

Reef Rescue Research & Development

Technical Report

Predicting economic costs of improving
grazing management in the Herbert,
Burdekin and Fitzroy Catchments
RRRD039



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Predicting economic costs of improving grazing management in the Herbert, Burdekin and Fitzroy Catchments (RRRD039)

An output of RRRD39: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders

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Contents

Contents	i
List of Figures.....	ii
List of Tables.....	ii
Acronyms.....	iii
Acknowledgements	iii
Executive Summary	1
Introduction.....	2
Project Objectives	3
Background knowledge.....	3
Methods	5
Land type selection	5
Case study characteristics.....	6
Biophysical simulations.....	10
Economic Model	14
Unit of analysis decision- making level.....	15
Results	19
Discussion.....	31
Conclusions.....	33
References.....	34
Appendix 1: Full results for all land types	38

List of Figures

Figure 1: Concept model for the integration of management systems.....	5
Figure 2: Distribution of land types incorporating the three catchments.	8
Figure 3: Distribution of all modelled land types across the region.	10
Figure 4: Integration of biophysical components into the economics sub-model.....	15
Figure 5: Grazing enterprise types for Burdekin and Fitzroy regions	16
Figure 6: Results for Black Basalt land type with 0 tree basal area.	20
Figure 7: Results for Black Basalt land type with 1.4 tree basal area	20
Figure 8: Results for Goldfields land type with 0 tree basal area.	21
Figure 9: Results for Goldfields land type with a tree basal area of 3.0.	22
Figure 10: Results for NLIB on deeper soils land type with 0 tree basal area.	22
Figure 11: Results for NLIB on deeper soils land type with 3.5 tree basal area.	23
Figure 12: Results for Red Basalt land type with 0 tree basal area.	23
Figure 13: Results for Red Basalt land type with 3.9 tree basal area.	24
Figure 14: \$/t cost to reduce sediment by land type and start condition – 0 tree basal area.	29
Figure 15: \$/t cost to reduce sediment by land type and start condition – with trees.....	30

List of Tables

Table 1. Land types previously modelled under <i>Paddock to Reef Monitoring and Modelling</i> ..	7
Table 2 Land types modelled under this project.....	8
Table 3 Parameters modelled for the land types modelled.	12
Table 4. Characteristics of previously modelled land types from <i>Paddock to Reef Monitoring and Modelling</i> project.	13
Table 5. Median length slope factors for all modelled land types across <i>Paddock to Reef Monitoring and Modelling</i> project and this research.	14
Table 6. Adult Equivalents for the stock flow.	16
Table 7. Land type parameters and variable costs.	18
Table 8. Predicted cost (\$/t) of sediment reductions of all land types – 0 tree basal area.....	26
Table 9 Predicted cost (\$/t) of sediment reductions of all land types– with trees	27
Appendix: Table 10. Full results for all land types – 0 tree basal area.	38
Appendix: Table 11. Full results for all land types – with trees.	42

Acronyms

GBR	Great Barrier Reef
GBRMPA	Great Barrier Reef Marine Park Authority
NRM	Natural Resource Management
QDAFF	Queensland Department of Agriculture, Fisheries and Forestry
RRRC	Reef and Rainforest Research Centre Limited
RRRD	Reef Rescue Research & Development

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Executive Summary

Recent research has identified that poor water quality is having negative impacts on the health of the GBR (Haynes, Brodie et al., 2007; Brodie, Devlin et al., 2011). The prime determinant for the changes in water quality entering into the GBR has been attributed to the grazing industry, for sediment pollutants, and sugarcane for nutrient pollutants. The focus of this report is the trade-offs that occur in the grazing industry between land types, land condition, grazing pressure, economic implications and subsequent sediment emissions.

The report employs a bioeconomic model methodology to understand the biophysical and economic trade-offs for twelve land types in the Fitzroy, Burdekin and Herbert basins. The twelve land types explored in the report were black basalt, brigalow blackbutt, coolibah floodplains, goldfields, loamy alluvial, narrow leaved ironbark on deeper soils, narrow leaved ironbark on shallower soils, narrow leaved woodlands, open downs, red basalt, silver leaved ironbark and silver leaved ironbark on duplex.

Bioeconomic modelling captures the biophysical aspects of grazing production systems such as pasture growth, pasture species composition, sediment exported, and subsequent animal growth. The model then integrates these variables into an economic framework which allows enterprise, sales, variable costs and subsequent profit to be estimated. To allow for climate variability, the model has 20 random start years followed by 20 consecutive years, capturing the profits and resulting sediment losses.

The results of the bioeconomic modelling highlighted the importance of the inherent productivity of the land type, land condition and tree basal area. Land types with poor land condition and of low productivity provided the greatest opportunity for low cost sediment reductions. Understanding the economically optimal grazing pasture utilisation rate provided insights into the policy mechanisms required for sediment reductions.

The report further informs the trade-offs between grazing pressure, economic implications and subsequent sediment exported. A key contribution is measured outcomes of investments, highlighting the efficient allocation of public funds for incentives and extension programs. It addresses a key criticism of past natural resource management programs through providing measured outcomes and through understanding the relationship between the biophysical and economic factors.

Introduction

Significant pressures on the Great Barrier Reef (GBR) from poor water quality, climate change and fishing impacts has prompted government programs and policies to improve Reef health (Haynes, Brodie et al., 2007; Kroon, Kuhnert et al., 2011; Waterhouse, Brodie et al., 2011). Although there are numerous factors impacting the GBR it is agreed that improved management practices for land based activities can improve water quality and improve the resilience of the Reef (Brodie, McKergow et al., 2003; Haynes, Brodie et al., 2007; Waterhouse, Brodie et al., 2011). The grazing and sugarcane industries are the dominant source industries for sediment and nutrient pollutants, respectively, and are located in catchments adjacent to the GBR. Whilst there is significant funding being allocated to improved water quality outcomes from these industries, there is limited understanding of the cost required to achieve reductions and therefore limited information to inform targeting of investments.

The State and Federal governments formed Reef Plan in 2009 which led to the development of a number of targets, actions, strategies and subsequent programs. Following this, the federal government through its Caring for Our Country program funded an incentive program termed Reef Rescue. This accelerated landholder practice change through funding on-ground property level works (Waterhouse, Brodie et al., 2011). The Queensland Government also introduced regulations to target sugarcane and grazing activities in priority areas (Burdekin and Wet Tropics catchments) to reduce the amount of sediment, nutrients and pesticides discharged to the GBR (Queensland Government, 2009).

The focus of this study was to further inform cost effective sediment reductions from the grazing industry in the Herbert, Burdekin and Fitzroy catchments. It is well established that increased levels of bare ground, and poor land condition from over grazing, result in increased sediment exported from paddocks into waterways. The two largest catchments adjacent to the GBR are the Fitzroy and Burdekin Basins respectively, consisting of approximately 278,188 km² with grazing being the dominant land use. The Herbert catchment is 9,843 km² of which 7,330 km² is under grazing. The sediment loads for the Fitzroy were estimated at 4.1 million tonnes per year, of this 2.9 million is attributed to human activity (Queensland Government, 2011). For the Burdekin catchment an estimated 4.7 million tonnes are leaving the catchments of which an estimated 4.1 million tonnes are attributed to human activity (Queensland Government, 2011). The sediment loads for the Wet Tropics, of which the Herbert is but 1 of 7 catchments, was estimated to be 1.4 million tonnes per year, with 1.1 million tonnes related to human activity (Queensland Government, 2011).

Recent programs such as Caring For Our Country and The Natural Heritage Trust program have faced criticism due to the absence of a measure for outcomes, lack of prioritisation and for failing to combine biophysical and economic outcomes (Pannell, 2009; Morrison, McAlpine et al., 2010; Pannell and Robertson, 2010). Similarly, a core matter of concern for natural resource management is the inefficiency associated with selection of suitable projects for funding, which has been attributed to poor mechanism design. For example, Rolfe et al. (2007) documented that many government support programs implement grants which involve a set payment for an action irrespective of the opportunity cost borne by the

landholder, resulting in an inefficient allocation of funds. Other inefficiencies relate to the poor links between payments and actions, where most programs focus on inputs (such as the supply of riparian fencing) rather than having the focus of outcomes (improved water quality) (Rolfe, Fihue et al., 2007).

This report aims to address these knowledge gaps and further inform opportunities for cost effective sediment reduction, through gaining an increased understanding of the trade-offs between grazing pressure (pasture utilisation), profit and subsequent sediment exported. The report reviews and builds on modelling from economic work completed under the Reef Plan program *Paddock to Reef Monitoring Modelling and Reporting* (Star and Donaghy, 2009; Star and Donaghy, 2010; Star, Whish et al., 2012) to improve the targeting of investments at a catchment level and understanding of the impact of landscape heterogeneity.

Project Objectives

The aims for the research were:

- To understand the trade-offs between pasture utilisation and profit on four select land types across the Herbert, Burdekin and Fitzroy basins.
- To understand the economic costs at a catchment level, by integrating data for eight land types previously modelled for the *Paddock to Reef Monitoring, Modelling and Reporting Program*.
- To develop an understanding of the cost for achieving a range of measured sediment reductions.

The overall objective of the project was to better understand and quantify the costs associated with sediment reductions on different land types within the catchments.

Background knowledge

Land uses such as grazing and clearing of native vegetation for agriculture have increased pollutant transport to the Great Barrier Reef (GBR) (Fabricius and De'ath, 2004; Gordon, 2007; Haynes, Brodie et al., 2007; Kroon, Kuhnert et al., 2011; Waterhouse, Brodie et al., 2011). Increased bare ground from grazing pressure contributes significant sediment when summer dominant rainfall occurs and there is little ground cover to stabilise the soil (Karfs, Abbott et al., 2009).

Pastures consist mainly of native species these are the main source of herbage for livestock, while perennial grasses also provide valuable ground cover which prevents soil decline and erosion. Drought and heavy grazing, either singularly or in combination, can result in the decline and death of perennial pasture species (McIvor, 2001). Stocking rate is a key variable in determining the viability and sustainability of grazed lands and has been the focus of considerable research conducted (McIvor and Monypenny, 1995; Ash and Stafford Smith, 1996; Chilcott, Sandral et al., 2005; Hamilton, Chilcott et al., 2008).

Natural resource management policy is concerned with managing the agricultural-environmental components of land, water, marine, and biodiversity impacts on the environment (Morrison, McAlpine et al., 2010). There has been increased pressure for Federal and State governments to spend money efficiently and demonstrate measurable outcomes to justify where funds have been allocated. The knowledge required to do this involves understanding the interactions between biophysical aspects, opportunity cost, management implications and determining which policy options allow targeted investment in improved water quality outcomes. Essentially understanding the associated costs and benefits of achieving an improvement in the natural resource (Bennett, 2005; Whitten and Bennett, 2005; Mazur and Bennett, 2008).

Catchment scale natural resource management involves complex issues and decisions that affect a wide variety of stakeholders. Designing efficient NRM policies requires assessment of the environmental impacts with consideration of the costs and benefits of different management practices in an integrated manner. Comparisons of different management systems allow investments to be targeted and policy options considered further. Rolfe and Windle (2011) identified the lack of bioeconomic studies relevant to the production and economic tradeoffs from grazing, and the subsequent cost of sediment reductions.

To ensure a complete information base on which these decisions can be made, an integration of bio-physical modelling and economic valuation within a framework of benefit cost analysis provides the best method of obtaining cost and demand information (Mazur and Bennett, 2008). Bioeconomic models best describe this method of integration and inform policy and program mechanisms through comparing the net social benefits of alternative courses of action. The ability of bioeconomic models to effectively model complex relationships and compare different management scenarios with the 'business as usual' scenario allows the management practice to be quantitatively assessed. Often a multidisciplinary team is required to be involved in the modelling process to ensure the correct interpretation of the problem and to clearly define the objectives of the decision makers. Bioeconomic modelling has the ability to provide information regarding the scale, nature, and distribution of the potential cost and benefits of particular management practices (Whitten and Bennett, 2005).

Methods

The methodology employed to analyse the costs of sediment reduction for the case studies of interest was bioeconomic modelling, a simulation modelling technique. The methodology of bioeconomic modelling incorporates information from biophysical aspects of the grazing production system with the economic implications of a grazing business. This allows the integration of the management systems (economic sub model) with the underpinning use of the land resource (biophysical sub model). To further understand the complex interactions a concept model was developed (Figure 1), ensuring the required aspects of the issue were accounted for.

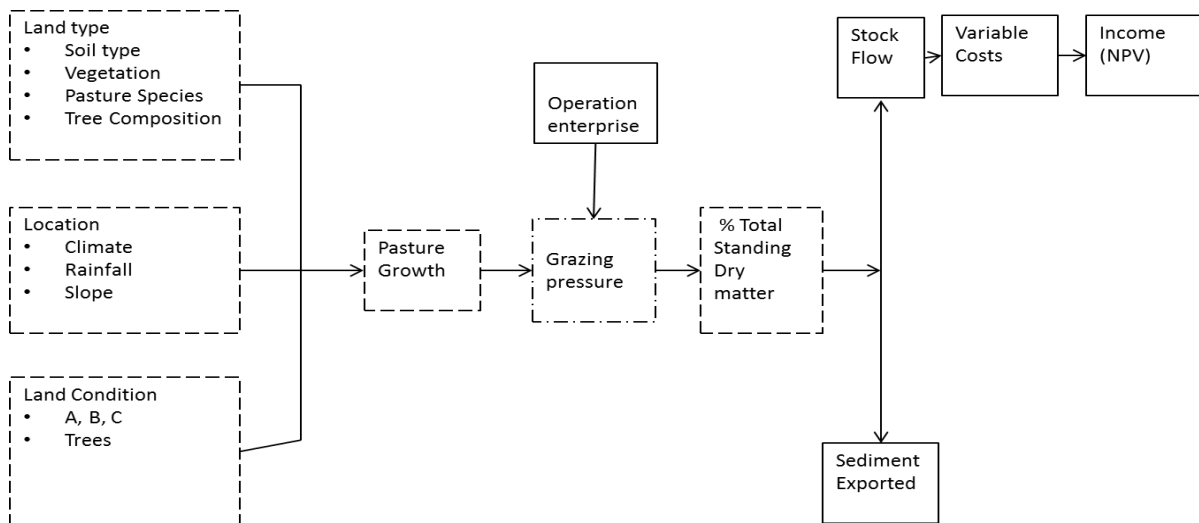


Figure 1: Concept model for the integration of management systems.

Land type selection

Climate, land type and land condition all influence the capacity of land to support livestock (McIvor, Bray et al., 2010). Climate is a key driver of pasture productivity. The timing (seasonality) and amount of rainfall is essential to pasture establishment and growth, and determines the length of a growing season where temperature, sunlight and rainfall are conducive to pasture growth (McIvor, Bray et al., 2010).

Soil, vegetation and slope are major determinants of a land type's capacity to capture the rainfall and produce useful forage. Pasture production of a land type is related to the fertility (particularly nitrogen) and water holding capacity of the soil. Similarly, the ability of pasture species to use water and nitrogen efficiently, the competitive (water and nutrients) relationship between tree and pasture, and the position of the land type in the landscape also affect pasture production (MLA, 2007).

The condition of the land, and the resilience of the land type to grazing, also influences pasture productivity and the long term carrying capacity of a land type. A poor condition, degraded land type will have less capacity to capture rainfall and produce useful pasture

(processes involved include replacement of perennials with annuals, reduced photosynthesis, reduced grass basal area, reduced surface cover, reduced seed banks, reduced infiltration and increased runoff and soil loss) and less resilience to the impacts of grazing compared to the same land type in better condition. The interaction between climate, land type, slope, land condition and grazing pressure determines risk of accelerated soil loss.

Climate and land type characteristics determine the carrying capacity at which the enterprise can operate, the grazing pressure that is economically optimal, and an associated sediment load. Managing a grazing business includes the financial implications of operating, and the variable costs and sales associated with a herd.

