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Grazing pressure, land condition, productivity and profitability of beef cattle grazing buffel grass pastures in the subtropics of Australia: a modelling approach

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Abstract. There is widespread evidence that beef cattle land managers in Queensland are using stocking rates for perennial pastures that are substantially higher than recommended guidelines, and some indication that these decisions are motivated by perceived financial and economic benefits. Considerable effort has been, and is currently being, applied by public-sector organisations to encourage producers to reduce grazing pressure from beef cattle across Queensland's pastoral lands. A better understanding of the relationships among stocking rate, land condition and profitability of beef-grazing enterprises is imperative to better inform cattle producers and policy makers. The present study assessed the effect of grazing pressure and land condition on the productivity and profitability of a steer-turnover enterprise utilising buffel grass (*Cenchrus ciliaris*) pastures in central Queensland. A property-level, regionally relevant herd model was used to determine whole-of-business productivity and profitability over a 30-year investment period. Growth paths for steers from weaning to marketing were developed for 16 scenarios encompassing a range of pasture-utilisation rates (30%, 35% and 50% of annual biomass growth), land condition (A, B and C) and market targets (feedlot entry at 474 kg or slaughter at 605 kg). The economic effect of each scenario was assessed by comparison to a base scenario of 30% pasture utilisation and turn-off of slaughter steers. Our analyses demonstrated a large economic advantage from increasing grazing pressure above 30% utilisation for buffel grass pastures, even with assumptions of declining land condition and animal performance. For instance, producing slaughter steers under a 50% pasture-utilisation regime with a continuous decline in land condition from A to C (and, hence, productivity) over Years 10–30 was AU$21 772/annum more profitable than was a 30% pasture-utilisation strategy, which is widely recommended as closer to a long-term, safe utilisation rate. The present research has provided insights into the relationship between grazing pressure and economic returns of beef producers over the medium term. However, it should be considered as a scoping study due to the paucity of data for effects of utilisation rate on the productivity of buffel grass pastures and, hence, on land-condition rating. Further research is required to better understand the effects of utilisation rate of buffel grass, and other sown pasture grass and legume species, on plant biomass production, plant-diet quality for cattle, land-condition decline and cattle productivity.

Additional keywords: farm management economics, stocking rate, steer, tropical pastures.

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Introduction

The beef cattle industry makes an important contribution to the Australian economy. In 2014–2015, it accounted for ~21% (AU$11.5 billion) of the total gross value of farm production and ~23% of the total value of farm-export income (ABARES 2017). The Fitzroy Natural Resource Management (NRM) Region of central Queensland is an important beef-producing area of Australia and, in 2014–2015, produced ~11% of Australia's gross value of cattle from ~12.4 million hectares of pasture (ABS 2014, 2016). However, the Queensland beef industry will continue to be challenged by pressures on long-term financial performance and viability due to an ongoing disconnect between asset values and returns, high debt levels and a declining trend in 'terms of trade' (McCosker *et al*. 2010; McLean *et al*. 2014). There is evidence that land managers are stocking native and sown perennial pastures at substantially higher rates than those recommended by research and government agencies, and there are some indications that these decisions are motivated by perceived financial and economic benefits (Shaw *et al*. 2007; Beutel *et al*. 2014; Rolfe *et al*. 2016; Bowen *et al*. 2018). The adverse consequences for Great Barrier Reef water quality of livestock grazing in catchment areas are well documented (Thorburn *et al*. 2013), with grazing lands contributing ~74% of the total suspended sediment (Brodie *et al*. 2003; Thorburn and Wilkinson 2013) and more than 60% of nitrogen and phosphorus (Kroon *et al*. 2012) to the reef. Consequently, much effort is currently applied in the river catchments flowing to the Great Barrier Reef lagoon, including in the Fitzroy River catchment, to encourage a reduction in grazing pressure by the beef cattle industry (The State of Queensland 2013). The objective of the present scoping study was to evaluate the implications of level of grazing pressure and land condition on the productivity and profitability of a beef cattle enterprise based on perennial buffel grass (*Cenchrus ciliaris*) pasture systems in central Queensland.

Materials and methods

Approach

The implications of various buffel grass pasture-utilisation rates, land condition and steer-market targets on productivity and profitability of a beef enterprise were investigated for a representative beef cattle property in central Queensland by using a case-study method to allow detailed analysis of the farm business (Yin 1994). Steer growth paths (liveweight change over time) for steers from weaning to marketing were developed for each scenario from interrogation of existing datasets and from the expert opinion of experienced Department of Agriculture and Fisheries, Queensland, staff, as described in more detail below. The economic effect of each of these growth paths was then assessed by comparison to a baseline production system of turning off finished steers, as the current optimum growth path for steers grazing buffel pastures in the central Queensland region (Chudleigh *et al*. 2017).

