Managing ground cover for economic and sustainability outcomes on grazing lands in the Great Barrier Reef Lagoon catchments.

Literature Review

2019

Queensland Government

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Executive summary

This literature review identifies information regarding the interaction between grazing land management (GLM) practices, ground cover and economic outcomes. The review focuses on research conducted in northern Australian rangelands and specifically, the Great Barrier Reef lagoon (GBRL) catchment areas. It is limited to publically available peer reviewed journal papers and reports by government and industry research bodies. The aim of this review is to expand on information contained in the report "Understanding the economics of grazing management practices and systems for improving water quality run-off from grazing lands in the Burdekin and Fitzroy Catchments" (Moravek, et al., 2016) about the economic implication of adopting management practices that improve ground cover.

The review identified the following papers relevant to each section:

- Ground cover and sediment runoff: seven (7) studies. The studies examine the relationship between ground cover levels and associated runoff and/or sediment concentration in runoff from grazing land.
- Grazing land management (GLM). These studies identify (where possible) relationships between specific GLM practices, ground cover and/or land condition and economic outcomes.
    - stocking intensity: 14 studies
    - wet season spelling: seven (7) studies
    - mechanical intervention: six (6) studies

The findings and gaps identified from the review include:

- The available literature supports the claim that deteriorating ground cover is contributing to increased sediment and nutrient runoff to the GBRL.
- Results of several trials establish decreased sediment concentration and increased infiltration rates associated with increasing ground cover levels.
- A need to determine the relationship between ground cover and pasture quality. High levels of ground cover do not necessarily translate to high quality pastures.
- There is limited published trial data to support animal productivity and pasture response assumptions necessary for the bio economic modelling of management strategies such as wet season spelling.
- Minimal data is available around the economics of changing between strategies such as high intensity stocking and sustainable grazing practices.

Table of contents

Table of figures

Table of tables

1 Report Purpose and Scope

The purpose of this literature review is to expand on information contained in the report "Understanding the economics of grazing management practices and systems for improving water quality run-off from grazing lands in the Burdekin and Fitzroy Catchments" (Moravek, et al., 2016) about the economic implication of adopting management practices that improve ground cover. However, Moravek *et al*. (2016) reviewed broader land condition studies; whereas this literature review focuses on only one aspect of land condition – ground cover. Ground cover is seen as an important management tool due to the relative ease (compared to monitoring land condition) of viewing ground cover data across extensive grazing properties.

The grazing land management practices reviewed by Moravek *et al.* (2016) were those found in the Paddock to Reef (P2R) Water Quality (WQ) Risk Framework (Queensland Government, 2014). The performance indicators and practices of the P2R WQ Risk Framework relevant to that review are in Table 1.1. This review also seeks to update information with respect to the new P2R WQ risk framework (Table 2.1) which has changed since Moravek *et al.* (2016) conducted their review.

Table 1.1 - Paddock to Reef Water Quality Risk Framework (Excerpt from (Moravek, et al., 2016)

	Indicators & Associated Practices
Hillslope	**Performance Indicator 1:** Average stocking rates imposed on paddocks are consistent with district long-term carrying capacity benchmarks for comparable land types, current land condition, and level of property development
	Performance Indicator 2: Retention of adequate pasture and groundcover at the end of the dry season, informed by (1) knowledge of groundcover needs and (2) by deliberate assessment of pasture availability in relation to stocking rates in each paddock during the latter half of the growing season or early dry season.
	Performance Indicator 3: Strategies implemented to recover any land in poor or very poor condition (C or D condition).
	Performance Indicator 4: The condition of selectively-grazed land types is effectively managed

The scope of the review has a focus on research conducted in northern Australian rangelands and specifically, the catchments draining into the Great Barrier Reef lagoon (GBRL), where possible. It is further limited primarily to peer reviewed journal papers and reports by government and industry research bodies. A brief summary is provided on the biophysical importance of the different practices with respect to sediment runoff; however, the focus of this report is to identify economic outcomes of adopting grazing land management practices that improve ground cover.

Lastly, the review will identify gaps in knowledge and data that limit understanding of the economic implications of improving ground cover on grazing lands in the GBRL catchments.

2 Background

Grazing is the dominant land use in the GBRL catchments, covering approximately 75% of the total area (Waters, et al., 2014). The Whole of GBR Technical Report (Waters, et al., 2014) identifies that the Burdekin and Fitzroy natural resource management (NRM) regions are responsible for ~70% of the modelled total suspended sediment load into the GBRL and that ground cover is one of the most important factors affecting sediment runoff from hillslope erosion. Ground cover was defined as the percentage of ground covered by plant material and litter (Roth, et al., 2004). Without cover, rain cannot be intercepted and slowed prior to becoming an erosive force, stripping away unstable topsoil (McIvor, et al., 1995). A study in the Burdekin catchment found that sediment export to the coast has increased by five times the natural rate (pre-European loads ~1875 to 2545 kilo tonnes per year (Kroon, et al., 2013)) and approximately 85% of this load originates from only 10% of the land (Roth, et al., 2003).

Keeping sufficient ground cover through an established palatable pasture base is vital for stabilising soil and improving grazing productivity (Phelps, et al., 2011). An increased flow of sediment and nutrients off grazing land can negatively affect water quality, the health of marine ecosystems and productivity of commercial fisheries breeding grounds. From a grazier's perspective, excessive runoff can mean losing valuable nutrients and water from pasture, and consequently affecting the potential productivity of the land. (Roth, et al., 2003).

To address the issues of low groundcover, the current Reef 2050 Water Quality Improvement Plan (2017-22) has a target of 90% of grazing lands having greater than 70% ground cover at the end of the dry season (The State of Queensland, 2018). To achieve this target, the current Paddock to Reef (P2R) Water Quality Risk Framework (Queensland Government, 2019) for the grazing industry uses weighted performance measures, one of which states that properties need ground cover above 75%, in any one year, to be rated as a low water quality risk, this measure has a 30% weighting for Hillslope management. (Table 2.1)

Table 2.1 - P2R risk water quality grazing framework

Hillslope (pasture) management	Lowest risk (A)	Moderate – Low risk (B)	Moderate risk (C)	High risk (D)
Ground cover thresholds are monitored and objectively managed to inform paddock management and used to inform SR and pasture management decisions. (30%)	**Annual ground cover thresholds are maintained at >75% across the whole property**v. Forage budgets as per the GLM, Stocktake, grazing charts or equivalent process are undertaken on a seasonal basis in each paddock to monitor ground cover changes and the density of 3P pasture species. Ground cover trends and	**Annual ground cover thresholds are maintained at 70-60% across the whole property**. Forage budgets as per the GLM, Stocktake, grazing charts or equivalent process are undertaken on a seasonal basis across the property to monitor ground cover changes and the density of 3P pasture species. Any	**Annual ground cover thresholds are maintained at <60% across the whole property**. Forage budgets as per the GLM, Stocktake, grazing charts or equivalent process are undertaken on an annual basis in most paddocks to monitor ground cover changes and the density of 3P pasture species. Changes are rarely used to	**Annual ground cover thresholds are maintained at <50% across the whole property**. No form of forage budgeting is undertaken.

	changes are monitored using FORAGE or VegMachine. Any changes are used to inform stocking rate.	changes are used to inform stocking rate.	inform stocking rate.	