To ensure a representative mix of land types were selected for both this report and economics projects in the *Paddock to Reef Monitoring, Modelling and Reporting Program*, expert opinion was used to develop the bioeconomic regarding land type productivity, production system and biophysical interactions. These experts included rangelands pasture scientists, agronomists, natural resource management officers, extension officers, landholders and catchment modellers.

They were:

Department of Agriculture, Fisheries and Forestry, Queensland

- Bob Shepherd – Senior Extension Officer
- Mick Sullivan – Senior Extension Officer
- Dr Terry Beutel – Senior Scientist

Department of Natural Resources and Mines, Queensland

- George Bourne – Senior Natural Resource Management Officer,
- Dr Mark Silburn – Principal Scientist,
- Cameron Dougall – Natural Resource Management Officer
- Peter Donaghy – Regional Director of Mines, Central (formerly Manager, Strategic Projects and Planning, DAFF)

NQ Dry Tropics

- Dr Ian Dight – Planning and Integration Manager
- Diana O'Donnell – Project Manager

Fitzroy Basin Association

- Rachel Bryan – Healthy Waterways Coordinator

Case study characteristics

The bioeconomic model for this project was designed to encompass the three catchments for the GBR of the Herbert, Burdekin and Fitzroy. Grazing lands exhibit large amounts of heterogeneity across soil, vegetation and land form characteristics, however only a limited

number could be modelled because of the time investment required for each one. Another key consideration was the land types that have previously been modelled under past projects so that the land types selected added to, rather than duplicated existing data. Similarly, a good cross section of the range of land types was required to get a broader understanding of the trade-offs. These previously modelled land types can be found in Table 1 with a description found in Table 2. In this project these land types were updated with revised practices.

Four land types were selected for modelling based on the following criteria:

- Geographical location
- Land type coverage (%) of the catchment
- Inherent productivity
- Decreasing ground cover trend
- Susceptibility to erosion, and likelihood of soil loss

Table 1. Land types previously modelled under *Paddock to Reef Monitoring and Modelling*

Land type	Area (ha)	Catchment predominantly found	Productivity
Brigalow blackbutt	1,024,460	Fitzroy	High
Coolibah floodplains	320,239	Fitzroy	High
Loamy alluvials	625,050	Fitzroy	High
Narrow-leaved ironbark on shallower soils	624,558	Burdekin	Low
Narrow-leaved ironbark woodland	1,056,490	Fitzroy	Medium
Open downs	284,987	Fitzroy	High
Silver-leaved ironbark	2,611	Burdekin	Medium
Silver-leaved ironbark on duplex	626,859	Burdekin	Low

Based on the criteria discussed above, the narrow leaved ironbark on deeper soils, red basalt, black basalt and goldfields land types were selected (shown in Table 2). Figure 2 shows the distribution of these land types across the Herbert, Burdekin and Figure 3 illustrates the land types selected across the three Basins.

Table 2 Land types modelled under this project.

Land type	Area (ha)	Catchment predominantly found	Productivity
Black basalt	166,203	Burdekin	High
Goldfields	1,516,860	Burdekin	Low
Narrow-leaved ironbark on deeper soils	365,455	Herbert/Burdekin	Medium
Red basalt	755,629	Herbert/Burdekin	High

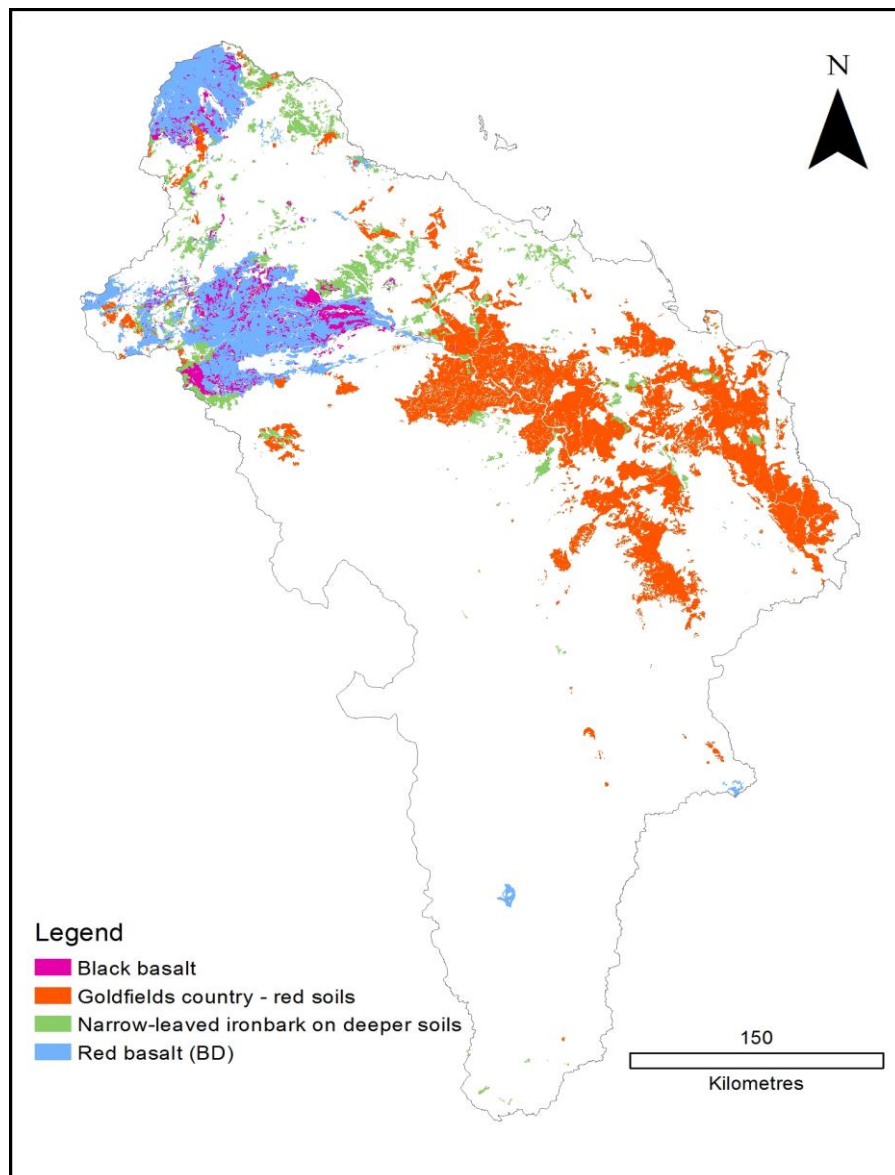


Figure 2: Distribution of land types incorporating the three catchments.

Narrow leaved ironbark on deeper soils are undulating duplex plains, or deep red earth tablelands. The vegetation is narrow leaved ironbark in association with box, bloodwoods, silver leaved ironbark, lemon scented gum, poplar gum and ghost gum woodlands. The soil are red or yellow earths or duplex, with the preferred perennial grass species being black speargrass, kangaroo grass, desert Mitchell grass, hairy panic, and forest blue grass (Whish, 2010).

Black basalt are gently undulating plains. The woody vegetation that is typical includes treeless grass plains with scattered black tea-tree, or open mountain coolabah or bloodwood woodlands. Generally there is no understorey. The soil is described as self-mulching cracking clays, with variable surface stone cover. The preferred pasture species includes Queensland bluegrass, curly bluegrass, black speargrass, curly and hoop, Mitchell grass and tall cup grass (Whish, 2010).

Red basalt can be described as level to gently undulating plains. The woody vegetation consists of narrow-leaved ironbark open woodland associated with ghost gums, blood wood and grevillias. The preferred pasture species includes desert bluegrass, black speargrass, kangaroo grass, curly bluegrass, giant speargrass, plume and brown sorghum. The soil is generally shallow, reddish brown clay loam grading to light clay (Whish, 2010).

Goldfields country can be described as gently undulating to undulating rises. The woody vegetation is narrow leaved ironbark and gum topped bloodwood woodland with occasional forest red gum and Reid river box along drainage lines. The preferred pasture species includes desert blue grass, forest blue grass, curly blue grass, cotton panic, black spear grass, and kangaroo grass. The soil can be described as brown loam over red clay duplex soil (Whish, 2010).

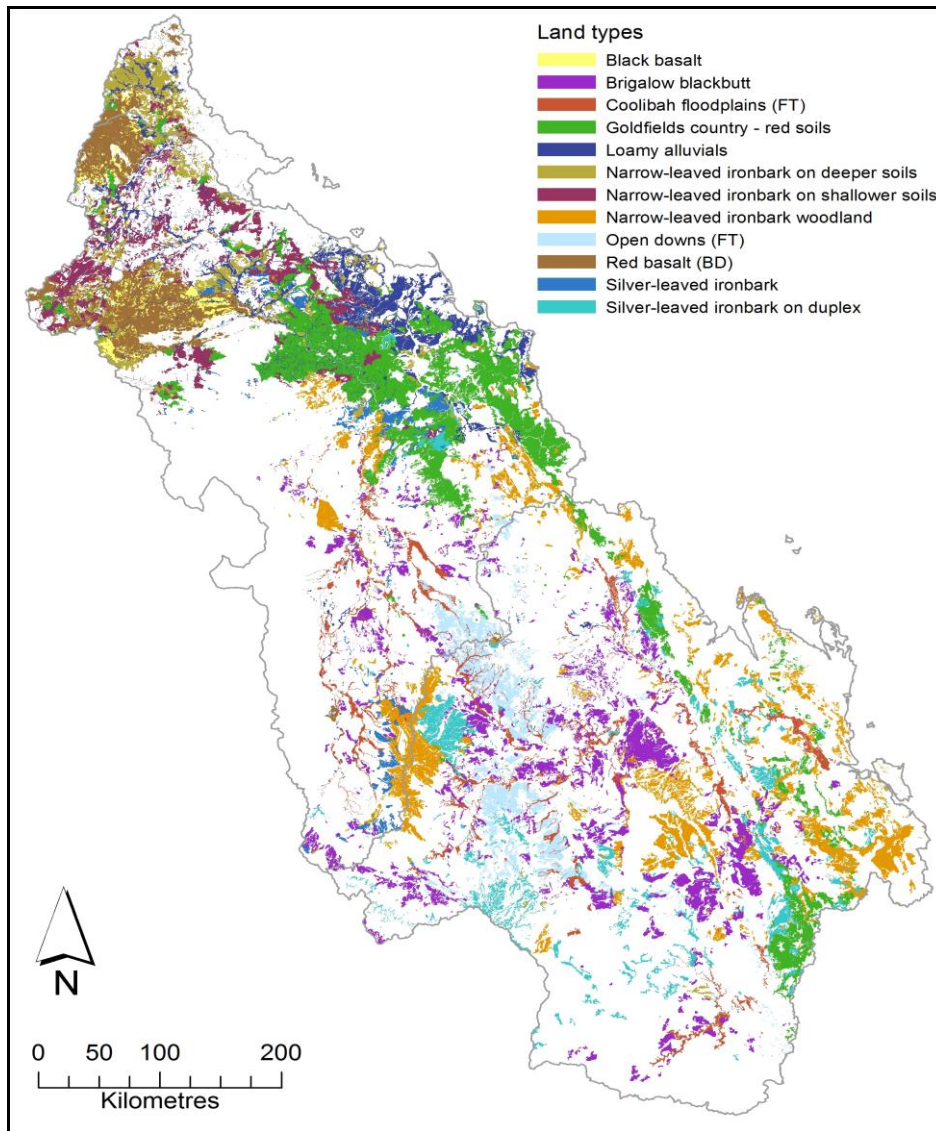


Figure 3: Distribution of all modelled land types across the region.

Biophysical simulations

The biophysical model consists of two sub-models; the pasture production model and the animal production model. The two have feedback loops into each other depending on the rainfall and pasture growth. This section explores the temporal and spatial scale of the model, along with the recursive features of the model.

To understand the interaction between different management practices the bioeconomic model was developed at the property scale. The GRASP pasture and animal production model was used to simulate the impacts of climate, grazing pressure, trees, and pasture condition on grazing land types within the Herbert, Burdekin and Fitzroy regions (McKeon, Ash et al., 2000; Rickert, Stuth et al., 2000). GRASP is an empirical, point-based native pasture model which was developed for semi-arid and tropical grasslands (Day, McKeon et al., 1997; Littleboy and McKeon, 1997). To ensure the impacts of climate, as a main driver of

pasture productivity, were not specific to one period, 20 randomly selected climate windows from 1893-1983 were modelled. Each climate window was 20 years as this was considered a length of time that was relevant to both producers managing their enterprises and biophysical interactions.

Starting years for the 20 climate windows, each of 20 years, randomly selected for simulations were as follows:

1896	1917	1942	1962
1902	1924	1945	1967
1904	1929	1949	1971
1912	1936	1956	1981
1915	1941	1960	1983

In addition to the 20 climate windows, tree basal area, initial pasture condition, and grazing pressure were modelled for each land type. Tree basal area is the cross-sectional area of a tree measured as squared metres in one hectare. Tree basal area is the measurement used in the GRASP model to simulate the impacts trees have on pasture productivity by competing with grasses for nutrients and water. Both cleared and an 'average' tree basal area were modelled for each land type. The 'average' tree basal areas represented tree cover of an undeveloped land type and were estimated from literature and expert advice. Table 3 indicates the tree basal area simulated for each land type.

Land condition as defined by the Grazing Land Management (GLM) ABCD framework (Chilcott, Sandral et al., 2005) is the capacity of land to respond to rain and produce useful forage. The ABCD land condition framework has been widely used and adopted in the northern Australian grazing industry (for example GLM and Stocktake education workshops, Land Condition Photo Standards for the Burdekin Dry Tropics Rangelands) (Karfs, Abbott et al., 2009) and has underpinned some recent State and federal initiatives (for example State Rural Leasehold Land Strategy, Reef Plan & Reef Rescue projects).

The ABCD framework differentiates between land condition classes by considering the soil, pasture and woodland components of a landscape. The best condition class "A" is where the grazing land has good coverage of palatable, productive and perennial pasture species, less than 30 per cent bare ground in most years, few weeds, good soil condition with no surface erosion and no woodland thickening. "D" condition land has a general absence of any perennial pasture species, forbs or grasses, and evidence of severe erosion or scalding, and thickets of woody plants that cover large areas (Chilcott, Sandral et al., 2005). "B" and "C" condition land lie between these extremes.

Land types were parameterised to represent the three land condition classes; "A", "B" and "C". For modelling purposes, "D" condition land was not included as the definition of "D"

condition requires mechanical intervention for land condition improvement. These costs vary considerably across the catchments and therefore were not considered in this report. The decline in perennial grasses under heavy grazing is simulated in GRASP by linking percentage perennials to a yearly time scale derived by Ash and Smith (1996) from observed data (McKeon, Ash et al., 2000). The state of the resource (percent perennials) is indicated on a scale that ranges from zero (lightly grazed, 90% perennials) to 11 (heavily grazed, one percent perennials). Depending on the condition of resource, the state of a land type can change up and down in response to the impacts of heavy grazing.

Utilisation of pasture growth thresholds that dictate whether the resource condition degrades or recovers were derived for each land type following consideration of the long-term safe utilisation rates (Whish, 2011). Threshold values that relate to utilisation of green material of total growth by the end of the growing season, were modelled for all land types considered in this report.

Three starting pasture conditions for the beginning of each of the 20 year climate windows, were modelled for the land condition of interest. The estimated land condition, state (McKeon et al 2000), percent perennials in starting pasture conditions, tree basal area, and rainfall are shown in Table 3.

Table 3 Parameters modelled for the land types modelled.

Land type	Narrow-leaved ironbark on deeper soils	Red basalt	Black basalt	Goldfields
Rainfall (mm)	801	748	640	644
Timbered TBA (m²)	3.5	3.9	1.4	3
Cleared TBA (m²)	0	0	0	0
Percent perennials start condition A (%)	88	88	88	88
Percent perennials start condition B (%)	60	60	60	60
Percent perennials start condition C (%)	20	20	20	20

TBA = Tree Basal Area

Previously modelled land types used similar modelling parameters, as shown below in Table 4.

