Impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement. Part III: Economic analysis of rehabilitation techniques in the Burdekin River catchment to improve water quality flowing from grazing lands onto the Great Barrier Reef.

RRRD.024 Final Report for the Australian Government's Caring for Our Country Reef Rescue Water Quality Research and Development Program

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Impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement

Project RRRD.024 Final Report Part III

Economic analysis

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Purpose of Document

This is an economic analysis of the rehabilitation treatments at the experiment site at Spyglass, including costs of the contour and diversion banks, mechanical disturbance treatments and potential cattle production, based on the amount and composition of pasture produced in each treatment over the first three years of the project period (2012-2014).

This document is designed to be read and interpreted alongside other reports and papers published for the project RRRD.024 – '*Impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement*'. This report assesses the potential economic impact of the rehabilitation treatments at the Spyglass experiment site in the Burdekin Catchment.

Executive Summary of Economic analysis

Poor grazing land condition reduces the productivity of grazing enterprises and has been linked to increased sediment loads entering the Great Barrier Reef Lagoon. There are several methods for rehabilitating degraded lands with varying levels of investment. The subsequent environmental and economic outcomes have previously been largely unquantified. This document assesses the potential economic impact of the rehabilitation treatments in the Burdekin Catchment for the project RRRD.024 – 'Quantifying the impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement'.

Three mechanical intervention treatments and a control (no treatment) were evaluated on loamy alluvial soils at Spyglass Research Facility. These were: deep ripping, chisel ploughing and crocodile seeding. All treatments were seeded. Treatments varied in cost on a per hectare basis with deep ripping requiring \$260.85 ha^{-1}, chisel ploughing \$210.85 ha^{-1}, and crocodile seeding was least cost requiring \$150.85 ha^{-1}. Treatments also varied in benefits, particularly pasture yield and subsequent potential carrying capacity. From highest to lowest the potential average carrying capacity was deep ripping, chisel ploughing and crocodile seeding, with 25.3 AE 100 ha^{-1}, 20.5 AE 100 ha^{-1} and 13.4 AE 100 ha^{-1}, respectively. The control averaged 7.9 AE 100 ha^{-1}.

Despite apparent differences in costs and subsequent benefits, each treatment returned very similar economic results, particularly as measured by the internal rate of return. The internal rate of return (IRR) of chisel ploughing was highest (4.55%), followed by crocodile seeding (4.37%) and lastly, deep ripping (4.36%). This suggests that while spending more money and performing higher intervention might increase productivity the most, it does not necessary return more on a dollar for dollar basis. Despite positive IRRs, none of the treatments returned a positive net present value at the default parameters, suggesting funds could be better used elsewhere.

It is recommended that producers investigate their eligibility for funding programs (such as Catchment organisations or Land Care) which assists with upfront costs of rehabilitation of degraded lands. This will allow producers to reduce losses and provide public benefits in the form of reduced sediment and nutrient runoff.

Introduction

Project RRRD.024 is a land rehabilitation project quantifying the effectiveness of different mechanical land rehabilitation methods on soil health, pastures, sediment and nutrient runoff losses on D-condition, bare grazing lands of the Burdekin and Fitzroy catchments. The project measured the effects of mechanical land rehabilitation methods in restoring the health of and reducing the runoff from grazing lands.

Sediment runoff due to excessive grazing is believed to be a key contributor to total sediment loads into the Great Barrier Reef Lagoon (Roth, *et al.*, 2003). Increasing sediment loads have been identified as one factor in causing degradation of coastal ecosystems within the Great Barrier Reef Lagoon through an increase in anthropogenic activities including agriculture, land-clearing, urban and industrial development among other causes (Kroon, *et al.*, 2012). It is assumed that the majority of these sediments originate from grazing land (Roth, *et al.*, 2003).

The Burdekin catchment spans 14 million hectares (Figure 1) and carries an estimated 1.4 million head of cattle on grazing lands (Meat and Livestock Australia, 2014) which accounts for approximately 90% of the land use (Queensland Government, 2012). The Gross Value of Production (GVP) from meat cattle from Queensland in total was $3.45 Billion in 2011-2012 (Autralian Bureau of Statistics, 2013) with approximately 10 to 12 percent of the total originating in the Burdekin catchment.

Ground cover, land condition and pasture productivity are primary factors in environmental outcomes such as sediment runoff and in beef industry productivity and profitability. Land condition is described as per the 'ABCD' land condition framework (Chilcott, *et al.*, 2005). Under this framework, bare, scalded or eroded areas are classified as D-condition, which is described as having either very few or no perennial grasses, severe erosion or scalding and/or thickets of woody plants. D-condition land supports only 0–20% of the potential carrying capacity of the same land in A-condition and therefore is a significant opportunity cost to producers (Queensland Government, 2011). Land condition has declined over much of the tropical woodlands due to over-utilisation of pastures and in extreme cases of land condition deterioration there is limited potential for profitable production (MacLeod, *et al.*, 2004). Recent estimates show that approximately 10% of the Burdekin catchment is in D-condition (Beutel, *et al.*, 2014). This report considers the potential economic benefits to be gained from rehabilitation of grazing land from D-condition to a higher land condition rating of C or B.