Source: (Queensland Government, 2019)

Ground cover is a subcomponent of land condition. Land condition is defined as the capacity of grazing land to respond to rain and produce useful forage and is assessed in terms of soil and pasture condition (Ash, et al., 2002). In grazing lands, land condition is usually measured under the ABCD land condition framework (Table 2.2), with 'A' being highest condition and 'D' being lowest condition (Chilcott, et al., 2005). However, high ground cover can be due to less desirable pasture species such as Indian Couch (*Bothriochloa pertusa)*, potentially resulting in lower land condition rating.

Table 2.2 - Land condition classes as per GLM modules (Excerpt from (Bartley, et al., 2014))

Class	% organic cover at end of dry season	% 3P grasses[A]	General conditions	Risk of erosion
A	50–70%	>80%	Good coverage of 3P grasses, good soil condition, low erosion and no woodland thickening	Low
B	40–50%	60–80%	Decline in 3P grasses, signs of erosion, low amounts of woodland thickening	Moderate
C	20–40%	10–60%	Large amounts of less preferred species, high erosion, woodland thickening occurring	Moderate-High
D	<20%	<10%	Lack of perennial grasses/forbs, severe erosion and scalding, presence of woody vegetation	High

As ground cover is only one facet of land condition, there is only broad agreement between the two and notable exceptions exist. For instance, a nine (9) year study across 24 properties (Bastin, et al., 2012) investigating land condition (from expert judgement) and seasonally adjusted ground cover (from remote sensing) found two (2) properties to have declined in land condition had maintained ground cover and four (4) properties with improving land condition demonstrated no improvement in ground cover. The study concluded that there was good agreement between groundcover and land condition when land condition was stable, however, little to no agreement was apparent with ground cover for properties recorded to improve or decline land condition during the study. Furthermore, a report to Reef Rescue Research and Development (Beutel, et al., 2014) stipulates that short-term ground cover levels relate to land condition class; however, the ability to discriminate between classes using cover is limited at the higher end of the spectrum. This is due to the inability of cover level to determine pasture composition, which is a major component of land condition differentiation.

Figure 2.1 - The land degradation cycle (Excerpt from (Passmore & Brown, 1991))

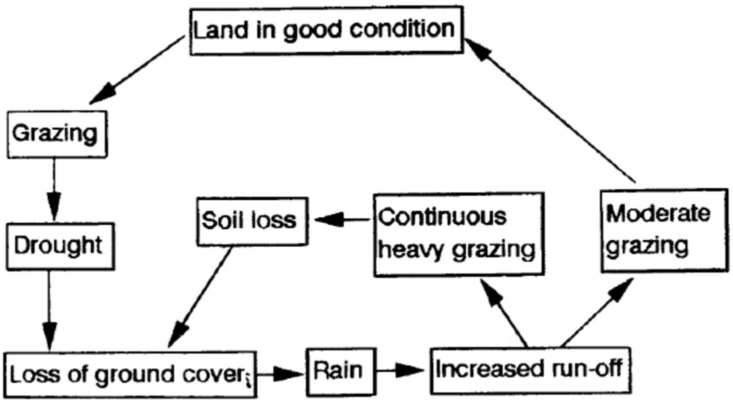


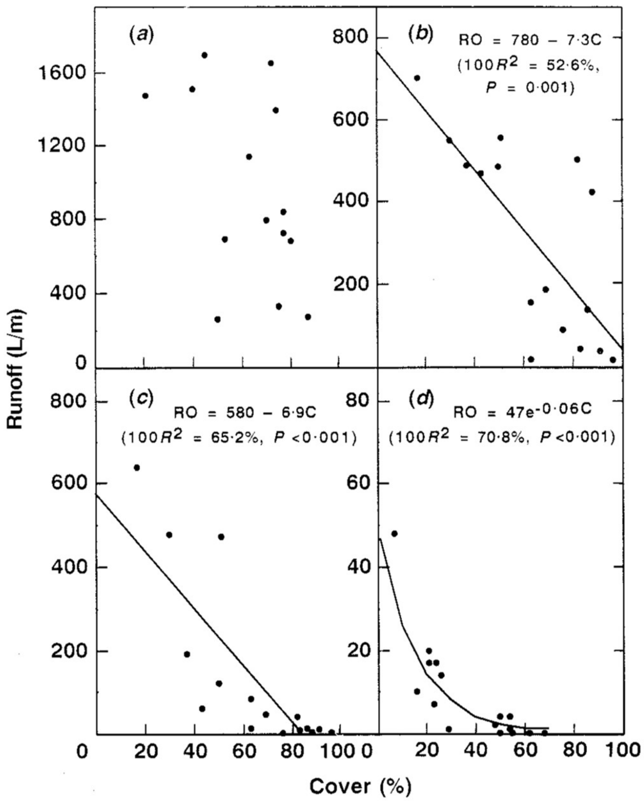
Figure 2.1 illustrates the basic cycle of land condition maintenance or degradation brought about by grazing strategy and variable climate. While the environmental implications of changing land condition are well understood across a number of land types, the economic results of moving from one land condition to another are not as consistent (Moravek, et al., 2016). This is because the result is largely dependent on the specific combination of circumstances; current condition, scale of degradation, land type, target condition state, the costs and benefits of moving to a different land condition and the resources available to the land manager.

3 Ground cover & sediment runoff

This section examines literature related to ground cover and sediment runoff from grazing lands in northern Queensland.

McIvor *et al.* (1995) studied the relationship between pasture management, runoff and soil movement on a site near Charters Towers. The replicated trial results show that ground cover is the pasture characteristic most closely correlated to runoff and soil movement. It concludes that the influence of cover on runoff depends on the size and intensity of the rainfall event. As seen in Figure 3.1, runoff declines with increasing cover over all rainfall events except for during the heaviest rainfall intensities (greater than 45mm/h). For rainfall events with less than 50mm total and less than 15mm/h intensity, cover levels of 40% are sufficient to reduce runoff to low levels. For higher intensity, large rainfall events, higher cover levels are necessary to reduce runoff. In very intense events, the volume of water can entirely exceed the infiltration capacity of the soil, irrespective of cover level.

