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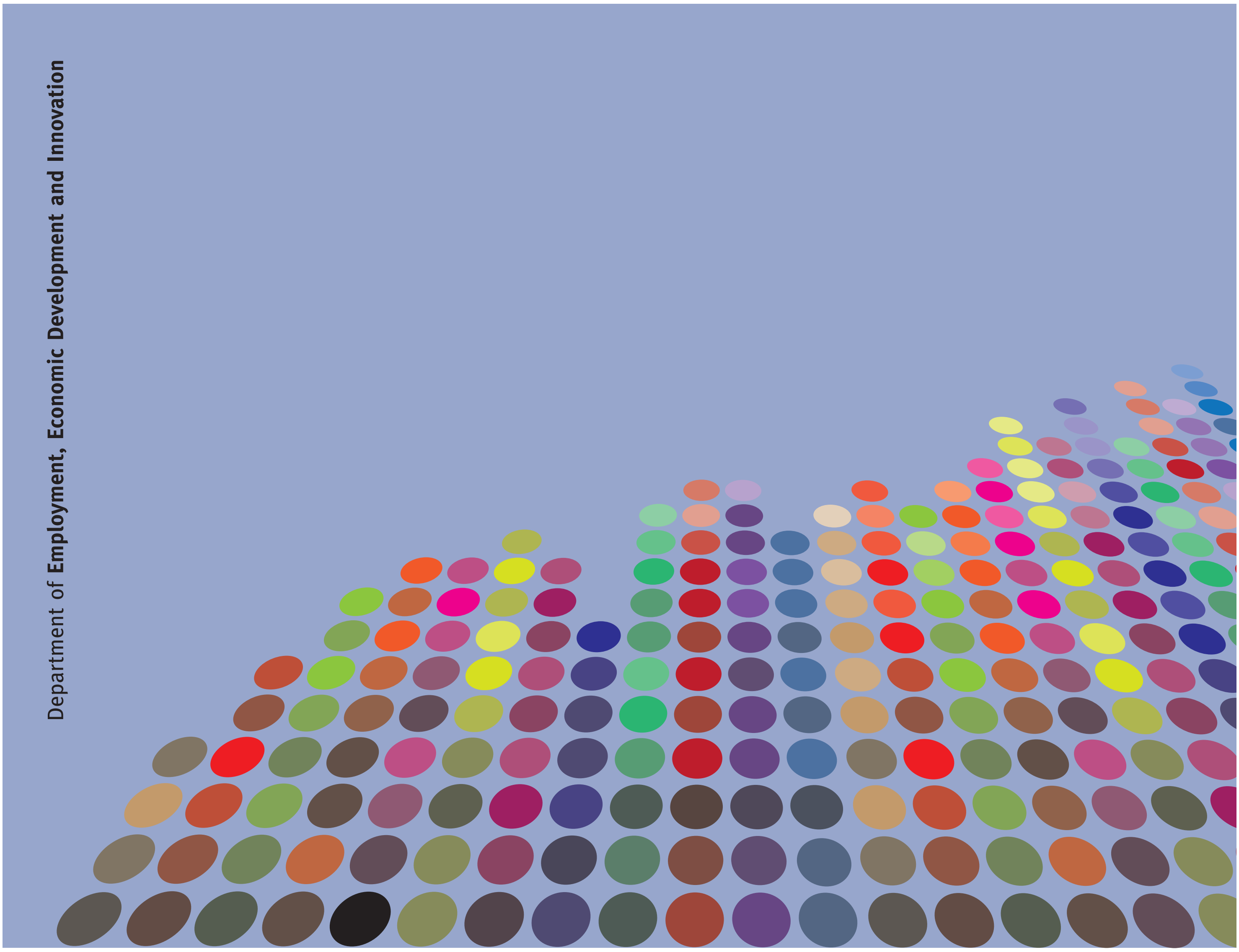

# Economic modelling of grazing systems in the Fitzroy and Burdekin catchments

Report to the Fitzroy Basin Association through funding from the Australian Government's Caring for our Country

FITZROY BASIN ASSOCIATION

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# Economic modelling of grazing systems in the Fitzroy and Burdekin catchments

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# 1 Introduction

The Great Barrier Reef (GBR) is the largest reef system in the world; it covers an area of approximately 2,225,000 km² in the northern Queensland continental shelf. There are approximately 750 reefs that exist within 40 km of the Queensland coast. Recent research has identified that poor water quality is having negative impacts on the GBR (Haynes et al. 2007). The Fitzroy Basin covers 143,000 km² and is the largest catchment draining into the GBR as well as being one of the largest catchments in Australia (Karfs et al. 2009). The Burdekin Catchment is the second largest catchment entering into the GBR and covers 133,432 km².The prime determinant for the changes in water quality entering into the GBR have been attributed to grazing, with beef production the largest single land use industry comprising 90% of the land area (Karfs et al. 2009). Extensive beef production contributes over $1 billion dollars to the national economy annually and employs over 9000 people, many in rural communities (Gordon 2007).

The GBR represents about 17% of the worlds coral communities, and is the largest World Heritage Area (Packett et al. 2009). It contains 438 coral reefs and 462 km² of sea grass, providing dugong habitat, supporting fisheries and is a significant tourism destination both nationally and internationally (McKergow et al. 2005). Tourism generated by the extensive biodiversity of the GBR brings in over $3.5 billion dollars per annum to the Australian economy (Gordon 2007). The value of both the GBR for its biodiversity, tourism attraction and World Heritage listing status is obviously worth securing for future generations; however the pastoral industry and beef production is also an industry which contributes significantly to the state economy. This situation creates challenges for policy makers, state and federal government s and the community as to how best allocate public funds to ensure that both the GBR and the grazing industry can co-exist.

The Fitzroy Basin and Burdekin Basins have also undergone extensive changes by clearing of Brigalow (*Acacia harpophylla*) for the purpose of grazing and cropping (Packett 2009). Catchments with high levels of clearing for cattle grazing and cropping show the largest increases in sediment exported compared with natural conditions (McKergow et al. 2005). Recent estimates of modelled post-development, long-term annual suspended sediment export from the Fitzroy River Basin to the GBR lagoon range from three to four and half million tonnes per year (Packett et al. 2009). Karfs (2009) also recognised that increased ground cover and improved land condition can prevent excessive amounts of sediments entering streams and rivers. Sediment loads from such a large industry can impact corals through smothering when particles settle out, by decreasing light availability, coral photosynthesis, and growth. This can result in changes to the coral population, structure, colony size, and decreased growth and survival (Haynes et al. 2007).

Governments have developed a range of programs to achieve reductions in the sediment load entering the Great Barrier Reef Lagoon. Although it is agreed that land degradation is one of national significance, in the past government policy has been poorly implemented and often contradictory (Laurence et al. 2004). Recent programs such as Caring For Our Country and The National Heritage Trust program have faced criticism due to the absence of measures for outcomes, lack of prioritisation and failure to combine biophysical and economic outcomes (Pannell 2009).

In 2003 a Reef Water Quality Plan was developed by the Australian and Queensland Governments. It is in this document that the goal of ‘halting and reversing the decline in water quality entering the Reef within 10 years' is stated (The State of Queensland and Commonwealth of Australia 2003). In this report the Fitzroy and Burdekin Basins are identified as 'high risk' for the categories of bio-physical risk, social risk, development risk and risk to marine industries. A key objective was to reduce the load of pollutants from diffuse sources entering the Reef. The strategies outlined include:

- Self-management approaches;
- Education and extension; and;
- Economic incentives.

(The State of Queensland and Commonwealth of Australia 2003)

The plan outlines self management approaches for land holders to include sustainable land management through programs such as:  best management practices, property resource management planning, and environmental management systems (The State of Queensland and Commonwealth of Australia 2003). Education and extension services are identified in the strategy to encourage collaboration between government departments and land holders to increase sustainable agricultural practices. It is from this extension work that the plan targets, as a priority, sediment contributions from grazing cattle in high risk catchments (The State of Queensland and Commonwealth of Australia 2003). The economic incentive strategy includes analysing the costs and benefits of best management practices that will lead to improved water quality (The State of Queensland and Commonwealth of Australia 2003).

Acting on the Reef Water Quality Plan the Fitzroy Basin Association released 'The Fitzroy Basin Water Quality Improvement Plan (Current Version) December 2008'. In this report the Association sets its long, intermediate and short term outcomes. The report identifies a self management approach strategy through education and extension and identifies voluntary adoption of best management practices to improve water quality. An objective of this is to encourage optimal pasture utilisation rates to improve land condition with chronic low ground cover and land types susceptible to erosion. The report also identifies a short term goal of reducing suspended sediment concentrations to 13 mg/L at the high peak flow of the wet season by 2014. Current concentrations are at 19 mg/L (Fitzroy Basin Association 2008).

The Burdekin Catchments natural resource management (NRM) organisation, North Queensland Dry Tropics released targets to be achieved by 2014 also. These targets were 50% of fair land condition to be increased to good condition lands, 20% of land currently in poor condition to be increased to fair and 50% of very poor lands to be rehabilitated by 2024 (Burdekin Dry Tropics Board 2005).

In order to reach these targets, programs that the Fitzroy Basin, and Burdekin Dry Tropics NRM has taken part in include the Natural Heritage Trust (NHT) programs, the National Action Plan for Salinity and Water Quality (NAPSWQ), and more recently Caring For Our Country programs (CFOC). These programs have typically involved payments to land holders for cost sharing or as incentives to improve infrastructure or changing management actions (Rolfe et al. 2007).

Reviews have suggested national programs such as the Caring For Our Country and the Natural Heritage Trust program have fallen short of achieving desired goals because investments were not prioritised with integrated bio-physical and economic data (Pannell 2009). It was also noted that 'environmental problems are often technically complex and uncertain. Sound decisions about their management need to be based on good knowledge about (a) the degree of threat or damage to environmental assets at risk, and (b) the extent to which this threat or damage can be reduced by particular changes in management. In many cases, generic knowledge is not sufficient – we need locally specific knowledge' (Pannell 2009). National programs have also been identified as having many inefficiencies.

Inefficiencies have been noted in relation to the selection of suitable projects for funding. In some cases this is due to design of the mechanism. 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 land holder. Other inefficiencies relate to the link between payments and actions, where most programs focus on inputs (such as the supply of riparian fencing) rather than having a focus on outcomes (improved water quality) (Rolfe et al. 2007).

There has been increased pressure for natural resource management groups to spend money efficiently and have measurable outcomes to justify where monies have been allocated. The knowledge required to do this involves understanding the interactions between biophysical aspects, opportunity cost, management implications and determining which targeted investment in improved water quality outcomes can be achieved most efficiently.

This report contributes knowledge on the environmental and economic trade-offs that occur between grazing and sediment exported, and the most efficient targeting of funding dollars.

# 2 Project objectives

'Economic modelling of grazing systems in the Fitzroy and Burdekin catchments' was a joint project with the Fitzroy Basin Association and the Queensland Department of Employment Economic Development and Innovation. The project was formed under the federally funded Caring For Our Country and the Reef Rescue programs. The project objectives were as follows;

- Quantifying the costs of over-utilising available pasture and the resulting sediment leaving a representative farm for four of the major land systems in the Burdekin or Fitzroy catchments and identifying economically optimal pasture utilisation rates.
- Estimating the cost of reducing pasture utilisation rates below the determined optimal.
- Using this information, guide the selection of appropriate tools to achieve reduced utilisation rates e.g. extension process versus incentive payments or a combination of both.
- Model the biophysical and economic impacts of altering grazing systems to restore land condition e.g. from C condition to B condition for four land systems in the Burdekin or Fitzroy catchments.