Restoring land condition

Although grazing lands are more profitable at higher land conditions, to rehabilitate D-condition land, by definition, mechanical or chemical intervention is required. These interventions can incur a significant capital expense. Furthermore, different treatment methods require different levels of input, resulting in complex analysis to determine the most effective and economical intervention suited to a particular degraded site.

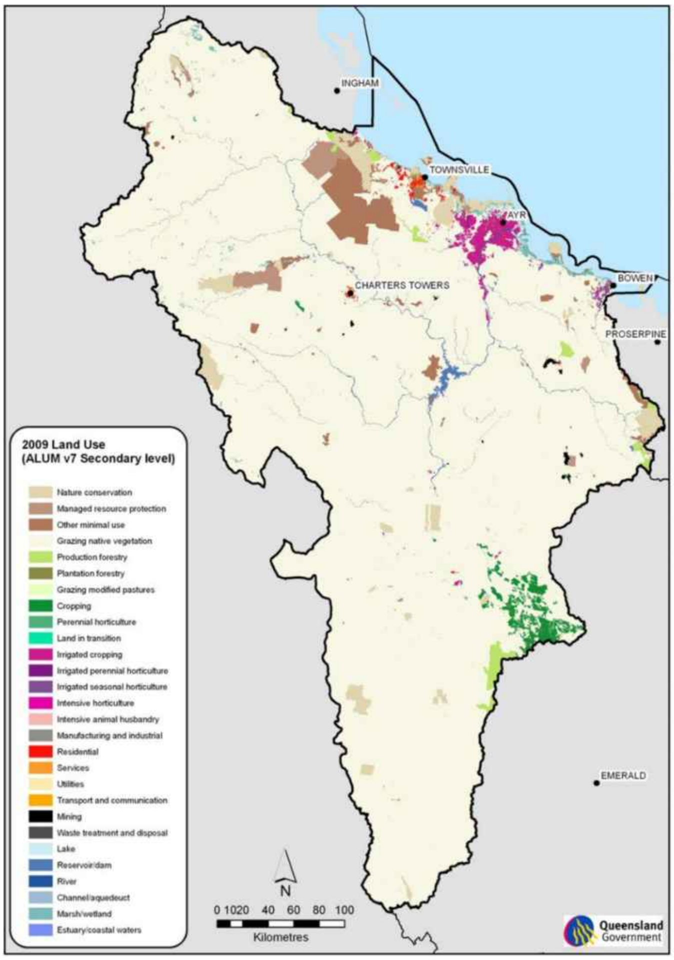

Figure 1. Burdekin Catchment land use mapping (Source: Queensland Government, 2012)

Project description

The effectiveness of mechanical and other treatments in rehabilitating degraded D-condition land were quantified in an experiment conducted the Queensland Government's Spyglass Beef Research Facility, located in the Burdekin basin west of Townsville. Rehabilitation treatments were also conducted in the Fitzroy Basin, near Banana and Injune. The focus on this report will be the mechanical treatments at Spyglass. The soil disturbance treatments at Spyglass included deep ripping, chisel ploughing and crocodile plough seeding. All treatments were compared to a control treatment which received no mechanical intervention. Treatments were monitored for a number of outcomes including pasture composition (species % and kg ha^{-1}) and pasture yield was measured in dry matter (kg ha^{-1}). Cattle were excluded from the treatments, so the impact of livestock grazing on the efficacy of the treatments is not quantifiable.

This analysis assesses the potential economic implications from the field results of the first three years, 2012-2014, after the mechanical treatments were applied in the Spyglass trial.

Site and treatment description

The experiment site is situated in the Upper Burdekin catchment approximately 130 km north of Charters Towers and 110 km west of Townsville, located at 19˚33'66"S, 145˚81'54"E. The major landtype of the experiment is loamy alluvial with three soil types: a crusty deep black vertosol (Ug5.15); a deep grey sodosol (Dy3.13); and a sodic brown dermosol (Dy3.13). Tree basal area (TBA) on the experiment is zero, although there are smaller shrubs present. These shrubs are not considered to be affecting pasture production. Each treatment was 1-2 ha in size. The loamy alluvial land type is one of 33 major land types in the Burdekin Catchment (McIvor, 2012) and is classified as of moderate fertility (Queensland Government, 2011).

There were three mechanically treated plots in the experiment. They were deep ripping at a depth of 50 cm, chisel ploughing to 20 cm, and crocodile plough seeding with pits to 10 cm. The layout of the experiment is shown in Figure 2.

The site was located adjacent to a creek and below a hill slope. This necessitated the construction of both a diversion bank along the creek and two contour banks across the lower hill slope, to avoid further water erosion across the site from external water sources during the pasture establishment phase.