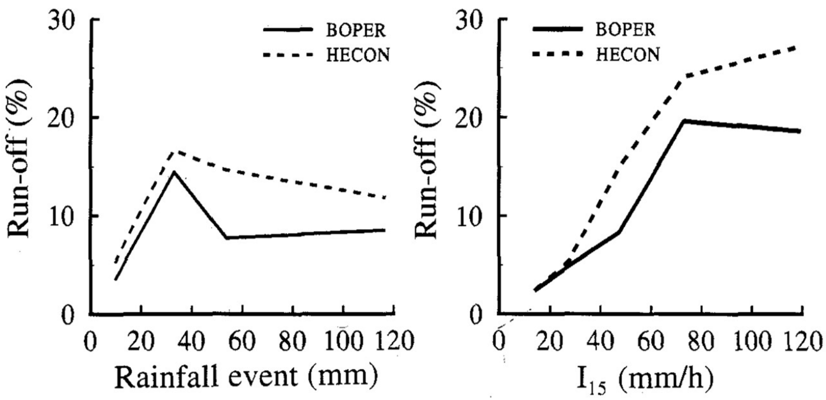
Figure 3.1 - Cover runoff relationship (Excerpt from (McIvor, et al., 1995))



Scanlan *et al.* (1996) conducted a study measuring runoff and soil movement on grazed woodlands in Charters Towers and Greenvale over five (5) years. The results were similar to McIvor *et al.* (1995), demonstrating that runoff increased linearly with rainfall intensity and decreased linearly with cover level. With rainfall extremes (greater than 75mm or less than 10mm), cover has little effect on runoff. This study also reveals a relationship between pasture species and runoff. The sites were dominated by one of either; the naturalised *Bothriochloa pertusa* (Indian couch), or native perennial tussock grasses, principally *Heteropogon contoutus* (black speargrass).

At a low rainfall intensity, pasture species has no effect on runoff (Figure 3.2). At rainfall intensities greater than 30mm/h, the black speargrass pasture produced more runoff than the Indian couch pasture. Scanlan *et al.* (1996) notes the differences exist even at the same ground cover level, an outcome that identifies pasture species as a further caveat to the cover and runoff relationship initially demonstrated by McIvor *et al.* (1995). It postulates that Indian couch's stoloniferous[1] cover distribution allows for better surface detention than the tussocks of black speargrass's (Scanlan, et al., 1996). This result is in contrast to other studies that show native tussock grass species root structure is capable of providing deeper infiltration than stoloniferous species, which may result in less runoff (Jackson & Ash, 1998; Roth, et al., 2004). Additionally, Bartley *et al.* (2010) and Bartley *et al.* (2009) consider recovered pasture dominated by Indian couch as fragile due to its low biomass relative to other native pasture species.

Figure 3.2 - Runoff & pasture species (Excerpt from (Scanlan, et al., 1996))



The effect of pasture type (BOPER – Indian couch; HECON – black speargrass) and rainfall event size (mm) or intensity (mm/h) on runoff percentage (%).

In 1999 (O'Reagain, et al., 2005), a trial to measure nutrient loss and water quality was established at the Wambiana grazing trial near Charters Towers. It monitored five (5) one (1) hectare (HA) catchment plots, on sedimentary landscapes, under different grazing strategies for five (5) years. Runoff from sediment traps was measured, along with samples from rivers and creeks surrounding the trial site, during runoff events. There were 10-12 runoff events per site during the experimental period, despite there being rainfall exceeding 40mm on 23 occasions. O'Reagain *et al.* (2005) attributes the small number of events to the low propensity for surface runoff in sedimentary, low slope landscapes. There was no statistically significant difference between grazing treatments in terms of percentage runoff, sediment loss or water quality over the short time period. The authors state that periods in excess of 20 years may be required to detect definitive trends in improvement of water quality runoff from grazing lands as a result of grazing management actions.

A study was conducted in the Burdekin that measured the effect of stocking rate reduction and spelling on sediment runoff from grazing land. Results were reported on after six (6) (Bartley, et al., 2010) and 10 years (Bartley, et al., 2014). The trial sites were located in the Weany Creek catchment that is part of the Dalrymple land system, characterised by the granodiorite land type and is a high erosion area. Across all three sites, pasture biomass and percentage ground cover increased under improved pasture management strategies. Flume data was collected to better understand whether yield changes were attributable to changed pasture management or temporal changes in rainfall (Bartley, et al., 2010). At the beginning of the trial, ground cover was 33-45% and pasture biomass ~60kg dry matter (DM) per hectare. After a reduction from one (1) adult equivalent

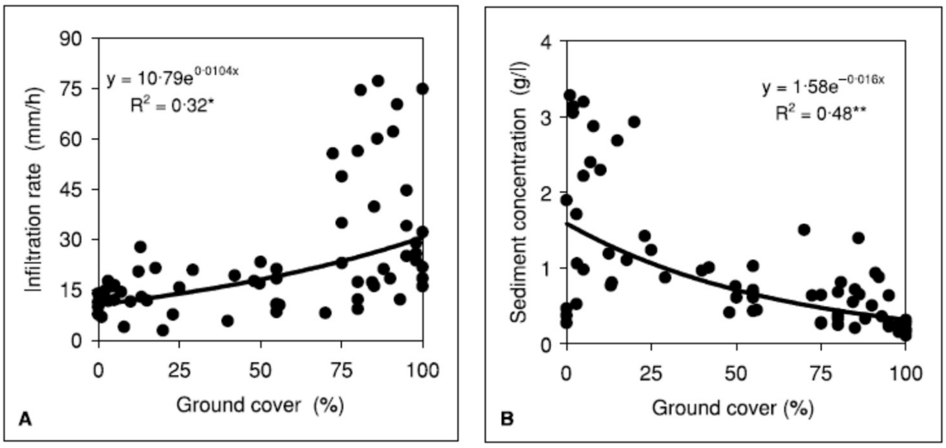
[1] Stoloniferous refers to a plant bearing stolons, which are stems growing beneath the soil surface forming roots at the nodes and new plants from the buds (commonly known as runners).

(AE) to four (4) HA (the historical stocking rate of the paddocks) to a more conservative 1AE:7-9HA for eight (8) years, groundcover was ~80% and yield >1100kg DM/HA. Pasture biomass, while increasing, was lower than expected for this landscape due to the high proportion of Indian couch that became established during the pasture recovery (Ash, et al., 2011). On two (2) of the three (3) sites, sediment yield declined (66-70%) in conjunction with increased cover (high proportion Indian couch) (Bartley, et al., 2010). This is consistent with Scanlan *et al.* (1996)'s comments on the stoloniferous nature of Indian couch, making it highly useful to recover bare soil and protect soil from erosion.

The trade-off is that animal productivity from Indian couch dominated pasture is thought to be below that of more desirable productive, perennial and palatable (3P) grasses (Ash, et al., 2011). However, findings from a trial measuring steer live weight gains (LWG) and pasture yield on native pasture compared to native pasture over sown with Indian couch (Jones, 1997) found this was not the case. The five (5) year trial, sited in eucalypt woodland 50km south-west of Townsville, found that at low stocking rates (0.3 steers/ha) there was negligible difference in LWG and yield between native and Indian couch pastures. However, at medium (0.6 steers/ha) and high (0.9 steers/ha) stocking rates, the Indian couch pasture gave higher pasture yields and steer gains, than native pastures.