A property-level, regionally relevant herd model was used to determine whole-of-business productivity and profitability over a 30-year investment period. Change was implemented by altering the herd performance and inputs of the base scenario to construct the new scenario. The comparison of the two scenarios, one of which reflected the implementation and results of the proposed change from a common starting point, was the focus of the analysis. Discounted cash-flow (DCF) techniques were applied to look at the marginal returns associated with any additional capital or resources invested within farm operations. The DCF analysis was compiled in real (constant value) terms, with all variables expressed in terms of the price level of the present year (2017). It was assumed that future inflation would affect all costs and benefits equally. It should be noted that as there is no evidence that market value of the land asset declines in response to declining land condition, the land value after 30 years was held constant across scenarios. Excel spreadsheets were developed using the methodology described by Gittinger (1982) and Robinson and Barry (1996), and applied by Makeham and Malcolm (1993) and Campbell and Brown (2003). The spreadsheets contained livestock schedules linked to cash flow and investment budgets for the base scenarios, and for each alternative scenario for an interval of 30 years. This allowed for a marginal analysis comparing the base scenarios with the other scenarios to be completed.

Representative case-study beef cattle property and enterprise

The modelled enterprise was a steer-turnover property situated in the Fitzroy NRM region in central Queensland, near Rolleston, with the predominant land type considered to be Brigalow softwood scrub (Whish 2011) that had been cleared of timber and developed to sown pasture in the 1970–1980s with buffel grass the predominant species, as is typical for the region (Thornton and Elledge 2013; DNRM 2017). The area of the property available for grazing was 1000 ha. *Bos indicus* crossbred steers were purchased as weaners (200 kg in May) and grazed on buffel grass pastures until marketing as either feed-on steers (450 kg at the feedlot) or finished steers for slaughter (310 kg carcass weight). These two key markets were selected as representative of the most common sale targets of steers off buffel grass in the central Queensland region (Bowen *et al*. 2015*a*). Feed-on steers were required to reach 474 kg liveweight in the paddock before sale, to allow for a loss of 5% liveweight during transit to the feedlot. Finished steers were required to reach 605 kg in the paddock before sale to allow for the same loss of 5% liveweight before slaughter, while assuming a dressing percentage of 54% at slaughter (Wythes *et al*. 1983; McKiernan *et al*. 2007). The price basis for each class of livestock was derived from Roma store sale data, and JBS Australia Dinmore abattoir (Ipswich, Queensland) respectively, between July 2008 and November 2015, which were taken to be representative of long-term averages. Freight costs for steers were calculated as described in Bowen *et al*. (2015*b*). Steers entering the property as weaners were treated for ticks (AU$2.00/head) and vaccinated against clostridial diseases (AU$0.80/head).

Pasture and animal production

The representative A condition baseline buffel grass pasture (Scale A–D; Quirk and McIvor 2003) was considered to reflect optimal capacity of the land to produce useful forage as indicated by soil and pasture condition, extent of woodland thickening or other weed encroachment. This baseline pasture was assigned a utilisation rate of 30% of the annual pasture biomass growth, which has been suggested as a safe pasture utilisation for this land type for long-term sustainability (Whish 2011) on the basis of research for native pasture communities (Silcock *et al*. 2005; Orr *et al*. 2010; Orr and Phelps 2013; O'Reagain *et al*. 2014; Hall *et al*. 2017). This was adopted in the absence of any data for buffel grass utilisation rates in central Queensland Brigalow land types. Comparative scenarios were modelled for buffel pastures in A land condition, but with increases to 35% and 50% pasture utilisation in Year 1 of the analysis. In addition, the 50% utilisation scenarios were modelled assuming that buffel pasture declined from A to B or C land condition during the 30-year period of the analysis. A representative scenario for pasture considered to be initially in B land condition was also initially modelled with 30% pasture utilisation (the secondary base scenario) and then 50% utilisation. There was no available data to inform the nature of the potential decline in buffel pasture productivity, and land condition, under increasing utilisation rates, so a range of possibilities was examined as detailed below.

