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Economically viable land regeneration in Central Queensland and improved water quality outcomes for the Great Barrier Reef

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Abstract. The impact of excessive sediment loads entering into the Great Barrier Reef lagoon has led to increased awareness of land condition in grazing lands. Improved ground cover and land condition have been identified as two important factors in reducing sediment loads. This paper reports the economics of land regeneration using case studies for two different land types in the Fitzroy Basin. The results suggest that for sediment reduction to be achieved from land regeneration of more fertile land types (brigalow blackbutt) the most efficient method of allocating funds would be through extension and education. However for less productive country (narrow leaved ironbark woodlands) incentives will be required. The analysis also highlights the need for further scientific data to undertake similar financial assessments of land regeneration for other locations in Queensland.

Additional keywords: benefit-cost analysis, rangelands, sediment.

Introduction

The Fitzroy Basin in Central Queensland is the second largest catchment area in Australia covering 143 000 km^2. As the largest catchment for the Great Barrier Reef lagoon there is substantial interest in reducing discharges in sediments and nutrients to the reef (Karfs *et al.* 2009). Excessive sediment loads can impact on corals through smothering when particles settle out, by decreasing light availability, coral photosynthesis, and growth. This can result in decreased growth and survival and consequent changes to the coral population, structure, colony size (Haynes *et al.* 2007). Grazing is listed as the prime determinant of changes in water quality with beef production the largest single land use industry comprising 90% of the relevant land area (Karfs *et al.* 2009). Extensive beef production contributes over $1 billion dollars to the national economy annually and employs over 9000 people, many in rural communities (Gordon 2007). This means that mechanisms to improve overall water quality in the Fitzroy River have to be sensitive to their effects on potential production, economic returns and employment.

The Fitzroy Basin has undergone extensive changes in past decades through the clearing of brigalow (*Acacia harpophylla*) for the purpose of grazing and cropping (Packett *et al.* 2009). Catchments with high levels of clearing for cattle grazing and cropping show the largest increases in sediment exported per unit area compared with natural conditions (McKergow *et al.* 2005). Increasing ground cover and improving land condition can reduce or prevent excessive amounts of sediments entering streams and rivers (Karfs *et al.* 2009). This research provides a case study approach for two land types in the Duaringa area of Central Queensland (Fig. 1) on the economic viability for a private landholder to regenerate land from 'D' (very poor) condition to 'B' (good) condition using an ABCD land condition rating assessment as commonly employed by State land management agencies in northern Australia (Chilcott *et al.* 2005). This improvement in land condition implies increased ground cover throughout the year, providing environmental benefits of reduced sediment runoff. An associated private benefit is an increase in carrying capacity. Botanical nomenclature in this paper is according to Bostock and Holland (2007).

The case study canvassed two different scenarios to regenerate land in a modelling framework, so both private gains and losses are involved. As those gains and losses are dependant on a number of biophysical factors and management actions, a modelling approach was employed to assess the net private benefits of improving land condition for two land types in central Queensland. The private costs and marginal benefits were then included in an investment analysis which was discounted over a 20 year period to estimate the present value of a stream of future private benefits. The results identify the net private marginal benefits of making the land management changes. This research identifies if there are private incentives to improve land