A trial conducted by Roth (2004) demonstrated the effect of grazing induced soil surface condition on infiltration and runoff. Roth (2004) states that ground cover, together with near surface soil structure and soil hydrologic function, encompass soil surface condition. The six (6) sites were located on extensively grazed woodlands in the Burdekin River catchment. The soil was generally characterised by inherently low fertility, prone to compaction and crusting (key factors influencing runoff and infiltration in semi-arid savannas) with some small areas of more fertile basalt soil. Treatments were replicated two to four times per category on each site and ranged from heavily grazed to enclosed sites that had not been grazed for 15 years. In accordance with other trials (McIvor, et al., 1995; Roth, et al., 2003; Scanlan, et al., 1996) results established decreased sediment concentration and increased infiltration rates associated with increasing ground cover (Figure 3.3).

Figure 3.3 - Cover, infiltration & sediment runoff (Excerpt from (Roth, 2004))



A study using bio-economic modelling to better understand the economic implications of adopting sustainable management practices was conducted (Donaghy, et al., 2007). Using GRASP[2] (Day, et al., 1997) and spreadsheets, a representative property at Raby Creek in central Queensland was

[2] GRASP uses climate and land type data to simulate pasture growth, animal live weight gains and stocking rate for a location over a nominated time period. (MacLeod, et al., 2010)

simulated over 20 years to observe environmental and economic trade-offs from varying stocking rates on native black speargrass pasture for a range of climate sequences. The results

Table 3.1 displays the economic and sediment run off impacts of running stock at different utilisation rates with starting perennial grass condition of either 90% or 32%. For both conditions, there is an economically optimal grazing pressure as a percent of utilisation rate (60% and 40% respectively). Given that sediment export increases with utilisation rate, these results identify the opportunity cost of sediment reduction to the grazier. For example, with a 90% start condition, if the grazier changed from 60% utilisation (the profit maximising rate) to 50% utilisation the opportunity cost of the sediment saved would be ~$6,500 of profit per annum.

Table 3.1 - Economic and environmental trade-offs (Excerpt from (Donaghy, et al., 2007))

% Peren start cond	Grazing Pressure as % Utilization	Expected NPV incr rel 20% utiln	expected total sediment exported (t)	marginal increase in sediment exported (t)	Expected OPP cost per tonne sed redn	Times out of 5 terminates in State 1	Years out of 100 Pasture Condition is in State 2	Years out of 100 Pasture Condition is in State 3
90%	20%		2,110			5	0	0
90%	30%	276,060	2,749	639	$432	5	0	0
90%	40%	431,353	3,527	777	$200	5	0	0
90%	50%	539,804	4,542	1,015	$107	5	1	0
90%	60%	565,352	6,821	2,279	$11	3	17	0
90%	70%	401,276	16,287	9,467	-$17	0	39	28
32%	20%		2,388			5	1	0
32%	30%	254,143	3,099	711	$357	5	2	0
32%	40%	370,116	4,173	1,073	$108	5	7	0
32%	50%	313,344	8,189	4,016	-$14	4	24	8
32%	60%	81,343	18,293	10,104	-$23	0	59	33
32%	70%	-212,273	28,540	10,247	-$29	0	37	63

The most important application of GRASP is the simulation of pasture growth for different land types for the purpose of the calculation of safe carrying capacities applied in the GLM framework (The GRASP Modelling Team, 2010). While the model is used to predict LWG on native grass pastures of northern Australia it is unable to predict LWG from tropical legume-based pastures (Hill, et al., 2009). While GRASP gives good insights into the responses of pastures under various management practices, when put into a bio-economic model the resulting model is not as dynamic or as flexible as a real world grazing enterprise (Jones, et al., 2016).

4 Grazing land management for profitability and sustainability

The following sub-sections identify the significance of grazing land management practices relative to ground cover, with a more specific focus on reviewing literature that provides an economic outcome.

Highly variable rainfall in semiarid grazing systems causes major fluctuations in annual forage growth (Ash, et al., 2011; O'Reagain, et al., 2011). Responsive grazing management is therefore integral to sustaining the long-term productivity and health of grazed rangelands. Grazing as a land use covers over 3.2million km^2 of rangelands (McKeon, et al., 2004) in Australia and much of this area has been, and will be, periodically affected by drought. Excessive grazing pressure together with below average rainfall in the growing season, results in loss of perennial grasses (McKeon, et al., 2004). 3P grasses are the native grasses preferred by cattle that tend to decrease in abundance under heavy utilisation (Ash, et al., 2002). Loss of vegetation cover from heavy grazing leads to soil erosion and further pressure on the remaining pasture (Scanlan, et al., 1994). Once damaged, perennial root systems require above average rainfall and lower grazing pressure to recover. Pastoral managers have the ability to prevent or accelerate pasture degradation and promote or inhibit its recovery through day-to-day decisions (McKeon, et al., 2004)

There are many factors that contribute to degradation of pasture and thus numerous strategies to manage for sustainability, under expected rainfall variability, in semiarid grazing lands. Practices recommended to manage ground cover and/or land condition include; conservative stocking strategies, pasture resting, prescribed burning, mechanical intervention or property development with strategic fencing and water points (Hunt, et al., 2014; Phelps, et al., 2011). However, there is little data on the economic viability of sustainable grazing practices relative to short-term, profit maximising management practices that are often less sustainable in nature such as continuous, heavy utilisation rates (O'Reagain, et al., 2011). For degraded land in either C or D condition, strategies for rehabilitation tend to involve exclusion and/or mechanical intervention rather than simple changes to grazing land management (Phelps, et al., 2011; Star, et al., 2011).

4.1 Stocking intensity

Continuous, year-long grazing over extensive paddocks has been the traditional stocking method used throughout history (McKeon, et al., 2004). This management style, when applied with little consideration to timing and extent of destocking during dry seasons, has caused degradation of grazed landscapes in northern Australia (Hall, et al., 2014; McKeon, et al., 2004). A theoretical relationship, between animal production and stocking intensity, is given by Rose (1998) which suggests that as stocking rate increases, animal production per head and production on a per area basis both initially increase. If stocking rates continue to increase, per head productivity eventually peaks and begins to fall although per area production may continue to increase. Eventually, as stocking rates increase further, production per head and per unit area will both decline. At lower stocking rates, individual animal performance is maximised, however, total production is depressed due to the low production per unit area.

The main continuous grazing strategies include:

- Moderate to light stocking, which is calculated at long term carrying capacity (LTCC), or 15-30% utilisation, depending on the land type.

- Heavy stocking rate usually at twice the LTCC (O'Reagain & Bushell, 2011).
- Variable stocking that matches stocking rate to seasonal forage supply, targeting a certain utilisation rate of available standing pasture where there is usually one or two key points in the year where numbers are adjusted.
- Rotational grazing that uses a more intensive system of smaller paddocks and rotates stock through the system. (Hall, et al., 2014; O'Reagain, et al., 2014).

Increasing concern about land degradation led to a study in the Dalrymple Shire (Hinton, 1995) which collected and analysed 10 years of financial and ecological data. The aim was to observe interactions between property management (particularly stocking rate), ecological resources and business profitability. The study did find significant correlations between soil condition and soil productivity and gross margins however, the authors suggest it was imprudent to infer a notable cause and effect relationship between ecological measures of land condition and livestock or financial performance. Further to this, inherent soil fertility is difficult to change at extensive scales. Finally, the study did discern a significant correlation between degradation of resources at the property size and some low performing properties (Hinton, 1995).