The GRASP pasture growth model (McKeon *et al*. 2000; Rickert *et al*. 2000) was used to simulate annual long-term, median buffel grass-pasture biomass production for the location, for A, B and C land condition, and using 100 years of historical rainfall and climate data to June 2016 (Table 1). Buffel grass pastures were assumed to have 2 m^2/ha tree basal area, which is considered typical for the region (P. Jones, pers. comm.).

Quarterly steer growth rates for buffel grass pastures in A, B or C land condition were exogenously derived, with reference to available empirical data for diet dry-matter digestibility, seasonal rainfall data and liveweight gain (QDPI 2003; Bowen *et al*. 2010, 2015*a*; Table 1). Since there was limited available data for buffel grass pastures to inform these assumptions, the basic premise adopted was that diet digestibility and, hence, liveweight gain would decrease with increased pasture utilisation due to reduced ability for selection (Stobbs 1975). Furthermore, it was assumed that, for buffel grass pastures in B and C land condition, the encroachment of other species (such as Indian couch (*Bothriochloa pertusa*) and annual species), as well as declining pasture vigour, would result in reduced average annual diet digestibility and, hence, reduced cattle liveweight gain. It is recognised that the reverse situation (i.e. greater cattle liveweight gain on degraded pastures) can occur under some seasonal circumstances (e.g. O'Reagain and Bushell 2011), but the present analysis was intended to represent the median, long-term situation.

The carrying capacity (for a standard adult equivalent; Table 1) and stocking rate (of steers of the designated breed and age) for each scenario were calculated as the product of the median annual pasture biomass production (see above) and the specified utilisation level, divided by the annual pasture consumption of the steers. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2016), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical cattle and diets (McLennan 2014), was used to calculate the average cattle dry-matter intakes of pasture over each 12-month period.

Alternative production scenarios and the criterion used to compare the scenarios

Growth paths for steers grazing buffel grass pastures from weaning to marketing were developed for 16 scenarios as defined in Table 2. The economic criterion was net present value (NPV) at the required rate of return (5%; taken as the real opportunity cost of funds to the producer). The NPV was calculated as the net returns (income minus costs) over the life of the investment, expressed in present-day terms. The NPV was amortised at a 5% discount rate over the life of the investment to identify the annual average improvement in profit generated by the implementation of the alternative growth path.

Results

The average modelled production outputs from the steer-turnover enterprise, for scenarios where production did not change over time (Scenarios 1–5, 9 and 13–16), are given in Table 3. Scenarios producing feed-on steers resulted in more steers carried per 1000 ha and a greater total beef production than in comparative scenarios producing finished steers. Increasing utilisation rates above 30% for land in A condition resulted in more steers carried and greater total beef production for the same given target steer market (i.e. feedlot or abattoir). All B-condition scenarios resulted in fewer steers carried per 1000 ha and a lower beef production than for the comparative A-condition scenario.

The scenario producing the greatest economic performance was A50_FOa, where utilisation of buffel pastures in A land condition was increased from 30% to 50% with a change in target steer market from abattoir to feedlot steers, and assuming that there was no decline in land condition over the 30 years of analysis (considered as an upper threshold; Table 4). This scenario produced an additional profit of AU$47 759/annum compared with the base scenario (A30_F). The higher utilisation rate of 50% was more profitable than the baseline, even with

Table 1. Assumed pasture and steer-growth parameters for buffel grass pastures, growing on Brigalow softwood-scrub land type near Rolleston in central Queensland, in either A, B or C land condition and with varying levels of utilisation of annual pasture biomass growth

Land condition (scale A to D) defined in Quirk and McIvor (2003); DMD, dry-matter digestibility; LWG, liveweight gain; AE, adult equivalent, defined in terms of the forage intake of a 2.25-year old, 450-kg *Bos taurus* steer at maintenance, consuming a diet of the specified DMD and walking 7 km/day (McLean and Blakeley 2014)

Biological parameter	A condition		B condition		C condition
	30% and 35% utilisation	50% utilisation	30% utilisation	50% utilisation	50% utilisation
Median, annual pasture biomass production (kg DM/ha)	5100		3800		2300
Average annual diet DMD of grazing cattle (%)	57	55	54	53	52
Steer LWG on buffel grass pasture					
Average, annual LWG (kg/head)	180	173	168	165	148
Average, annual daily LWG (kg/head over 365 days)	0.49	0.47	0.46	0.45	0.41
Summer daily LWG (kg/head over 90 days)[A]	0.80	0.79	0.79	0.78	0.77
Autumn daily LWG (kg/head over 92 days)	0.73	0.71	0.69	0.68	0.66
Winter daily LWG (kg/head over 92 days)	0.35	0.33	0.31	0.30	0.15
Spring daily LWG (kg/head day over 91 days)	0.10	0.07	0.05	0.05	0.05
Carrying capacity (AE/ha)	0.47 and 0.55[B]	0.75	0.33	0.53	0.31

[A]The seasonal periods were considered to be summer: December, January and February; autumn: March, April and May; winter: June, July and August; and spring: September, October and November.