Table 4. Characteristics of previously modelled land types from *Paddock to Reef Monitoring and Modelling* project.

	Narrow-leaved ironbark woodland	Narrow-leaved ironbark on shallower soils	Silver-leaved ironbark	Silver-leaved ironbark on duplex soils	Open downs	Loamy alluvials	Brigalow blackbutt	Coolibah floodplains
Rainfall (mm)	1120	655	733	590	615	620	580	964
Tree basal area (m²)	6	3	7.5	5	0.5	4	3	9
Cleared (m²)	0	0	0	0	0	0	0	0
Percent perennials start condition A (%)	80	88	88	88	88	88	88	88
Percent perennials start condition B (%)	70	60	70	70	60	60	70	70
Percent perennials start condition C (%)	20	20	20	20	20	20	20	20

To examine the full range of grazing impacts on pasture productivity, surface cover and sediment run-off, 13 pasture utilisation rates were simulated for each land type. Pasture utilisation rates measure the grazing pressure, and represent the proportion of the total standing dry matter (TSDM kg/ha) remaining at the end of the growing season (end of May) that was used to calculate the stocking rate for the following year. The following utilisation rates (%) were modelled: 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%.

The relationships used in the GRASP model to calculate daily soil loss were derived from experimental data collected from red duplex hillslopes near Charters Towers in the Burdekin region (Scanlan and McIvor, 2010). However the empirical relationships do not have the capacity to adjust for the known effects of hillslope length and slope on soil loss (Renard, Forster et al., 1997; Silburn, 2011) that may differ from the experimental sites where the data was collected. The Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), that uses length (L) and slope (S) adjustments (or LS), has been shown to relate well to measured soil losses on a range of slopes in grazing lands in Queensland (Silburn, 2011; Silburn, 2011).

GRASP predicted soil losses were adjusted to more closely correspond to modelled land type slopes. RUSLE length slope factors (LS) were derived from digital elevation model for the slopes where experimental data was collected from Scanlan et al. (1996), and for modelled land types. GRASP predicted soil losses for modelled land types were divided by the average RUSLE length-slope (LS) factor for the Scanlan et al. (1996) sites and multiplied by the mean LS for the modelled land type. Thus, on land types typically steeper than those measured by Scanlan et al. (1996), predicted soil losses will increase and, on flatter land types, predicted soil losses will decrease. Sediment exported to the reef was calculated using a delivery ratio

of 1 in 8 which is the estimated level of sediment movement in a hectare that actually leaves the paddock (Dougall, Carrol et al., 2008).

The median length slope factor used for the land types are shown in Table 5.

The amount and intensity of rainfall determines not only pasture productivity but runoff and soil loss. Annual live weight gain was calculated in GRASP from percent utilisation of pasture growth and percentage of green days during the year where the pasture growth index was above a specified threshold. The pasture growth index is a function of soil water, solar radiation and temperature indices. The GRASP biophysical simulated outputs were then integrated with the economic model.

Table 5. Median length slope factors for all modelled land types across *Paddock to Reef Monitoring and Modelling* project and this research.

Land type	Slope factor
Black basalt	0.2826
Brigalow blackbutt	0.3263
Coolibah floodplains	0.2284
Goldfields	0.6284
Loamy alluvials	0.3145
Narrow-leaved ironbark on deeper soils	0.4715
Narrow-leaved ironbark on shallower soils	0.8130
Narrow-leaved ironbark woodland	0.7077
Open downs	0.3215
Red basalt	0.3480
Silver-leaved ironbark	0.3890
Silver-leaved ironbark on duplex	0.6588

Economic Model

The biophysical results were integrated into an economic model designed to explore the economic implications of different pasture utilisation rates for each land type and estimate subsequent sediment exported. The economic model estimated the annual return averaged over climate files, for different utilisation rates, so that the effect on production of change in utilisation could be predicted. This enabled estimation of the dollar cost of reducing a tonne of sediment for each land type for a range of pasture conditions. This component of the model considered further the scale and unit of decision making along with recursive ability of the model.

The GRASP simulation provided much of the production and the soil loss data to determine the economic and environmental implications. The variables that provided the most information into the economic model were the number of head per hectare, live weight gain per head and sediment run-off (tonnes).

Unit of analysis decision- making level

The landholder level was selected as the unit of analysis due to the landholder's ability to change management practices and because the opportunity cost of changing management systems is borne by the landholder. Key parameters were derived from Reef Plan Action Six grazing management practice survey data. It also allowed the model to integrate the biophysical outcomes into the economic model. The key parameters utilised in the economic sub-model were the Adult Equivalents (AE's) per hectare which is a unit measurement equivalent to a 450kg steer per hectare, and live weight gain per AE (Figure 4).

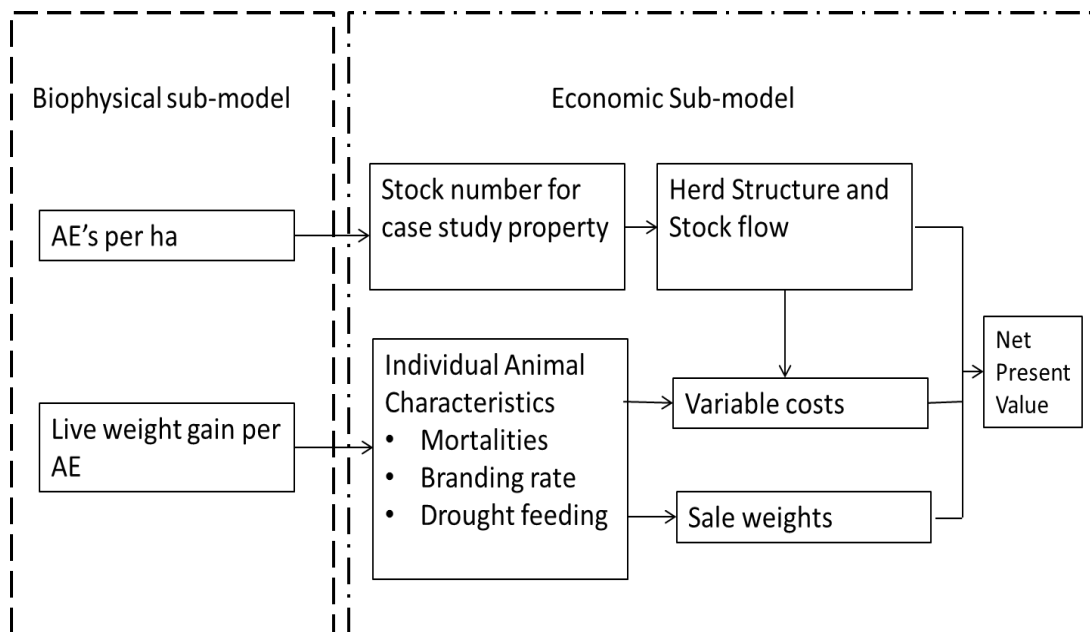


Figure 4: Integration of biophysical components into the economics sub-model.

The economic model developed a 20 year stock flow to match the climatic data and the simulated stocking rate. This was done to demonstrate the economic implications of adjusting stocking rate, and to allow the production data to be fully reflected. This accounts for any lag effects of adjusting the stocking rate in the base herd (it may require a few years for the base herd to re-build and visa versa). Similarly, 20 years is the estimated average time one person manages the property for and implements management change.

The land type, location, land condition, pasture growth and sediment exported factors were included in the biophysical sub-model. These parameters provide an insight along with the Action Six: grazing management practice data to inform which land types and locations would operate on particular land types. The dominant enterprise types from the survey were “breeding and finishing” and “breeding and selling store cattle” (see Figure 4). The

survey information also provided insights into the variable costs and the diversity between enterprise operations.

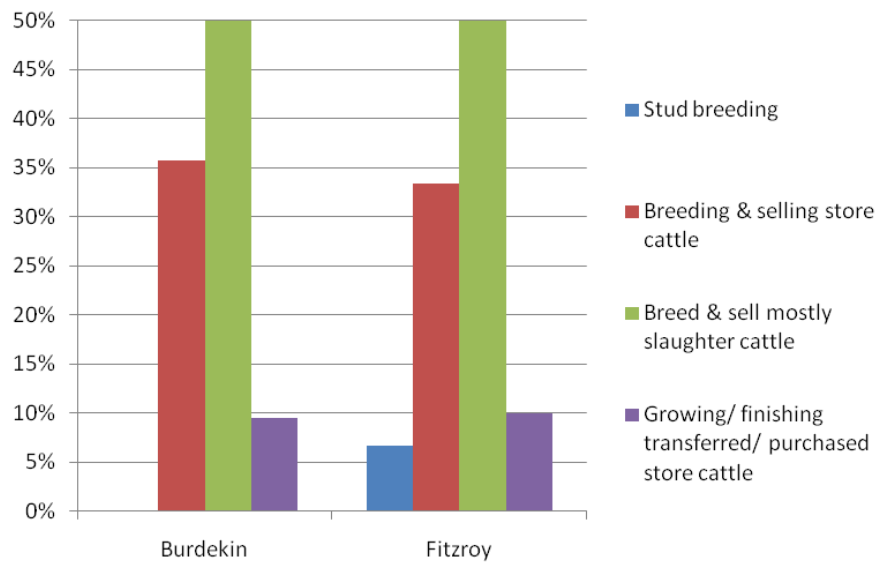


Figure 5: Grazing enterprise types for Burdekin and Fitzroy regions

It was assumed that the breeding and selling of store cattle would have occurred on the less fertile land types and the breeding and finishing (slaughter cattle) on the medium to higher productivity land types.

For the stock flow to reflect a representative property the AE's for each animal class were based on the Breedcow Dynama program (Holmes, 2011) and are listed in Table 6.

Table 6. Adult Equivalents for the stock flow.

Animal Class	AE's (1AE=450kg steer)
Calves	0.35
Heifer Weaners	0.5
Steer Weaners	0.5
Heifers 1yr	0.73
Steers 1 yr	0.78
Heifers 2 yrs	0.98
Steers 2 yrs	1.14
Cows 3-10 yrs	1.10

- A base herd was developed for Year 1, with the stock numbers adjusted up or down depending on the available AE's determined by GRASP for the available pasture. The sales percentage and the percentage of male and female animals were determined from the DAFF grazing management survey data.
- When there is an opportunity to purchase trade cattle they are purchased while maintaining the female to male ratio of the base herd.
- Two representative properties of 5,000 ha and 10,000 ha were selected and assumed to be one homogenous block of the one land type. Although it is understood there is significant amount of heterogeneity, these representative properties provide a basis for comparison.
- Mortality was calculated in the stock flow sub-model for both the dry herd and for the breeding herd. This was dependent on the live weight gain and was derived from MacLeod et al. (2004). The dry herd was considered to be yearling heifers and steers up to two years old. A maximum 30% breeding mortality rate was applied for the Burdekin and 20% for the Fitzroy was applied. The equation was calculated as a function of live weight gain (MacLeod et al., 2004).

$$\text{Mortality (breeders)\%} = 6 + 94e^{-0.027(\text{LWG}+50)}$$

$$\text{Mortality (dry stock)\%} = 2 + 88e^{-0.034(\text{LWG}+50)}$$

- Branding rates for the breeding herd were based on MacLeod et al. (2004) and were determined as a function of live weight gain. A 20% to 75% branding rate range and 30% to 75% on more fertile land types was used to reflect the variation in typical herd in the land type and region. The equation is as follows:

$$\text{Branding \%} = 30 \leq 15.6 + 0.488 \times \text{LWG} \leq 75$$

- It was assumed that in years with less than 50 kilogram live weight gain per head that drought feeding would occur, based on the work completed by (MacLeod, Ash et al., 2004). When annual live weight gain was less than 50 kgs per/head then a urea-molasses lick supplement (Urea 8%-M8U) was fed, with three days of M8U feeding for each kilo of live weight gain less than 50 kg. For example when the live weight gain was simulated by GRASP to be only 10 kg, then the M8U ration was fed for 80 days (50 kg – 10 kg = 40 kg x 3 days/kg = 120 days). Where GRASP simulated a live weight loss the ration was urea-molasses fortified with cottonseed meal (urea 3%, cottonseed meal 10% - M3UP38) fed with one day of feeding for each kilo of weight loss in addition to the M8U supplement. For example if an animal was simulated to lose 20 kgs then there would be 20 feeding days of M3UP38 supplement plus 100 days of M8U supplement.

Variable costs and net present value were factors in the economic sub-model. The grazing pressure section was pivotal for the stock flow, influencing animal production depending on the live weight gain. The variable cost and income were based on the following assumptions:

- When drought selling is required a price penalty is incurred on cattle sold. As a result, breeders sell for \$1.25 per kilo and steers for \$1.45 per kilo.
- If in the following year AE's increased they were re-purchased at the same ratio as the base herd in the previous year.

- All animal health costs and drought feeding were calculated on a per AE basis.
- Interest on additional livestock capital was calculated at 6%.

The variable costs, property size, and enterprise used are shown in Table 8, with data based on a combination of expert opinion, Action Six, grazing management surveys and the Beef CRC representative herd templates for Northern Australia.

Table 7. Land type parameters and variable costs.

Land type	Property Size (ha)	Enterprise	Average Total Variable Cost (\$/AE)
Black basalt	10,000	Breed and finish	24.54
Brigalow blackbutt	5,000	Japanese Oxen	26.22
Coolibah floodplains	5,000	Japanese Oxen	26.22
Goldfields	10,000	Breed and finish	24.54
Loamy alluvials	10,000	Store Steers	21.36
Narrow-leaved ironbark on deeper soils	10,000	Breed and finish	24.54
Narrow-leaved ironbark on shallower soils	10,000	Store Steers	21.36
Narrow-leaved ironbark woodland	5,000	Store Steers	22.01
Open downs	10,000	Breed and finish	24.54
Red basalt	10,000	Breed and finish	23.54
Silver-leaved ironbark	10,000	Breed and finish	21.36
Silver-leaved ironbark on duplex	10,000	Store Steers	21.36

To estimate the subsequent income at each pasture utilisation level a partial analysis was used. This compares a base case scenario with other management practices. For this case the base case was 10% TSDM and all other levels of grazing pressure were compared to this management scenario. As there were 20 blocks of consecutive years, each of these blocks were compared to the base case of the different levels of pasture utilisation.

To ensure that the income was estimated in today's dollar terms (as a dollar today is not worth the same in 20 years), the marginal accumulated benefit was discounted at 6% real interest rate. Six per cent was selected as at time of analysis the average business loan was 7.5% (Canstar, 2012). Given that a real interest rate does not include inflation which at analysis was 1.5%, the discount rate of 6% was selected (Reserve Bank of Australia, 2012). For each 20 year block a net present value which is an estimate of net income was calculated. It must be noted that no fixed costs or overheads were included in the estimation of income. To account for the 20 different blocks, all the resulting net present values were then averaged.

Results

The results are presented in land type groups to allow comparisons between start condition, with and without trees. The net present value curve shows the net present value averaged over the 20 year blocks. The net present value is presented on the left axis of the following graphs. The sediment exported curve (measured on the right axis) is based on the productivity, soil characteristics and pasture utilisation rate of the land type. It is important to note that the two Y axes on each graph have different scales, and zero (the start point) is not aligned.

The net present value curve presents two shapes depending on the productivity of the land type. Firstly, higher productivity land types generally have a NPV curve which is bell shaped. The peak of the bell curve represents the estimated economically optimal pasture utilisation rate. Conversely, the lower productivity land types present a NPV curve that declines in linear form. The two curves reflect the inherent productivity of the land type, based on soil type and resilience. The shape of the curve informs which policy mechanism allows the most efficient allocation of funds and largest sediment reduction. For example on higher productivity land types (eg. black basalt) where landholders are operating past the optimal peak of the curve, income is being forgone and a significant amount of sediment is being exported. Where landholders have higher than optimal stocking rates the most efficient allocation of funds would be education and extension, to reduce grazing pressure, increase NPV and reduce the sediment exported. Conversely, for landholders operating below the economic optimal grazing pressure, to achieve a further reduction in sediment exported through decreased grazing pressure, incentives will be required as income will be forgone by reducing grazing pressure further. On lower productivity land types (eg. silver leaved iron bark) the most efficient allocation of funds would be to education and extension, as on these land types, any move to reduce grazing pressure increases the NPV as well as reducing the sediment exported. In fact, on these low productivity land types, education and extension may assist some producers to significantly reduce grazing pressure, as this will also significantly improve their profitability.