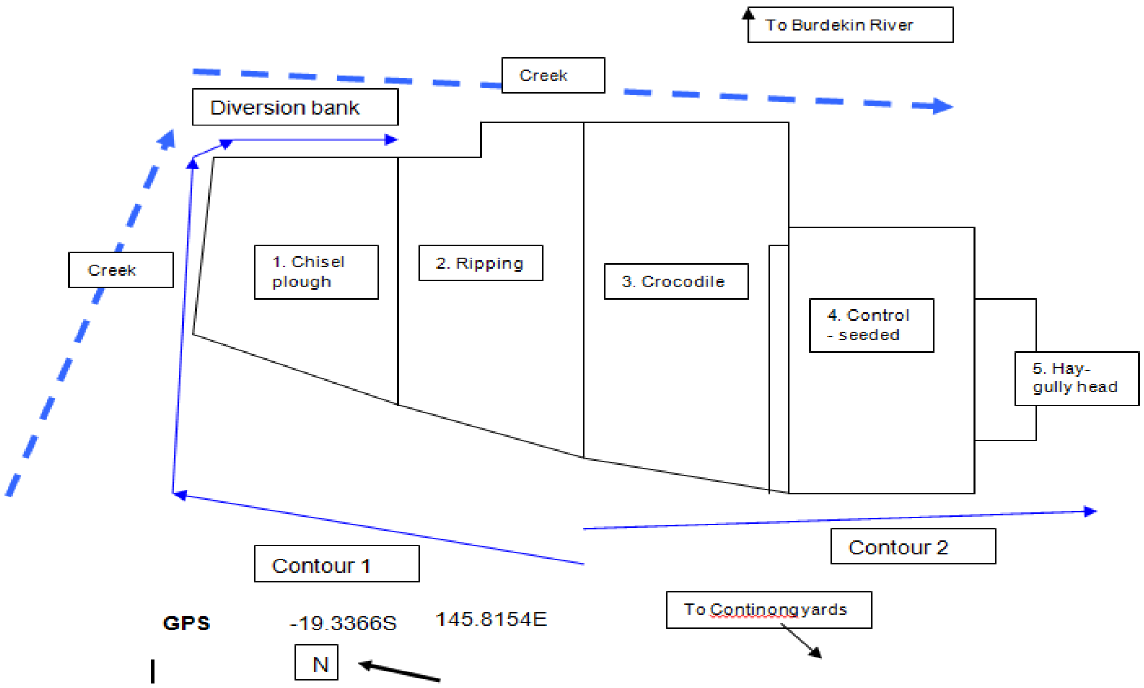

Figure2. Treatment layout of the Spyglass experiment site

All treatments were seeded with the same mix of tropical pasture cultivars. The pasture grass and legume cultivar mix (Table 1) shows that \$74.85 ha^{-1} was spent on seeding. This reflects a higher price than is recommended for commercial properties, as some species were included for research purposes. Suitable species selection is soil type and site specific for commercial properties and may differ from the cultivars used in the Spyglass experiment in both quantity and composition. A commercial pasture cultivar mix cost is approximately \$40.00 ha^{-1}. The impact on pasture yield produced by different cultivar mixes was not evaluated.

Table 1. Seeding mixture used, rate and price.

Species / cultivar	Price ($ kg^{-1})	Units (kg ha^{-1})	Total ($ ha^{-1})
Buffel grass cvv. Gayndah / USA	9.25	1.0	9.25
Rhodes grass cvv. Katambora/Callide	9.00	0.5	4.50
Creeping bluegrass cv. Bisset	19.41	0.5	9.71
Sabi grass cv. SupaSab	11.00	0.5	5.50
Angleton grass cv. Floren	23.64	0.5	11.82
Indian bluegrass cv. Keppel	19.00	0.5	9.50
Butterfly pea cv. Milgarra	4.82	1.0	4.82
Shrubby stylo cv. Seca	11.00	0.5	5.50
Caribbean stylo cvv. Amiga / Verano	11.00	0.5	5.50
Caatinga stylo cvv. Primar / Unica	17.50	0.5	8.75
Total cost			**74.85**

Economic assumptions and methodology

A number of assumptions were necessary due to the short, three year, duration of the experiment, particularly given the long time- frames required for changes in landscape condition and functionality. The exclusion of cattle meant no data was available for animal production or any possible interactions between the rehabilitation treatments and grazing animals. Where possible, assumptions were based on past research and where this was not possible, expert opinion was sought.

Extrapolating the experiment

As the costs and results were based on small areas of approximately one to two hectares, each variable was extrapolated to 100 ha. Treatment outcomes such as pasture yield, measured on a per hectare basis, were assumed to occur across 100 ha. Costs associated with performing the mechanical work were estimated by the contractor for the specific land type and land attributes at the experiment site, such as soil type, tree basal area and rockiness, at a 100 ha scale.

Initial costs

Estimates of the experimental treatment costs were provided by Bob Shepherd (Principal Extension Officer, DAF, Charters Towers) and verified by the contractor who performed the work on the site. The cost of each treatment was assumed to include the necessary contour and diversion bank costs as well as the pasture seeding cost. Breakdowns of the treatment costs are shown in Table 2. Total costs for each treatment are shown in Table 3. The treatment costs are considered to be typical of those likely to be incurred by a beef producer undertaking rehabilitation work where contractors are used. Producers engaging their own machinery should undertake their own costings.

Table 2. Breakdown of treatment costs.

Treatment	Price ($)	Units	Units	Total cost ($)
Contour bank	4.00	metre	600	2,400
Diversion bank	4.00	metre	300	1,200
Seeding	74.85	ha	100	7,485
Deep ripping	150.00	ha	100	15,000
Chisel ploughing	100.00	ha	100	10,000
Crocodile plough seeding	40.00	ha	100	4,000

Table 3. Total treatment costs (per 100 ha and per 1 ha).