[B]Carrying capacity figures at 30% and 35% pasture utilisation respectively.

Table 2. Alternative production scenarios for a steer-turnover enterprise utilising buffel grass pasture
Land-condition scale from A to D, as defined in Quirk and McIvor (2003)

Scenario number	Scenario code	Target market	Starting land condition	Utilisation of annual pasture biomass growth (%)	Land-condition decline	Final land condition
1	A30_FO	Feed-on steers	A	30	Nil	A
2	A30_F	Finished steers	A	30	Nil	A
3	A35_FO	Feed-on steers	A	35	Nil	A
4	A35_F	Finished steers	A	35	Nil	A
5	A50_FOa	Feed-on steers	A	50	Nil (upper threshold)	A
6	A50_FOb	Feed-on steers	A	50	Linear decline from A to B over Years 20–30	B
7	A50_FOc	Feed-on steers	A	50	Linear decline from A to B over Years 10–20, then remain in B over Years 20–30	B
8	A50_FOd	Feed-on steers	A	50	Linear decline from A to B over Years 10–20, then linear decline from B to C over Years 20–30	C
9	A50_Fa	Finished steers	A	50	Nil (upper threshold)	A
10	A50_Fb	Finished steers	A	50	Linear decline from A to B over Years 20–30	B
11	A50_Fc	Finished steers	A	50	Linear decline from A to B over Years 10–20, then remain in B over Years 20–30	B
12	A50_Fd	Finished steers	A	50	Linear decline from A to B over Years 10–20, then linear decline from B to C over Years 20–30	C
13	B50_FO	Feed-on steers	B	50	Nil (upper threshold)	B
14	B50_F	Finished steers	B	50	Nil (upper threshold)	B
15	B30_FO	Feed-on steers	B	30	Nil	B
16	B30_F	Finished steers	B	30	Nil	B

Table 3. Modelled production outputs from a steer-turnover enterprise for scenarios examining alternative pasture-utilisation levels and land condition of buffel grass pasture
LWG, liveweight gain. Scenarios are defined in the Table 2

Scenario	Steers/1000 ha	Days to achieve target weight	Average LWG over total grazing period (kg/day)	Beef production (kg/ha.annum)
A30_FO	249	615	0.45	37
A30_F	161	851	0.48	26
A35_FO	291	615	0.45	43
A35_F	188	851	0.48	30
A50_FOa	384	631	0.43	56
A50_Fa	230	942	0.43	33
B50_FO	261	649	0.42	37
B50_F	157	970	0.42	22
B30_FO	163	643	0.43	23
B30_F	97	961	0.42	14

assumptions of land condition declining to B during the 30-year period, with an additional profit of +AU$44 082 (A50_FOb) and +AU$34 034 (A50_FOc) compared with the baseline, and under assumptions of land condition declining to C during the 30-year period (A50_FOd), with an additional profit of +AU$30 663/annum compared with the baseline. Producing finished steers (cf. feed-on steers) from buffel grass pastures utilised at 50% (A50_Fa–dc) also resulted in a substantially greater profitability than did the baseline scenario of producing finished steers from buffel grass pastures utilised at 30% (A30_F), with an additional profit of +AU$21 772–34 145/annum compared with the baseline. Furthermore, utilising buffel grass pastures in B condition at 50% was more profitable than utilising the same pastures at 30%, with AU$30 814–39 467 extra profit/annum compared with the baseline.