All modelled land types show a large jump in net present value from 15% utilisation to 20% utilisation for all start conditions. This reflects the GRASP modelling for the regeneration threshold, therefore modelling effects are identified. This means that the marginal increase in net present value between 15% TSDM and 20% TSDM is high relative to the marginal change in sediment exported for the same pasture utilisation, and results in a high opportunity cost relative to sediment exported. Therefore, there is a higher cost for sediment reductions from 20% TSDM to 15% TSDM across all land types.

The black basalt results demonstrate the impact of the inherent productivity on the net present value, and the impact of soil type and low slope on the sediment exported. This high productivity land type results in the net present value peaking at 25% TSDM for both “A” and “B” start condition with no trees and an NPV of \$4,668,296 and \$2,745,696 respectively (Figure 6). The net present value peaks at 25% TSDM for “C” start condition with no trees a NPV of \$2,265,286 (Figure 6 and Appendix A). Any producer operating past this peak is achieving a lower net present value than they could if they reduced their grazing pressure to the peak.

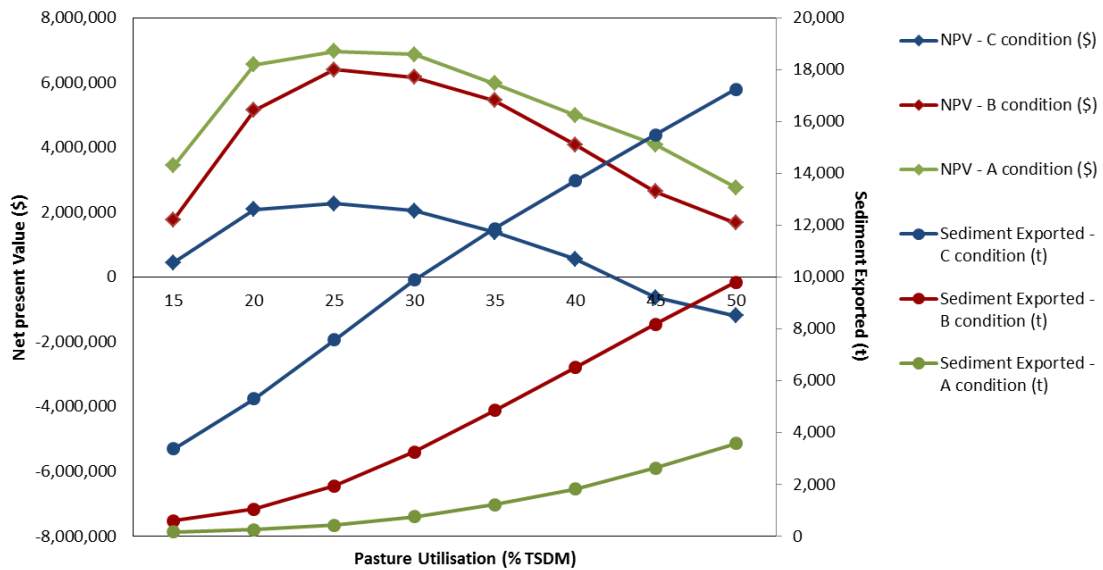


Figure 6: Results for Black Basalt land type with 0 tree basal area.

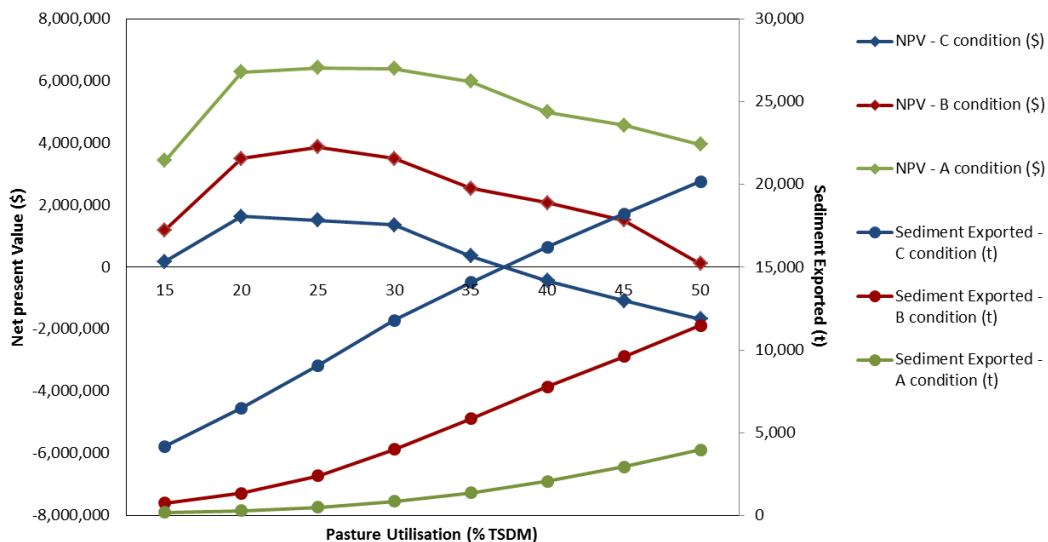


Figure 7: Results for Black Basalt land type with 1.4 tree basal area

The impact of trees is noted between the cleared and trees scenarios with all net present values lower when operating in a tree scenario (Figure 7). However, for black basalt, the modelled trees scenario has a 1.4 tree basal area which is relatively low compared to the other land types, so even with trees, the net present values are still significantly large while the sediment exported remains relatively low.

The black basalt land type achieves the largest net present value across all land types modelled with the lowest level of landscape slope (thus low sediment exported). This results in an extremely high cost per tonne to reduce sediment even when trees are present. In addition, the significant increase in net present value between 15% TSDM and 20% TSDM for black basalt results in the cost per tonne for sediment reduction being very expensive relative to other land types.

The goldfields land type results (Figures 8 and 9) show that the economically optimal pasture utilisation is 20% TSDM for B and C starting land conditions, and 30% TSDM for A start condition. However, the results highlight the importance of land condition on the net present value, as at the economically optimal pasture utilisation of 30% TSDM the “A” start condition net present value of \$4,674,053 is substantially more than the “B” (\$2,516,873) or “C” (\$1,148,839) start conditions (Figure 8).

The impact of trees on the net present value and on the sediment can be seen in the comparison between the cleared scenario (Figure 8) and the treed scenario (Figure 9) where the net present values are lower for the tree scenario across the three starting conditions. The tree scenario also has higher sediment exported for each start condition. This makes the cost per tonne to reduce sediment a cheaper option on scenarios with trees due to the combination of both a lower net present value and higher sediment exported. For example at 30% TSDM in “A” start condition the net present value is \$ \$4,674,053 and \$1,934,532 for the cleared scenario (Figure 8) and treed scenario (Figure 9) respectively. At the same point, 30% TSDM, the sediment exported is 24,513t and 42,089t for the cleared and treed scenarios respectively over the 20 year period. The higher sediment exported from the treed scenario is due to the higher areas of bare ground underneath trees that is more prone to erosion.

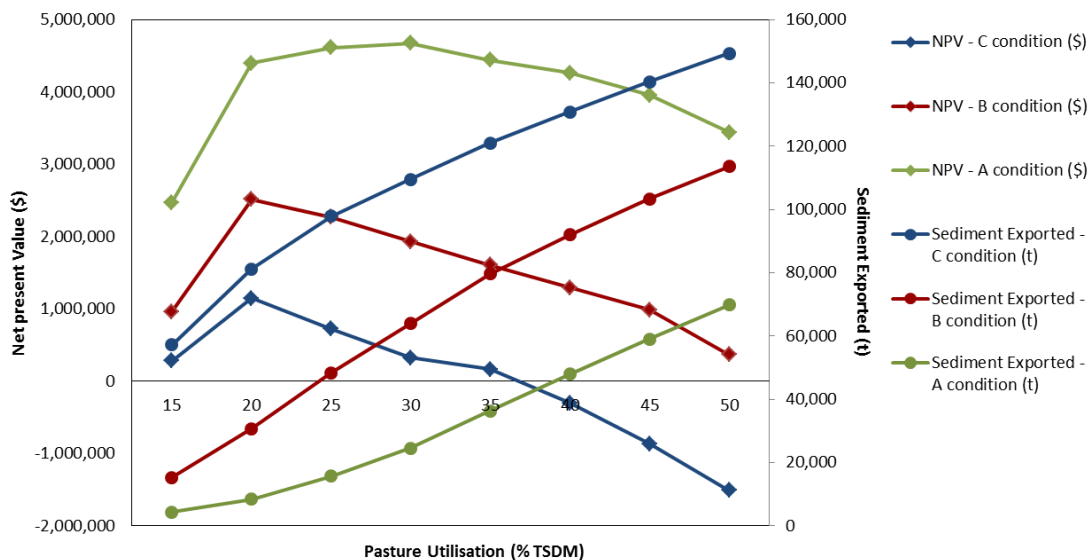


Figure 8: Results for Goldfields land type with 0 tree basal area.

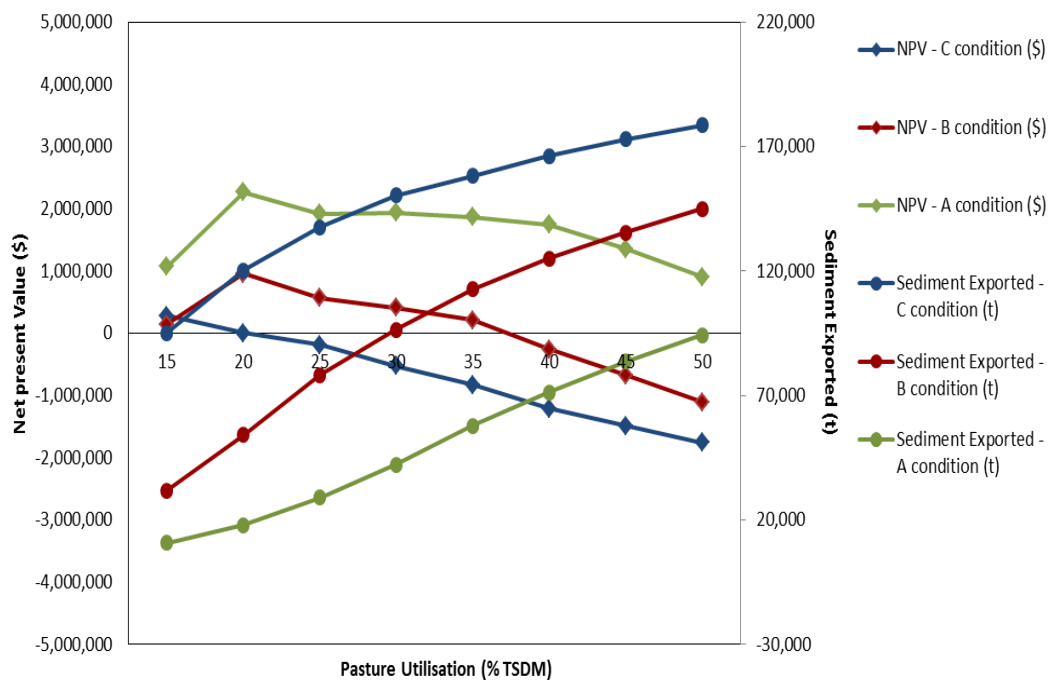


Figure 9: Results for Goldfields land type with a tree basal area of 3.0.

In the narrow leaved iron bark on deeper soils (Figures 10 and 11) and red basalt (Figures 12 and 13) land types, the impact of high rainfall and favourable climate resulted in a high number of green days. This results in an early peak in the net present value curve, after which the net present value curve flattens out, maintaining the net present value at higher levels of utilisation. These land types illustrate the importance of climate and in these particular cases the rainfall masks the inherent productivity of the land type.

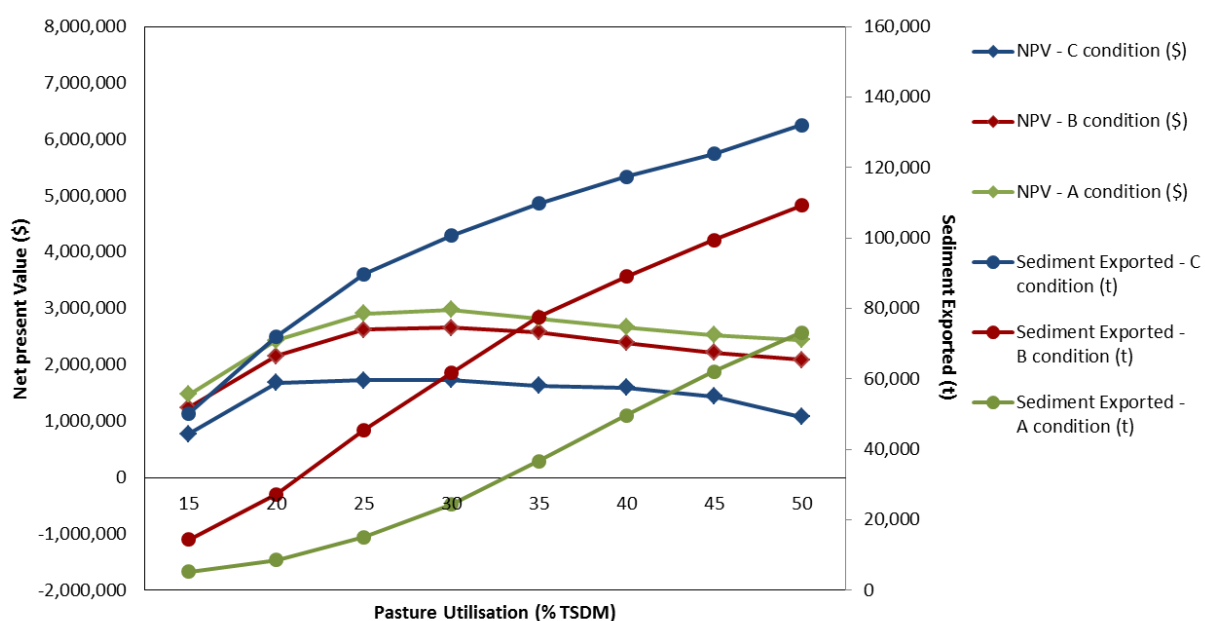


Figure 10: Results for NLIB on deeper soils land type with 0 tree basal area.

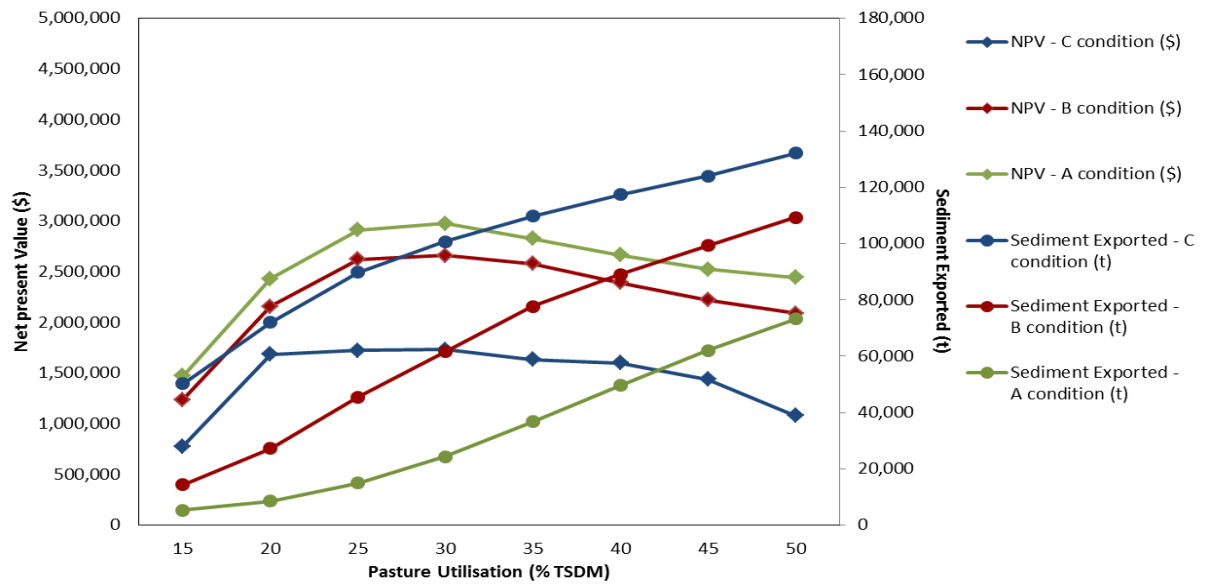


Figure 11: Results for NLIB on deeper soils land type with 3.5 tree basal area.