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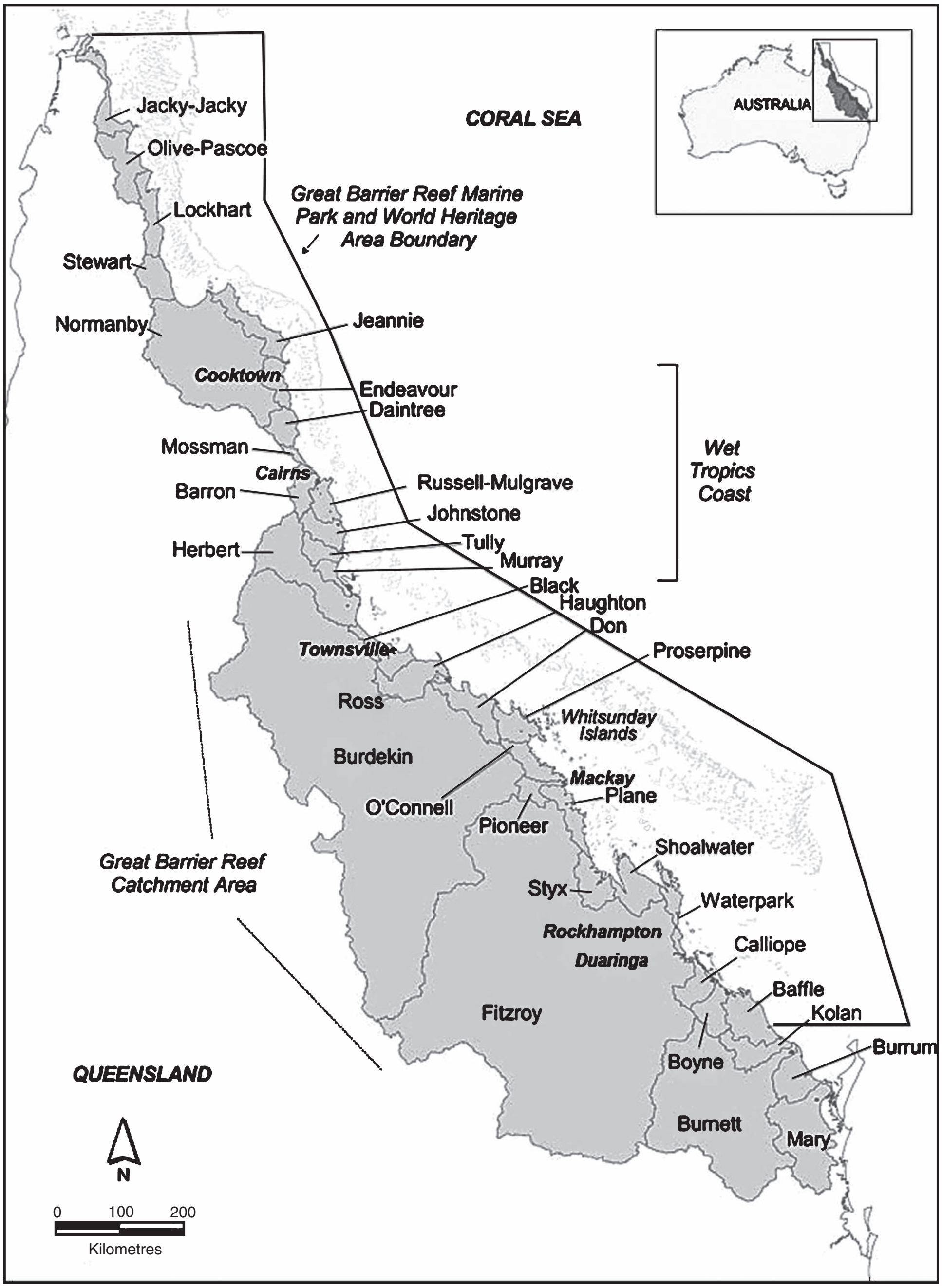

Fig. 1. Map of all the catchments that enter into the Great Barrier Reef, with significant towns and case study site (Duaringa) identified (Queensland Government 2009).

management, which will generate sediment reductions, improved reef health and other public benefits.

Materials and methods

The research followed a case study approach for the Duaringa (Latitude: –23°42′ 35.7268″ Longitude: 149°41′ 39.1699″) area for brigalow blackbutt and narrow leaved ironbark woodlands. These land types were selected to explore the effect of the inherent fertility and productivity of the land types under similar climatic conditions. Duaringa also provided a location where both land types co-existed and where there was an increasing trend in the bare ground index.

The purpose of this research was to determine the economic viability of regenerating two different land types in the Fitzroy Basin from 'D' condition to 'B' condition as this provides a significant increase in ground cover and an associated decrease in exported sediment. The analysis involved determining what the biophysical treatments were and the capital expenditure required to achieve the land condition improvement. The case study investigated two scenarios to examine both the large capital expenditure and the impacts of opportunity costs on the net private benefit. This information was used in an investment analysis framework, with economic viability determined by comparing the marginal benefit of land regeneration over 20 years to the initial capital cost.

Limited specific research data exists on the regeneration of Australian rangelands (MacLeod and Johnston 1990) but specific components such as pasture recovery have been researched in some relevant areas (Burrows *et al.* 1990; Ash *et al.* 1995; Northup *et al.* 2005; Orr *et al.* 2006; Stokes *et al.* 2006; Silburn 2011). Therefore, assumptions were derived from the results of previous studies and other technical information to populate the analysis. Where there were knowledge gaps, a combination of expert opinion and technologies were implemented.

Study site

The land types chosen for this case study were brigalow blackbutt (*Acacia harpophyll*) and narrow-leaved ironbark (*Eucalyptus crebra*) woodlands, two common vegetation types in the Fitzroy Basin that are generally representative of good and poor quality grazing lands in the region. The brigalow blackbutt case study was based on a 5000 ha property, and the narrow-leaved ironbark case study was based on a 10 000 ha property. These property sizes were chosen to reflect the average size of properties predominantly in these vegetation types and used for finishing and breeding cattle respectively. Both were assumed to be located in the central Queensland area of Duaringa, roughly in the centre of the Fitzroy catchment. This was done to ensure that many of the variables would be similar, such as the distance to markets, rainfall and production costs.