To meet these objectives expert opinion was sought in various areas to ensure the project parameters were scientifically and economically valid. Expert opinion was sought from;

**Peter Donaghy** – Manager Regional Economic Service, Department of Employment, Economic Development, and Innovation

**Professor John Rolfe** – CQ University Australia

**Gavin Peck** – Senior Pasture Agronomist (Sown Pastures), Department of Employment, Economic Development and Innovation

**Joe Scanlan** – Principal Scientist, Department of Employment, Economic Development and Innovation

**George Bourne** – Senior Natural Resource Management Officer, Department of Environment and Resource Management

**Dr Mark Silburn** – Principal Scientist, Department of Environment and Resource Management

**Bob Sheppard** – Senior Extension Officer, Department of Employment, Economic Development and Innovation

It is from this guidance that land types were selected, and land regeneration time frames and methods derived. Similarly, it was determined that to be able to quantify the trade-offs between pasture utilisation and sediment run-off a bioeconomic model combining modelled biophysical attributes from GRASP and a whole farm economic model, of representative Fitzroy and Burdekin grazing properties would be required.

To report on these objectives this report will explore the two economic methods, firstly is the cost-benefit analysis of land regeneration followed by the bioeconomic modelling.

# 3 Literature review

It has been recognised that there is a positive relationship between improved land condition, ground cover and the reduction of excessive sediment entering into streams and rivers (Karfs et al. 2009). Stocking numbers and management strategies have been described as the most significant variables affecting the productivity and sustainability of grazing enterprises (Ash & Stafford Smith 1996).

Land condition changes have often been explained as changes in pasture composition, ground cover, weed species, soil condition and degree of woodland thickening. Ecological responses and changes in animal production have also been linked with these declining conditions (Ash et al. 1995). Extreme pressure on rangeland resources through over-grazing has the potential to have severe consequences for the resource and its future productivity both economically and ecologically (MacLeod & McIvor 2008). Inappropriate grazing strategies particularly in responses to climatic variability have resulted in depletion of native grasses and decline in land condition (MacLeod & McIvor 2007).

Degradation can be defined as the ‘reduction in the natural capital of the land to provide goods and services from livestock production’ (Campbell et al. 2006). Land condition has been classified by relating the productive carrying capacity of the land and the contaminant run-off. It is also separated into the different land types and associated soil types and vegetation (Fitzroy Basin Association 2008). The ABCD land condition framework was developed by Meat and Livestock Australia (MLA) in Partnership with the Department of Primary Industries and Fisheries (table 1).

It has often been demonstrated that stocking rate is the most important variable in sustainable grazing management (Ash et al. 2002; Ash & Stafford Smith 1996). The

*Table 1 Land condition classification*

| Land condition classification | Perennial grasses* | Bare ground | Weeds | Soil condition | Woodland thickening |
|---|---|---|---|---|---|
| A | Good coverage | Less than 30% in most years | Few weeds and no significant infestations | Good, no erosion, good surface condition | No sign, or only early signs |
| B | Some decline in 3P grasses and increase in other less favoured species | More than 30% but less than 60% in most years | Increase in less favoured grasses or weeds | Some decline, some signs of previous erosion and current signs of erosion | Some thickening in density of woody plants |
| C | General decline of 3P grasses, large amount of less favoured species | Greater than 60% in most years | Large amounts of less favoured species | Obvious signs of past erosion and/or susceptibility currently high | General thickening of woody plants |
| D | General lack of any perennial grasses or forbs | | | Severe erosion or scalding resulting in hostile environment for plant growth | Thickets of woody plants cover most of the area |

* Described as palatable, productive and perennial (3P)

(Chilcott et al. 2005)

importance of understanding the different ecological thresholds and the impact of this on carrying capacity  of various pasture species is highlighted by Ash & Smith (2003). Carrying capacity is the measure of pasture available and the pasture required by the grazing stock. This is often determined by visual assessment, and significant prior knowledge which is largely based on past experience (Hamilton et al. 2008). The development of technologies, and pasture modelling has allowed this process to be more knowledge based, aiding decision making (Hamilton et al. 2008). Various other studies have explored the impact of different grazing pressure on plant-animal relationships (Ash et al. 1995), evaluating ecological impacts (Ash & Stafford Smith 1996) and the impact of grazing on pasture recovery (Orr et al. 2006). These studies have all had the common focus on sustainable management of rangelands. The Grazing Land Management Workshops (Chilcott et al. 2005) define pasture utilisation as 'the proportion of potential pasture growth that is consumed by livestock'. It is from this definition that the safe long term (5–10 year) carrying capacity is calculated (Chilcott et al. 2005).

There have been a number of studies into grazing strategies and the impact on rangeland production and biological interaction (Campbell.B 2006; MacLeod et al. 2004; MacLeod & McIvor 2008; O'Reagain et al. 2009; Orr et al. 2006; Stokes et al. 2006). Long term grazing trials have been completed to explore the impact of grazing and animal production over various grazing strategies. O'Reagain et al. (2009) explored the impact of different grazing strategies on animal production. The study concluded that live weight gains per head reduced at a heavier stocking rate and there were increased costs of drought feeding,

$$\text{Stocking rate (ha/AE)} = \frac{\text{Forage demand (kg/AE)}}{\text{Pasture growth (kg/ha) x pasture utilisation \%}}$$

Where: AE = adult equivalent (1 AE = 450 kg steer)
= 3650 kg (10 kg/day for 365 days a year)

*(Chilcott et al. 2005)*

*Carrying capacity calculation*

and management costs in years of low rainfall. O'Reagain et al. (2009) also challenged the assumption that sustainable management is not profitable as the lighter stocking rate had good individual production performance and did not require drought feeding.

Grazing impacts on land condition in tropical woodlands was investigated; the study observed the impact of grazing pressure on the standing crop, basal area, size and spacing of grass tussocks of the herbaceous vegetation and the implications for soil properties (Northup et al. 2005). The results indicated that increased grazing pressure lead to less standing crop, which was more widely dispersed. The results from this study indicated that for land condition to improve in tropical eucalypt woodlands, time periods required may be economically non-viable.

Orr et al. (2006) explored the recovery of pasture after drought and the composition of pasture species. Recovery of pasture back to good pasture condition was assessed on high yields, basal area and desirable perennial grasses. The results indicated that exclusion of stock for short periods of time (12 months) especially during winter and in years when rainfall is average or below will not ensure pasture condition with perennial native species improves. These results however differed to the results of the ECOGRAZE project (Ash et al. 2002).

The ECOGRAZE project was developed to show the impacts of spelling, fire and climate on land condition in open eucalypt woodlands in northern Australia (Ash et al. 2002). The research was conducted over eight years and showed that grazing management is the main variable affecting land condition. Early wet season spelling ensured that a higher rate of pasture utilisation was possible and would enable increased cash flow to be allocated to increased watering and fencing (Ash et al. 2002)

McIvor (2001) explored regeneration of pastures exposed to a range of grazing pressures in a period of low rainfall. The research measured the regeneration of these pastures when unstocked and exposed to higher rainfall. McIvor (2001) also developed a criterion to predict the capacity of over-grazed pastures to regenerate by relating pasture performance during the regeneration phase to initial pasture condition. The research explored the impact of regeneration on both native and sown pasture species and the results indicated that regeneration is dependant on growing conditions, not only exclusion of stock (McIvor 2001). In the trial the areas of fertile soil regenerated from C condition in two to three years and from D condition in three or more years through the exclusion of stock (McIvor 2001)

Studies in rangelands in the United States of America have also had explored stocking rates and the sustainability of rangeland ecosystems (Teague et al. 2009). The research has been concerned with the management of grazing for ecological and production outcomes along with opportunistic and conservative stocking rates. Higgins et al (2007) implemented simulation models to determine the effect of stocking rates that were adjusted to the available management as opposed to having a conservative stocking rate. The conservative stocking was the most attractive economically and ecologically especially when the practice of fire and control of abundance of trees were implemented (Higgins et al. 2007). Simulation models developed by Teague (2009) have also been implemented in research to examine the implications of achieving three alternate management goals of: maintaining current range condition, maximising profit, and improving range condition over thirty years. The results demonstrated that earning capacity is four times greater in rangelands that are in excellent condition than poor condition rangelands. Maximum short term and long term profit was attained at variable stocking rates (Teague et al. 2009). Stocking at a lower rate to improve or maintain rangeland health would incur an opportunity cost in the income forgone (Teague et al. 2009).

To understand plant animal relationships better there have been various computer simulation models developed in Australia. These include GrassGro (Moore et al. 1997), APSIM (Keating et al. 2003; McCown et al. 1996) and GRASP (Littleboy and McKeon 1997; McKeon et al. 2000) and the SGS Pasture Model/DairyMod/EcoMod suite are Australian plant production models utilising regional soil and historical climate data (Johnson et al. 2003, Johnson et al. 2008). GrassGro, GRASP and APSIM also allow the incorporation of seasonal weather forecast information (e.g. SOI phase forecasting system of Stone et al. (1996). Both GrassGro and the SGS Pasture Model/DairyMod/EcoMod suite were designed and validated for temperate pasture systems across southern Australia or New Zealand and as a result would probably require extensive re-parameterisation before reliably simulating tropical pasture or forage growth. However, GRASP has been calibrated for over 40 tropical perennial grass pasture communities in Queensland based on previous grazing trials that have existed.

Owens et al. (2003) explored the interactions of GRASP and two sediment delivery models. The study explored the Scanlon runoff approach in comparison to an USDA model. The Scanlon model determines runoff by partitioning rainfall and infiltration using an imperial function derived from ground cover, daily rainfall, rainfall intensity and soil water deficit.

Run-off = cover x (rain-(1-rainfall intensity/110)
x soil water deficit.

Where run-off is daily run-off (mm), cover is calculated from standing biomass and litter, rain is daily rainfall (mm), rainfall intensity in a 15 minute period for the day (mm/hr) and the soil water deficit is the deficit of the top two profile layers. The USDA run off model calculates runoff as a function of daily rainfall and soil water contents weighed by soil depth. The study demonstrated the accuracy and importance of the Scanlon model and the parameters that are important for run-off estimates. It identified that both models resulted in a similar results for the selected location.

To achieve environmental improvements in complex systems such as grazing it is difficult to identify the economic implication. To address this complex issue a key technique known as bioeconomic modelling will be utilised.

# 4 Bioeconomic modelling

In order to increase the efficiency and effectiveness of natural resource management investment, investments are required to be prioritised to the activities and locations that have the potential to generate the highest net value to society over time. In order 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 is required (Mazur & Bennett 2008).

To explain and predict cause and effect relationships in ecosystems and then determine the economic affect, bioeconomic modelling was devised (Bennett 2005). Bioeconomics was defined by Oriade and Dillon (1997) as ‘a mathematical representation of a biological system which describes biological process and predicts the effects of management decisions on those processes’. Bioeconomics is a relatively new method in environmental economics. Oriade and Dillion suggested in 1997 that it was a growing area and was described as relatively novel by Dent and Anderson (1971). It has been applied to numerous aquaculture systems, and cropping production systems however is still only applied to a limited number of grazing systems. The use of environmental economics has been growing in Australia with an increase in public interest and political debate (Bennett 2005).

The biological system can be encompassed into different types of economic models. It is this economic link that makes available the connection between the production system and the environmental impact (Cacho 1997). Bennett (2005) describes the contribution of bioeconomic modelling as ‘varying from straightforward considerations of the costs of alternative resource use strategies to complex integrations of biophysical models of ecological farming systems with social cost-benefit analysis and policy advice’.

Bioeconomic modelling is increasingly being implemented for use in environmental economics. It is flexible in that it can be applied in a wide variety of contexts. Researchers who have developed bioeconomic models have often used them to draw policy conclusions or make statements regarding the incentives that stakeholders face (Bennett 2005).