The impact of trees can still be seen in the narrow leaved ironbark on deeper soils land type with the treed scenario resulting in lower net present values (Figure 11). The impact of land condition is pronounced for this land type, particularly the difference in net present value between “B” start condition and “A” start condition for both the cleared and treed scenarios. In the cleared scenario (Figure 10) with an “A” start condition, the net present value curve peaks at \$2.91 million at 30% TSDM. Whilst the net present value peaks at 30% TSDM for “B” start condition with an net present value of \$2.66 million. Similarly, the sediment exported more than doubles as the start condition declines from “A” to “B”. For example at 30% TSDM with trees (Figure 11) the sediment exported in “A” condition is 24,337 tonnes while in “B” condition 61,609 tonnes is exported.

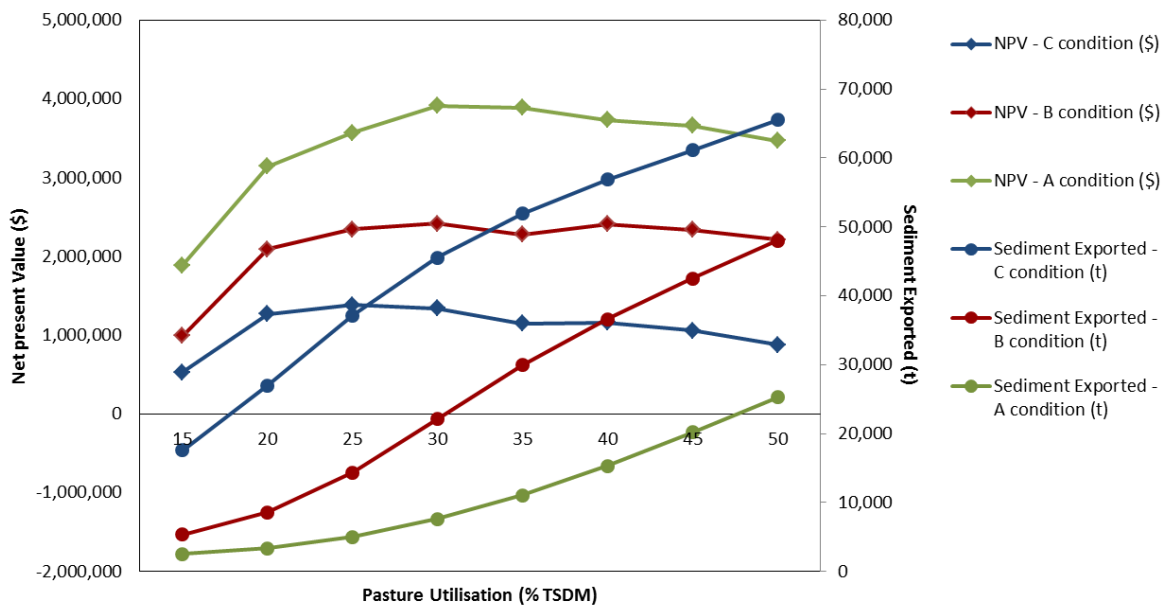


Figure 12: Results for Red Basalt land type with 0 tree basal area.

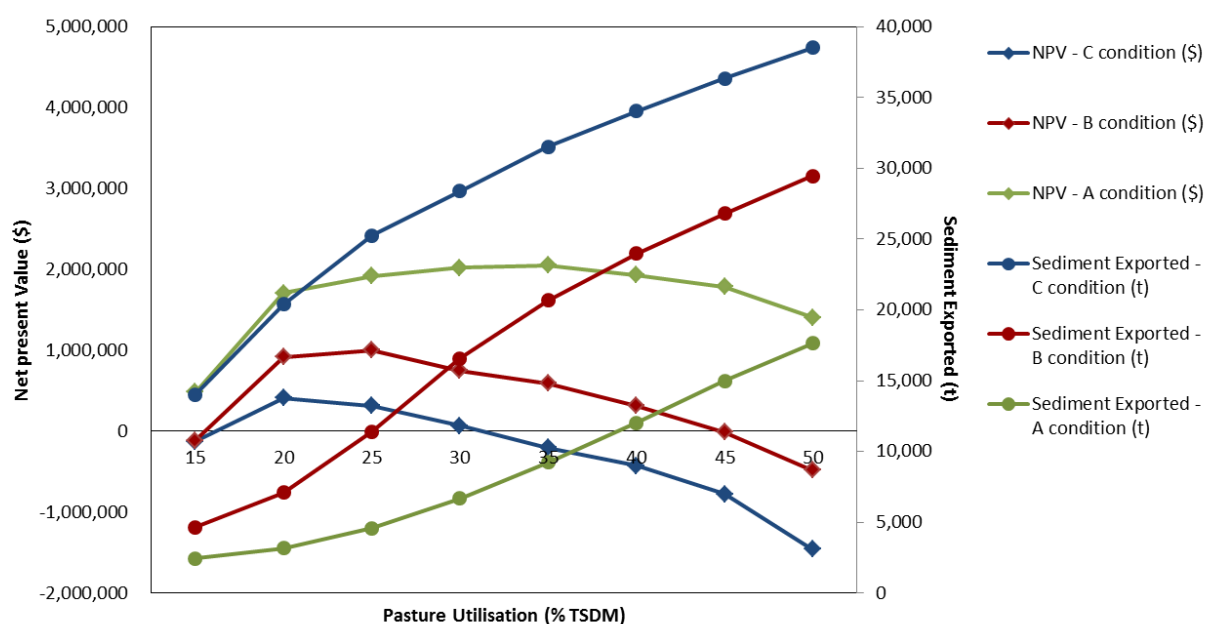


Figure 13: Results for Red Basalt land type with 3.9 tree basal area.

The red basalt results (Figures 12 and 13) also illustrate the impact of a medium productivity land type in a high rainfall area. The net present value curves only begin to trend down at higher pasture utilisation rates (past 50% TSDM), as there are a high number of green days due to being in a higher rainfall region. Again the impact of start condition on net present value, and sediment exported is illustrated clearly and reflected in the subsequent predicted cost of sediment reductions.

Table 8 illustrates the estimated dollar per tonne (\$/t) cost of reducing sediment exported from cleared scenarios, for each step down in the pasture utilisation increments. Table 9 shows the \$/t cost of reducing sediment exported for the scenarios with trees. The cost to reduce sediment is calculated as the difference between the net present value of the two pasture utilisation rates (essentially the opportunity cost), divided by the difference between the tonnes of sediment exported from the same two pasture utilisation rates. The range between land types and start conditions reflects the heterogeneity that exists between the Herbert, Burdekin and Fitzroy catchments.

In Tables 8 and 9, the range of \$/t costs provides insights into the characteristics of more cost effective sediment reductions, where the economically optimal pasture utilisation rate occurs, the shape of both the net present value and sediment curves and therefore the most cost effective policy or program. Although the scenarios with trees provide more cost effective options relative to the same land type in a cleared scenario, the comparison amongst land types conditions and trees provides insights into the most cost effective mix of targeted sediment reductions.

From the cleared scenarios the cheapest sediment reductions can be achieved from silver leaved ironbark on duplex soils (Table 8 SLIB on duplex) in “C” condition, with 28 cents per tonne of sediment exported to move from 20% TSDM back to 15% TSDM. The next cheapest option is narrow leaved ironbark on deeper soil (Table 8 NLIB deeper soil) in “C” start

condition with a predicted cost of 75 cents per tonne of sediment exported to move from 20% TSDM back to 15% TSDM.

The silver leaved ironbark on duplex soils (Table 8 SLIB duplex soil) demonstrates the impact of lower productivity land types and predicted costs of sediment reductions with opportunities for incentive below \$10 per tonne for all start conditions. Conversely, the higher costs of sediment reductions arise from black basalt, brigalow blackbutt, coolibah flood plains, and open downs, reflecting the productivity of these land types, as well as the low slope and soil characteristics. A negative cost means that no incentives are required to achieve reductions in sediment exported. Rather, funding on education and extension is required to assist producers understand that their economic position will be enhanced if they reduce their pasture utilisation, and simultaneously reduce sediment exported. The grey shaded numbers in Tables 8 and 9 represent the cheapest \$/t cost for each land type and condition that would have to be paid as an incentive to reduce sediment exported through use of incentive payments.

The scenarios where a tree basal area was considered (Table 9) provide insights into the viability of particular land types when trees are incorporated into the analysis. There are a couple of land types which resulted in only negative costs for sediment reductions. These negative costs were generally associated with lower productivity land types, in low to average rainfall areas. The tree basal modelled was considered the average tree basal area for each particular land type, therefore, in reality there will be a wide range of tree basal areas associated with each land type. It is expected that those land types are not viable for pastoral operations at the scale of operations used in the models, or that specialist operations with the very low operational costs can exist.

The variation in costs per tonne of sediment between land types was also notable with black basalt having a predicted cost of \$15,746.90 per tonne in "A" start condition and 19 cents per tonne for narrow leaved ironbark in "C" condition on deeper soils (Table 9).

Table 8. Predicted cost (\$/t) of sediment reductions of all land types – 0 tree basal area.

Cost to reduce sediment (\$/t)	Start Condition	Pasture Utilisation (%TSDM)							
		15	20	25	30	35	40	45	50
Black Basalt	C	132.58	393.62	298.63	206.45	116.19	41.05	-40.63	-69.50
Black Basalt	B	2,956.66	4,897.85	3,297.08	1,891.59	1,122.88	626.70	322.28	171.21
Black Basalt	A	20,722.30	25,594.46	15,968.14	9,167.49	4,924.90	2,724.89	1,546.32	771.14
Brigalow blackbutt	C	427.26	575.18	511.75	302.49	155.67	159.16	151.56	139.13
Brigalow blackbutt	B	949.33	1,352.65	1,499.80	1,593.14	1,260.43	1,160.21	1,130.24	811.01
Brigalow blackbutt	A	1,150.47	1,536.78	1,716.57	1,855.37	1,799.76	2,066.20	2,061.90	1,935.34
Coolibah floodplains	C	289.76	1,568.36	1,106.03	779.23	297.93	73.15	-172.26	-566.91
Coolibah floodplains	B	2,317.20	4,275.82	3,107.17	2,386.59	1,998.72	1,801.48	1,379.94	650.89
Coolibah floodplains	A	4,844.20	7,387.33	6,182.62	5,209.55	3,967.84	3,207.64	2,835.92	2,568.89
Goldfields	C	4.97	14.14	7.39	2.98	1.35	-2.32	-6.16	-10.10
Goldfields	B	62.76	82.10	46.95	30.23	20.19	14.07	9.56	3.22
Goldfields	A	572.76	523.34	293.60	190.68	122.23	88.96	67.05	49.31
Loamy alluvials	C	565.21	200.55	77.58	19.86	-3.20	-20.97	-42.78	-55.51
Loamy alluvials	B	4,607.94	1,786.75	489.62	154.31	64.42	17.50	-21.33	-48.49
Loamy alluvials	A	15,911.65	6,085.66	1,399.25	387.48	151.29	75.01	16.92	-36.22
NLIB deeper soil	C	15.46	23.38	19.20	17.19	14.87	13.63	11.62	8.17
NLIB deeper soil	B	86.11	79.43	57.59	43.18	33.23	26.86	22.34	19.12
NLIB deeper soil	A	277.79	283.18	193.49	122.25	76.99	53.69	40.72	33.38
NLIB shallower soil	C	18.66	-168.07	-212.60	-326.49	-384.25	-439.32	-520.59	-588.35
NLIB shallower soil	B	19.35	20.22	20.01	18.24	16.48	14.58	13.04	11.92
NLIB shallower soil	A	42.16	40.57	32.94	27.23	22.57	19.52	17.38	16.03
NLIB woodland	C	-2.06	0.75	-19.76	-31.23	-43.73	-64.45	-94.19	-157.31
NLIB woodland	B	84.97	62.42	-4.03	-111.55	-159.51	-286.63	-455.52	-835.08
NLIB woodland	A	331.40	237.15	103.85	-41.71	-79.10	-197.71	-446.05	-762.91
Open downs	C	-191.57	-81.66	-38.10	-31.47	-37.03	-46.82	-57.39	-67.65
Open downs	B	-127.93	291.82	135.04	64.88	22.41	3.83	-15.98	-26.51
Open downs	A	808.33	1,709.18	831.57	335.96	165.30	123.67	85.81	51.55
Red Basalt	C	29.97	47.06	37.23	29.41	22.10	20.38	17.27	13.43
Red Basalt	B	184.11	244.27	163.78	109.29	76.11	65.86	55.02	46.14
Red Basalt	A	746.86	939.12	711.37	514.92	350.95	243.33	181.07	137.46
SLIB	C	6.31	1.64	-5.54	-18.75	-35.61	-52.41	-67.07	-77.09
SLIB	B	75.62	71.12	27.98	-1.84	-19.81	-38.82	-62.05	-73.52
SLIB	A	491.44	234.76	125.74	40.24	-6.87	-26.55	-57.18	-70.70
SLIB on duplex	C	2.05	0.29	-9.45	-8.71	-16.04	-47.29	-111.13	-140.48
SLIB on duplex	B	19.41	20.51	6.12	1.24	-5.08	-24.25	-51.26	-89.37
SLIB on duplex	A	129.53	86.01	34.66	12.47	6.55	-7.08	-29.33	-60.20

Table 9 Predicted cost (\$/t) of sediment reductions of all land types– with trees

Cost to reduce sediment (\$/t)	Start Condition	Pasture Utilisation (%TSDM)							
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Brigalow blackbutt	B	949.33	1,352.65	1,499.80	1,593.14	1,260.43	1,160.21	1,130.24	811.01
Brigalow blackbutt	A	1,150.47	1,536.78	1,716.57	1,855.37	1,799.76	2,066.20	2,061.90	1,935.34
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NLIB deeper soil	A	277.79	283.18	193.49	122.25	76.99	53.69	40.72	33.38
NLIB shallower soil	C	18.66	-168.07	-212.60	-326.49	-384.25	-439.32	-520.59	-588.35
NLIB shallower soil	B	19.35	20.22	20.01	18.24	16.48	14.58	13.04	11.92
NLIB shallower soil	A	42.16	40.57	32.94	27.23	22.57	19.52	17.38	16.03
NLIB woodland	C	-2.06	0.75	-19.76	-31.23	-43.73	-64.45	-94.19	-157.31
NLIB woodland	B	84.97	62.42	-4.03	-111.55	-159.51	-286.63	-455.52	-835.08
NLIB woodland	A	331.40	237.15	103.85	-41.71	-79.10	-197.71	-446.05	-762.91
Open downs	C	-191.57	-81.66	-38.10	-31.47	-37.03	-46.82	-57.39	-67.65
Open downs	B	-127.93	291.82	135.04	64.88	22.41	3.83	-15.98	-26.51
Open downs	A	808.33	1,709.18	831.57	335.96	165.30	123.67	85.81	51.55
Red Basalt	C	29.97	47.06	37.23	29.41	22.10	20.38	17.27	13.43
Red Basalt	B	184.11	244.27	163.78	109.29	76.11	65.86	55.02	46.14
Red Basalt	A	746.86	939.12	711.37	514.92	350.95	243.33	181.07	137.46
SLIB	C	6.31	1.64	-5.54	-18.75	-35.61	-52.41	-67.07	-77.09
SLIB	B	75.62	71.12	27.98	-1.84	-19.81	-38.82	-62.05	-73.52
SLIB	A	491.44	234.76	125.74	40.24	-6.87	-26.55	-57.18	-70.70
SLIB on duplex	C	2.05	0.29	-9.45	-8.71	-16.04	-47.29	-111.13	-140.48
SLIB on duplex	B	19.41	20.51	6.12	1.24	-5.08	-24.25	-51.26	-89.37
SLIB on duplex	A	129.53	86.01	34.66	12.47	6.55	-7.08	-29.33	-60.20

Figures 14 and 15 present the \$/t cost to reduce sediment graphically to show the range of costs across the pasture utilisation levels for each land type and start condition. The smallest incentive that would be required to be paid if incentives were chosen as the policy mechanism are marked in green. Where there is no green bar, this indicates that there is a negative \$/t cost across all pasture utilisations for this land type and start condition, meaning that education and extension are required solely. Note that the \$/t cost for “A” start condition scenario for coolabah flood plains, brigalow blackbutt and black basalt land types go off the top of the graph’s scale (Figures 14 and 15). These land types, particularly black basalt have very expensive \$/t costs to reduce sediment movement. The scale of the graph has been set to allow easier viewing of the \$/t costs for the remaining land types and

start conditions, as incentives should always be targeted towards the land types and land conditions that have lower \$/t costs to reduce sediment.