In subtropical Queensland (Mundubbera, Burnett Mary catchment), a five (5) year grazing trial aimed to quantify the relationship between stocking rates, animal productivity, economic returns and pasture stability (MacLeod & McIntyre, 1997). Steers were run continuously in native pasture oversown with legumes at four (4) stocking rates ranging from very low (0.15 steers/ha) to high (0.9 steers/ha). There was no statistically significant relationship between stocking rate and legume/land condition interaction. The results documented an increase in total productivity per hectare grazed with increased stocking rates, while, individual animal productivity was maximised at lower stocking rates. The moderate stocking rate (0.6 steers/ha) returned the highest economic returns overall.

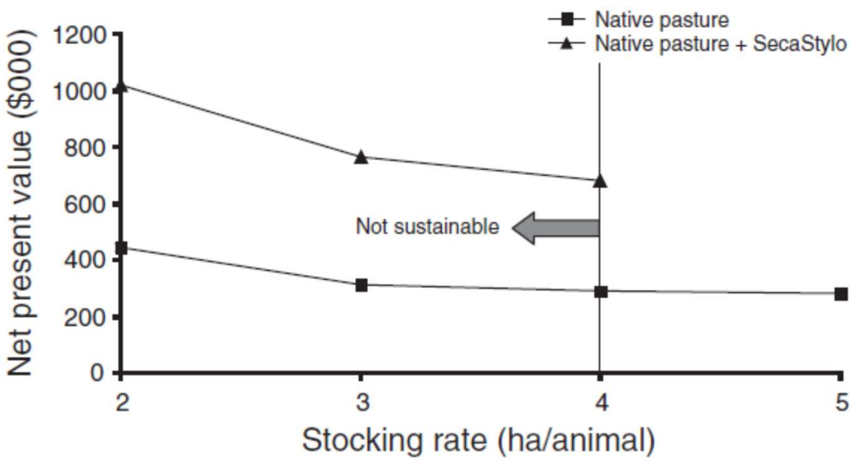
More recently, a comprehensive study of 18 beef business in the northern Gulf (Rolfe, et al., 2016) aimed to shed light on the social and economic drivers of management decisions. Results identified one third of the sample proactively manage stocking strategy and routinely spell grazing land. These businesses were also characterised by high average equity (92%). The study suggested that businesses with low profitability and poor equity appeared to be more inclined to overstock. General observations drawn from the analysis were that those in a good financial position tend to have adopted more sustainable stocking practices in order to maintain land condition, and those with significant financial pressure found destocking decisions unfeasible. However, there was not a significant relationship between land condition and financial position in the analysis (Rolfe, et al., 2016).

Management goals are a driver of stocking strategy. Teague *et al.* (2009) simulated the economic and ecological effects resulting from three alternative management goals using continuous grazing in semi-arid savannah rangelands. The goals included; maintaining current rangeland condition, and maximising profit or improving rangeland condition over 30 years. It was found that maximum short and long term profit is attained at higher stocking rates than would maintain rangeland condition and significantly higher than would recover condition. There is an opportunity cost incurred with the lighter stocking rates required for maintaining/recovering rangeland condition. This is due to reduced livestock production lowering per property profitability.

Bowen and Chudleigh (2018) modelled the interaction of varying grazing pressure and land condition combinations on animal performance and whole of business profitability for a representative buffel grass, steer turnover enterprise in central Queensland over 30 years. Similarly to Teague *et al.,* (2009), there was a significant economic advantage ($21/ha - $47/ha per annum) to increasing grazing pressure (30% increasing to 50% utilisation), even in instances where the strategy was likely to cause individual animal productivity and or land condition to decline.

The Galloway Plains stocking rate trial (Burrows, et al., 2010) measured steer live weight gains in an extensive grazing study on black speargrass pasture in coastal Central Queensland. Animal supplementation, sowing of legumes and a range of stocking rates were the main treatments studied. The net present values (NPV's) calculated from the animal production data over 13 years are given in Figure 4.1.1. Annual LWG's per head were higher at lighter stocking rates, however, with increased stocking rate LWG per hectare also increased. Similar to other studies, this result drives profit maximising returns at high stocking rates despite the potentially damaging effects on pasture quality (Bowen & Chudleigh, 2018; Burrows, et al., 2010; Teague, et al., 2009). The addition of legumes to the native pasture produced consistently higher LWG (20-60 kg/hd) and the greatest economic returns across all treatments (Figure 4.1.1). The authors conclude that, despite the increased returns from high stocking on both pasture types, four (4) hectares (ha) per steer is the optimal stocking rate on both pasture types as less than this is unsustainable for long term pasture productivity (data not presented in paper) (Burrows, et al., 2010).

Figure 4.1.1 - Galloway Plains: NPV analysis of stocking rates (Excerpt from (Burrows, et al., 2010))



The ECOGRAZE trial (Ash, et al., 2011) also observed the effect of utilisation rates (25-75%) on pasture, starting from different land condition states at three sites over eight (8) years (Table 4.1.1). There was a significant detrimental effect to basal area for perennial grasses from increasing utilisation rates across the board. Ground cover on the 75% utilisation treatments was observed to be lower than those with 25-50% utilisation, with the exception of two treatments in state one condition; 50% utilisation without rest on site C (U50R-) and 50% utilisation with rest on site B (U50R+) (Table 4.1.1). While the desirable 3P grasses declined from either utilisation or drought, exotic grasses tended to invade, which, in the case of Indian couch grass, is assumed to retain reasonable ground cover while sacrificing pasture quality. Therefore, high cover level, while an important component of land condition, does not necessarily indicate good quality grazing.

Table 4.1.1 - Effect of grazing treatment on cover (Excerpt from (Ash, et al., 2011))

Treatment	Cover		
	Site A	Site B	Site C
State I			
U25R−	74.5	68.4	60.0
U50R−	77.1	69.9	52.7
U50R+	68.3	53.1	58.2
U75R−	60.7	57.1	56.4
State II			
U25R−	63.9	62.3	59.3
U50R−	62.3	56.4	56.3
U50R+	63.2	56.5	58.1
U75R−	53.3	50.2	50.5

Values given as mean percent cover over the experimental period.

GRASP[2] and ENTERPRISE[3] were applied (MacLeod, et al., 2010) to model a representative property (located near Duaringa QLD) for the projected outcomes of; heavy, constrained and variable stocking as well as wet season spelling and prescribed fire treatments for grazing land, over 26 years. Results indicated the alternative stocking strategies were more profitable than fixed heavy stocking. However, variable stocking yielded inconsistent results due to incurring sporadic episodes of forced selling in dry seasons after herd build up in good years. Wet season spelling and prescribed burning appeared to return economic advantages over doing nothing, though, it was noted that there was minimal data to base the pasture and animal production response assumptions on for the simulation.