Bioeconomic modelling has been implemented to predict natural resource outcomes and costs in forestry production systems. An example of this is the work completed by Cacho et al (2001) that explored the use of forestry as a means to control dryland salinity in the Liverpool plains. Cacho (1997) implemented a model to assess forestry as a means of income and to prevent the water table from rising further. The model examined the production system in relation to the growth of the trees and crops and the other options available to reduce salinity and ensure that future crop production would continue. The research found that although forestry did not represent a viable means of income alone, it did ensure that the water table would not increase further and crop production could be continued (Cacho et al. 2001). The model allowed the additional benefits of forestry establishment to be evaluated.

In the past bioeconomic modelling has been used to examine the effect of land degradation and stocking rates in rangelands, and to examine the impacts of higher wool prices, increased discount rates and lower property size on land degradation. The results demonstrate that producers would risk the degradation that occurs with higher stocking rates in response to these variables (Bennett 2005).

Recently in the USA there has been increased use of bioeconomic models for rangeland and grazing management practices. Research has included the impact of over grazing on the species composition and the increase of less productive pasture species when over grazing occurs (Finnoff et al. 2008). Cooper (1997) also examined the resilience of rangelands in recovery from over grazing. This  allowed environmental efficiency of programs that promote the recovery of private rangelands by offering financial incentives to be explored (Cooper & Huffacker 1997). The evaluation of natural resource policies and mechanisms have been explored by  Haffaker et al  (1990)  who determined the trade-offs between a policy for controlling wild horse populations and the impact on the western livestock industry. The results concluded that the legislation is possibly economically inefficient (Huffaker et al. 1990).

Bennett (2005) describes bioeconomic modelling as the least controversial method used in environmental economics, however Bennett (2005) does note that inadequacies have arisen from the past due to the omission of considering the benefit side of the issue. Bennett (2005) explains that this is due to the lack of science linking alternative management actions with environmental attributes, and the valuation of these outcomes has been problematic.

Currently there is literature on grazing systems and sustainability in regards to rangeland systems in Australia. However there is limited literature combining the biophysical and economic aspects of grazing. There also is limited literature based on Australian rangelands exploring production system outcomes with a natural resource outcome. This literature review clearly identifies that there is a need for further biophysical and economic information to develop more efficient policy and programs to improve land degradation.

The development of bioeconomic models in the USA that combine the biophysical and economic data to explore the trade-offs between industry and natural resource management policy has been rapidly expanding particularly for rangeland issues. It is from this previous work that this research intends to contribute to the knowledge of bioeconomic modelling and complete an analysis on the economic and environmental trade offs of reducing a tonne of sediment into the Great Barrier Reef lagoon from grazing lands. Bioeconomic modelling provides a strong platform to encompass both the biophysical stimulation data and the economic model to allow an analysis of the outcomes.

# 5 Selection of land types

The land types were selected on geographical location, percentage of the catchments that consisted of particular land types, decreasing ground cover over the past four years, erosion susceptibility and sedimentation run-off. They were also selected in consideration of previous bioeconomic modelling that was completed under the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust extension project, 'Enhancing Input to the CQSS2'.

The land types that were selected were silver leaved ironbark, based on previous grazing and soil loss trials, high susceptibility to erosion and decreasing trend in ground cover. Spotted gum on ranges for its high percentage in C condition within the Fitzroy Basin, and Goldfields for it high percentage of D condition and susceptibility to erosion.

As there is high climatic variability such as varying rainfall and undulation the geographical location was pivotal, to ensure that different aspects of the catchment were represented. Dougall et al (2008) reports that approximately 50 percent of the total flow from the Isaac catchment discharges into the Great Barrier Reef Lagoon (GBRL), the eastern part of this sub catchment is the Connors region which has relatively high annual rainfall (Dougall et al 2008). Abbott et al (2008) and Beutell & Karfs (2010) have also defined areas within the two catchments which have increasing bare ground and these locations were also taken into consideration whilst selecting the climate location. Results from Star & Donaghy (2009) indicate that climatic location has a significant impact on the cost to reduce a tonne of sediment; therefore one land type was selected with two climate stations modelled to explore this interaction further.

Silver-leaved ironbark was selected to be modelled for two climate stations with Nebo and Springvale climate files selected. The productivity between the two varies due to increased rainfall at Nebo and different soil characteristics. Silver-leaved ironbark can be described as open woodlands of silver-leaved ironbark, with a false sandalwood, prickly pine, dead finish, desert oak, vine tree and currant bush understorey. The preferred pasture species include desert blue grass, black speargrass, kangaroo grass, Queensland bluegrass, and forest bluegrass. The soil can be described as having textured contrast soils, with the subsoil very erosive when exposed, with some soils dispersive.

Duaringa was the selected climate file modelled for the spotted gum land type. This land type can be best described as occurring on mountains and ranges, with an understorey of wattles, zamia and red ash may be present. The preferred pasture species is black speargrass, kangaroo grass, hairy panic, and desert blue grass. Spotted gum is a commercial timber species and the land type occurs on step slopes with rocky and shallow soils.

Goldfields country was selected with the climate station of Virginia Park. The land type is described as open woodland with patchy understorey of false sandalwood and corkwood wattle. The preferred pasture composition is desert bluegrass, Queensland bluegrass, curly bluegrass, black speargrass and kangaroo grass. The soil is self mulching black, sometimes, red and brown and cracking clays.

# 6 Economics of land regeneration

Analysis of the costs and benefits associated with adoption of improved grazing management practices is required to determine the effect on the profitability and economic sustainability of grazing enterprises. Combined with the economic viability of capital investment to achieve improved land condition this will inform future natural resource management programs and targeted funding.

The land condition to be regenerated was initially D condition. It was defined as D condition due to large scalds and increased erosion due to overgrazing. It was assumed to have poor pasture composition with little productive, perennial pasture species and with significant soil loss. The land was regenerated to B condition and to C condition. A separate case study explored the regeneration from C condition to B condition.

To reflect the change in pasture production that occurs through the regeneration process the stocking rate was altered reflecting that productivity increases as the land regenerates. The affect of tree basal area was also accounted for with scenarios modelled using pasture production and therefore stocking rates for a cleared landscape and for an average tree basal area (TBA) for that land type. For land types where a totally cleared scenario was unrealistic, the analysis was only completed for a treed scenario (i.e. spotted gum on ridges). The stocking rate (ha/AE) used in the modelling for each land condition and TBA scenario (table 2) reflects the land types inherent productivity.

To estimate the economics of land regeneration a series of assumptions and scenarios were made to develop gross margins per adult equivalent, these were developed from the Beef CRC herd templates and through the use of BreedCow Dynama to reflect the area and land type parameters. The assumption was made that the enterprise across all land types was turning off store steers. The gross margins per AE (450 kg steer) inclusive of interest on livestock capital used for each land type and locations were as follows:

- Silver-leaved ironbark, Nebo: $152.15
- Silver-leaved ironbark, Springvale: $149.51
- Spotted gum on ridges, Duaringa: $110.26
- Goldfields, Charters Towers: $151.25

The total area managed was 5,000 ha for each land type, and three scenarios were considered and analysed for the regeneration of 500 ha; 1000 ha; 2000 ha and 3000 ha of the property.

## Regeneration D condition to B condition

The initial treatment for the silver-leaved ironbark was to rip and re-seed with a pasture mix of creeping blue grass (80%) and Rhodes grass (25%) along with a mix of Caribbean stylo and shrubby stylo for the Nebo location. For the Springvale location the method was to over sow with shrubby stylo and buffel grass and Medway Indian couch based on previous work, and land type descriptions (Queensland Government 2008). The goldfields method for regeneration was based on a current case study and involved cutter barring and re-sowing a

*Table 2. Estimated safe carrying capacities (SCC ha/AE) for four cleared land types and land condition (ABCD)*

| | | SCC ha/AE Land condition | | | | | SCC ha/AE Land condition | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Land types** | **Tree basal area ($m^2$/ha)** | **A** | **B** | **C** | **D** | **Tree basal area ($m^2$/ha)** | **A** | **B** | **C** | **D** |
| Goldfields-red soils | 0 | 4 | 5 | 9 | 20 | 3 | 7 | 9 | 15 | 34 |
| Silver-leaved ironbark high productivity | 0 | 3 | 5 | 8 | 17 | 7.5 | 8 | 11 | 18 | 40 |
| Silver-leaved ironbark low productivity | 0 | 7 | 9 | 15 | 33 | 5 | 34 | 45 | 76 | 170 |
| Spotted gum ridges | | | | | | 11 | 108 | 144 | 239 | 539 |

mixture of buffel grass, seca and verano stylo, green panic, butterfly pea and silk sorghum.

It was assumed that the initial sown pastures would produce viable plants due to little competition from other pasture species, and in the second year would have a sufficient seed bank to allow for further plant recruitment. Campbell (2006) made reference to the resilience of a land type and its ability to regenerate after rainfall. They identified that often it is not the 3P grasses (productive, perennial and palatable) that regenerate after long periods of degradation, and this provided a basis for sowing pasture. The spotted gum presents challenges to re-sow pasture species due to it shallow soils and therefore the recommended method was to totally de-stock for five years of consecutive wet season spelling and a gradual re-stock to B condition.

Each of the steady state case study scenarios modelled assumed annual average rainfall which is represented in table 3. This assumption is based on the importance of rainfall as a variable for regeneration determined by Orr et al. (2006). The gradual introduction of stock was based on the findings by McIvor (2001) who determined that on a fertile soil the regeneration period was three or more years following the exclusion of stock, along with the re-seeding and improved productivity of the area. As there was ripping and re-seeding on some of the land types the stocking rates where changed to reflect this, as stock were gradually re-introduced. Due to the variation in inherent fertility between the land types, the regeneration periods and time frames for regeneration reflected this. The wet season spelling assumption was based on Ash et al. (2002) in the EOCGRAZE project which found that a wet season spell of 6–8 weeks every three to four years was an effective method to maintain 3P grasses.

*Table 3. Average long- term annual rainfall*

| | | |
|---|---|---|
| Silver leaved ironbark | Nebo | 733 mm |
| Silver leaved ironbark | Springvale | 590 mm |
| Spotted gum ridges | Duaringa | 715 mm |
| Goldfields | Virginia Park | 599 mm |

*Table 4. Land regeneration from D condition to B condition time frames, and capital expenditure*

| | Year 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver-leaved ironbark – Nebo | Rip, re-seed with a mix of Rhodes grasss and creeping bluegrass (mix with a 20% Rhodes grass and 80% creeping bluegrass) along with a mix of Caribbean stylo and shrubby stylo (4.5 kg/ha) | D | C | C | B | B | B | B | B | B | B |
| Wet season spelling | | 8 wks | 8 wks | 8 wks | 8 wks | | | | | | |
| Silver-leaved ironbark – Springvale | Over sown with shrubby stylo (Siran or Seca) buffel grass and Medway Indian couch at a rate 4 kg/ha | D | D | C | C | C | B | B | B | B | B |
| Wet season spelling | | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks |
| Burn | | | | | | Burn | | | | | Burn |
| Spotted gum – Dauringa | No mechanical intervention | D | D | D | D | D | C | C | C | C | B |
| Wet season spelling | | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | | | | 8 wks | |
| Goldfields | Cutter bar and re-seed with buffel (0.5kg/ha), stylo (Seca and Verano) 2kg/ha, green panic (0.25kg/ha), butterfly pea (0.5kg/ha) and silk sorghum (0.25kg/ha) | D | D | B | B | B | B | B | B | B | B |

Table 4 outlines the assumptions used for the time frames and the regeneration methods which were determined through literature and expert opinion, although it is recognised that these are assumptions and variation does occur.

To account for different scenarios that occur at a management level three scenarios were modelled. To take into consideration the issue of scale, four areas were also modelled. The scenario and scale factor were as follows:

- **Whole paddock declined scenario:** The whole paddock area was declined and required regeneration, through the modification of stocking rates and pasture improvement. However no capital changes such as fencing or watering points were required.