The case study enterprises differed to reflect the inherit productivity of each land type. The brigalow blackbutt was modelled to turn off a Japanese oxen class of animal (~580 kg/beast liveweight) with an annual gross margin for a steady state herd of $218 per adult equivalent (an adult equivalent is based on a standard reference weight of a 450 kg steer). The narrow-leaved ironbark woodlands turned off 18 month old store steers (~360 kg/beast liveweight) with an annual gross margin for a steady state herd of $151 per adult equivalent (AE). These gross margins were modelled using Breedcow Dynama (Holmes 2011) and expert opinion (Best 2007; Queensland Primary Industries and Fisheries Beef CRC, Northern Territory Government and Western Australian Department of Agriculture and Food 2009). The gross margins have been calculated to reflect prices and costs at writing.

Grazing enterprises involve a number of animal classes with varying costs and sale prices by class. A breeding enterprise for either Japanese oxen class or store steers will also involve turnover of the breeding herd and bulls. The assumptions used to calculate the gross margins were based on a self-replacing steady state herd and are listed in Tables 1 and 2.

Brigalow blackbutt is a land type that is described as brigalow scrub with emergent blackbutt or yapunyah (*Cambagiana*) with an understorey of false sandalwood (*Eremophila mitchellii*), yellowwood (*Terminalia oblongata*) or wilga (*Geijera parviflora*). Preferred native pasture composition is Queensland bluegrass (*Dichamthium sericeum* subsp. *sericeum*), desert bluegrass (*Bothriochloa ewartiana*), forest bluegrass (*Bothriochloa bladhii subsp. Bladhii*), black speargrass (*Heteropogon contortus*), bull Mitchell grass (*Astrebla squrrosa*)

Table 1. Herd parameter assumptions

Assumptions used	Japanese oxen	18-month-old store steers
Maximum turn-off age	2–3 years	18 months
Age at joining females	1 year	2 years
Branding rate (%)	74	74
Mortality rate (%)	2	2

Table 2. Japanese oxen gross margin assumptions and 18-month store steer gross margin assumptions

	Japanese oxen gross margin – brigalow blackbutt				
	Weaners	Females 1–2 years	Females 3+ years	Steers 2–3 years	Bulls
Average sale weight (kg)	–	420	445	580	700
Average sale price ($/kg)	–	1.60	1.35	1.57	1.20
Variable costs					
Average animal health ($/head)	11.22	2.20	1.11	6.70	10.01
Average fodder, licks and supplement ($/head)	24.75	12.10	6.43		
Levies and charges ($/head)	14.30	14.00	5.00	14.30	5.00
Average freight ($/head)	6.53	10.00	11.98	10.84	15.00
Average gross margin per adult equivalent ($/AE)	218.00	–	–	–	–
	18-month store steers gross margin – narrow-leaved ironbark woodlands				
	Weaners	Females 1–2 years	Females 3+ years	Steers 1–2 years	Bulls
Sale weight (kg)	–	330–420	320–480	360	700
Sale price ($/kg)	–	1.69–1.50	1.35	1.87	1.2
Variable costs					
Animal health ($/head)	10.82	2.20	1.11	6.70	10.01
Fodder, licks and supplement ($/head)	32.75	22.7	25.94		
Levies and charges ($/head)	14.30	14.30	5.00	14.30	5.00
Freight (average $/head)	6.53	10.02	11.98	10.85	15.00
Average gross margin per adult equivalent ($/AE)	151.42	–	–	–	–

and kangaroo grass (*Themeda triandra*) (Queensland Government 2008). Suitable sown pastures include buffel grass (*Pennisetum ciliaris*), rhodes grass (*Chloris gayana*), leucaena (*Leucaena leucocepala*) and shrubby stylo (Seca) (*Stylosanthes scabra* cv. *Seca*) (Queensland Government 2008).

Narrow-leaved ironbark woodlands occur on eucalypt duplex plains and consist of narrow-leaved ironbark (*Eucalyptus crebra*), lemon-scented gum (*Corymbia citriodora*), large-fruited bloodwood (*Corymbia clarksoniana*), pink bloodwood (*Corymbia intermedia*), and ghost gum (*Corymbia dallachyana*) woodlands (Queensland Government 2008). The understorey consists predominantly of paperbark teatree (*Melaleuca fluviatilis*), quinine tree (*Petalostigma pubescens*), and red ash (*Alphitonia excelsa*). The preferred native pasture species composition includes black speargrass (*Heteropogon contortus*), kangaroo grass (*Themeda triandra*), desert bluegrass (*Bothriochloa ewartiana*), hairy panic (*Panicum effusum* var. *effusum*), and forest bluegrass (*Bothriochloa bladhii* subsp. *bladhii*) (Queensland Government (2008). The suggested suitable sown pastures are buffel grass (*Pennisetum ciliaris*) and shrubby stylo (Seca) (*Stylosanths scabra* cv.*Seca*) (Queensland Government (2008).

