock Australia Limited: Sydney.)

Chisholm, A. H., and Dillon, J. L. (1971). 'Discounting and Other Interest Rate Procedures in Farm Management. Professional Farm Management Guidebook No. 2.' (Agricultural Business Research Institute (ABRI), University of New England: Armidale, NSW.)

Corfield, J. P., and Nelson, B. S. (2008). Scaling up from Ecograze – the Virginia Park experience. *In*: 'Proceedings of the 15th Biennial Conference of the Australian Rangeland Society'. 28 Sept.–2 Oct. 2008. (Australian Rangelands Society: Charters Towers, Qld.)

Fordyce, G., Smith, D., Cooper, N., Batterham, I., Shaw, K., and Webber, I. (2001). 'Site report: Swan's Lagoon 1994–1999, Northern Stocking Rate Demonstration, QDPI Project 1480.' (Queensland Department of Primary Industries: Charters Towers, Qld.)

Hacker, R. B., and Tunbridge, S. B. (1991). Grazing management strategies for reseeded rangelands in the East Kimberley region of Western Australia. *The Rangeland Journal* **13**, 14–35. doi: 10.1071/RJ9910014

Hodgkinson, K. C., Ludlow, M. M., Mott, J. J., and Baruch, Z. (1989). Comparative responses of the savanna grasses *Cenchrus ciliaris* and *Themeda triandra* to defoliation. *Oecologia* **79**, 45–52. doi: 10.1007/BF00378238

MacLeod, N. D., Ash, A. A., and McIvor, J. G. (2004). An economic assessment of the impact of grazing land condition on livestock performance in tropical woodlands. *The Rangeland Journal* **26**, 49–71. doi: 10.1071/RJ04004

MacLeod, N. D., and Johnston, B. G. (1990). An economic framework for the evaluation of rangeland restoration projects. *Australian Rangeland Journal* **12**, 40–53. doi: 10.1071/RJ9900040

MacLeod, N. D., and McIvor, J. G. (2008). Quantifying production-environment tradeoffs for grazing land management – a case example from the Australian rangelands. *Ecological Economics* **65**, 488–497. doi: 10.1016/j.ecolecon.2007.07.013

Makeham, J. P., and Malcolm, L. R. (1992). 'The Farming Game Now.' (Cambridge University Press: Cambridge)

McIvor, J. G. (2001). Pasture management in semi-arid tropical woodlands: regeneration of degraded pastures protected from grazing. *Australian Journal of Experimental Agriculture* **41**, 487–496. doi: 10.1071/EA00045

McIvor, J. G., Ash, A. J., and Cook, G. D. (1995). Land condition in the tropical tallgrass pasture lands: 1. Effects on herbage production. *The Rangeland Journal* **17**, 69–85. doi: 10.1071/RJ9950069

Mott, J. J., Ludlow, M. M., Richards, J. H., and Parsons, A. D. (1992). Effects of moisture supply in the dry season and subsequent defoliation on persistence of the savanna grasses *Themeda triandra*, *Heteropogon contortus* and *Panicum maximum. Australian Journal of Agricultural Research* **43**, 241–260. doi: 10.1071/AR9920241

Post, D., Bartley, R., Corfield, J., Nelson, B., Kinsey-Henderson, A., Hawdon, A., Gordon, I., Abbott, B., Berthelsen, S., Hodgen, M., Keen, R., Kemei, J., Vleeshouwer, J., MacLeod, N., and Webb, M. (2006). 'Sustainable Grazing For a Healthy Burdekin Catchment.' (CSIRO: Canberra.)

Smith, D. R., Fordyce, G., Shaw, K. A., Smith, P. C., and Laing, A. R. (2001). Northern Stocking Rate Demonstration. Project Report NHT.962011. National Heritage Trust, Canberra.

Tothill, J. C., and Gillies, C. (1993). 'The Pasture Lands of Northern Australia. Occasional publication No. 5.' (Tropical Grasslands Society of Australia: Brisbane.)

Manuscript received 9 September 2008; accepted 3 February 2009