Treatment	Total cost ($)	$ ha^{-1}
Deep ripping	26,085	260.85
Chisel ploughing	21,085	210.85
Crocodile plough seeding	15,085	150.85
Control		

Calculating stocking rate and carrying capacity

Stocking rate is defined as the number of stock (in Adult Equivalents, AE) per unit of area at a particular time: usually expressed as hectares per animal or per Adult Equivalent (AE) (Chilcott, *et al.*, 2005). To determine adult equivalent ratings of cattle, Kleiber's law of metabolic weight (Kleiber, 1932) was used, with a 450 kg animal used as the base for one (1) adult equivalent.

Carrying capacity is defined as the stocking rate an area can carry over the long-term, such as five to ten years or longer, while maintaining or improving land condition. Carrying capacity is linked to safe stocking rates over longer periods, rather than annual adjustments due to variation in seasonal pasture yield related to more recent seasonal rainfall. Stocking rate is influenced by a number of factors, including pasture yield, pasture composition and size (weight) of the animal grazing the pasture. The available pasture yield (quantity) has most influence on number of animals a pasture can carry, while the proportion of legumes has a strong effect on pasture quality and consequently on the growth rate of the cattle (outlined in section 4.4).

Measured pasture yield and composition is shown in Figure 4. While no statistical analysis could be performed due to non-replication of treatments, mean legume and grass yield across the large plots were consistently higher in the mechanical treatments than in the control. Deep ripping grew the highest yields in 2012 (3420 kg ha^{-1}), 2013 (2860 kg ha^{-1}) and 2014 (2965 kg ha^{-1}), followed by chisel ploughing (3352 kg ha^{-1}, 2139 kg ha^{-1}, 2007 kg ha^{-1}) and crocodile plough seeding, which grew the least amount of pasture of the mechanical treatments with 2304 kg ha^{-1}, 1306 kg ha^{-1} and 1289 kg ha^{-1} of dry matter respectively. These treatments outperformed the control which grew the least amount of pasture of 1848 kg ha^{-1}, 420 kg and 622 kg ha^{-1} of dry matter over the three years respectively. Indian bluegrass was the dominant grass species across the experiment site.

Legume yields for 2012, 2013 and 2014 followed a similar trend to total pasture yield, with the deep ripping producing the highest yields (1432 kg ha^{-1}, 1559 kg ha^{-1}, 1929 kg ha^{-1}), followed by chisel ploughing (1025 kg ha^{-1}, 1129 kg ha^{-1}, 930 kg ha^{-1}), and the crocodile plough seeding treatment (168 kg ha^{-1}, 727 kg ha^{-1}, 221 kg ha^{-1} respectively). The control treatment grew 195 kg ha^{-1} in 2012 which was similar to the crocodile plough seeding, however, it showed no improvement in 2013 and 2014 with yields of 141 kg ha^{-1} and 140 kg ha^{-1} respectively.

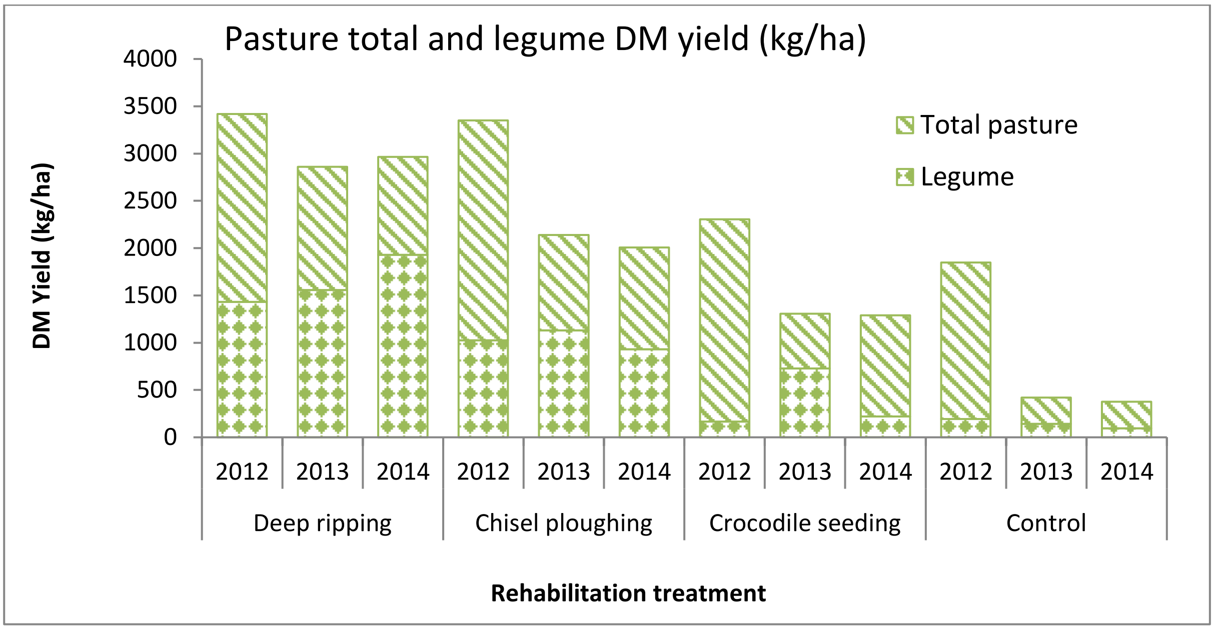

Figure 4. Pasture yield (kg ha^{-1}) and composition (%) for years 2012, 2013 and 2014