Discussion

The present study has provided insights into the implications of level of grazing pressure and land condition for the profitability of beef cattle production from extensive buffel grass pasture systems. The present study should be considered a scoping study due to the paucity of data for effects of utilisation rate on the productivity of buffel grass pastures (or any sown tropical grasses under comparable rangeland conditions) and, hence, on land condition rating. Our approach was to consider a range of pasture-utilisation rates and corresponding rates of land-condition decline for buffel grass pastures starting in A condition. Due to the limitations of available data, a normative model was used with transitions, which may or may not appropriately reflect the dynamics of pasture growth

Table 4. Modelled annualised marginal return on investment (extra profit/annum over 30 years) for a steer-turnover enterprise for scenarios examining alternative pasture-utilisation levels and land condition of buffel grass pasture

Scenarios are defined in the Table 2

Scenario	Annualised marginal return on investment
A30_FO	AU$2803
A30_F	Base scenario for A land condition[A]
AB35_FO	AU$16 770
A35_F	AU$13 170
A50_FOa	AU$47 759
A50_FOb	AU$44 082
A50_FOc	AU$34 034
A50_FOd	AU$30 663
A50_Fa	AU$34 145
A50_Fb	AU$29 635
A50_Fc	AU$24 952
A50_Fd	AU$21 772
B50_FO	AU$39 467
B50_F	AU$30 814
B30_FO	AU$6848
B30_F	Base scenario for B land condition[B]

[A]Scenarios for A land condition were compared with the base scenario of A30_F.

[B]Scenarios for B land condition were compared with the base scenario of B30_F.

under declining land condition. Despite these limitations, the study has provided insights into the drivers of high stocking rates commonly applied on commercial beef cattle properties in northern Australia.

The analysis has demonstrated a large economic advantage from increasing utilisation above 30% of annual biomass growth for buffel grass pastures, even under assumptions of declining land condition and animal performance occurring over the medium term. For instance, producing slaughter steers under a 50% pasture-utilisation regime with a continuous decline in land condition from A to C (and, hence, productivity) over Years 10–30 was AU$21 772/annum more profitable than a 30% pasture-utilisation strategy. The sensitivity of profit to pasture-utilisation rate was demonstrated by the substantial increase of AU$13 170–16 770 extra profit/annum over 30 years in annualised marginal return from increasing utilisation of buffel grass pastures in A condition by only 5% (30–35%).

Bio-economic modelling undertaken by Star *et al*. (2013) for the Fitzroy River catchment produced results consistent with our conclusions, with profit optimised at higher rates of pasture utilisation (60%) on a Brigalow land type in A condition and supporting buffel grass pasture. Research reported by Burrows *et al*. (2010) for a native, *Heteropogon contortus*-dominated, pasture type in central Queensland also found that returns over 13 years were greatest at the highest pasture-utilisation rate (61%), despite indications that land condition was declining. However, in studies where market penalties were applied or market incentives forgone, or where management included provision of high-cost feed to cattle in dry years, then higher stocking rates in extensive grazing systems resulted in lower overall returns than did moderate or low stocking rates (MacLeod and McIntyre 1997; MacLeod *et al*. 2004; O'Reagain *et al*. 2011).

Few studies other than the present study have attempted to identify the full costs, including the opportunity costs, of implementing changed grazing management strategies and no previous studies have involved marginal economic analysis at the property level that incorporated the impact of the implementation phase.

Due to lack of data on the impacts of drought on buffel pastures grazed at higher utilisation rates, no attempt was made in the present study to differentiate among growth paths for possible interactions of pasture-utilisation rate with drought years and the consequences for pasture health and land-condition decline. Incorporation of any potential effects of episodic events with unknown frequency and impact is unlikely to change the relative values of the results, but could reduce the absolute value of parameters for all growth paths. Further, as there is no evidence that the level of management skill applied varies with the level of grazing pressure applied, we assumed that the level of management skill for each grazing strategy was the same and that the response to episodic events such as drought would, therefore, also be the same, have the same relative impact on returns, and not change the ranking of the scenarios.

Compounding the apparent economic incentive to apply high grazing pressure, tropical grass pasture systems have shown resilience to heavy grazing pressure. Long-term grazing trials on native pasture communities in Queensland (Silcock *et al*. 2005; Orr *et al*. 2010; Orr and Phelps 2013; O'Reagain *et al*. 2014; Hall *et al*. 2017) indicate that it may take decades to seriously affect land condition at high levels of pasture utilisation. Therefore, there is little immediate feedback to beef-enterprise managers to demonstrate that increasing utilisation rates above those recommended have any effect other than to increase their business viability. As shown by Rolfe *et al*. (2016), beef-enterprise managers who are already in financial difficulty, or have lower levels of equity, are very unlikely to forego fully utilising their pasture resources. Furthermore, the present analysis indicated that financially sound beef enterprises with pastures in good starting condition can build a financial buffer against changed circumstances, and increase wealth, by increasing pasture utilisation. There has been little grazing research with buffel grass or other sown grass or legume–grass pastures, comparative to that for native pasture systems (cited above), to determine pasture-utilisation (grazing pressure) effects. In the absence of such data, the precautionary principle has been followed in recommendations of 30% as a safe utilisation of annual biomass growth of buffel grass pastures, similar to that recommended for native pasture systems. However, general observation, and limited data from south-western Queensland (Johnston 1996), have indicated that buffel grass pastures are likely to be more resilient than many native pastures when grazed heavily and, hence, it is possible that higher utilisation rates, >30%, may be having little impact on buffel grass pasture productivity and land condition. Although it is possible that heavily utilised buffel grass pastures may be more prone to invasion by less productive pasture species, such as Indian couch, and susceptible to the increasing, but poorly understood, 'pasture dieback' phenomenon (Buck 2017).