A representative property in the Charters Towers region was modelled using experimental data and GRASP[2] simulations (MacLeod, et al., 2004). It aimed to identify linkages between land condition, animal production and economic outcomes at varying stocking rates. The study applies the state-and-transition model (Westoby, et al., 1989) for land condition where (in order of declining condition); State I is perennial tussock grasses, State II is perennial-annual grasses and State III is annual grasses and forbs. Results given in Table 4.1.2 indicate the poor production and profit from State III land supports the opinion that continued grazing of this land is unfeasible. For States I and II, however, the relationship is less obvious. There are improved economic outcomes expected while increasing stocking rate on State I, while enterprise profit is maximised under low stocking on State II land. A limitation of these results is that this simulation does not predict the length of time that the land will remain in its current condition under a given grazing pressure.

Table 4.1.2 - Financial performance of the enterprise from 100 year simulation (Excerpt from (MacLeod, et al., 2004))

	Stocking rate (ha/AE)		
	10	6.7	5
	State I		
Net Profit ($'000)	103	149	155
Years with negative return on capital (%)	22	23	21

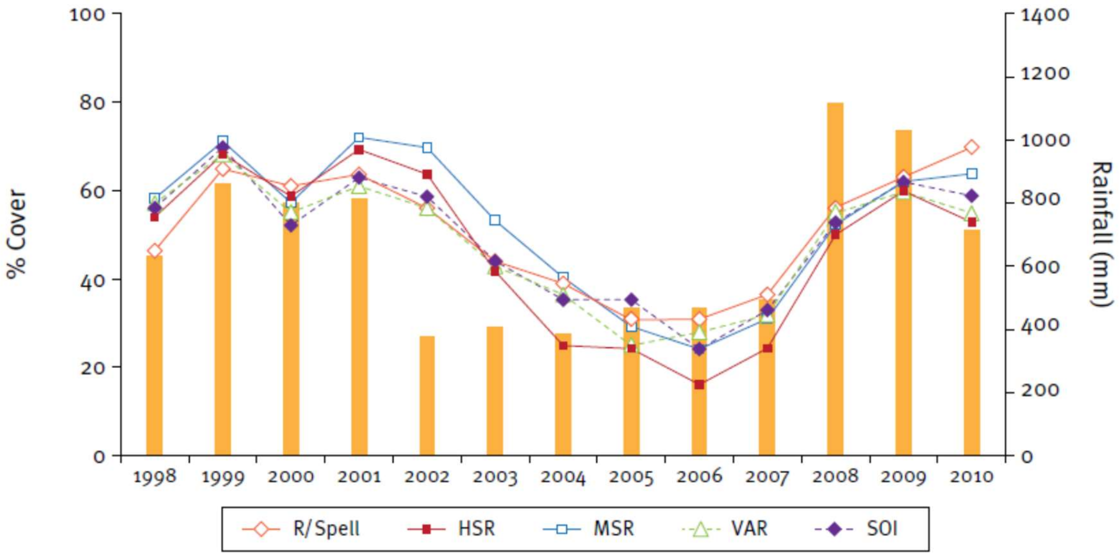
[3] ENTERPRISE is a herd economic model that integrates data from GRASP to project a range of profitability measures. (MacLeod, et al., 2010)

	State II		
Net Profit ($'000)	157	97	-91
Years with negative return on capital (%)	19	29	40
	State III		
Net Profit ($'000)	-56	-646	-1,270
Years with negative return on capital (%)	59	72	82

Simulations of a range of stocking strategies across 28 locations in Queensland and the Northern Territory aimed to extend grazing trial results to estimate pasture and LWG changes over time (Pahl, et al., 2016). GRASP[2] was used to simulate animal productivity and pasture growth from the grazing strategies and climate variability across the 28 locations. The same land type (Reid River box woodland) was applied for all locations to eliminate land type impact from the effects of rainfall variability. This simplification may reduce the accuracy of pasture growth between locations. There was a fixed conservative stocking strategy (LTCC) and 55 different flexible stocking strategies simulated beginning from two (2) pasture condition states (88% perennial / 60% perennial). Results showed that for all except the highest rainfall group (664-1253mm annual rainfall) fully or highly flexible stocking resulted in the best cattle productivity, while fixed or very low flexibility stocking gave the best pasture condition.

O'Reagain *et al.* (2011) reports on 12 years of an ongoing grazing trial in northern Queensland that commenced in 1997. The trial aimed to quantify the relative performance of grazing strategies in a variable climate. The stocking strategies selected were used by graziers in the area or recommended for managing climate variability. The strategies trialled included; moderate stocking (MSR), heavy stocking (HSR), variable stocking (VAR), southern oscillation index variable stocking (SOI) and rotational wet season spelling (R/Spell). Ground cover data was recorded for the trial, see Figure 4.1.2. The trial aimed to represent a commercial steer trading enterprise with most stock sold to the meatworks and those below specification sold locally. In five (5) of seven (7) years gross margins for the paddocks were calculated with a $0.20/kg price premium for stock sent to the meatworks from the lighter stocking treatments.

Figure 4.1.2 - Wambiana grazing trial: ground cover (Excerpt from (O'Reagain & Bushell, 2011))



The trial results indicated HSR earned large positive margins during wetter years but declined in the dry with high drought feeding expenses. MSR and VAR reflected the greatest Total Gross Margins (TGM) over the period of analysis, followed by SOI and R/Spell; HSR returns the lowest TGM at around half of VAR. The assumption regarding price premiums together with the high cost of occasionally feeding hay to steers in the HSR treatment, result in the Wambiana analysis suggesting that heavy stocking is far less profitable in the medium to long term, in contrast to stocking at LTCC, with or without the inclusion of a spelling or variable stocking strategy. The combination of MSR and R/Spell is seen as likely to result in the best land condition, pasture biomass and ground cover outcomes (O'Reagain & Bushell, 2011). O'Reagain *et al.,* (2011) does recognise the need for appropriate economic analysis at the whole of business level in conjunction with land condition assessments and the inclusion of breeding animals before conclusions about the likely economic impact at the farm level of the trial results should be reached.

Hall *et al.* (2014) sought to study alternative stocking methods on nine established commercial properties, over four (4) years under the variable conditions of growing season, labour supply, markets and forage availability. The three (3) broad categories included continuous, extensive and intensive rotations. Pasture and soil surface condition, including ground cover, were assessed. The results demonstrated no statistically significant difference between pasture or soil surface characteristics and stocking method across the sites. The study concluded there was no conclusive evidence of pasture or production advantages from rotational grazing over continuous during the study period. Like Teague *et al.* (2009), this highlighted the importance of past/future management goals and decisions in current/eventual rangeland condition. Hall *et al.,* (2011) provided a partial budgeting method to evaluate the impact of changing grazing systems for this project and gave an example of a Rockhampton based cell grazing case study. The analysis covered changing from a 1630AE herd to 1840AE's through development of fencing and watering points to implement cell grazing. The result (assuming production benefits from the system change are realised) was economically viable (return of ~10% on investment) after a payback period of ~8.5 years (Hall, et al., 2011).