Land regeneration

Land condition has been defined (Chilcott *et al.* 2005) as the capacity of land to respond to rain and produce useful forage, and is also a measure of how well the grazing ecosystem is functioning. Land condition is defined within the ABCD framework ('A' and 'D' being the extremes of 'best' and 'worst').

The properties used for modelling in these case studies were assumed to be primarily in 'B' condition with a portion of the property in also 'D' condition. The degraded 'D' condition of the land was due to over-grazing and therefore had developed large scalds and erosion. The land resource base for both land types was assumed to be previously cleared but demonstrated early signs of re-growth.

Land that has declined to 'D' condition is described as requiring more than simple changes in grazing management and requires a large input of external energy to improve condition (Chilcott *et al.* 2005). The initial treatment necessary for both the land types was to deep rip and re-seed with buffel grass and shrubby stylo, applying limited gazing pressure until the pastures were established. Re-sowing quality pasture species was required as Campbell *et al.* (2006) have identified that often it is not the 3P grasses (productive, perennial and palatable) that regenerate after long periods of degradation. For each of the steady state case study scenarios the seasonal conditions were assumed to be average (long term average rainfall of 699 mm) for the Duaringa area. This assumption removes variation in the speed of land regeneration due to rainfall (Orr *et al.* 2006). It should be noted that climate variability is not accounted for in this study.

The rate of introduction of stock was based on McIvor (2001) who determined that, with re-seeding on fertile soil (such as brigalow blackbutt), the regeneration period was three or more years following a reduced stocking rate. Due to the difference in fertility of the narrow leaved ironbark woodlands, and the resulting difference in pasture growth (Chilcott *et al.* 2005), the regeneration period for narrow leaved ironbark woodlands was assumed to be over five years. The analysis assumed that as regeneration to 'B' condition was implemented management practices such as wet season spelling and fire were also used and could be managed together with stocking rates (Table 3 summarises these assumptions and the source from which they have been derived).

In order to determine the whole-property impact of land regeneration, the carrying capacity was calculated as the sum of the 'B' condition land carrying capacity and the degraded 'D' condition land carrying capacity. The carrying capacities (measured in adult equivalents) were calculated using expected pasture growth (kg/ha.year) and a carrying capacity formula (Chilcott *et al.* 2005). Table 4 summarises the impact of land degradation on the whole property carrying capacity for brigalow blackbutt, and Table 5 summarises the impact of land degradation on the whole-property carrying capacity for narrow-leaved ironbark woodlands.

It is realistic to assume that degraded areas do not fit neatly into existing paddocks, and that there are different options to manage the treatment of rehabilitated areas. The effects of management actions are summarised using two scenarios.

Scenario one: fencing and destock of degraded portion scenario

It was assumed in the 'Fencing and destock of degraded portion scenario' that the degraded area occurred in proximity of an existing watering point. The degraded area was required to be fenced off from the rest of the paddock and a new watering point installed. In the analysis the degraded area was removed from grazing for the first twelve months whilst the area was ripped and re-seeded and then a gradual re-introduction of stock occurred until it had regenerated to the 'B' condition. Where additional stock were required to be purchased to utilise the greater pasture production of the 'B' land condition, interest on additional livestock capital was charged at 6%.

The capital costs to restore the land involved ripping with a three tyned ripper approximately 6 m apart using a 120 kW D7 bulldozer at $80.46/ha, and planting buffel grass (2 kg/ha) and shrubby stylo (2 kg/ha) with the seed costing $7.00/kg and $16/kg respectively. Contract fencing per kilometre was assumed to be $5000 and one kilometre allocated to every 100 ha of degraded area. Costs of installing watering points were based on laying polythene pipe at a ratio of one kilometre for every 100 ha of degraded area. The installation of a poly tank was assumed to be $5000 and the installation of a trough was $1200. As the degraded area increased it was assumed that more than one watering point would be required.

For the brigalow blackbutt case study it was assumed that one watering point would be required for 500 ha, two watering points would be required for 1000 ha and that three additional watering points would be required for 2000 ha. The total cost per hectare was $239 for 500 ha, $239 per hectare for 1000 ha, and $236 per hectare for 2000 ha.

The narrow leaved ironbark woodlands also followed this same method of regeneration, however the treated areas were assumed to be larger. The costs per hectare were assessed at: $239 per hectare for 1000 ha, $236 per hectare for 2000 ha and $233 per hectare for 4000 ha.