  Area of whole paddock (ha)
  500 1000 2000 3000
- **Total exclusion scenario:** Part of the paddock required regeneration and therefore capital improvements such as fencing (1 km to every 100 ha of decline land), watering points and stocking rate modifications and pasture improvements were required.

  Area of whole paddock (ha)
  500 1000 2000 3000

  Portion of declined land (ha)
  500 1000 2000 3000
- **Partial exclusion scenario:** Part of the paddock required regeneration; however an alternative method of locking the whole paddock up, and receiving an opportunity cost for stock in the portion of the paddock was borne instead of capital expenditure.

To determine if scale impacted the economic result four areas were selected and formed the basis of the analysis. The areas selected were:

Area of whole paddock (ha)
1000 2000 3000 4000

Portion of declined land (ha)
500 1000 2000 3000

# 7 Capital costs

The capital costs incurred by any grazier transitioning from D land condition to B land condition will vary substantially based on the degradation, and the land types resilience. The capital costs that have been included in this economic analysis are focused on regeneration from scalds and erosion due to over grazing. The costs for each scenario are shown in table 5, although for each grazier this list would be different. Therefore, the capital costs used in the analysis represent just one possible investment scenario.

*Table 5. Capital costs*

| Land regeneration costs | $/ha/km |
|---|---|
| Chisel plough | 35.45 |
| Pasture mix 75% Rhodes grass 25% Creeping blue grass @ 4kg/ha | 44.4 |
| Shrubby secca stylo @ 3kg/ha | 48 |
| Fencing | 5000 |
| Waters | |
| poly pipe | 5000 |
| poly tank | 5000 |
| trough | 1200 |

*Table 6. Capital costs for regeneration ($/ha)*

| | Area regenerated | | | |
|---|---|---|---|---|
| Scenarios | 500 | 1000 | 2000 | 3000 |
| Silver-leaved ironbark – Nebo | | | | |
| Whole paddock | 87.85 | 87.85 | 87.85 | 87.85 |
| Total exclusion | 212.65 | 256.45 | 250.25 | 248.18 |
| Partial exclusion | 87.85 | 87.85 | 87.85 | 87.85 |
| Silver-leaved ironbark – Springvale | | | | |
| Whole paddock | 10.52 | 10.52 | 10.52 | 10.52 |
| Total exclusion | 135.32 | 179.12 | 178.18 | 170.8533 |
| Partial exclusion | 10.52 | 10.52 | 10.52 | 10.52 |
| Spotted gum – Duaringa | | | | |
| Whole paddock | 0 | 0 | 0 | 0 |
| Total exclusion | 124.8 | 168.6 | 162.4 | 160.3333 |
| Partial exclusion | 0 | 0 | 0 | 0 |

# 8 Regeneration C condition to B condition

The time frames for regeneration of the land types replicated the land types fertility and rainfall location. As C condition does not require any mechanical intervention there were no capital costs, only the opportunity cost of a lighter stocking rate whilst in C condition. Therefore, only the whole paddock scenario and partial exclusion scenario were analysed to determine the economic return. The time frames are tabulated on table 7.

*Table 7. Land regeneration time frames and methods from C condition to B condition*

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver-leaved ironbark – Nebo | | C | C | C | B | B | B | B | B | B | B |
| Wet season spelling | | 8 wks | 8 wks | 8 wks | 8 wks | | | | | | |
| Silver-leaved ironbark – Springvale | | C | C | C | C | B | B | B | B | B | B |
| Wet season spelling | | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks |
| Burn | | | | | | Burn | | | | | Burn |
| Spotted gum – Dauringa | | C | C | C | C | B | B | B | B | B | B |
| Wet season spelling | | 8 wks | 8 wks | 8 wks | 8 wks | 8 wks | | | | 8 wks | |
| Goldfields | | C | B | B | B | B | B | B | B | B | B |
| Wet season spelling | | 6 mths | 6 mths | 4 wks | | | | 4 wks | | | |

# 9 Economic analysis

An investment analysis has been undertaken to determine if the increases in gross margin are sufficient to cover the costs associated with changing management practices. The investment analysis framework implicitly accounts for the opportunity cost of the decision.

A discount rate of 5% has been used to convert the future cash flows of the grazing business to their present values (value in today's dollar terms). This accounts for the generally large initial capital costs associated with making the change and the smaller but longer term benefits of the change over the life of the investment. The result is the net present value (NPV) of future cash flows, and provides decision makers with a profitability indicator for selecting investments from an economic perspective. The net present values calculated in this work take into account the difference in gross margin for the different land condition classes and the capital and annual costs incurred in moving to B land condition.

A positive NPV implies that the investment earns a rate of return in excess of the opportunity cost of capital and the business will be better-off over the 20 year period of analysis by the amount of the NPV if the investment is undertaken. On the contrary, a negative NPV for an investment indicates that the business will be worse off if the investment is made.

# 10 Economics of land regeneration results

The economics of land regeneration will be presented by land type, with regeneration from D condition to B condition followed by regeneration of C condition to B condition land. It is important to note that the scale of the graphs varies with each scenario and must be considered before interpreting the graphs.

## Silver-leaved ironbark – Nebo

### Regeneration from D condition to B condition

The results presented in figure 1 illustrate the impacts of land regeneration for silver leaved ironbark at Nebo with a tree basal area of 7.5 $m^2$. With the impact of trees limiting pasture productivity the marginal benefit of land regeneration was insufficient to cover the initial capital expenditure. This resulted in the total exclusion scenario being extremely unviable with a negative return of -$457,762 for 3000 ha. The partial exclusion scenario also unviable at -$61,837 for the 3000 ha as it also had the opportunity cost of forgone income from the remainder of the paddock not being utilised. At extremely large areas (3000 ha) the whole paddock scenario which had the least capital expenditure associated with it was viable with a return of $23,238.

The impact of trees was also significant. This was reflected in the carrying capacity of the land type, as trees compete with pasture species for nutrients and water. The affect of no trees resulted in all scenarios shifting up and increasing the economic viability of the investment. The results illustrate that for the Whole paddock scenario and the partial exclusion scenario where the capital costs were not as significant as the total exclusion scenario, there is increased ability to achieve a positive return on investment for very large areas. For example in the whole paddock scenario with a tree basal area of 7.5 $m^2$ the net present value for 1000 ha regenerated from D condition to B condition is $-7,276 (figure 1), and with zero basal area the net present value is $83,270 (figure 2).

The analysis included different areas to regenerate in order for the affect of scale to be accounted for. The expectation that scale would allow for increased economic returns was confirmed, and is a result of increased marginal returns from increased stocking rate to adequately cover the initial capital investment.

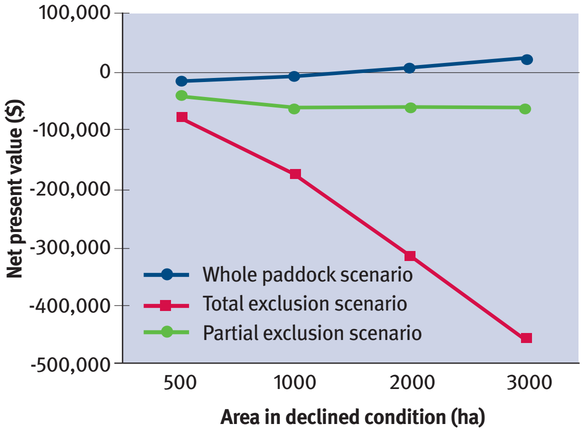

*Figure 1. Silver-leaved ironbark –Nebo tree basal area 7.5 $m^2$. Regeneration from D condition to B condition*

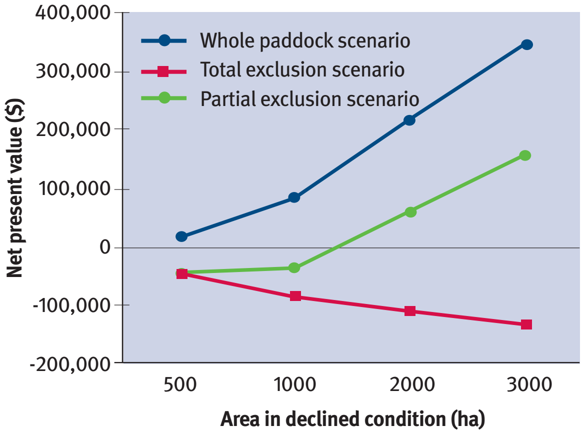

*Figure 2. Silver-leaved ironbark – Nebo with zero tree basal area. Regeneration from D to B condition*

## Regeneration from C condition to B condition

As the time frame for regeneration was decreased in comparison to regeneration from D condition to B condition, and the ability for regeneration to occur without mechanical intervention, both scenarios resulted in a positive return on investment (figures 3 and 4) greater than regeneration from D condition to B condition.

The impact of trees on the net present value increased notably with the increase for the whole paddock for 1000 ha increasing from $23,706 to $204,380 or an 87% increase in net present value. It also must be considered that the time period for regeneration was significantly less which also influences this result.

The results for regeneration of C to B condition are summarised in table 8 and again demonstrate the impact of trees and scale.

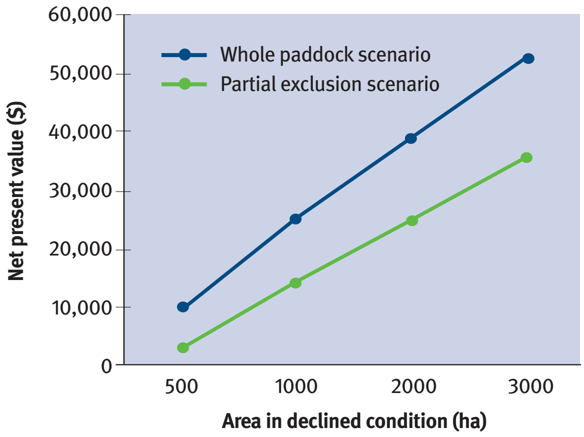

*Figure 3. Silver-leaved ironbark – Nebo tree basal area 7.5 $m^2$. Regeneration from C condition to B condition*

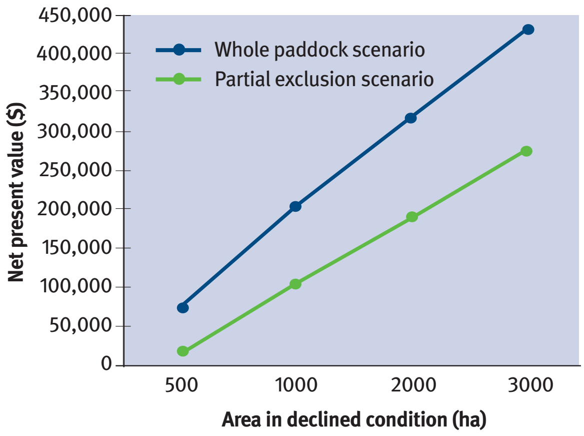

*Figure 4. Silver-leaved ironbark – Nebo zero tree basal area. Regeneration from C condition to B condition*

*Table 8. Silver-leaved ironbark – Nebo regeneration from C condition to B condition net present values*

| **Area regenerated (ha)** | **500** | **1000** | **2000** | **3000** | **500** | **1000** | **2000** | **3000** |
|---|---|---|---|---|---|---|---|---|
| **Tree basal area ($m^2$)** | **7.5** | **7.5** | **7.5** | **7.5** | **0** | **0** | **0** | **0** |
| Whole paddock scenario | $9,899 | $25,305 | $38,931 | $52,558 | $77,404 | $204,380 | $316,124 | $427,867 |
| Partial exclusion scenario | $3,202 | $14,102 | $25,002 | $35,902 | $16,340 | $101,967 | $187,595 | $273,222 |

## Spotted gum – Duaringa

### Regeneration from D condition to B condition

The spotted gum with the climate station of Duaringa does not have the same inherent level of productivity as the silver leaved ironbark at Nebo and therefore the time frames and methods to regenerate from D condition to B condition and C condition to B condition are more extensive. Only spotted gum with a tree basal was included in this analysis as it is representative for the Fitzroy catchment, a cleared analysis was not undertaken as this is not realistic. The characteristic of dispersive soils hinders any re-establishment of pasture species and therefore, with long periods of no stock the economics of regeneration from D condition to B condition is not economically viable for any scenario or area size modeleed. The total exclusion has the largest capital costs with fencing and additional waters resulting in the lowest return for all areas, for both the partial exclusion scenario and the whole paddock scenario there is no pasture establishment costs. The poor economic results suggests graziers are unlikely to voluntarily regenerate spotted gum in Duaringa without financial incentives.