The range covered by the black line indicates the highest and lowest cost per tonne of sediment over the pasture utilisation rates for the particular land type, and start condition. The range of cost per tonne of sediment also highlights the risk of investment in sediment reductions. Scenarios that exhibit a large amount of variation (longer black lines) also exhibit higher amounts of risk in purchasing sediment reductions. This is due to the dynamic nature of grazing production and the difficulty within a season to specifically target a particular pasture utilisation rate.

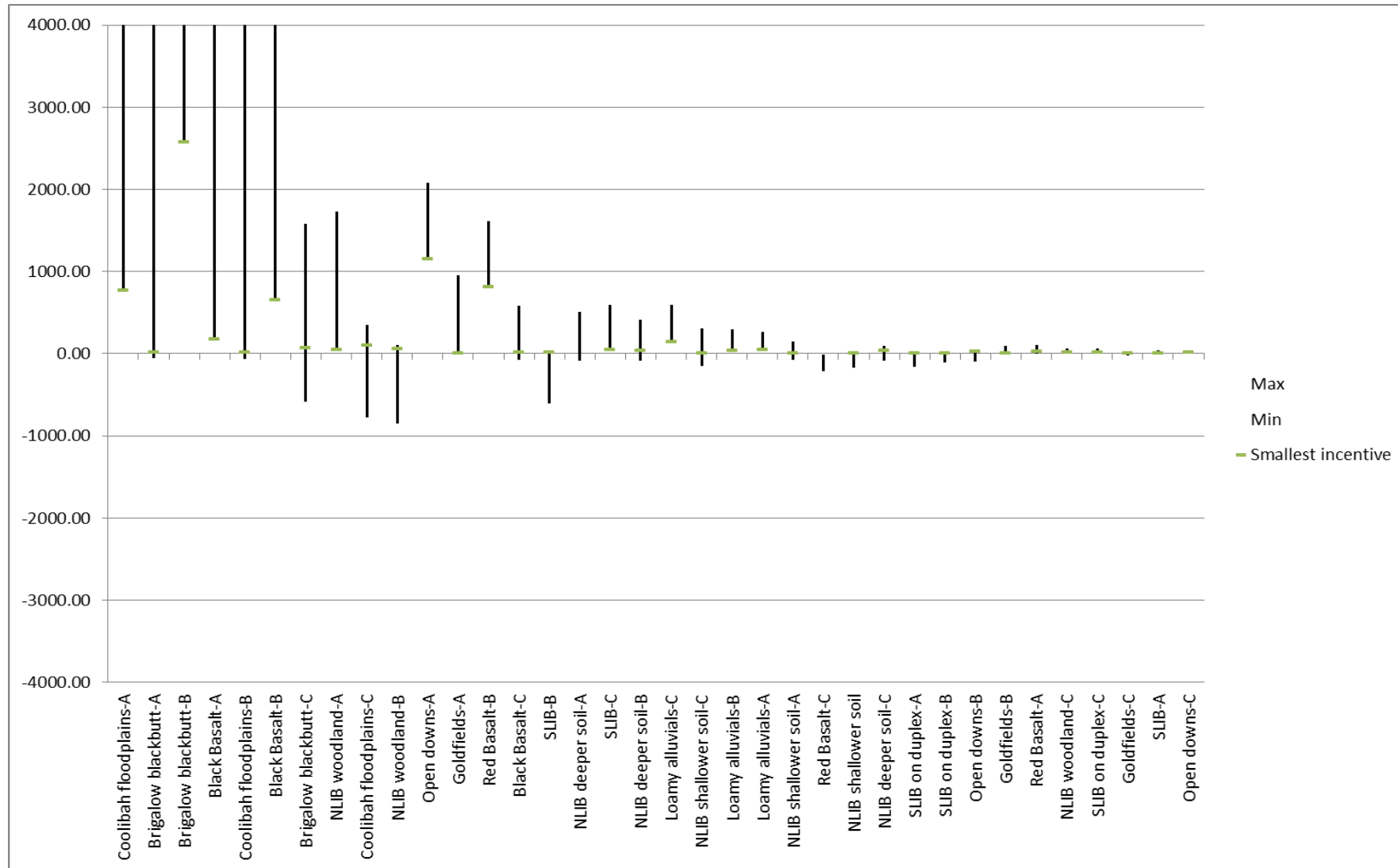


Figure 14: \$/t cost to reduce sediment by land type and start condition – 0 tree basal area.

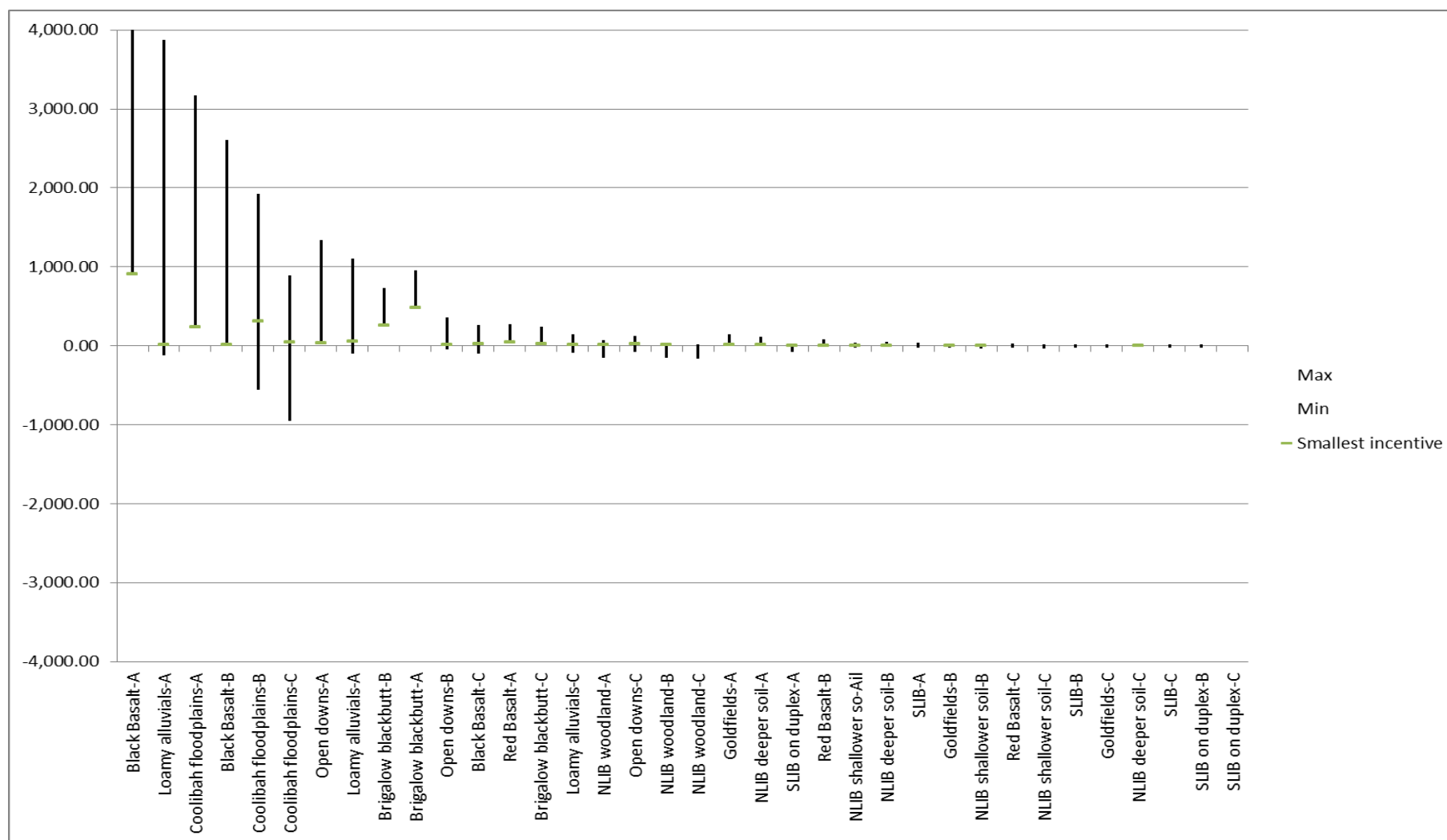


Figure 15: \$/t cost to reduce sediment by land type and start condition – with trees.

Discussion

This report has applied bioeconomic modelling to provide an understanding of the trade-offs between sediment, pasture utilisation and profit that exist across a selection of land types and locations in the selected Great Barrier Reef Catchments. The analysis allows an opportunity cost to be estimated and a greater understanding of the cost per tonne of sediment reduced. The results provide insights into the range of costs (dollars) per tonne of sediment and highlight the complexity of cost effective targeting of funds. This complexity highlights the multifaceted interactions and the impact of biophysical factors such as land type, location, slope and impact of trees.

The productivity of the land type is a key parameter in the cost of sediment reduction, as it influences the types of enterprise that can be operated on the particular land type, as well as relating soil type and slope, key factors driving sediment movement. The combination of these three factors (enterprise, soil, slope) generally result in variations in costs per tonne of sediment reduced. Land types with a lower inherent productivity operate lower value enterprises, are situated on poorer soils which are more susceptible to soil run-off, and often have a greater degree of slope. Conversely, land types with higher inherent productivity tend to have more profitable enterprises and lower levels of sediment movement resulting in a lower cost per tonne of sediment.

The interaction between location and climate presents challenges as high rainfall areas continue to produce pasture even at high pasture utilisation and therefore the sediment exported and cost per tonne of sediment reductions is higher. Higher rainfall can effectively mask the land types' lower productivity. The location is a key parameter as the green days or days when the level of moisture, sunlight and warmth influence pasture growth is critical to both profitability and sediment emissions impacting on the cost of sediment reductions. This can be noted clearly in the narrow leaved ironbark on deeper soils and the red basalt which were modelled in the Herbert catchment with a higher rainfall and associated number of growing days.

The impact of trees versus no trees is also reflected in the cost per tonne of sediment exported. Trees in a landscape create competition between trees and pasture for nutrients, water and light. This results in decreased pasture production and reduced ground cover, with subsequent high amounts of sediment exported.

The initial start condition provides a basis to begin the simulations, and identifies the initial pasture production and species composition. The minimum starting condition modelled was "C" condition as the definition of "D" is that the land requires mechanical intervention to initiate recovery in a reasonable time frame. The results highlight the importance of start condition as poorer start condition ("C" condition) provide cheaper sediment reductions as opposed to the better start condition of "B" or "A". This is due to the higher pasture coverage leading to less bare ground and therefore sediment, but also attributed to the increased net present values as a result of increased live weight gains, higher branding rates, lower mortalities and less days and animals being drought feed even in low rainfall years.

The range of values for sediment reduction costs has positive and negative values for most land types. The positive costs of sediment reductions present the opportunity cost for landholders to reduce grazing pressure and forgo income. These are values where the landholder has not reached the economically optimal grazing pressure and therefore involves opportunity cost in reducing pasture utilisation. The values which are negative present opportunities where over the long term the landholder is making a loss, by operating past the economically optimal point. The economically optimal point represents that for the management assumptions used in the model this is the optimal utilisation rate.

The range of costs from 15% pasture utilisation through to 70% pasture utilisation provides an indication of the risk of targeted investments and the variance which climatic effects have on achieving outcomes. For NRM group seeking to target investments the range provides an understanding of the variance in outcomes that occur from landholders operating at different levels of grazing intensity. Therefore land types with a relatively small range of costs provides a lower risk option for targeting investment than land types which demonstrate large amount of variation.

The range of combinations of variables and the interactions between them results in a wide range of costs to reduce sediment movement. This range is a key consideration when targeting investments as it provides insights into the quantity of sediment reductions that are available and the policy or program mechanism that provides the most cost effective solution. The range reflects the marginal changes between opportunity cost and sediment exported. For example black basalt in "A" condition presented some of the most expensive reductions in sediment, due to a significant increase in production, and subsequent profit (increase in net present value of \$2,296,590) between 15% TSDM and 20%TSDM, however the resulting change in sediment exported is relatively marginal (81 tonnes).

The confidence intervals that surround the use of both the biophysical and GRASP modelling must also be considered along with the complexity of the integration. This analysis involves an implicit assumption that the reduction in sediment loss at the paddock level will subsequently generate a reduction in sediment export into the lagoon. The study also has not considered the impact of gully erosion or the cumulative impacts of a suite of management practices, only focusing on pasture utilisation (stocking rates). Similarly, it must be considered that landholders are able to manage more dynamically then the model resulting in the optimal pasture utilisation not been so pronounced. Therefore resulting in the range in cost per tonne of sediment reduced being an important factor to consider.

Other limitations of the study should be noted. The bioeconomic model is simplistic in assuming that each modelled property consists of one land type and that the pasture utilisation rates are applied uniformly across each property. The assumption that landholders are always profit maximising and have perfect knowledge should also be noted as not fully realistic. Similarly, the assumption that landholders business management follows one particular set of practices does not account for the heterogeneity that exists amongst landholders skills, business structure and goals of the business.

Conclusions

The report findings highlight the complexity of estimating costs of practice change using a bioeconomic model and the heterogeneity that occurs at both a spatial level and at management levels. This report identifies various costs for sediment reductions, highlighting the importance of consideration of landscape factors when making investment decisions for sediment reductions.

This work shows the potential for this type of analysis to provide more sophisticated modelling of the relevant trade-offs. This study could be expanded to cover all the major land types in the Fitzroy and Burdekin basins, as well as to address some of the caveats noted. Future development of these approaches should help governments and agencies to substantially improve the allocation of resources for environmental improvements.

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Appendix 1: Full results for all land types

Appendix: Table 10. Full results for all land types – 0 tree basal area.