Table 3. Land regeneration assumptions

Time period	Intervention	Source
	Brigalow blackbutt	
0	Deep ripped re-seed with buffel grass	Queensland Government (2008)
	Average rainfall	
		Orr *et al*. (2006)
		Campbell *et al*. (2006)
		MacLeod *et al*. (2004)
1	No stock for 12 months	McIvor (2001)
2	Stocked to a D condition stocking rate	McIvor (2001)
3	Stocked to a C condition stocking rate	McIvor (2001)
4	Wet season spelling for 6 weeks	Ash *et al*. (2002)
	Fire management	Paton (2004)
	Stocked to a B condition stocking rate	
5–20	Stocked to a B condition stocking rate	McIvor and Monypenny (1995)
	Narrow-leaved ironbark woodlands	
0	Deep ripped re-seeded with buffel grass.	Queensland Government (2008)
	Average rainfall	
		Orr *et al*. (2006)
		Brown and Ash (1996)
1	No stock for 12 months	McIvor (2001)
2	Stocked to a D condition stocking rate	Chilcott *et al*. (2005)
3	Stocked to a D condition stocking rate	
4	Stocked to C condition stocking rate	Paton (2004)
	Wet season spelling for 8 weeks	Ash *et al*. (2002)
	Fire management	
5–20	Stocked to a B condition stocking rate	

Table 4. Reduction in brigalow blackbutt property carrying capacity as the degraded area increases
Total property area is 5000 ha

Degraded area – portion of total property (ha)	0	500	1000	2000
Percentage of whole property degraded (%)	0	10	20	40
C condition(1/7.5 ha) – number of total adult equivalents (AE)	1111	1066	1020	930
D condition(1/17.38 ha) – number of total AE	1111	1029	946	782

Table 5. Reduction in narrow-leaved ironbark property carrying capacity as degraded area increases
Total property area is 10 000 ha

Degraded area – portion of total property (ha)	0	500	2000	4000
Percentage of whole property in decline (%)	0	5	20	40
C condition (1/18.25 ha) – number of total adult equivalents (AE)	932	913	855	778
D condition (1/36.5 ha) – number of total AE	932	899	800	669

Scenario two: destock entire paddock scenario

The ‘Destock entire paddock scenario’ involved the degraded area being a part of a larger paddock. The degraded area of the paddock was restored by completing the re-seeding. A consequence of this is no additional fencing or watering point costs but an opportunity cost is borne of excluding grazing from the whole paddock whilst pasture is getting established. Where stock could not be accommodated elsewhere in the property they were sold in the first year and repurchased when the land had regenerated. As additional stock were purchased over the original stocking level, interest on the additional livestock capital required was charged at 6%. The portion of the paddock in degraded condition differed for the two land types to reflect the property size. The ratio of degraded land to the rest of the paddock is tabulated in Table 6.

Due to the whole paddock being taken out of production there is a decreased capital expenditure for both land types. The capital costs per hectare are $126 for the ripping and re-seeding. However, the income forgone in opportunity cost varies between the two land types as the carrying capacity, and gross margins differ. Figure 2 provides an overview of the case study components for the analysis.

Economic analysis

An economic analysis of the private trade-offs was undertaken using an investment analysis. This methodology determines if the

Table 6. Portion of larger paddock degraded scenario areas

Brigalow blackbutt			
Area of entire paddock (ha)	1000	2000	2500
Area of paddock degraded (ha)	500	1000	2000
Percentage of paddock degraded (%)	50	50	80
Narrow-leaved ironbark woodlands			
Area of entire paddock (ha)	2000	3000	5000
Area of paddock degraded (ha)	1000	2000	4000
Percentage of paddock degraded (%)	50	67	80

accumulated marginal benefit over a number of years is sufficient to cover the initial capital cost of the improvement once discounted. The investment criterion was taken over 20 years, and a 6% real discount rate was applied. The 20 year time period is the estimated time that one manager or owner will maintain control of the property to reap any benefits or costs of land condition improvement. A discount rate ensures that future benefits or costs are translated into today's current dollar value. The discount rate was chosen as it represents an approximation of the real discount rate in Australia over the previous three years. The net present value (discounted stream of future benefits and costs) can be interpreted as the estimated return or loss that is reaped from the investment in today's dollar terms (Sinden and Thampapillai 1995).

An investment analysis has been undertaken to determine if the increases in gross margin as land condition is improved are sufficient to cover the costs associated with changing management practices. The investment analysis framework implicitly accounts for the opportunity cost of the decision by comparing the net economic returns of improving land condition ('D' condition) to the status quo ('B' condition). This accounts for the generally large initial capital costs associated with regenerating land, interest on changes of capital as stock are either sold or purchased to meet stocking requirements, and the smaller but longer term benefits of the change (improved carrying capacity) over the life of the investment. The result is the net present value (NPV) of future cash flows, and provides decision makers with a profitability indicator for selecting investments from an economic perspective. The net present values calculated in this research account for the differences in whole property gross margin, capital and annual costs incurred in moving to the new management class. The net present value is calculated by Sinden and Thampapillai (1995) as:

$$NPV = (B_0 - C_0) + (B_1 - C_1)/(1+i)^1 + \cdots + (B_t - C_t)/(1+i)_t/(1+i)^t \quad (1)$$

where, B_0 = initial benefit, C_0 = initial cost, B_t = benefit year $t = 1...20$, C_t = cost, t = year 1...20, i = interest rate.