As well as the apparent resilience of perennial pastures in Queensland's rangelands, they appear slow to recover once grazing pressure is reduced. Research with two native pasture systems in Queensland showed that wet-season spelling strategies did not improve land condition over a 5-year period (Jones *et al*. 2016). There is no available data on recovery of degraded buffel grass pastures. If tropical grass pastures, including buffel grass pastures, are slow to recover under a reduced grazing-pressure regime, the economic consequences of strategies to reduce grazing pressure and to spell pastures may not be positive. Furthermore, pasture and land-condition recovery is likely to depend on how severely rainfall infiltration and soil-surface friability have been diminished during the decrease in land-condition rating (R. Silcock, pers. comm.). Our analysis identified the economic advantage of stocking a B-condition buffel grass pasture to achieve a 50% utilisation and producing feed-on steers when compared with a reduced grazing pressure to achieve a 30% utilisation of the same B-condition pasture to produce finished steers. The higher utilisation rate and younger age of steer turn-off generated about AU$40 000/annum additional profit, which increased farm profit from AU$10 000/annum to AU$50 000/annum. This increase in economic (and financial) performance could be the difference between business survival and business failure in the short to medium term and this consideration is likely to greatly outweigh the possible damage being done over the medium to longer term to the land resource – in the mind of the current beef-enterprise manager.

The adverse consequences for Great Barrier Reef water quality due to livestock grazing in catchment areas are well documented (Thorburn *et al*. 2013) and much effort is currently employed by public-sector organisations to encourage a reduction in the grazing pressure applied by beef enterprise managers (The State of Queensland 2013). However, the Queensland beef industry will continue to be challenged by pressures on long-term financial performance and viability (McCosker *et al*. 2010; McLean *et al*. 2014). Hence, a better understanding of the trade-off between stocking-rate decisions and economic sustainability for Queensland grazing enterprises is imperative to better inform producers and policy makers.

One strategy that can be used to rapidly improve productivity, from a buffel grass pasture in B or C condition, is conversion (if the land and soil type is suitable) to a sown legume–grass pasture such as leucaena (*Leucaena leucocephala* spp. *glabrata*)–grass pasture. Research in the Fitzroy NRM region has shown that leucaena–grass pasture systems result in nutrient and sediment loads in runoff water that are similar to those for A-condition buffel grass pasture (Thornton and Elledge 2013). Furthermore, legume–grass pasture systems, and particularly leucaena–grass, have been shown to be the most profitable forage option for beef cattle production in central Queensland, with gross margins/ha.annum 1.5–1.9 times that of perennial grass pastures (Bowen *et al*. 2018). There appears to be an opportunity to encourage a reduction in high utilisation rates of buffel pastures, and to potentially improve outcomes for the reef, by promoting legume adoption by beef producers. However, targeted research, development and extension activities that focus on reducing the riskiness of leucaena, and alternative pasture legumes, is required.

In conclusion, this examination of the effects of grazing pressure and land condition on productivity and profitability of perennial, buffel grass pasture systems has provided valuable insights into the interaction between grazing pressure and financial returns. Further research is required to better understand the effects of utilisation rates of buffel grass, and other sown grass and legume species, on plant biomass production, land-condition decline, cattle diet quality and cattle productivity. Such data would better inform carrying capacity assessments and forage budgeting by beef producers and industry. Furthermore, these data would allow improvement of existing modelling capabilities which, in turn, will better inform whole-farm economic analysis. Given the importance of understanding declining land condition, sediment and nutrient runoff to the reef, and corresponding trade-offs with animal production and economic outcomes for producers, research to better elucidate these responses should be given high priority.

Conflicts of interest

The authors declare no conflicts of interest.

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