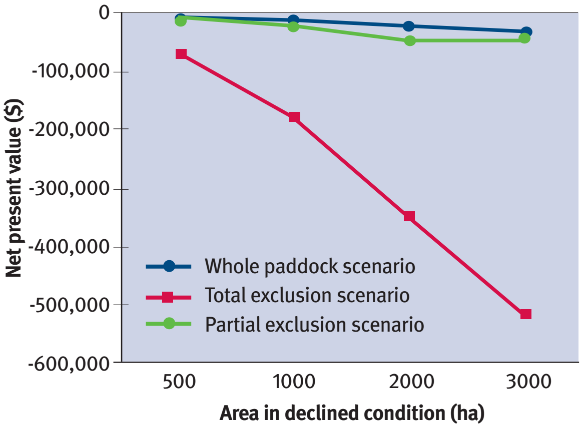

*Figure 5. Spotted gum – Dauringa with 11 tree basal area. Regeneration from D condition to B condition*

### Regeneration from C condition to B condition

The regeneration from C to B took significantly less time and with no capital costs the marginal benefit was significant enough to cover the reduced stock in the regeneration years. This resulted in a positive net present value for the larger areas; however this too was still quite marginal with the largest net present value having a return of only $5,294 for 3000 ha.

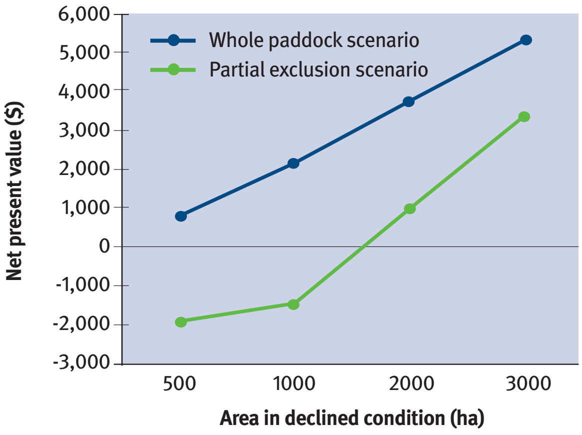

*Figure 6. Spotted gum – Dauringa with 11 tree basal area. Regeneration from C condition to B condition*

## Silver-leaved ironbark – Springvale

### Regeneration from D condition to B condition

The silver-leaved ironbark in Springvale had long regeneration time frames and re-sowing of pasture species. Large losses occur for scenarios with a tree basal area and in many cases the benefits have not been sufficient to cover the cost of the regeneration. For the total exclusion scenario with an area of 3000 ha the cost for regeneration is $625,000 (figure 7). Due to the lower productivity of the land type this initial investment is not re-couped.

The only positive results occur when there is a zero tree basal area and only for the whole paddock scenario which has the lowest capital costs, and for a large area to be regenerated. It can be noted the two of the scenarios intersect at 1000 ha (figure 8). This is due to the costs in capital expenditure and the opportunity cost to be at a similar level when the two intersect.

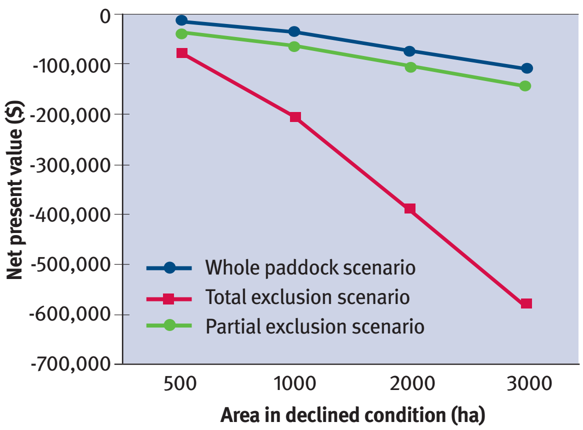

*Figure 7. Silver-leaved ironbark – Springvale with 7.5 tree basal area. Regeneration from D condition to B condition*

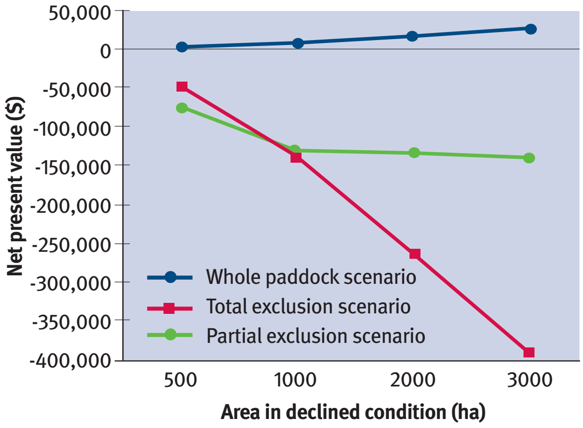

*Figure 8. Silver-leaved ironbark – Springvale D condition to B condition zero tree basal area*

### Regeneration from C condition to B condition

The results of land regeneration from C to B (figure 9) reflect the low productivity of the land type, the impact of trees on the scenario shifted the results down. Both scenarios replicated each other however the axis scale must be observed, as there is a significant difference. The partial exclusion scenario has the added opportunity cost and therefore has a lower net present value for all areas as apposed to the whole paddock scenario.

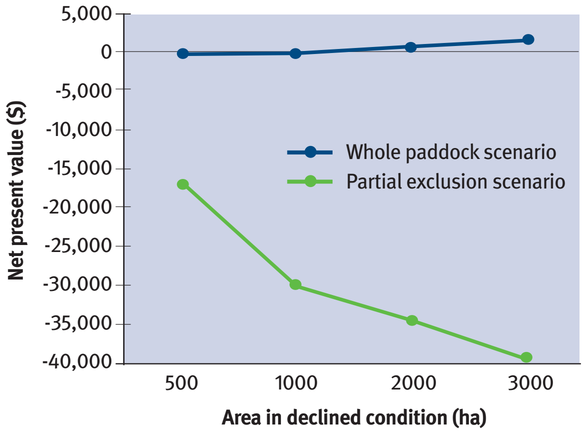

*Figure 9. Silver-leaved ironbark – Springvale with 7.5 tree basal area. Regeneration from C condition to B condition*

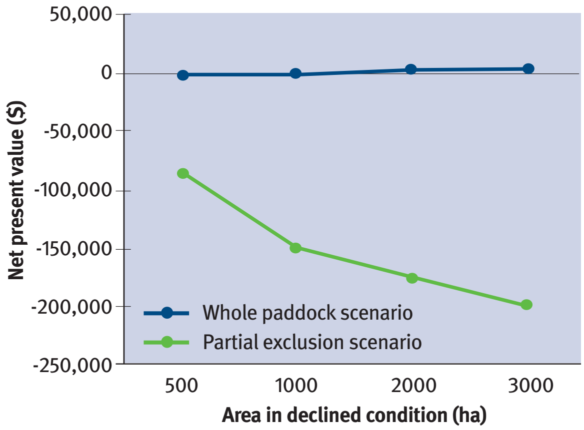

*Figure 10. Silver-leaved ironbark – Springvale with zero tree basal area. Regeneration from C condition to B condition*

## Goldfields – Charters Towers

### Regeneration from D condition to B condition

The results of the Goldfields reflect the relative productivity of the land with regeneration from D to B condition being economically viable for larger areas for the partial exclusion and whole paddock scenario. It can also be noted that at 3000 ha for all areas the two viable scenarios become closer and closer to each other. This represents increasing economies of scale for the partial exclusion scenario. Again the impact on tress was significant, and without trees all scenarios for the 3000 ha were viable (figure 12).

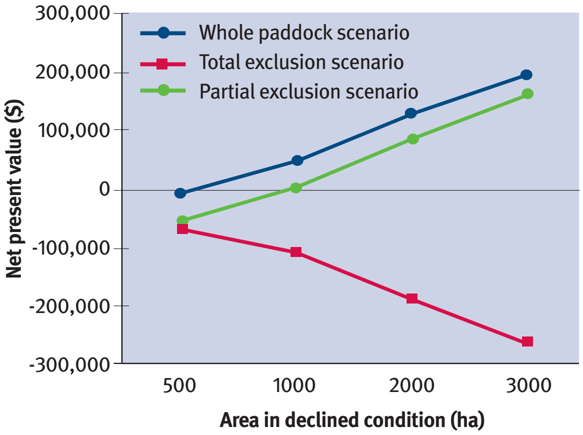

*Figure 11. Goldfields – Charters Towers with 3 tree basal area. Regeneration from D condition to B condition*

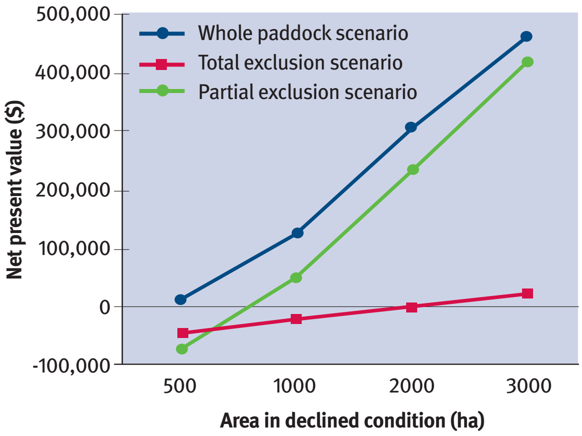

*Figure 12. Gold Fields – Charters Towers with zero tree basal area. Regeneration from D condition to B condition*

### Regeneration from C condition to B condition

The results of the regeneration from C to B condition indicated that for areas over 1000 ha the economic feasibility was achieved. In figure 14 it can be noted that at 3000 ha both scenarios join this indicates were the threshold for economies of scale occurs. Again the importance of trees was significant although the two graphs (figures 13 and 14) appear to be similar it is important to note the net present value scale difference.

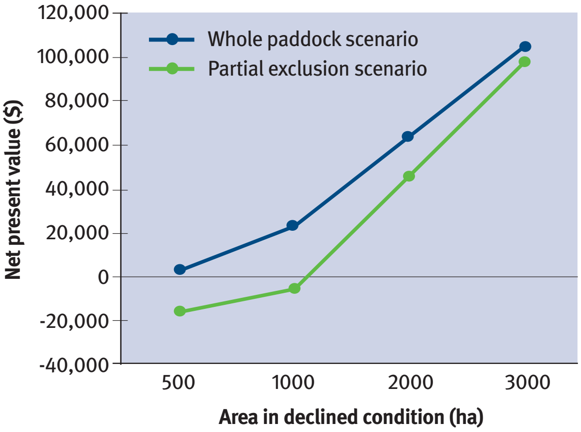

*Figure 13. Goldfields – Charters Towers with 3 tree basal area. Regeneration from C condition to B condition*

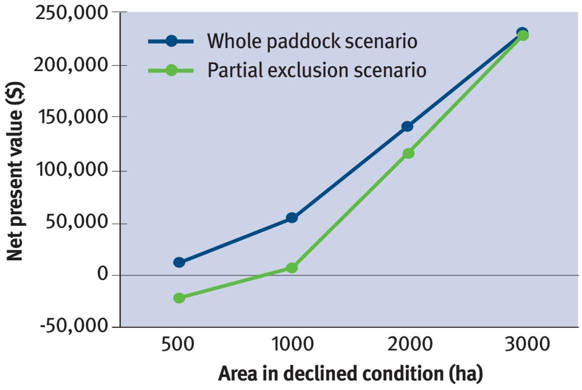

*Figure 14. Goldfields – Charters Towers with zero tree basal area. Regeneration from C condition to B condition*

# 11 Bioeconomic modelling

The protection of the Great Barrier Reef is a priority project for Natural Resource management in Australia. With the high contribution to sediment load that the grazing industry contributes the effort to reduce sediment exported off these lands is imperative. Currently there is asymmetric information regarding where national programs and regional natural resource management groups should be allocating funds. Past national natural resource management investments such as the National Action Plan for Salinity and Water and the Natural Heritage Trust program have fallen short of achieving desired goals because investments were not prioritised with integrated bio-physical and economic data (Pannell 2009).