A number of assumptions were made in determining the stocking rate for treatments, particularly for the forecast period. For years one to three, measured total pasture and legume yields were used (Figure 3). For years four through 20, average yield from the first three years was used. This was considered a reasonable assumption for a number of reasons. Firstly, the 2012, 2013 and 2014 wet seasons were above average, average and below average seasons for the experiment, with recorded rainfall of 775 mm, 533 mm and 361 mm, respectively. Median rainfall for the area is 521 mm. These seasons represented the top 20, median and lowest 20 percentiles of historical rainfall for the Hillgrove rainfall station as recorded in the Rainman program (Clewett *et al.* 2003) and are shown in Table 4. Hillgrove is adjacent to Spyglass and has longer rainfall records.

Table 4. Historical rainfall (mm) and deciles for Hillgrove (Source: Rainman).

Rainfall Decile	mm	Trial Rainfall
10%	871	
20%	748	775 (2012)
30%	668	
40%	571	
50%	521	533 (2013)
60%	470	
70%	429	
80%	365	361 (2014)
90%	262	

Secondly, treatments, not including the control, grew an average yield of 3128.3 kg ha^{-1} in 2012, 2165.5 kg ha^{-1} in 2013 and 2379.3 kg ha^{-1} in 2014. The yield results were compared with pasture growth tables (Table 5) developed through the GRASP model (Littleboy and McKeon 1997) (Day *et al.* 1997). The pasture growth models predict pasture growth in years of median rainfall (50%), high rainfall year (rainfall decile 30%) and lower rainfall years (rainfall decile 70%). The pasture growth table was only used as a comparison and not used for any modelling, however, these suggest that the overall land condition at the experiment site increased to B-condition in 2013 and subsequently declined to C-condition in poorer seasons. These predications are in line with experiment observations and further suggest that using the average yields in the forecast period is reasonable.

Another assumption was that mechanical treatments were excluded from cattle for one year to allow establishment of legumes and grasses. Cattle exclusion for pasture and legume establishment is widely recommended at a practical level and is assumed in other economic analysis of land rehabilitation (Peck *et al.* 2011), (Gowen *et al.* 2012).

Table 5. GRASP modelled pasture yield (kg ha-1) table for loamy alluvial land type in A, B, C and D-condition for a range of tree basal area levels at Spyglass.

Rainfall	Decile 50%				Decile 30%				Decile 70%			
Land condition	A	B	C	D	A	B	C	D	A	B	C	D
TBA (m2/ha)												
0	3703	2777	1666	741	3759	2820	1692	752	2284	1713	1028	457
1	3517	2638	1583	703	3611	2708	1625	722	2022	1517	910	404
2	3297	2473	1484	659	3428	2571	1543	686	1842	1381	829	368
4	2716	2037	1222	543	3090	2318	1391	618	1464	1098	659	293
6	2286	1715	1029	457	2792	2094	1256	558	1180	885	531	236
8	2012	1509	906	402	2586	1939	1164	517	1034	776	465	207
10	1774	1331	798	355	2375	1781	1069	475	909	682	409	182
12	1539	1154	693	308	2176	1632	979	435	817	613	368	163
15	1214	911	546	243	686	515	309	137	686	515	309	137
20	873	655	393	175	528	396	238	106	528	396	238	106
Rainfall (mm)	574				445				732			

To determine stocking rate, a long term carrying capacity formula was used (Chilcott *et al.* 2005). The formula for this calculation is: (Pasture Growth * Pasture Utilisation) / (Forage Demand (kg AE^{-1}). Pasture utilisation was set at 30%, which is the recommended utilisation rate for the alluvial land type (Karfs, *et al.*, 2009). As a result of this calculation, stocking rate is equal to long–term carrying capacity with the results shown in Table 6. Residual yield requirements were ignored, which allowed the control treatment to be modelled with stock numbers. However, if an arbitrary residual yield was required, for example, 1000 kg ha^{-1}, then the carrying capacity of treatments which yielded below 1000 kg ha^{-1} would be zero (0). This would have a significant effect on the economic outcomes.

Table 6. Calculated carrying capacities in Adult Equivalents per 100 hectares for years 1, 2, 3, and 4 to20.

Treatment / Year	1	2	3	4 - 20
Deep ripping	0	23.5	24.4	25.3
Chisel ploughing	0	17.6	16.5	20.5
Crocodile plough seeding	0	10.7	10.6	13.4
Control	15.2	3.5	5.1	7.9

Calculating a gross margin

Gross margins were initially applied to consider the relative profitability of the treatments. Gross margins are an economic method to analyse changes in farm business practices which focuses on the changes in costs and benefits of the alternatives faced by the enterprise. This information can then be added back into the whole farm budget to ultimately inform the profitability of the whole enterprise. Gross margins analysis has been used extensively in agricultural economics for a range of pasture improvement and land rehabilitation scenarios (Star, *et al.*, 2013).