4.2 Wet season spelling

Wet season spelling of grazed pasture is proposed as a strategy to avoid lasting impacts of defoliation and to allow for recovery of 3P grasses to maintain or recover land condition (MacLeod, et al., 2009; O'Reagain, et al., 2014). The ECOGRAZE project (Ash, et al., 2002) included rotational wet season spelling in various grazing treatments after the first significant rainfall event in November every year. The treatment was an eight week spell before cattle reintroduction, however, the stock were held on non-experimental pastures during this time as opposed to rotating through another plot or agisted as would be normal industry practice. The pasture response and economic analysis does not take into account the short term increase in stocking rate on other plots or the agistment expense that would occur in this case. The study found that land condition was maintained under continuous conservative stocking (25% utilisation, no spell) or early wet season spell followed by 35% utilisation. From the simulation of the financial viability of these strategies, the economic optimum was wet season spelling with 35% utilisation. The key finding from wet season spelling was it allowed a sustainable increase in pasture utilisation as 3P grasses were able to sufficiently recover during the rest period (Ash, et al., 2002).

Orr & O’Reagain (2011) report on perennial grass response to; wet season spelling (rotational full wet season spell in three paddock system and 30% utilisation), stocking at LTCC (20-25% utilisation) and heavy stocking (40-50% utilisation) on open eucalyptus savannah country at Wambiana (near Charters Towers) from 1998 to 2010. The trial failed to identify any impact of wet season spelling on survival, recruitment or basal area of any perennial grass species studied (Orr & O'Reagain, 2011). This is inconsistent with Ash *et al.,* (2002)’s assumption that wet season spelling allows sustainable increase in pasture utilisation as 3P grasses can recover in the rest period, an assumption that is applied in modelling scenarios such as (Roth, et al., 2004; Post, et al., 2006; Scanlan, et al., 2014).

Scanlan *et al.,* (2014) published a set of guidelines for implementing pasture rest as a possible strategy to improve land condition in northern Australia. The guidelines were developed from limited experimental data and literature published for this location and GRASP simulation modelling. The important factors for pasture resting that emanated from this review include; the beginning land condition, stocking rate during non-rest, rest timing, duration and frequency, pasture response to rest and utilisation rates, growing conditions and maintenance stocking rate (where land condition is maintained under continuous grazing pressure). The authors expanded on the wet season spelling scenarios from the ECOGRAZE project with GRASP simulation applying different stocking rates. The simulation took into account the reduction in overall carrying capacity in a rest cycle compared with continuous grazing. The simulation demonstrated negligible/no benefit from resting at low stocking rates or high stocking rates. An eight (8) percent increase in perennial grasses was the highest response recorded at a moderate stocking rate (1AE:7.7HA), however, the economic analysis of the scenarios was not conducted (Scanlan, et al., 2014).

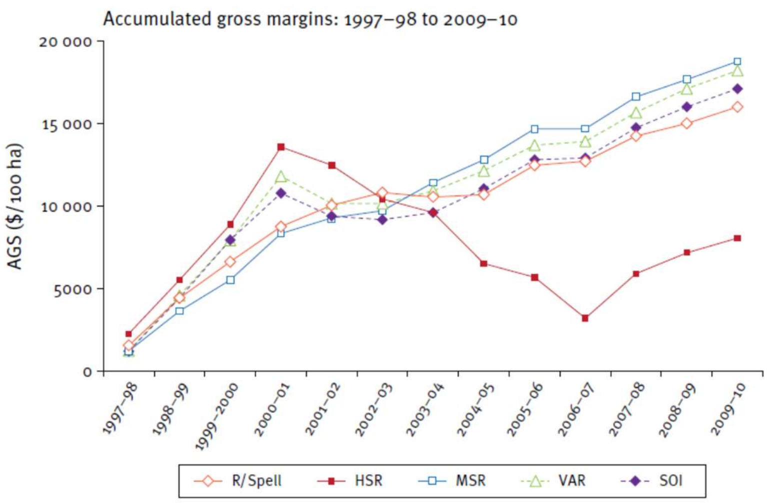
A discussion paper (Roth, et al., 2004) draws on the ECOGRAZE results to consider controlling sediment loss in the Burdekin. It recommends that wet season spelling as a way to reduce grazing pressure and improve land condition, particularly where there is apparent risk of erosion on hillslopes or gullies. The frequency of spelling recommended, every one (1) to four (4) years, is dependent on current land condition and desired utilisation rate for the business. A field study on Virginia Park Station on C condition Goldfields country in the Burdekin, running from 2002-2006, aimed to link grazing land management practices to the findings from Roth *et al.* (2003) regarding declining ground cover and sediment loss. The study implemented grazing practices based on ECOGRAZE guidelines in Ash *et al.* (2002). Pasture response from the early wet season spell was insufficient after the suggested time of eight (8) weeks. As Virginia Park Station pasture was dominated by Indian couch, it was then decided a full length wet season spell following the first significant rain event on a biennial or annual basis and setting stocking rate to retain a 40% end of dry ground cover residual would be required to begin recovering the pasture. From this decision, a small visible pasture response was recorded (Post, et al., 2006). From the results of the demonstration, the financial implications of recovering the land condition was modelled over 20 years. The authors used a comparative analysis to assess the marginal difference between the enterprise continuing without recovering land condition (C/C+ to C/D+) and if the enterprise improved land condition (C/C+ to B) through wet season spelling (although the pasture response to achieve this change was based on assumptions). The analysis returned a positive marginal NPV for improving land condition, suggesting it is an economically attractive option (Post, et al., 2006). There are, however, problems with the analysis that casts doubt as to the reliability of these results. The scenarios being compared do not start with the same total gross margin (TGM) in year zero (0) and the differences in herd capital between systems are not included in the NPV calculation.

MacLeod *et al.* (2009) sought to assess the economic outcomes of wet season spelling through scenario modelling. The simulation uses regionally specific parameters, however, due to the lack of quantitative data from wet season resting trials, the authors deem the carrying capacity and animal productivity assumptions as heuristic. Similar to Post *et al.* (2006), the model suggests there are economic benefits to be gained from using wet season spelling together with conservative stocking to recover land condition in northern Australian beef enterprises. MacLeod *et al.* (2010) conducted a similar simulation, this time using GRASP[2] and ENTERPRISE[3], which found the same result.

The effect of wet season spelling regimes on pasture was trialled at a site near Clermont (Monteagle) and at one near Charters Towers (Wambiana) by Jones *et al.,* (2016). Five (5) years of data from Monteagle and three (3) years of data from Wambiana showed the importance of moderate stocking to attain even a small pasture response. The overall land condition did not substantially improve in this timeframe, and seasonal conditions appeared to be the main influencer of pasture yield. The economics of different grazing strategies applied on Wambiana grazing trial are given in

Figure 4.2.1 where 'R/Spell' is the wet season spell treatment. The results show that continuous medium stocking, followed by variable stocking and southern oscillation index stocking, are predicted to be more economically viable than the wet season spelling option. However, wet season spelling is more profitable than heavy stocking.