It has been expressed that ‘environmental problems are often technically complex and uncertain’. Robust decisions about their management need to be based on good knowledge about the degree of threat or damage to environmental assets at risk, and the extent to which this threat or damage can be reduced by particular changes in management. In many cases, generic knowledge is not sufficient – we need locally specific knowledge (Pannell 2009).

To increase the efficiency and effectiveness of natural resource management investment, investments are required to be prioritised to the activities and locations that have the potential to generate the highest net value to society over time. A complete information base on which these decisions can be made is imperative and an integration of bio-physical modelling and economic valuation within a framework of benefit cost analysis is required (Mazur & Bennett 2008).

## Model development

In order to ensure that the climate variability was reflected and demonstrated the impacts of higher grazing pressure over an extended period of time, twenty initial start years were selected. The initial start years were chosen using a random number generator for the years between 1893–1983 and were selected in this method to ensure independence for statistical analyses. From these initial start years another 20 consecutive years were modelled (e.g. 1896–1916). A period of twenty years was selected as this represents an indicative period in which management is held by one particular party.

The twenty starting dates for the 20 year simulations were as follows:

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

For these start years there were three additional variables which were selected. These were tree basal area, initial start condition, and grazing pressure. Tree basal area can be described as the meters squared in one hectare that trees compete with pasture for nutrients and water. Tree basal area was implemented to reflect the ‘average’ type of trees found in the land type. To simulate a cleared landscape for land types where this is realistic a simulation with 0 m$^2$/ha was also included (table 9). demonstrates the tree basal area simulated for each of the land types modelled.

*Table 9. Tree basal area*

| Land type | Tree basal area (m$^2$/ha) | |
|---|---|---|
| Goldfields country – red soils | 0 | 3 |
| Silver-leaved ironbark | 0 | 7.5 |
| Silver-leaved ironbark on duplex | 0 | 5 |
| Spotted gum ridges | | 11 |

Initial start condition of 20 percent perennials, 70 percent perennials, and 88 percent perennials were also simulated. The start conditions selected were reflective of an A condition, B condition and C condition pasture species composition and total standing dry matter (TSDM), and was done to provide insight into the impacts of grazing pressure on the land type and the impact that this has on sediment run-off and economic performance (i.e. to identify where investments should be focused to minimise the cost of reducing sediment loads).

To examine the full range of impacts on sediment run-off and the relationship between sediment run-off and grazing pressure 13 grazing pressure intervals were simulated with each of the climate points. The grazing pressures were maintained for all of the land types selected and were based on the total standing dry matter left at the end of the growing season (April). The percent utilisation of this remaining standing dry matter was as follows;

10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%

Utilisation 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 2010). Threshold values based on utilisation of green material of total growth by the end of the growing season (30 April) .

The decline in the percent of desirable perennial grasses under heavy grazing is simulated by linking percent perennials to a condition scale derived by Ash et al. (1996) from observed data (McKeon et al. 2000). The condition of the resource (percent perennials) is indicated by a scale that ranges from state 0 (lightly grazed, 90% perennials) to state 11 (heavily grazed, zero 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. The potential rate of change between states for degradation or recovery is one state annually.

Across the land types, the loss of desirable perennial grasses associated with heavy utilisation was simulated by changing model parameters these changes are described in table 10.

*Table 10. Degradation and recovery threshold values based on utilisation of green material of total growth by the end of the growing season (30 April) for four land types in Fitzroy Basin.*

| Land type | Recovery threshold | Degradation threshold |
|---|---|---|
| | % dry matter utilisation | |
| Goldfields – red soils | 15% | 35% |
| Silver-leaved | 15% | 35% |
| Silver-leaved ironbark on duplex | 15% | 35% |
| Spotted gum ridges | 10% | 25% |

Annual live weight gain was calculated from percent utilisation and percentage of days during the year where pasture growth index was above a threshold. The growth index is calculated using green growth, soil water, nitrogen and temperature indices. An additional 15 kg/hd/yr live weight gain occurs on years pasture is burnt.

Run-off was simulated based on the function of surface cover, rainfall intensity, and soil-water deficit. Soil loss was simulated based on the function of runoff, cover and slope. The full report from the GRASP simulation can be found in appendix A.

## Economic model

- The property size was 5000 ha, and was assumed to be a homogenous block of one land type, although it is acknowledged that it is not reality verbatim, it does reflect a high percentage of managed areas for the catchments. A case study approach allows for comparisons between land types to be estimated.
- The enterprise selected was trade store steers for all land types, although it is acknowledge that this is a limitation of the study. An owner operator wage and other fixed costs have not been included in the analysis as the analysis focuses on the grazing enterprise rather than whole farm profit.
- 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.
- Mortality was calculated both for the dry herd and for the breading herd, and was dependent on the live weight gain. The calculation for mortality was derived from Macleod et al. (2004). The dry herd was considered to be calves and yearling heifers and steers. A breeding mortality rate was applied with a minimum of 20% for mortality rates. The equation was calculated as a function of live weight gain.

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

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

  *(MacLeod et al. 2004)*
- Branding rates was based on MacLeod et al (2004) and were determined as a function of live weight gain and this had a maximum rate of 75% and a minimum of 30% to reflect the regions average. The equation is as follows:

  $$\text{Branding \%} = 30 \leq 15.6 + 0.488 \times LWG \leq 75$$
- It was assumed that in years where there was less than 50 kg live weight gain that drought feeding would occur. It is also based on the work completed by MacLeod et al (2004). The rules implemented in the model were; when live weight gain was less than 50 kg per/hd then a urea-molasses lick supplement (urea 8%-M8U) was fed. The feeding rule was two days of M8U feeding for each kilo of live weight gain less than 50 kg. For example, when live weight gain was simulated by GRASP to be 10 kg, then the M8U ration was fed for 80 days. Where GRASP simulated that there would be a live weight loss then a ration of urea-molasses fortified with cottonseed meal (urea 3%, cottonseed meal 10% – M3UP38) was fed with one day of feeding for each kilo of weight loss. For example if an animal was simulated to loose

20 kg then there would be 20 feeding days of M3UP38 supplement and 100 days of M8U supplement.

- The AEs given to each animal class were based on the BreedCow Dynama program and are listed in table 11.

*Table 11 Adult equivalent*

| Animal class | Equivalent AEs (1 AE = 400 kg steer) |
|---|---|
| Calves | 0.35 |
| Heifer weaners | 0.28 |
| Steer weaners | 0.28 |
| Heifers 1 yr | 0.73 |
| Steers 1 yr | 0.78 |
| Heifers 2 yrs | 0.98 |
| Steers 2 yrs | 1.14 |
| Cows 3–10 yrs | 1.1 |

- A base herd was initially developed for year one, however depending on the available AE's determined by GRASP the base herd was multiplied across all animal classes or divided across all animal classes to adjust stock numbers up or down depending on available pasture. From this base herd the percentage sales and the percentage of male and females were determined.
- When there is an opportunity to purchase trade cattle they are purchased in numbers that maintain the ratio of females to males of the base herd.
- The percentage sales each year and the sale prices were kept constant. The percentage sales and the price per kilo are listed below in table 12.

*Table 12 Percentage herd sales and price*

| Animal class | Percentage of base herd sold (%) | |
|---|---|---|
| | Trade store steers | Price $/kg |
| Calves | 0 | 0 |
| Heifer weaners | 30 | 1.69 |
| Steer weaners | 0 | 0 |
| Heifers 1 yr | 42 | 1.57 |
| Steers 1 yr | 100 | 1.90 |
| Heifers 2 yrs | 42 | 1.35 |
| Steers 2 yrs | 0 | 1.90 |
| Cows 3–9 yrs | 42 | 1.35 |
| Cows 10 yrs | 100 | 1.35 |

- In order to ensure that the pasture utilisation is at the required level, particularly at the higher utilisation levels there was a high amount of variation in stock numbers from year to year. In these cases there was drought selling and purchasing. In order to ensure that the required reduced number of AEs were met additional drought sales occurred across the herd. 15% of the AEs required to be reduced were in weaners, 30% of AEs required to be reduced were in steers 1 yr old, and 45% of the AEs required to be reduced were of breeders.
- When drought selling occurs a price penalty is incurred on the cattle sold, demonstrating the low demand for stock during these periods.
- If the following year AEs increased they were bought back at the same ratio as the base herd in year one.
- Sediment exported was calculated using a delivery ratio of 12.5% which is the estimated level of sediment movement in a hectare that actually leaves the paddock and enters into the Great Barrier Reef Lagoon. This was derived in consultation with Cameron Dougall as a result of his report 'Enhanced sediment and nutrient modelling and target setting in the Fitzroy Basin.' (Dougall et al. 2008).

# 12 Results

The results will be presented in land types for each start condition groupings and tree basal areas. This allows for a more comparative analysis of the results over land types. An illustration of results and summary of net present value, sediment exported, AEs at each level of pasture utilisation and cost of reducing a tonne of sediment are presented for each scenario.

## Silver-leaved ironbark – Nebo

### C start condition

This was the most productive of the four land types and locations due to it's high but variable rainfall and the ability for soil to utilise water effectively. This land type also presents interesting implications due to its close proximity to the coast. Figure 15 illustrates the economically optimal pasture utilisation rate which is at 25% TSDM with the net present value at $407,170. This rate of pasture utilisation, results in an estimated 28,960 tonnes of sediment exported over the 20 year period, to reduce a tonne of sediment at this level of pasture utilisation the cost would be $13 per tonne as this would be the opportunity cost borne by the grazier for decreasing pasture utilisation. At 20% pasture utilisation the cost is increased to $22 per tonne of sediment which is due to an increased income forgone and decreased sediment exported. The sediment curve initially increases and then marginally increases at the pasture utilisation increases; this is attributed to the soil type of silver-leaved ironbark whereby once the initial layer of soil has been removed the clay subsoil is then eroded at a slower rate.

The implication of trees and competition with pasture species for water and nutrients can be observed in figure 16 where the start condition again is C however there is a tree basal area of 7.5 $m^2$ per hectare. In this particular case the grazier has a negative net present value for all pasture utilisation rates, and therefore the price for sediment reductions is negative indicating that it presents a cheap option for sediment reduction through reductions in pasture utilisation.