A positive NPV implies that the investment earns a rate of return in excess of the opportunity cost of capital, and the business will be better off over the period of analysis. Conversely, a negative NPV for an investment indicates that the business will be worse off if the investment is made.

A benefit cost ratio was also calculated to determine the most desirable investment. This criterion examines the interaction between the discounted benefits and costs. When the ratio is greater than one the investment provides a net gain and is desirable. Therefore, when the ratio is less than one the investment is not viable (Sinden and Thampapillai 1995). The benefit cost ratio (BCR) can be expressed as:

$$BCR = B_0 + B_1/(1+i)^1 + \cdots + B_t/(1+i)^t/C_0 + C_1/(1+i) \quad (2)$$

To further understand the complexities of land regneration, sensitivity analysis was undertaken for variation in the discount rate and the gross margins. These two parameters were selected due to the variability that exists affecting the viability of the investment. The discount rate was varied from 4% through to 10% with 1% incremental changes. The effect of changing cattle prices was reflected by increasing and decreasing the gross margins by 5% and 10% increments.

The model was run for the two land types and the two management actions across three degraded areas. Sensitivity testing was then applied to each of these 12 treatments.

Results

Brigalow blackbutt

Fencing and destock of degraded portion results

Brigalow blackbutt has a positive NPV for treatment and regeneration of all areas (Table 7). If a land holder regenerates the portion of land in 'D' condition to 'B' condition using the

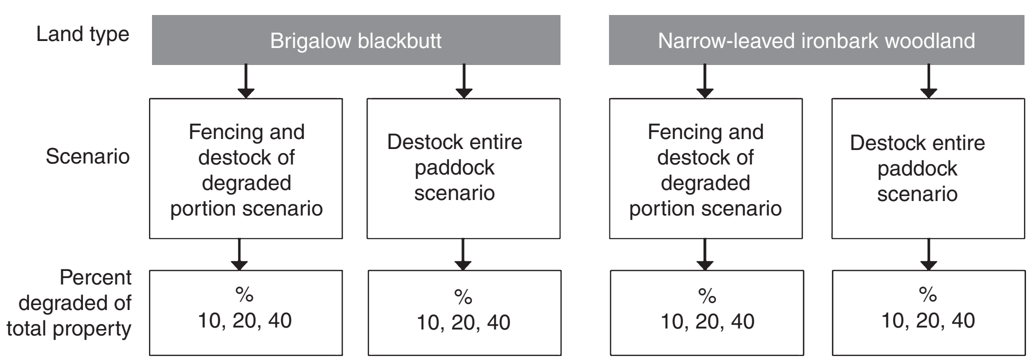

Fig. 2. Overview of the case study components for the analysis.

assumed capital costs, the investment would return $22502 for 500 ha regenerated, $45005 for 1000 ha, and $96210 for 2000 ha (Table 7). The BCRs were 2.26, 2.26 and 2.29 for 500 ha, 1000 ha and 2000 ha respectively, indicating that the benefit over time is sufficiently large to cover the initial capital costs. Based on this criteria land regeneration using this method is a viable investment option.

Destock entire paddock results

The regeneration method used in the destock entire paddock scenario involved part of the paddock beginning in 'D' condition. This part of the paddock was treated with ripping and re-seeding and the whole paddock removed from production.

Brigalow blackbutt yielded a positive NPV for all areas to be regenerated with an equal BCR of 2.71 for 500 ha and 1000 ha scenarios (Table 7). The 2000 ha scenario yielded a positive NPV of $208797 and a BCR of 3.57. In this particular case the area degraded was 80% of the paddock and therefore the production gains were more significant than the 500 ha and 1000 ha scenarios making the NPV and BCR higher.

Narrow leaved ironbark woodlands

Fencing and destock of degraded portion results

The analysis for the narrow-leaved ironbark woodlands do not result in any positive returns for any of the areas to be regenerated under the fencing and destock of degraded portion scenarios. This is due to the high investment cost in the regeneration process and the low productivity gains that are achieved. The time taken for the regeneration process to occur also hinders achieving positive returns. For 1000 ha to be regenerated there in a loss incurred of $150565 and a BCR of 0.73, for 2000 ha and 4000 ha the net present value was –$294931 and –$577462 respectively and with BCR's of 0.74 and 0.75 (Table 8). This indicates that it is a poor investment decision for the landholder to undertake such an investment.