There were a number of necessary assumptions used to develop the gross margins. Variables included liveweight gain, buying and selling prices and direct selling costs. Prices used for the analysis are from the BreedCow CRC Templates (Holmes, *et al.*, 2011) and were considered a long-term average price in 2011. These prices are \$1.70 kg^{-1} liveweight for purchased cattle and \$1.60 kg^{-1} liveweight for the sale cattle. It is acknowledged that there are price fluctuations, however with a very long analysis outlook it is more important to identify the relevant economic benefit between treatments. Sensitivity analysis has been performed to assess the price risk.

Liveweight gains for the Burdekin region are assumed to be equal to the moderate stocking rate treatment at Wambiana (Charters Towers) of 115 kg of liveweight per animal per annum (O'Reagain and Bushell 2011). Despite the Spyglass experiment having a different landtype to the Wambiana grazing trial, the relative difference between the control treatment and the rehabilitation treatments is the important factor. Further, liveweight gains in the northern forest, the geographical area in which the trial is located, is typically between 90–130 kg (McGowan *et al.* 2014). This suggests that the assumed 115 kg of liveweight gain is a reasonable estimate. A further 40 kg hd^{-1} $annum^{-1}$ benefit to liveweight gain was added where the legume proportion of pasture composition was above 10% (Burrows *et al.* 2010). While the experiment conducted by Burrows in central Queensland showed a 37 kg hd^{-1} $annum^{-1}$ benefit, other experiments in northern Australia reported liveweight gain from legumes of 30–60 kg hd^{-1} $annum^{-1}$ (Coates *et al.* 1997). Despite the control having 34% legume in 2013, total pasture yield was below 420 kg, which was less than one–third that of other treatments (Figure 3). In our economic modelling, steers were held on the treatments for a 12-month period, with an allocated annual liveweight gain used in the gross margin of 115 kg for the control treatment and 155 kg for the rehabilitation treatments (with legumes). Mortalities were calculated using the following formula: Mortality (dry stock) % = $2 + 88e^{-0.034(LWG + 50)}$ (Gillard and Moneypenny 1988). As a result, mortalities were 2.32% for the control treatment and 2.08% for the rehabilitation scenarios.

The target market identified in this economic analysis was for an export ox to dress 280 to 320 kg hd^{-1}. At an assumed dressing percentage of 53%, a liveweight of 530 kg to 603 kg is required to achieve the dressed weight. Therefore, the target weight was set to 600 kg. Based on expected liveweight gain, entry weights were 485 kg for the control treatment and 445 kg for the intervention treatments.

Transport costs (Table 7) and the Meat and Livestock Australia transaction levy ($5 hd^{-1}) remain the same between the two groups of cattle. These costs were determined using BreedCow and Dynama (Holmes 2009) (see Table 7 in that software). Distance to market was calculated as the distance from Spyglass to the closest meat processing facility, located in Townsville.

Table 7.Transport cost calculations.

	Price
Transport cost $/deck km^{-1}	$2.00
Distance (km)	160
Number of head per deck	20
Freight cost/head	$16.00

Interest or opportunity cost on livestock capital was determined using the average of the opening value plus closing value of livestock at an interest rate of 5%. For the two scenarios, control and rehabilitation, the gross margin before livestock interest was calculated as $111.48 and $178.70, respectively. Gross margins after livestock interest, for the control and rehabilitation scenarios, were calculated as $67.23 and $135.79 respectively, as shown in Table 8.

Table 8. Gross margins of the control versus rehabilitation treatments at Spyglass.

	Control	**Treatments**
Landed weight (kg)	485	455
Landed price ($ kg^{-1})	1.70	1.70
Gross purchase price ($ Steer^{-1})	824.50	756.50
LWG (kg annum^{-1})	115	155
Exit weight (kg)	600	600
Sale price ($ kg^{-1})	1.60	1.60
Gross sale price $	960.00	960.00
Levy cost $	5.00	5.00
Transport cost $	16.00	16.00
Opportunity cost $	44.61	42.91
Gross margin before interest $	111.84	178.70
Gross margin after interest $	67.23	135.79

Gross margins only identify the relative performance of the treatments and do not identify whether investing to undertake land rehabilitation is profitable.

Economic viability of land rehabilitation

To determine the economic viability of land rehabilitation in the Burdekin, a partial discounted cashflow analysis was used to calculate a Net Present Value (NPV) of each treatment. In this analysis, the NPV is the sum of the difference between the discounted net cash flows of each type of investment in land rehabilitation and the control. Therefore the net cashflow of the control scenario (*A*) was subtracted from that of a rehabilitation scenario (*B*). A range of discount rates were applied. Further, since all treatments incurred different levels of capital expenditure, an Internal Rate of Return (IRR) was calculated to determine the return on each additional dollar invested in rehabilitation. The IRR is defined as the discount factor required for the NPV to be zero (0). A discount factor of 10% was chosen due to potential returns on an alternative use of funds, such as debt reduction or stock investment. The initial cost of performing rehabilitation was treated as a tax deduction at the 30% marginal tax rate at the beginning of the project.

The discounting formula used was $NCF/(1+i)^t$. Where:

NCF *is net cashflow*, or all incomings and outgoings for time period *t.*

i *- is the discount factor*

t *- is the time period*

Results

In order for the experiment treatments to be economically sound, the partial discounted cashflow analysis must result in a positive NPV at the chosen discount rate. A positive NPV means that the project or activity returns more than alternative use of funds. The results of the partial discounted cash flow analysis are presented in Table 9. At the chosen discount rate of 10% none of the mechanical treatments achieved a positive NPV.