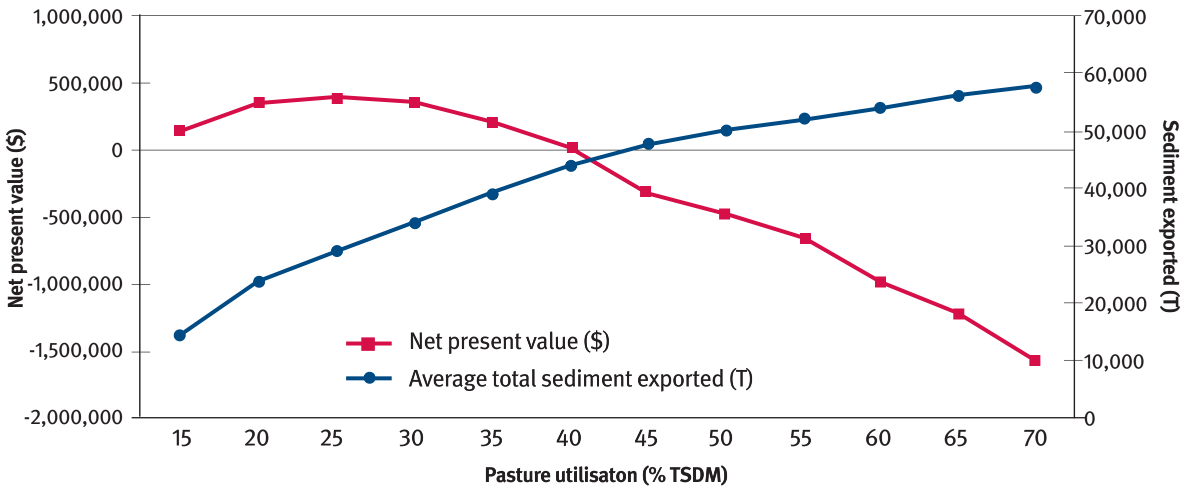

*Figure 15. Silver-leaved ironbark – Nebo, C start condition, zero tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 749 | 779 | 888 | 980 | 1060 | 1126 | 1202 | 1284 | 1368 | 1427 | 1500 | 1567 |
| Net present value ($) | 138,847 | 340,421 | 407,170 | 358,473 | 217,723 | 23,001 | -313,972 | -473,170 | -662,690 | -986,196 | -1,225,751 | -1,557,525 |
| Av total sediment (T) | 14,419 | 23,658 | 28,960 | 34,133 | 39,217 | 44,084 | 47,565 | 50,152 | 52,124 | 54,044 | 56,255 | 57,792 |
| $/T | 10 | 22 | 13 | -9 | -28 | -40 | -97 | -62 | -96 | -169 | -108 | -229 |

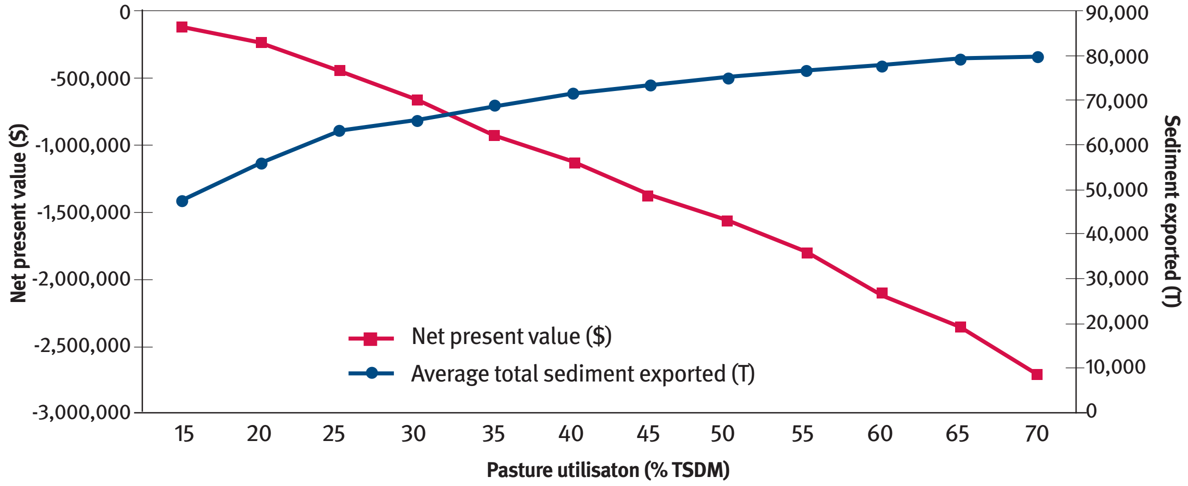

*Figure 16. Silver-leaved ironbark – Nebo, C start condition, 7.5 tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 289 | 333 | 363 | 412 | 446 | 477 | 513 | 545 | 574 | 605 | 634 | 662 |
| Net present value ($) | -109,555 | -239,774 | -444,509 | -669,911 | -906,679 | -1,105,726 | -1,373,338 | -1,563,605 | -1,778,642 | -2,102,003 | -2,339,361 | -2,707,932 |
| Av total sediment (T) | 47,846 | 55,831 | 63,177 | 65,656 | 68,675 | 71,525 | 73,312 | 74,984 | 76,685 | 77,871 | 78,908 | 79,892 |
| $/T | -2 | -16 | -28 | -91 | -78 | -70 | -105 | -114 | -126 | -272 | -229 | -375 |

## B start condition

When the silver-leaved ironbark starts in B condition with zero tree basal area the economically optimal point increases by 5% pasture utilisation in comparison with the C start condition to, 30% pasture utilisation (TSDM). At this level of pasture utilisation 23,376 tonnes of sediment is exported and the net present value is $733,598. If a grazier is operating at 35% they are operating past the economically optimal point and exporting an additional 6989 tonnes of sediment. If the grazier reduced their pasture utilisation level back to 30% they would reduce their sediment load by 7000 tonnes and be $14,400 better off (i.e. at $19/T). This suggests that an extension effort is required as it is currently a no-win situation with increased sediment exported and income forgone.

When there is a tree basal area the net present value for all pasture utilisation rates is negative indicating that the impact of trees is again significant. The impact of trees also results in a considerable increase in sediment exported for the same level of utilisation. For example at 25% pasture utilisation when there is a zero tree basal area 17,459 tonnes is exported, however when there is a tree basal area of 7.5 $m^2$ for the same utilisation rate 46,158 tonnes is exported.

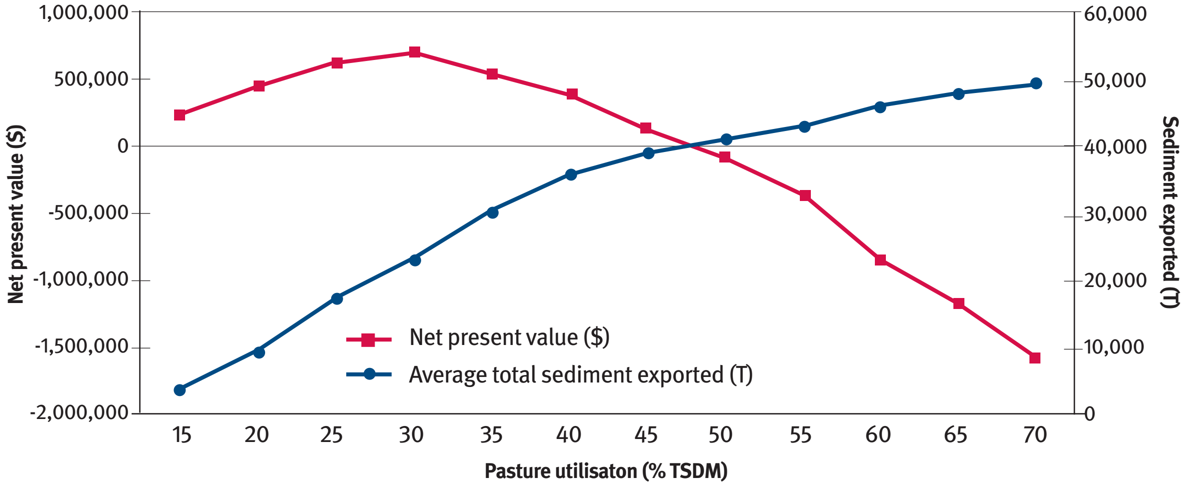

*Figure 17. Silver-leaved ironbark – Nebo, B start condition, zero tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 1,137 | 1,166 | 1,223 | 1,294 | 1,328 | 1,390 | 1,484 | 1,592 | 1,688 | 1,761 | 1,846 | 1,941 |
| Net present value ($) | 208,785 | 447,649 | 663,083 | 733,598 | 599,205 | 461,685 | 240,337 | 42,763 | -263,545 | -710,802 | -975,703 | -1,380,204 |
| Av total sediment (T) | 3,793 | 9,619 | 17,459 | 23,376 | 30,365 | 35,999 | 39,199 | 41,200 | 43,351 | 46,141 | 48,139 | 49,570 |
| $/T | 55 | 41 | 27 | 12 | -19 | -24 | -69 | -99 | -142 | -160 | -133 | -283 |

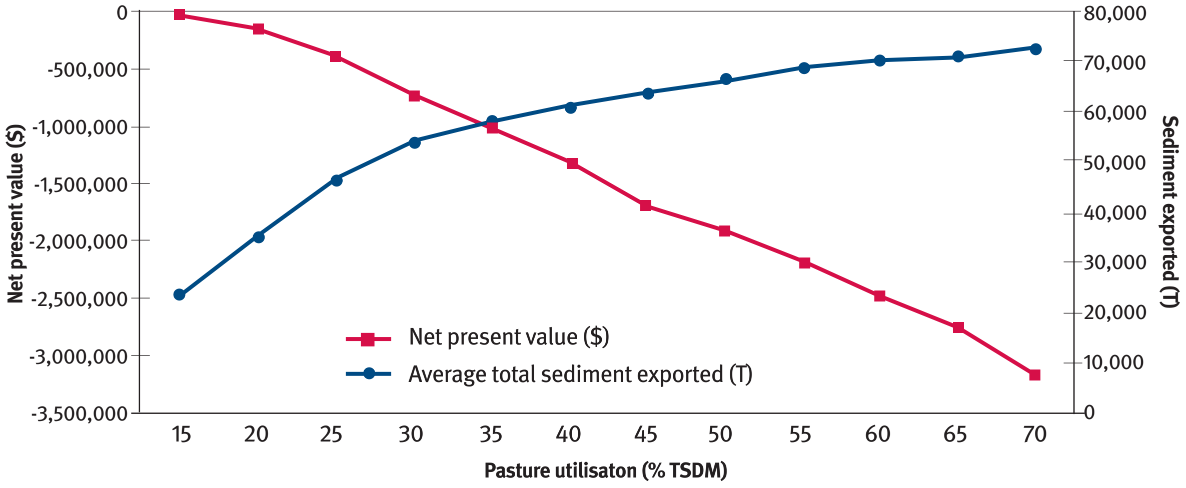

*Figure 18. Silver-leaved ironbark – Nebo, B start condition, 7.5 tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 479 | 525 | 532 | 553 | 596 | 631 | 671 | 707 | 730 | 766 | 809 | 831 |
| Net present value ($) | -20,153 | -136,422 | -397,094 | -710,506 | -990,251 | -1,326,369 | -1,678,941 | -1,906,018 | -2,162,831 | -2,456,046 | -2,741,941 | -3,133,860 |
| Av total sediment (T) | 23,688 | 34,991 | 46,158 | 54,185 | 58,098 | 61,622 | 64,065 | 66,113 | 68,771 | 70,091 | 70,882 | 72,389 |
| $/T | -1 | -10 | -23 | -39 | -71 | -95 | -144 | -111 | -97 | -222 | -361 | -260 |

### A condition

When the original start land condition is A, and the area is cleared the results demonstrate clearly a rise to a peak and then decreasing quickly. This is in part due to the resilience and the degradation and regeneration thresholds used in the GRASP modelling. The graph demonstrates that the economically optimal pasture utilisation is 30% TSDM, where the net present value is $950,006. At this level of pasture utilisation to reduce a tonne of sediment would be $48 due to the optimal economic peak. At 25% pasture utilisation the net present value is $649,556 this is significantly less than the net present value for 30%, the sediment exported is also almost half of the sediment exported at 30% (7915 tonnes) therefore the cost per tonne of sediment is still significant at $51 per tonne of sediment reduced. In this scenario is can be noted that the sediment curve is sigmoid shaped indicating that initially as the pasture utilisation increases there is a dramatic increase in the sediment exported. However due to the clay sub-soil when the higher pasture utilisation rates are reached and the clay sub-soil is reached these rates actually only marginally increase.