Figure 4.2.1 - Wambiana: economics of strategies (Excerpt from (O'Reagain & Bushell, 2011))



4.3 Mechanical intervention

In cases where the land has been damaged beyond the point of being able to naturally rehabilitate using careful management, mechanical intervention is required. This is country in 'D' land condition and characterised by; extensive gully systems, weed infestation or widespread scalding where large scale sediment export can occur. Strategies such as ripping and seeding, diversion banks, contour ripping, herbicide for weeds, infilling and revegetation can be applied to intervene (Phelps, et al., 2011; Roth, 2004).

4.3.1 Gully rehabilitation

A recent report, 'Managing gully erosion as an efficient approach to improving water quality in the Great Barrier Reef Lagoon' (Wilkinson, et al., 2015) provides a comprehensive review of literature in gully remediation. From a cost effectiveness (CE) point of view the relevant parts are surmised as follows;

Gully erosion is estimated to contribute 40% of the total fine sediment loads to the GBRL and overgrazing is a common reason for gully erosion; in the current climate, that makes it a high priority sediment reduction investment area (Wilkinson, et al., 2015).

Wilkinson *et al.* (2015) recommends a combination of techniques to promote sediment trapping efficiency, improve vegetation cover and reduce surface run off in grazing land. These include:

- Fencing around the gully to restrict grazing pressure and allow the control of timing of grazing when required.
- Avoid vegetation clearing, with the exception of weed species.
- Revegetating gully features with native perennial tussock grasses.
- Creating small porous check dams to allow for the capture of sediment and seed that will naturally revegetate small catchment areas.

These treatments vary in direct cost from $4,500 to $9,000 per kilometre of gully. To maximise the CE, it is advised to prioritise areas contributing the most sediment (Wilkinson, et al., 2015).

A case study on the CE of gully remediation across six properties in the Fitzroy was completed by Rust & Star (2017). Remediation techniques were site specific but included combinations of; various infrastructure developments, earthworks and stock exclusion. CE was evaluated at the paddock level over 10 years, where CE equalled the cost of the treatment divided by the benefit. Benefit was measured in terms of retained sediment by measuring annual growth of the gully. This was based on the 'long term average annual gully erosion load' and growth rates reported by the Fitzroy Basin Association (FBA) to give sediment saving per year once the gully stabilised (Rust & Star, 2017). CE ranged from around $67 to $516 per annual tonne of sediment across the properties. The study found remediation work became far more cost effective where sediment loss was the highest, a finding that agrees with Wilkinson *et al.,* (2015). It also highlighted the general expected variance in the cost magnitude of remediation work. It should be noted that these CE measures were relevant at the point of erosion not as delivered to the reef.

North Queensland Dry Tropics (NQDT) NRM group and DAF provided grant funding and technical advice to facilitate grazing land rehabilitation projects on as part of the Australian Government Reef Program targeting improved water quality. One case study for riparian fencing and gully rehabilitation was completed on Terry Creek Station in Collinsville, Queensland (NQ Dry Tropics, 2015). The gully rehabilitation method involved; reshaping the gully, constructing subdivision fences to allow stock exclusion, construction of a diversion bank and contour ripping sown with buffel/stylo pasture above the rehabilitated area. Three (3) kilometres of riparian fencing was also constructed on the Terry Creek frontage and a small dam built for stock watering purposes. The gully was successfully rehabilitated from D to B/A condition and ground cover improved by more than 80%, the expected sediment saving given as 4.5 tonne per year. There was a small marginal benefit (NPV = $164.65) to the producer from the rehabilitation when 60% of the capital outlay was covered through grants. The cost of sediment abatement is estimated to be $31.10 per tonne from a total project perspective (NQ Dry Tropics, 2015).

Another case study funded through the NQDT facilitated Reef Water Quality Grants was completed on Illamahta Station in Collinsville, Queensland (NQ Dry Tropics, 2015). In this case an active four (4) hectare gully contributing to a 50ha catchment and damaging fencing was rehabilitated. Methods applied included; construction of two (2) 600m diversion banks, water spreading structures, fence realignment and installation of a leaky brush weir. Even with 70% of the cost covered by grant funding the results show a marginal loss to the producer (NPV = -$2,230) from rehabilitating. This due to the lack of productivity gains from rehabilitating, however, the sediment savings are not valued in this analysis as this is a downstream benefit in the form of improved water quality. The average annual soil loss from the gully is estimated at 80 tonne per year and cost of the sediment abatement is $4.68 per tonne (NQ Dry Tropics, 2015).

4.3.2 Pasture rehabilitation

There were two case studies conducted on different land types in the Fitzroy (Star, et al., 2011) that modelled land rehabilitation (from condition ‘D’ to ‘B’) in an attempt to value the benefit of mechanical intervention. The two strategies used included; fencing and destocking the degraded portion, and destocking the whole paddock. The results indicate there are private benefits realised when rehabilitating the more fertile soil type (Brigalow blackbutt) for both strategies, however, on the less fertile soil type, (narrow leaved iron bark woodlands) there were no positive private returns.

A three (3) year trial, conducted at Queensland Government’s Spyglass Beef Research Facility in the Upper Burdekin (Moravek & Hall, 2014), sought to assess the effectiveness of rehabilitating ‘D’ condition land. The treatments trialled and their costs include; deep ripping ($260.85/ha), chisel ploughing ($210.85/ha) and crocodile seeding ($150.85/ha), none of which produced a positive economic result. Under sensitivity analysis (using a lower, 5%, discount rate, highest cattle prices and productivity levels) crocodile seeding and chisel ploughing returned positive NPV’s. The main conclusions drawn are that improving ‘D’ condition land will incur fairly large capital outlay that outweighs the benefits from the pasture improvements on loamy alluvial soils, and either reduction in implementation cost or improvement in productivity benefits would be required for rehabilitation to be profitable.

5 Summary, gaps & recommendations

The studies contained in this review evaluated sustainability and land condition with respect to operating at different land condition states and/or different production systems. Studies, however, have not analysed ground cover per se as a means of management or the costs and benefits of changing from one management system to another.

The information gaps identified in the literature review include:

- Ground cover is not well correlated to land condition (Bastin, et al., 2012; Beutel, et al., 2014) and perhaps yield, as stoloniferous grasses such as Indian couch (not a 3P grass) can indicate high ground cover, however, may have reduced pasture mass and quality.
- There were no quantified relationships between ground cover and animal productivity, a gap previously identified in the Reef Plan Action 4: Gap Analysis Report (Moravek, et al., 2016). Although, one trial (O'Reagain & Bushell, 2011) has collected steer live weight gain data and ground cover under different management practices, data that has the potential to be revisited for the land types it applies to.
- Studies have largely examined land condition as it impacts profitability, not directly assessing the costs of adopting improved management practices, especially, the transition times of management change.
- As identified in Moravek *et al.* (2016), there are no trials explicitly linking ground cover to profitability, although some data collected holds value for reanalysis to examine linkages.

Recommendations for future work include:

- Analysis of existing trial, commercial property level and market data to identify the impact of the level of ground cover on animal production. Quantifying these relationships will inform economic modelling.
- Conducting case studies on commercial properties characterised by improving ground cover, will improve understanding of the transition times, risks, costs and benefits of changing land management practices.

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