	Pasture Utilisation (%TSDM)							
	15	20	25	30	35	40	45	50
Black Basalt C condition								
10,000ha AE's	2,547	2,807	3,074	3,358	3,629	3,917	4,192	4,455
NPV (\$)	448,031	2,084,884	2,265,286	2,042,511	1,378,105	563,019	-629,008	-1,198,807
Sediment								
Exported (t)	3,379	5,297	7,586	9,893	11,861	13,716	15,482	17,249
\$/tonne								
Cost to reduce	133	394	299	206	116	41	-41	-69
Black Basalt B condition								
10,000ha AE's	3,812	4,352	4,683	4,939	5,186	5,458	5,731	5,989
NPV (\$)	1,766,982	5,152,594	6,402,654	6,170,267	5,450,028	4,080,541	2,635,947	1,677,478
Sediment								
Exported (t)	598	1,052	1,942	3,262	4,854	6,511	8,179	9,798
\$/tonne								
Cost to reduce	2,957	4,898	3,297	1,892	1,123	627	322	171
Black Basalt A condition								
10,000ha AE's	4,555	5,596	6,350	6,931	7,420	7,842	8,205	8,530
NPV (\$)	3,443,013	6,550,000	6,970,000	6,870,000	5,979,210	4,993,503	4,082,058	2,755,826
Sediment								
Exported (t)	166	256	436	749	1,214	1,833	2,640	3,574
\$/tonne								
Cost to reduce	20,722	25,594	15,968	9,167	4,925	2,725	1,546	771
Brigalow blackbutt C condition								
5,000ha AE's	664	846	1,000	1,048	976	1,047	1,126	1,173
NPV (\$)	1,155,900	1,848,459	2,120,535	2,092,890	1,850,046	2,133,706	2,238,010	2,290,241
Sediment								
Exported (t)	2,705	3,214	4,144	6,919	11,885	13,406	14,766	16,461
\$/tonne								
Cost to reduce	427	575	512	302	156	159	152	139
Brigalow blackbutt B condition								
5,000ha AE's	700	907	1,099	1,276	1,404	1,513	1,639	1,677
NPV (\$)	1,495,506	2,315,042	2,802,347	3,260,763	3,341,261	3,977,025	4,389,080	4,624,313
Sediment								
Exported (t)	1,575	1,711	1,868	2,047	2,651	3,428	3,883	5,702
\$/tonne								
Cost to reduce	949	1,353	1,500	1,593	1,260	1,160	1,130	811
Brigalow blackbutt A condition								
5,000ha AE's	706	914	1,110	1,294	1,468	1,639	1,791	1,915
NPV (\$)	1,724,253	2,501,677	3,022,056	3,509,871	3,694,268	4,432,820	4,879,346	5,381,324
Sediment								
Exported (t)	1,499	1,628	1,761	1,892	2,053	2,145	2,366	2,781
\$/tonne								
Cost to reduce	1,150	1,537	1,717	1,855	1,800	2,066	2,062	1,935
Coolibah floodplains C condition								
5,000ha AE's	543	609	602	607	657	711	764	823
NPV (\$)	238,307	1,848,459	1,980,881	1,820,263	772,267	201,639	-506,919	-1,720,746
Sediment								
Exported (t)	822	1,179	1,791	2,336	2,592	2,757	2,943	3,035
\$/tonne								
Cost to reduce	290	1,568	1,106	779	298	73	-172	-567
Coolibah floodplains B condition								
5,000ha AE's	635	771	811	818	838	861	909	957
NPV (\$)	881,569	2,270,269	2,941,256	3,483,869	3,671,593	3,977,025	3,320,014	1,682,250
Sediment								
Exported (t)	380	531	947	1,460	1,837	2,208	2,406	2,585
\$/tonne								
Cost to reduce	2,317	4,276	3,107	2,387	1,999	1,801	1,380	651
Coolibah floodplains A condition								
5,000ha AE's	661	831	953	1,023	1,020	1,046	1,086	1,146
NPV (\$)	1,550,000	2,940,000	3,691,854	4,450,468	5,121,586	5,401,526	5,460,090	5,381,324
Sediment								
Exported (t)	320	398	597	854	1,291	1,684	1,925	2,095
\$/tonne								
Cost to reduce	4,844	7,387	6,183	5,210	3,968	3,208	2,836	2,569

	Pasture Utilisation (%TSDM)							
	15	20	25	30	35	40	45	50
Goldfields	C condition							
10,000ha AE's	1,273	1,419	1,584	1,760	1,929	2,092	2,242	2,383
NPV (\$)	284,411	1,148,839	723,262	326,421	163,329	-303,387	-865,495	-1,508,557
Sediment								
Exported (t)	57,215	81,244	97,848	109,568	121,081	130,839	140,422	149,325
\$/tonne								
Cost to reduce	5	14	7	3	1	-2	-6	-10
Goldfields	B condition							
10,000ha AE's	2,064	2,227	2,358	2,506	2,654	2,797	2,945	3,084
NPV (\$)	961,059	2,516,873	2,272,419	1,931,148	1,607,519	1,293,452	987,918	365,376
Sediment								
Exported (t)	15,314	30,658	48,399	63,890	79,626	91,926	103,359	113,626
\$/tonne								
Cost to reduce	63	82	47	30	20	14	10	3
Goldfields	A condition							
10,000ha AE's	2,759	3,204	3,500	3,740	3,928	4,097	4,254	4,400
NPV (\$)	2,472,161	4,399,033	4,614,897	4,674,053	4,444,536	4,265,189	3,954,078	3,444,135
Sediment								
Exported (t)	4,316	8,406	15,718	24,513	36,363	47,945	58,970	69,840
\$/tonne								
Cost to reduce	573	523	294	191	122	89	67	49
Loamy alluvials	C condition							
10,000ha AE's	2,080	1,943	1,758	1,815	1,987	2,090	2,207	2,349
NPV (\$)	1,691,364	1,264,464	989,429	350,064	-69,017	-520,502	-1,168,633	-1,633,343
Sediment								
Exported (t)	2,992	6,305	12,754	17,628	21,592	24,820	27,318	29,423
\$/tonne								
Cost to reduce	565	201	78	20	-3	-21	-43	-56
Loamy alluvials	B condition							
10,000ha AE's	2,674	2,806	2,607	2,508	2,532	2,614	2,735	2,863
NPV (\$)	2,764,252	2,523,957	2,275,914	1,490,894	931,795	322,067	-455,901	-1,161,106
Sediment								
Exported (t)	600	1,413	4,648	9,661	14,465	18,404	21,370	23,943
\$/tonne								
Cost to reduce	4,608	1,787	490	154	64	18	-21	-48
Loamy alluvials	A condition							
10,000ha AE's	3,088	3,438	3,317	3,170	3,134	3,200	3,307	3,426
NPV (\$)	3,516,478	3,533,105	3,249,153	2,459,656	1,676,944	1,112,285	301,744	-749,137
Sediment								
Exported (t)	221	581	2,322	6,348	11,084	14,829	17,831	20,684
\$/tonne								
Cost to reduce	15,912	6,086	1,399	387	151	75	17	-36
NLIB deeper soil	C condition							
10,000ha AE's	1,193	1,377	1,561	1,761	1,975	2,180	2,375	2,554
NPV (\$)	776,468	1,683,520	1,724,027	1,731,165	1,633,058	1,599,240	1,440,532	1,080,054
Sediment								
Exported (t)	50,231	71,995	89,811	100,711	109,800	117,370	123,956	132,125
\$/tonne								
Cost to reduce	15	23	19	17	15	14	12	8
NLIB deeper soil	B condition							
10,000ha AE's	1,769	1,971	2,112	2,272	2,443	2,620	2,792	2,956
NPV (\$)	1,240,246	2,160,000	2,621,461	2,660,459	2,580,070	2,392,610	2,220,000	2,090,472
Sediment								
Exported (t)	14,404	27,195	45,518	61,609	77,637	89,093	99,386	109,311
\$/tonne								
Cost to reduce	86	79	58	43	33	27	22	19
NLIB deeper soil	A condition							
10,000ha AE's	2,215	2,657	2,952	3,178	3,362	3,517	3,663	3,803
NPV (\$)	1,471,022	2,431,545	2,912,369	2,975,237	2,825,893	2,664,268	2,525,371	2,442,538
Sediment								
Exported (t)	5,295	8,587	15,052	24,337	36,705	49,624	62,022	73,176
\$/tonne								
Cost to reduce	278	283	193	122	77	54	41	33

		Pasture Utilisation (%TSDM)							
		15	20	25	30	35	40	45	50
NLIB shallower soil		C condition							
10,000ha AE's	542	590	665	745	823	899	972	1,040	
NPV (\$)	14,522	-187,409	-360,236	-721,548	-942,316	-1,145,732	-1,449,363	-1,689,534	
Sediment									
Exported (t)	778	1,115	1,694	2,210	2,452	2,608	2,784	2,872	
\$/tonne									
Cost to reduce	19	-168	-213	-326	-384	-439	-521	-588	
NLIB shallower soil		B condition							
10,000ha AE's	796	807	859	926	1,000	1,073	1,143	1,210	
NPV (\$)	376,893	116,336	-81,918	-491,401	-750,973	-996,172	-1,343,348	-1,590,325	
Sediment									
Exported (t)	64,105	106,823	131,025	145,846	156,552	164,147	170,291	175,360	
\$/tonne									
Cost to reduce	19	20	20	18	16	15	13	12	
NLIB shallower soil		A condition							
10,000ha AE's	1,033	1,133	1,187	1,245	1,310	1,376	1,444	1,510	
NPV (\$)	788,793	673,031	544,383	218,877	-87,731	-419,749	-854,219	-1,178,157	
Sediment									
Exported (t)	34,895	59,937	88,428	109,282	125,189	136,480	145,293	152,417	
\$/tonne									
Cost to reduce	42	41	33	27	23	20	17	16	
NLIB woodland		C condition							
5,000ha AE's	545	518	553	603	671	742	808	871	
NPV (\$)	-60,822	41,466	-1,429,195	-2,601,674	-3,853,736	-5,856,527	-8,805,542	-15,081,521	
Sediment									
Exported (t)	29,478	55,101	72,334	83,304	88,135	90,873	93,488	95,871	
\$/tonne									
Cost to reduce	-2	1	-20	-31	-44	-64	-94	-157	
NLIB woodland		B condition							
5,000ha AE's	684	767	713	701	757	837	907	974	
NPV (\$)	728,357	804,077	-57,257	-1,657,280	-2,425,219	-4,408,998	-7,184,694	-13,058,541	
Sediment									
Exported (t)	8,571	12,882	14,200	14,857	15,204	15,382	15,773	15,637	
\$/tonne									
Cost to reduce	85	62	-4	-112	-160	-287	-456	-835	
NLIB woodland		A condition							
5,000ha AE's	723	895	914	827	883	950	1,026	1,100	
NPV (\$)	2,229,529	2,045,723	1,281,070	-603,340	-1,183,057	-2,913,226	-6,500,989	-11,567,169	
Sediment									
Exported (t)	6,728	8,626	12,336	14,466	14,956	14,735	14,574	15,162	
\$/tonne									
Cost to reduce	331	237	104	-42	-79	-198	-446	-763	
Open downs		C condition							
10,000ha AE's	1,818	1,722	1,469	1,410	1,455	1,520	1,593	1,669	
NPV (\$)	-1,537,160	-1,124,937	-913,786	-978,252	-1,330,831	-1,829,508	-2,388,778	-2,955,347	
Sediment									
Exported (t)	8,024	13,776	23,985	31,084	35,939	39,073	41,624	43,683	
\$/tonne									
Cost to reduce	-192	-82	-38	-31	-37	-47	-57	-68	
Open downs		B condition							
10,000ha AE's	2,360	2,587	2,404	2,190	2,132	2,144	2,190	2,250	
NPV (\$)	-263,643	1,185,574	1,357,778	1,176,674	567,438	113,938	-527,836	-951,313	
Sediment									
Exported (t)	2,061	4,063	10,055	18,136	25,321	29,761	33,039	35,887	
\$/tonne									
Cost to reduce	-128	292	135	65	22	4	-16	-27	
Open downs		A condition							
10,000ha AE's	2,620	3,200	3,378	3,255	3,156	3,128	3,162	3,227	
NPV (\$)	716,687	2,296,163	2,615,277	2,800,806	2,509,228	2,531,024	2,097,369	1,408,674	
Sediment									
Exported (t)	887	1,343	3,145	8,337	15,180	20,465	24,442	27,328	
\$/tonne									
Cost to reduce	808	1,709	832	336	165	124	86	52	

	Pasture Utilisation (%TSDM)						
	15	20	25	30	35	40	50
Red Basalt	C condition						
10,000ha AE's	1,472	1,637	1,793	1,965	2,161	2,370	2,576
NPV (\$)	527,242	1,268,883	1,382,826	1,339,126	1,147,783	1,158,546	1,056,130
Sediment							
Exported (t)	17,594	26,966	37,143	45,537	51,940	56,860	61,136
\$/tonne							
Cost to reduce	30	47	37	29	22	20	17
Red Basalt	B condition						
10,000ha AE's	2,055	2,377	2,556	2,682	2,833	3,005	3,186
NPV (\$)	989,643	2,092,488	2,344,650	2,416,307	2,276,719	2,411,807	2,338,546
Sediment							
Exported (t)	5,375	8,566	14,316	22,108	29,914	36,617	42,505
\$/tonne							
Cost to reduce	184	244	164	109	76	66	55
Red Basalt	A condition						
10,000ha AE's	2,369	2,947	3,363	3,677	3,942	4,164	4,532
NPV (\$)	1,887,852	3,143,998	3,571,505	3,912,147	3,888,744	3,730,000	3,660,000
Sediment							
Exported (t)	2,528	3,348	5,021	7,598	11,081	15,329	20,213
\$/tonne							
Cost to reduce	747	939	711	515	351	243	181
SLIB	C condition						
10,000ha AE's	592	616	701	774	837	889	950
NPV (\$)	187,094	80,000	-330,000	-1,311,258	-2,872,846	-4,752,869	-6,562,685
Sediment							
Exported (t)	29,660	48,665	59,571	69,919	80,671	90,681	97,842
\$/tonne							
Cost to reduce	6	2	-6	-19	-36	-52	-67
SLIB	B condition						
10,000ha AE's	899	921	966	1,022	1,049	1,098	1,172
NPV (\$)	590,000	1,407,106	1,004,729	-87,491	-1,237,184	-2,874,927	-5,002,954
Sediment							
Exported (t)	7,802	19,786	35,914	47,525	62,462	74,051	80,634
\$/tonne							
Cost to reduce	76	71	28	-2	-20	-39	-62
SLIB	A condition						
10,000ha AE's	1,040	1,182	1,280	1,321	1,270	1,330	1,406
NPV (\$)	1,691,234	1,879,132	2,047,291	1,152,934	-330,142	-1,561,000	-3,810,427
Sediment							
Exported (t)	3,441	8,004	16,282	28,654	48,036	58,794	66,643
\$/tonne							
Cost to reduce	491	235	126	40	-7	-27	-57
SLIB on duplex	C condition						
10,000ha AE's	593	594	664	746	825	899	963
NPV (\$)	201,234	40,547	-1,525,963	-1,505,269	-2,926,958	-8,995,638	-22,045,085
Sediment							
Exported (t)	98,144	141,218	161,483	172,747	182,463	190,219	198,379
\$/tonne							
Cost to reduce	2	0	-9	-9	-16	-47	-111
SLIB on duplex	B condition						
10,000ha AE's	928	920	899	1,000	1,075	1,131	1,193
NPV (\$)	801,293	1,604,293	740,578	163,598	-750,538	-3,898,561	-8,798,527
Sediment							
Exported (t)	41,290	78,237	121,032	132,328	147,661	160,783	171,635
\$/tonne							
Cost to reduce	19	21	6	1	-5	-24	-51
SLIB on duplex	A condition						
10,000ha AE's	1,137	1,271	1,196	1,264	1,313	1,368	1,431
NPV (\$)	2,775,530	3,276,571	2,856,519	1,254,397	795,836	-963,397	-4,325,722
Sediment							
Exported (t)	21,428	38,093	82,422	100,619	121,584	136,115	147,508
\$/tonne							
Cost to reduce	130	86	35	12	7	-7	-29

Appendix: Table 11. Full results for all land types – with trees.