Table 9. Results of the partial discounted cash flow analysis on NPV and IRR.

Treatment	**NPV (at 10%)**	**IRR**
Deep ripping	-$10,806	4.36%
Chisel ploughing	-$8,247	4.55%
Crocodile plough seeding	-$5,485	4.37%

The IRR, which shows the return on each extra dollar invested and the level at which the NPV is zero, shows the relative profitability between treatments. At the chosen levels of discount rates, liveweight gain and prices, chisel ploughing was highest at 4.55%, followed by crocodile plough seeding at 4.37% and deep ripping at 4.36%.

To assess the relative value of the key assumptions made in the analysis, sensitivity analysis was performed on the variables of purchase and sale price, extra weight gain provided by the rehabilitation activity and the discount rates. Purchase and sale prices were varied by 10 cents over a range of \$1.50 kg^{-1}–\$1.90 kg^{-1} for sales and \$1.40 kg^{-1}–\$1.80 kg^{-1} for purchases. Extra weight gain for rehabilitation activities were tested at 20 kg and 40 kg. Discounts rates were varied at 5%, 7.5%, 10% and 12.5%. The results of the sensitivity analysis at these four discount rates are shown in Tables 10-15. The highlighted rows are those reported in Table 9.

Table 10. Sensitivity results for deep ripping at 40 kg LWG advantage at four discount rates.

Purchase/Sale/ *i*	5.0%	7.5%	10.0%	12.5%	IRR
$1.50 / $1.40	-$4,906	-$9,389	-$12,515	-$14,739	3.04%
$1.60 / $1.50	-$3,314	-$8,230	-$11,660	-$14,102	3.73%
$1.70 / $1.60	-$1,722	-$7,071	-$10,806	-$13,466	4.36%
$1.80 / $1.70	-$130	-$5,912	-$9,951	-$12,829	4.95%

Table 11. Sensitivity results for deep ripping at 20 kg LWG advantage at four discount rates.

Purchase/Sale/ *i*	5.0%	7.5%	10.0%	12.5%	IRR
$1.50 / $1.40	-$10,213	-$13,686	-$16,058	-$17,708	0.79%
$1.60 / $1.50	-$8,974	-$12,813	-$15,439	-$17,269	1.44%
$1.70 / $1.60	-$7,736	-$11,941	-$14,821	-$16,830	2.04%
$1.80 / $1.70	-$6,498	-$11,068	-$14,202	-$16,391	2.26%

Table 12. Sensitivity results for chisel ploughing at 40 kg LWG advantage at four discount rates.

Purchase/Sale/ *i*	5.0%	7.5%	10.0%	12.5%	IRR
$1.50 / $1.40	-$3,543	-$7,138	-$9,675	-$11,504	3.20%
$1.60 / $1.50	-$2,248	-$6,182	-$8,961	-$10,964	3.90%
$1.70 / $1.60	-$952	-$5,227	-$8,247	-$10,425	4.55%
$1.80 / $1.70	$343	-$4,271	-$7,532	-$9,885	5.16%

Table 13. Sensitivity results for chisel ploughing at 20 kg LWG advantage at four discount rates.

Purchase/Sale/ *i*	5.0%	7.5%	10.0%	12.5%	IRR
$1.50 / $1.40	-$8,073	-$10,834	-$12,746	-$14,096	0.75%
$1.60 / $1.50	-$7,079	-$10,124	-$12,236	-$13,729	1.41%
$1.70 / $1.60	-$6,086	-$9,415	-$11,726	-$13,362	2.02%
$1.80 / $1.70	-$5,092	-$8,706	-$11,217	-$12,995	2.58%

Table 14. Sensitivity results for crocodile plough seeding at 40 kg LWG advantage at four discount rates.

Purchase/Sale/ *i*	5.0%	7.5%	10.0%	12.5%	IRR
$1.50 / $1.40	-$2,542	-$4,825	-$6,497	-$7,746	2.94%
$1.60 / $1.50	-$1,687	-$4,172	-$5,991	-$7,351	3.68%
$1.70 / $1.60	-$833	-$3,519	-$5,485	-$6,955	4.37%
$1.80 / $1.70	$22	-$2,866	-$4,980	-$6,559	5.02%

Table 15. Sensitivity results for crocodile plough seeding at 20 kg LWG advantage at four discount rates.

Purchase/Sale/ *i*	5.0%	7.5%	10.0%	12.5%	IRR
$1.50 / $1.40	-$5,917	-$7,627	-$8,864	-$9,778	0.01%
$1.60 / $1.50	-$5,287	-$7,161	-$8,517	-$9,518	0.68%
$1.70 / $1.60	-$4,657	-$6,694	-$8,169	-$9,258	1.31%
$1.80 / $1.70	-$4,028	-$6,228	-$7,821	-$8,998	1.91%

Economic analysis with external funding sources providing 40% of the rehabilitation costs

If there were external grants (e.g. Reef Rescue) offering 40% subsidy of the initial costs, and then using the Spyglass deep ripping treatment results instead of costing $26,085 for 100 ha rehabilitation, it would cost the producer $15,651, and could break-even or become profitable for his expenditure.