Table 7. Results for brigalow blackbutt

Scenario	Area of paddock degraded (ha)		
Fencing and destock of degraded portion	500	1000	2000
Net present value	$22 502	$45 005	$96 210
Benefit cost ratio	2.26	2.26	2.29
Destock entire paddock			
Net present value	$21 748	$43 495	$208 797
Benefit cost ratio	2.71	2.71	3.57

Table 8. Results for narrow-leaved ironbark woodlands

Scenario	Area of paddock degraded (ha)		
Fencing and destock of degraded portion	1000	2000	4000
Net present value	–$150 565	–$294 931	–$577 462
Benefit cost ratio	0.73	0.74	0.75
Destock entire paddock			
Net present value	–$96 306	–$148 713	–$253 526
Benefit cost ratio	0.53	0.81	0.03

Destock entire paddock results

The entire destock scenarios also generate negative returns, due a culmination of the capital cost required for regeneration, and the opportunity cost of destocking for an extended period of time. The NPV for 1000 ha was –$98463 with the NPV's for 2000 ha and 4000 ha –$153027 and -$262156 respectively. The BCR for the narrow leaved ironbark woodlands was 0.61 for 1000 ha, 0.89 for 2000 ha and 0.11 for 4000 ha (Table 8), indicating that in this case land regeneration would be a poor investment choice.

Sensitivity testing

The sensitivity testing for the discount rate in the case of brigalow blackbutt indicated that with a discount rate of 8% and higher, it is not a viable investment for the fencing and destock of a degraded portion scenario. This trend was not continued for the destock entire paddock scenario where at 8% it is a viable option for any scenario area (Table 9). Price sensitivity was also explored for the additional cattle purchased which had interest on livestock capital of 6% (Table 10) indicating that for the fencing and destock of degraded portion scenario a decrease in cattle prices by 10%

Table 9. Net present value results for discount rate sensitivity testing for brigalow blackbutt

Sensitivity testing Discount rate (%)	Area of paddock degraded (ha) 500	 1000	 2000
	Fencing and destock of degraded portion scenario		
4	$54 070	$108 141	$222 482
5	$37 245	$74 490	$155 180
6	$22 502	$45 005	$96 210
7	$9543	$19 086	$44 372
8	–$1886	–$3772	–$1344
	Destock entire paddock scenario		
4	$49 853	$99 707	$328 652
5	$34 787	$69 574	$264 612
6	$21 748	$43 495	$208 797
7	$10 438	$20 876	$160 014
8	$608	$1217	$117 256

Table 10. Net present value results for price sensitivity testing for brigalow blackbutt

Sensitivity testing Price change (%)	Area of paddock degraded (ha) 500	 1000	 2000
	Fencing and destock of degraded portion scenario		
–10	–$1688	–$3377	–$553
–5	$6562	$13 124	$32 447
0	$14 812	$29 624	$65 448
5	$23 062	$46 124	$98 449
10	$31 312	$62625	$131 450
	Destock entire paddock scenario		
	500	1000	2000
–10	–$1448	–$2895	$116 016
–5	$6463	$12 926	$147 659
0	$14 374	$28 748	$179 301
5	$22 284	$44 569	$210 944
10	$30 195	$60 390	$242 587

would result in the investment still being viable. For the destock entire paddock scenario when there is a 10 percent decrease in price all scenarios continue to yield a positive return.

In the case of the narrow leaved ironbark woodland the sensitivity testing of the discount rate and the gross margin indicated due to the land types' inherently low productivity the benefit of regeneration even with a 4% discount rate or with a gross margin increase of 10% was insufficient to cover the capital cost required (Tables 11 and 12).

Discussion

This analysis has explored the net private benefit of regenerating land condition in grazing enterprises from 'D' condition to 'B' condition. This then allows the most efficient mechanism to be identified for land regeneration to improve land condition resulting in improved water quality. The results highlight the complexity of the issue and the heterogeneity that exists across the Fitzroy Basin both in biophysical aspect but also in relation to regeneration methods and property characteristics.

The results of this analysis indicate that the inherit productivity of the land type both in the time period for regeneration and in the enterprise operation impact significantly on the results. For land regeneration in narrow-leaved ironbark woodlands there are further ecological and therefore economic challenges. The low inherent productivity demonstrated through longer regeneration time periods and low gross margins resulted in all scenarios yielding a negative return. This indicates that there is no private incentive for the landholder to undertake land regeneration.

The results from the brigalow blackbutt study indicate that land regeneration is an economically feasible option for landholders whilst using a 6% discount rate. With both management scenarios yielding positive returns it indicates that such an investment by a landholder would be economically viable and yield positive returns for all areas required to be regenerated. However, benefit cost ratios and sensitivity testing demonstrated that in some cases net private returns are negative, highlighting the importance of assessing scenarios individually.