		Pasture Utilisation (%TSDM)						
	15	20	25	30	35	40	45	50
Black Basalt	C condition							
10,000ha AE's	2,292	2,516	2,748	2,985	3,210	3,443	3,666	3,882
NPV (\$)	178,247	1,630,864	1,506,473	1,355,202	362,288	-441,816	-1,083,392	-1,664,370
Sediment								
Exported (t)	4,181	6,493	9,065	11,796	14,089	16,206	18,226	20,180
\$/tonne								
Cost to reduce	43	251	166	115	26	-27	-59	-82
Black Basalt	B condition							
10,000ha AE's	3,485	3,962	4,263	4,487	4,702	4,927	5,159	5,379
NPV (\$)	1,193,641	3,503,606	3,873,097	3,494,159	2,534,262	2,078,412	1,513,873	114,331
Sediment								
Exported (t)	768	1,352	2,415	4,013	5,858	7,781	9,612	11,476
\$/tonne								
Cost to reduce	1,555	2,591	1,604	871	433	267	157	10
Black Basalt	A condition							
10,000ha AE's	4,194	5,145	5,829	6,361	6,799	7,167	7,485	7,777
NPV (\$)	3,425,237	6,289,505	6,417,817	6,400,811	5,979,210	4,993,503	4,572,981	3,958,187
Sediment								
Exported (t)	198	304	513	870	1,380	2,074	2,957	3,964
\$/tonne								
Cost to reduce	15,746	18,773	11,359	6,682	3,934	2,186	1,405	907
Brigalow blackbutt	C condition							
5,000ha AE's	527	670	795	825	834	868	908	941
NPV (\$)	577,291	1,257,079	1,360,458	1,101,660	863,163	825,144	637,000	437,527
Sediment								
Exported (t)	4,535	5,461	6,445	9,813	13,633	16,682	18,695	20,687
\$/tonne								
Cost to reduce	127	230	211	112	63	49	34	21
Brigalow blackbutt	B condition							
5,000ha AE's	558	722	878	1,022	1,135	1,237	1,255	1,251
NPV (\$)	933,374	1,785,721	2,101,339	2,420,537	2,460,894	2,806,163	2,806,982	2,668,202
Sediment								
Exported (t)	2,697	2,892	3,061	3,364	4,256	5,142	7,974	10,475
\$/tonne								
Cost to reduce	346	618	687	720	578	546	352	255
Brigalow blackbutt	A condition							
5,000ha AE's	562	727	886	1,039	1,182	1,312	1,432	1,520
NPV (\$)	1,239,992	1,920,430	2,307,477	2,670,361	2,805,909	3,360,028	3,641,276	3,909,041
Sediment								
Exported (t)	2,574	2,749	2,879	3,020	3,243	3,566	3,943	5,026
\$/tonne								
Cost to reduce	482	699	801	884	865	942	924	778
Coolibah floodplains	C condition							
5,000ha AE's	305	364	401	418	435	451	472	503
NPV (\$)	-187,401	1,257,079	1,090,000	630,258	120,000	-880,329	-1,842,574	-2,840,000
Sediment								
Exported (t)	1,194	1,445	1,742	2,064	2,443	2,770	2,916	3,036
\$/tonne								
Cost to reduce	-157	870	626	305	49	-318	-632	-935
Coolibah floodplains	B condition							
5,000ha AE's	375	469	525	549	540	558	586	627
NPV (\$)	-428,552	1,720,000	2,100,000	2,350,000	2,460,894	2,105,824	750,000	-890,000
Sediment								
Exported (t)	793	901	1,161	1,512	1,840	2,287	2,410	2,500
\$/tonne								
Cost to reduce	-541	1,910	1,809	1,555	1,337	921	311	-356
Coolibah floodplains	A condition							
5,000ha AE's	361	460	537	580	592	611	652	702
NPV (\$)	179,180	2,320,000	3,092,954	3,505,826	3,525,963	3,665,963	3,641,276	1,895,923
Sediment								
Exported (t)	766	840	982	1,250	1,716	2,064	2,141	2,203
\$/tonne								
Cost to reduce	234	2,762	3,151	2,804	2,055	1,776	1,701	861

	Pasture Utilisation (%TSDM)							
	15	20	25	30	35	40	45	50
Goldfields	C condition							
10,000ha AE's	816	906	1,005	1,113	1,224	1,329	1,432	1,532
NPV (\$)	284,411	-125	-188,948	-529,251	-829,965	-1,212,463	-1,489,345	-1,760,175
Sediment								
Exported (t)	94,998	120,145	137,519	150,307	158,296	166,128	172,918	178,655
\$/tonne								
Cost to reduce	3	0	-1	-4	-5	-7	-9	-10
Goldfields	B condition							
10,000ha AE's	1,438	1,526	1,592	1,677	1,771	1,857	1,951	2,040
NPV (\$)	146,918	960,700	567,106	412,533	209,397	-253,361	-672,546	-1,106,929
Sediment								
Exported (t)	31,744	54,205	78,076	96,385	112,631	125,067	135,518	144,941
\$/tonne								
Cost to reduce	5	18	7	4	2	-2	-5	-8
Goldfields	A condition							
10,000ha AE's	1,985	2,300	2,497	2,638	2,761	2,873	2,969	3,067
NPV (\$)	1,069,333	2,271,966	1,916,832	1,934,532	1,864,872	1,743,973	1,354,581	907,586
Sediment								
Exported (t)	10,833	17,894	29,068	42,089	57,789	71,209	83,614	94,328
\$/tonne								
Cost to reduce	99	127	66	46	32	24	16	10
Loamy alluvials	C condition							
10,000ha AE's	1,404	1,239	1,139	1,175	1,249	1,323	1,397	1,466
NPV (\$)	796,013	216,111	-100,750	-844,538	-1,309,686	-1,817,447	-2,394,509	-2,832,380
Sediment								
Exported (t)	6,393	13,189	22,459	28,977	32,648	35,979	38,826	41,324
\$/tonne								
Cost to reduce	125	16	-4	-29	-40	-51	-62	-69
Loamy alluvials	B condition							
10,000ha AE's	1,896	1,912	1,735	1,656	1,672	1,731	1,802	1,870
NPV (\$)	1,561,747	1,056,139	628,198	-239,478	-804,688	-1,437,716	-2,195,865	-2,813,297
Sediment								
Exported (t)	1,441	3,929	10,495	18,190	23,828	27,867	31,188	34,110
\$/tonne								
Cost to reduce	1,084	269	60	-13	-34	-52	-70	-82
Loamy alluvials	A condition							
10,000ha AE's	2,251	2,626	2,599	2,486	2,454	2,476	2,530	2,592
NPV (\$)	2,157,877	2,055,474	1,747,480	961,544	220,510	-485,805	-1,456,127	-2,793,129
Sediment								
Exported (t)	559	1,222	4,026	9,786	15,526	20,006	23,593	26,680
\$/tonne								
Cost to reduce	3,858	1,683	434	98	14	-24	-62	-105
NLIB deeper soil	C condition							
10,000ha AE's	883	1,006	1,139	1,267	1,399	1,522	1,635	1,740
NPV (\$)	232,489	763,426	625,789	395,372	162,331	-87,528	-265,413	-554,003
Sediment								
Exported (t)	74,610	100,595	117,631	131,884	145,133	155,961	166,034	174,939
\$/tonne								
Cost to reduce	3	8	5	3	1	-1	-2	-3
NLIB deeper soil	B condition							
10,000ha AE's	1,359	1,505	1,584	1,688	1,801	1,913	2,018	2,125
NPV (\$)	406,484	1,569,082	1,594,751	1,459,460	1,190,505	1,032,448	685,122	443,084
Sediment								
Exported (t)	24,290	42,712	68,002	87,136	104,475	119,461	132,744	144,178
\$/tonne								
Cost to reduce	17	37	23	17	11	9	5	3
NLIB deeper soil	A condition							
10,000ha AE's	1,716	2,055	2,272	2,430	2,552	2,662	2,759	2,846
NPV (\$)	650,258	1,553,964	1,676,279	1,762,307	1,659,511	1,700,812	1,458,227	1,248,993
Sediment								
Exported (t)	10,289	15,791	25,864	39,370	56,005	71,379	86,563	100,746
\$/tonne								
Cost to reduce	63	98	65	45	30	24	17	12

Pasture Utilisation (%TSDM)								
	15	20	25	30	35	40	45	50
NLIB shallower soil		C condition						
10,000ha AE's	394	422	462	506	549	591	632	671
NPV (\$)	11,007	-247,242	-475,245	-951,910	-1,243,161	-1,511,520	-1,912,089	-2,228,937
Sediment								
Exported (t)	77,456	91,339	98,361	103,048	106,260	108,892	110,993	112,587
\$/tonne								
Cost to reduce	0	-2	-4	-7	-9	-11	-13	-15
NLIB shallower soil		B condition						
10,000ha AE's	564	571	604	645	690	735	778	820
NPV (\$)	285,685	153,478	-108,072	-648,286	-990,730	-1,314,211	-1,772,227	-2,098,054
Sediment								
Exported (t)	52,524	74,375	84,744	91,647	96,383	100,111	103,125	105,549
\$/tonne								
Cost to reduce	7	2	-1	-5	-8	-10	-13	-15
NLIB shallower soil		A condition						
10,000ha AE's	737	799	833	870	912	956	998	1,043
NPV (\$)	597,905	510,158	412,643	165,909	-115,740	-553,758	-1,126,938	-1,554,296
Sediment								
Exported (t)	33,307	50,549	65,423	75,355	82,390	87,722	92,021	95,435
\$/tonne								
Cost to reduce	24	13	8	3	-1	-5	-9	-12
NLIB woodland		C condition						
5,000ha AE's	204	230	243	258	277	298	317	340
NPV (\$)	-182,498	-328,970	-2,000,000	-3,310,000	-4,670,000	-6,800,000	-9,890,000	-16,270,000
Sediment								
Exported (t)	58,300	73,064	88,457	95,417	101,592	104,307	106,861	108,432
\$/tonne								
Cost to reduce	-3	-5	-23	-35	-46	-65	-93	-150
NLIB woodland		B condition						
5,000ha AE's	233	267	278	299	322	339	362	379
NPV (\$)	610,000	520,000	-640,000	-2,380,000	-3,290,000	-5,440,000	-8,340,000	-14,310,000
Sediment								
Exported (t)	44,455	59,328	77,200	84,315	91,520	96,171	98,672	101,823
\$/tonne								
Cost to reduce	14	9	-8	-28	-36	-57	-85	-141
NLIB woodland		A condition						
5,000ha AE's	242	297	317	332	359	375	397	422
NPV (\$)	2,139,227	1,874,429	830,645	-1,325,740	-2,048,906	-3,946,439	-7,677,430	-12,837,316
Sediment								
Exported (t)	39,681	47,459	64,610	75,181	82,618	88,669	92,008	94,475
\$/tonne								
Cost to reduce	54	39	13	-18	-25	-45	-83	-136
Open downs		C condition						
10,000ha AE's	1,703	1,590	1,358	1,312	1,345	1,404	1,465	1,533
NPV (\$)	987,564	370,259	-172,760	-463,516	-1,019,143	-1,544,950	-2,139,640	-2,646,664
Sediment								
Exported (t)	8,913	15,357	26,016	32,763	37,583	40,762	43,238	45,215
\$/tonne								
Cost to reduce	111	24	-7	-14	-27	-38	-49	-59
Open downs		B condition						
10,000ha AE's	2,227	2,425	2,227	2,030	1,974	1,986	2,019	2,074
NPV (\$)	850,000	987,564	1,099,596	952,712	310,127	-121,653	-567,881	-1,086,142
Sediment								
Exported (t)	2,452	4,811	11,684	19,872	27,117	31,466	34,786	37,516
\$/tonne								
Cost to reduce	347	205	94	48	11	-4	-16	-29
Open downs		A condition						
10,000ha AE's	2,486	3,024	3,170	3,034	2,939	2,916	2,954	3,016
NPV (\$)	950,000	2,115,635	2,371,991	2,525,467	2,182,584	2,173,866	1,700,443	1,090,258
Sediment								
Exported (t)	1,035	1,599	3,816	9,789	16,843	22,113	25,841	28,673
\$/tonne								
Cost to reduce	918	1,323	622	258	130	98	66	38

	Pasture Utilisation (%TSDM)							
	15	20	25	30	35	40	45	50
Red Basalt	C condition							
10,000ha AE's	1,008	1,099	1,221	1,352	1,469	1,588	1,699	1,803
NPV (\$)	-32,169	403,704	325,248	150,925	-30,830	-195,641	-506,133	-1,034,975
Sediment								
Exported (t)	32,299	46,925	58,153	65,355	72,596	78,367	83,707	88,687
\$/tonne								
Cost to reduce	-1	9	6	2	0	-2	-6	-12
Red Basalt	B condition							
10,000ha AE's	1,488	1,707	1,801	1,863	1,963	2,080	2,197	2,307
NPV (\$)	286,296	1,084,065	1,141,606	934,580	782,834	592,512	335,646	-14,380
Sediment								
Exported (t)	10,683	16,347	26,260	37,934	47,607	55,187	61,714	67,819
\$/tonne								
Cost to reduce	27	66	43	25	16	11	5	0
Red Basalt	A condition							
10,000ha AE's	1,738	2,151	2,440	2,643	2,812	2,955	3,077	3,193
NPV (\$)	917,693	1,870,389	2,036,631	2,121,853	2,001,410	2,070,300	1,929,145	1,644,243
Sediment								
Exported (t)	5,615	7,329	10,524	15,288	21,216	27,702	34,472	40,623
\$/tonne								
Cost to reduce	163	255	194	139	94	75	56	40
SLIB	C condition							
10,000ha AE's	229	263	286	325	353	377	405	431
NPV (\$)	-352,158	-246,597	-429,682	-675,402	-799,436	-1,036,062	-1,311,110	-1,632,431
Sediment								
Exported (t)	98,420	114,846	129,957	133,728	141,267	147,128	150,806	154,245
\$/tonne								
Cost to reduce	-4	-2	-3	-5	-6	-7	-9	-11
SLIB	B condition							
10,000ha AE's	379	415	420	437	471	499	530	558
NPV (\$)	-135,550	421,914	324,571	-562	-270,924	-662,685	-994,151	-1,254,262
Sediment								
Exported (t)	48,727	71,977	94,948	110,922	119,510	126,758	131,783	135,997
\$/tonne								
Cost to reduce	-3	6	3	0	-2	-5	-8	-9
SLIB	A condition							
10,000ha AE's	475	568	588	573	583	620	664	687
NPV (\$)	95,852	845,130	849,726	575,319	-13,558	-492,472	-726,072	-1,039,393
Sediment								
Exported (t)	28,616	38,645	57,574	81,356	99,099	106,555	111,332	118,304
\$/tonne								
Cost to reduce	3	22	15	7	0	-5	-7	-9
SLIB on duplex	C condition							
10,000ha AE's	199	219	241	272	279	300	314	333
NPV (\$)	-203,988	-360,441	-411,089	-506,269	-514,451	-557,235	-472,287	-451,273
Sediment								
Exported (t)	168,208	191,164	205,815	210,059	222,404	226,619	232,446	235,631
\$/tonne								
Cost to reduce	-1	-2	-2	-2	-2	-2	-2	-2
SLIB on duplex	B condition							
10,000ha AE's	231	260	287	312	324	352	377	399
NPV (\$)	-326,792	-683,095	-819,300	-1,032,949	-1,082,568	-1,153,706	-1,199,657	-1,165,227
Sediment								
Exported (t)	151,447	175,101	189,722	199,152	212,216	216,358	220,671	224,696
\$/tonne								
Cost to reduce	-2	-4	-4	-5	-5	-5	-5	-5
SLIB on duplex	A condition							
10,000ha AE's	255	289	328	354	376	399	422	447
NPV (\$)	2,054,329	1,636,335	579,463	-1,638,148	-2,390,070	-4,305,286	-8,072,606	-13,273,654
Sediment								
Exported (t)	140,675	163,705	176,046	186,717	198,353	205,380	211,013	214,729
\$/tonne								
Cost to reduce	15	10	3	-9	-12	-21	-38	-62