Subsidy of 40% results:

Internal Rate of Return	10.02%			
Required rate of return for alternative use of funds	5.00%	7.50%	10.00%	12.50%
Net Present Value of investment	$9,579	$3,953	$24	-$2,776

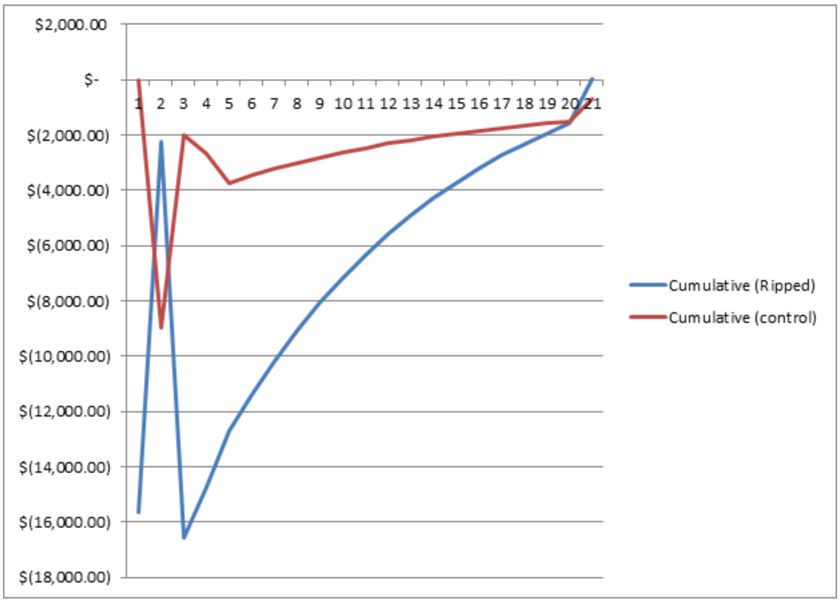

Figure 4. Cumulative returns from the deep ripping treatment with a 40% external subsidy compared with the control at Spyglass in the Burdekin catchment.

Discussion

None of the three mechanical rehabilitation plus seeding treatments produced a positive economic result. The analysis demonstrates that there are differences in treatments for pasture production and composition and small economic differences. Further, the IRR results show that initial outlays and subsequent improvement in carrying capacity can offset each other. For example, while deep ripping grew the highest pasture yield and established more legumes, it also had the largest initial outlay. This resulted in the treatment returning a slightly lower IRR than chisel ploughing which did not produce as much pasture or cost as much initially to establish.

Furthermore, the sensitivity analysis showed that at the lowest discount factor, 5%, and default price levels, no projects obtained a positive NPV. An increase in the value of cattle is reflected uniformly across the treatments and does little to change the outcome; however, at the highest prices and productivity levels, as well as the lowest discount factor, crocodile plough seeding and chisel ploughing returned positive NPVs. Since no treatments were profitable at the 40 kg hd^{-1} liveweight advantage attributed to rehabilitation, the profitability of the treatments were lower at the 20 kg hd^{-1}, resulting in larger potential losses. This highlights the need to assess options prior to treating degraded lands to achieve the best outcome.

This economic analysis demonstrates that D-condition land improvement can be achieved through mechanical intervention and seeding, but it is unlikely to be an acceptable investment for landholders in the situation represented by the Spyglass experiment site. In order for investment to become profitable, the productivity gains would have to higher than considered in our economic analysis. For beef producers in the Burdekin catchment to widely participate in D-condition land rehabilitation programs, significant external financial assistance with upfront capital costs would be required. This support means that producers could conduct D-condition land rehabilitation works and avoid the potential financial losses, while providing wider public benefits such as reducing sediment and nutrient runoff losses into the Great Barrier Reef Lagoon and possibly increased biodiversity in their pastures.

Property owners should interpret these results as a guide to possible rehabilitation outcomes on their property and should conduct their own assessment using property level investment analysis. The parameters would then be most relevant for their own landtype and grazing enterprise. Businesses should pay close attention to how their situation and management strategies differ to those assumptions used in this analysis, particularly if they set residual pasture dry matter yield targets. In that case, D-condition land would present a higher opportunity cost than presented in this analysis.

While the use of economic modelling avoids costly trial work with cattle, some assumptions made here may not necessarily be realistic, such as grazing having no effect on pasture growth. It is recommended that further research is undertaken to quantify grazing effects on rehabilitated D-condition landscapes in this environment.

Conclusion

This economic analysis of the experiment shows that mechanical interventions to improve land condition incur relatively large capital costs which outweigh the benefits of extra carrying capacity generated by the pasture improvement. The three treatments of deep ripping, chisel ploughing and crocodile plough seeding all produced negative NPV’s at the enterprise level. Furthermore, sensitivity analysis showed that these results were robust and substantial improvements in productivity or reductions in rehabilitation costs would be required in order for these experimental treatments to become profitable on a production basis. Any additional off-site benefits, both within the property and for the wider community, were not included in this analysis. Producers should check their eligibility for financial assistance from programs such as Reef Rescue to subsidise their rehabilitation costs. This may assist with rehabilitation capital cost where the work will have water quality improvements and benefits to the wider community, such as improved water quality flowing from cattle grazing lands into the Great Barrier Reef Lagoon.

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