The positive NPV for brigalow blackbutt land suggests that targeting funding towards extension and education activities to increase the awareness and understanding of land restoration economics is likely to achieve the greatest results in sediment reduction at least cost to society. The positive net present value achieved for large areas indicates that it is in the landholder's best interests economically to restore land, and therefore education and awareness is the most efficient method to achieve sediment reductions. However results may also be sensitive to transaction costs such as engagement, learning, social and implementation costs. These costs have not been accounted for in this analysis but should be considered further before an extension program is designed to increase participation of landholders (Pannell 1999).

The narrow-leaved ironbark woodlands involve greater financial challenges for the landholder to undertake land restoration under their own initiative. The results of this economic analysis also support the findings of Northup *et al.* (2005) that it may not be economically viable to regenerate eucalypt woodlands. However, if these land types offer the largest reduction in sediment runoff and therefore greatest water quality improvements, then this is where a large social benefit can be achieved. The financial challenges that the landholder face indicate that to achieve sediment reductions financial incentives may be needed.

The analysis contributes to areas of grazing economics where limited literature has been published on the economic options available in grazing to land holders. Some limitations of the study are recognised. Firstly, the difficulty in matching the biophysical information from previous studies with the economic assumptions to complete the analysis has been challenging. The deficiencies in the study are found in the inability to cover all scenarios that occur on properties and the practices in regeneration. It is acknowledged that the proposed methods of regeneration does not fit all classifications of 'D' condition land and that it may not be always possible to undertake the proposed methods to ensure that land regeneration does occur. However current scientific studies have been taken into account, and the assumptions used in the analysis have been matched as closely as possible to the literature to ensure that the regeneration modelling reflects these scientific findings. The analysis was undertaken assuming long term (100 years) average rainfall of 699 mm per annum; in reality rainfall variability

Table 11. Net present value results for discount rate sensitivity testing for narrow-leaved ironbark woodlands

Sensitivity testing Discount rate (%)	Area of paddock degraded (ha) 500	 1000	 2000
	Fencing and destock of degraded portion scenario		
4	–$129 572	–$252 943	–$493 487
5	–$140 775	–$275 350	–$538 300
6	–$150 565	–$294 931	–$577 462
7	–$159 148	–$312 096	–$611 793
8	–$166 695	–$327 190	–$641 980
	Destock entire paddock scenario		
4	–$81543	–$116 253	–$185 673
5	–$90 670	–$136 002	–$226 666
6	–$98 463	–$153 027	–$262 156
7	–$105 122	–$167 732	–$292 953
8	–$110 816	–$180 457	–$319 740

Table 12. Net present value results for price sensitivity testing for narrow-leaved ironbark woodlands

Sensitivity testing Price change (%)	Area of paddock degraded (ha) 500	 1000	 2000
	Fencing and destock of degraded portion scenario		
–10	–$159 395	–$312 590	–$612 780
–5	–$154 980	–$303 760	–$595 121
0	–$150 565	–$294 931	–$577 462
5	–$146 151	–$286 102	–$559 803
10	–$141 736	–$277 272	–$542 144
	Destock entire paddock scenario		
–10	–$106 943	–$169 988	–$296 076
–5	–$102 703	–$161 507	–$279 116
0	–$98 463	–$153 027	–$262 156
5	–$94 223	–$144 547	–$245 196
10	–$89983	–$136 067	–$228 236

(increasing with the impacts of climate change) will add additional complexities to the analysis which are not reflected in the results presented here.

To undertake more detailed analysis of the biophysical and economic trade-offs that occur with land regeneration the key variables required to be developed further are: a sediment export rate for particular land types, further scientific biophysical details on time frames for regeneration and the actual methods for land regeneration. In order to complete further analysis on other land types in other geographical locations further data collection would be required.

The impact of poor land condition on animal production has also not been accounted for. The impact on liveweight gain mortality and branding rates were assumed to remain constant as land transitioned from 'D' condition to 'B' condition. Only total stock numbers were adjusted to reflect production changes. It would be expected that animal production factors would be negatively affected on as land condition decreases but there has been limited research into the impacts of land condition and the production changes that occur (Ash and Stafford Smith 1996; Ash *et al.* 2002; O'Reagain *et al.* 2009; Paton 2004).

Conclusion

The economics of regeneration for two land types in the Fitzroy Basin were explored using two case studies. The results suggest that the most efficient method of achieving sediment reductions from brigalow blackbutt would be through extension and education activities as regeneration of land offers a positive investment decision. However landholders on narrow leaved ironbark woodlands are faced with financial barriers to undertake land regeneration, indicating that policies to reduce sediment exported will need to address the negative financial incentives involved. The results of both case studies show that policies to improve water quality into the Great Barrier Reef need to consider the variation in economic tradeoffs across different land types and management actions to be effective. The results of this research highlight the need for further biophysical work on land regeneration and for further research on the economic and environmental trade-offs facing landholders.

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