In A condition when there is a tree basal area of 7.5 $m^2$/ha the economically optimal point is reduced to a pasture utilisation of 15% TSDM. At this level of pasture utilisation the net present value is $163,108 with 1,673 tones of sediment exported. The only other pasture utilisation with a positive net present value is 20% TSDM with a net present value of $111,574 and the total tonnes of sediment exported being 3891 tones. Again the sediment curve is characterised by a sigmoid shaped curve indicating that at 35% pasture utilisation the majority of the top soil has been removed and the clay sub-soil is exposed and not eroding at a reduced rate.

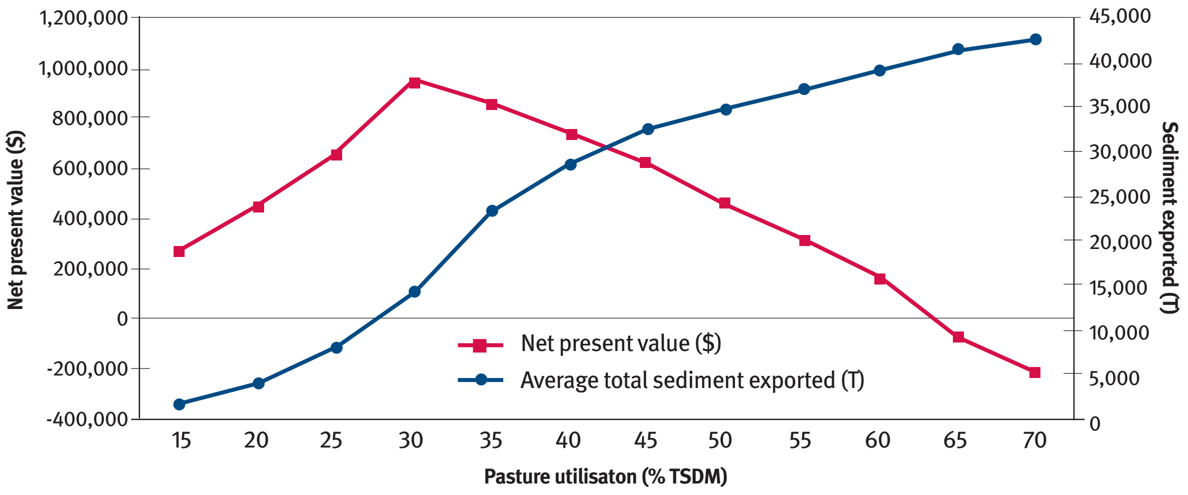

*Figure 19. Silver-leaved ironbark – Nebo, A start condition, zero tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 1,316 | 1,496 | 1,620 | 1,672 | 1,608 | 1,683 | 1,780 | 1,892 | 1,998 | 2,076 | 2,173 | 2,265 |
| Net present value ($) | 263,556 | 444,899 | 649,556 | 950,006 | 856,570 | 735,415 | 622,884 | 456,469 | 311,045 | 160,201 | -147,515 | -219,265 |
| Av total sediment (T) | 1,673 | 3,891 | 7,915 | 14,239 | 23,352 | 28,582 | 32,398 | 34,664 | 36,831 | 39,062 | 41,459 | 42,499 |
| $/T | 158 | 82 | 51 | 48 | -10 | -23 | -29 | -73 | -67 | -68 | -128 | -69 |

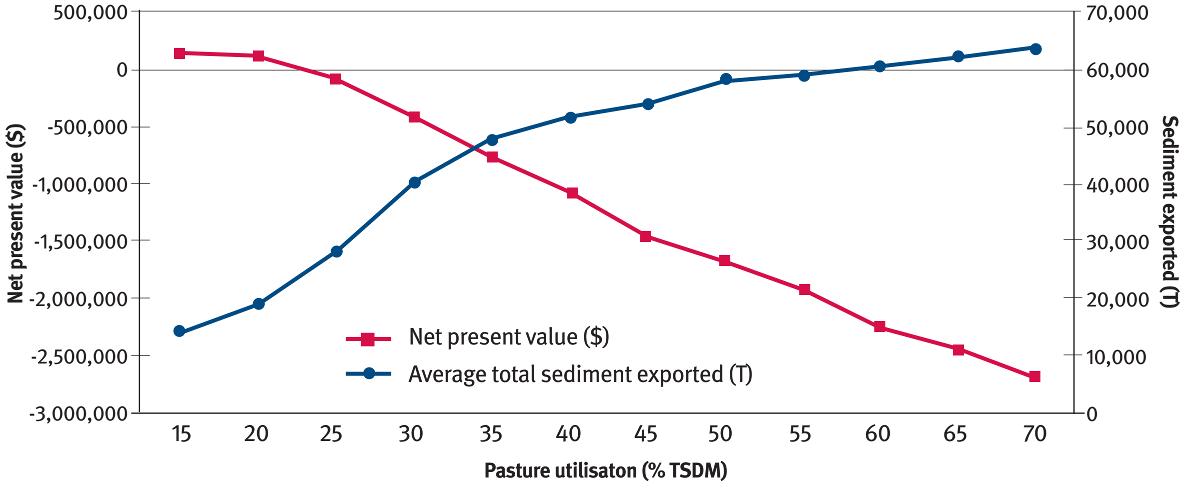

*Figure 20. Silver-leaved ironbark – Nebo, A start condition, 7.5 tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 601 | 719 | 745 | 725 | 738 | 785 | 840 | 869 | 908 | 942 | 990 | 1,015 |
| Net present value ($) | 163,108 | 111,574 | -76,397 | -405,360 | -758,284 | -1,086,758 | -1,462,456 | -1,681,784 | -1,915,423 | -2,250,414 | -2,440,821 | -2,710,294 |
| Av total sediment (T) | 1,673 | 3,891 | 7,915 | 14,239 | 23,352 | 28,582 | 32,398 | 34,664 | 36,831 | 39,062 | 41,459 | 42,499 |
| $/T | 12 | -11 | -20 | -26 | -47 | -91 | -162 | -65 | -119 | -242 | -124 | -140 |

## Silver-leaved ironbark – Springvale

The silver-leaved ironbark modelled from Springvale does not have the same rainfall as the silver leaved ironbark as Nebo, or the same soil characteristics, therefore the results between the two locations varied considerably in regards to both sediment exported and net present value. The impact of trees again impacted negatively on the net present value and in all start conditions for all silver leaved ironbark at Springvale scenarios yielded a negative result.

For the scenario with zero tree basal area with a start condition of C the economically optimal pasture utilisation rate was achieved at 15% pasture utilisation (figure 21) where the net present value is $62,741 and the average total sediment exported is 18,585 tonnes. To reduce this sediment would cost $3 per tonne or a total of $55,755 presenting an affordable option for a large sediment reduction. For the tree basal area scenario for 15% pasture utilisation the net present value is negative (figure 22) and this trend continues at a decreasing rate to 70% pasture utilisation.

To demonstrate the difference in sediment exported between the two silver leaved ironbark locations for the C start condition and zero tree basal area scenarios if the 15% pasture utilisation rate is compared, in the Nebo location the export rate is 14,419 tonnes and the Springvale location exports 18,585 tonnes over the twenty year period.

For B condition with again zero tree basal area the net present value curve has quite a flat top where the difference between 20% TSDM, 25% TSDM, and 30% TSDM is very marginal (figure 22), however the sediment exported increases dramatically from 14,815 at 20% TSDM to 25,362 at 30% TSDM. It is these types of scenarios that present inexpensive alternatives for large sediment reductions. To reduce grazing back from 30% pasture utilisation to 25% pasture utilisation would cost the grazier $4 per tonne of sediment reduced. Although having a B start condition, when trees where included in the scenario with a tree basal area of 5 m$^2$ all levels of pasture utilisation resulted in a negative net present value.

For silver-leaved ironbark starting in A condition with zero tree basal area (figure 25) the net present value curve follows a bell shaped curve, however the peak pasture utilisation rate is at 30% TSDM. At this level the net present value is $506,554 and the total sediment exported is 19,542 tonnes. The sediment curve has one large incremental jump from 7213 tonnes at 20% pasture utilisation to 15,608 tonnes at 25% pasture utilisation and then a further 3934 tonnes to 19,542 at 30% TSDM. To have a decrease of 12,329 tonnes and reduce pasture utilisation to 20% TSDM the cost would be $715,082, highlighting the increased expense when the net present value is high and the sediment exported is lower than in B condition.

This particular bell shaped curve for the net present value present some interesting interpretations and limitations of the economic sub-model in the bioeconomic model. The economic model interacts with buying and selling, interest on livestock capital and drought feeding. For this particular scenario although the stock numbers fluctuated at times resulting in some negative NPV the general stock numbers were comparatively low resulting in a lower livestock on capital, and less numbers that were drought feed, and traded. As a result the economic performance of this landtype was higher than the Goldfields.

Again when the same scenario was modelled with a tree basal area of 5 m$^2$ the results for all pasture utilisation rates were negative. This illustrated that trees have a more significant impact on net present value than starting land condition does.

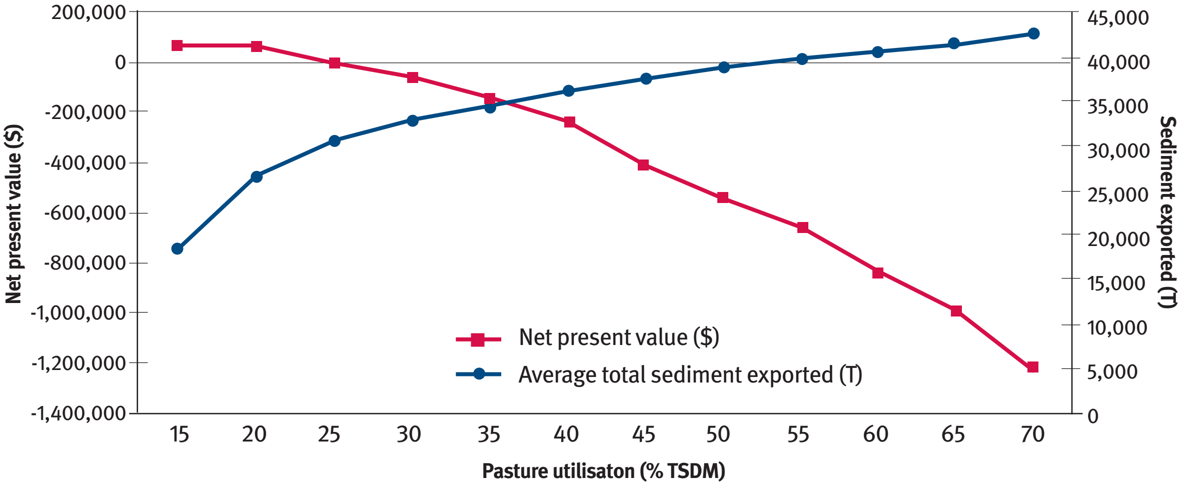

*Figure 21. Silver-leaved ironbark – Springvale, C start condition, zero tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 375 | 376 | 420 | 472 | 522 | 569 | 609 | 654 | 695 | 731 | 774 | 809 |
| Net present value ($) | 62,764 | 58,809 | -3,080 | -58,474 | -151,584 | -231,710 | -411,658 | -528,200 | -657,728 | -832,874 | -982,318 | -1,233,552 |
| Av total sediment (T) | 18,585 | 26,741 | 30,578 | 32,876 | 34,551 | 36,020 | 37,565 | 38,681 | 39,674 | 40,535 | 41,418 | 42,499 |
| $/T | 3 | 0 | -16 | -24 | -56 | -55 | -116 | -104 | -130 | -203 | -169 | -307 |

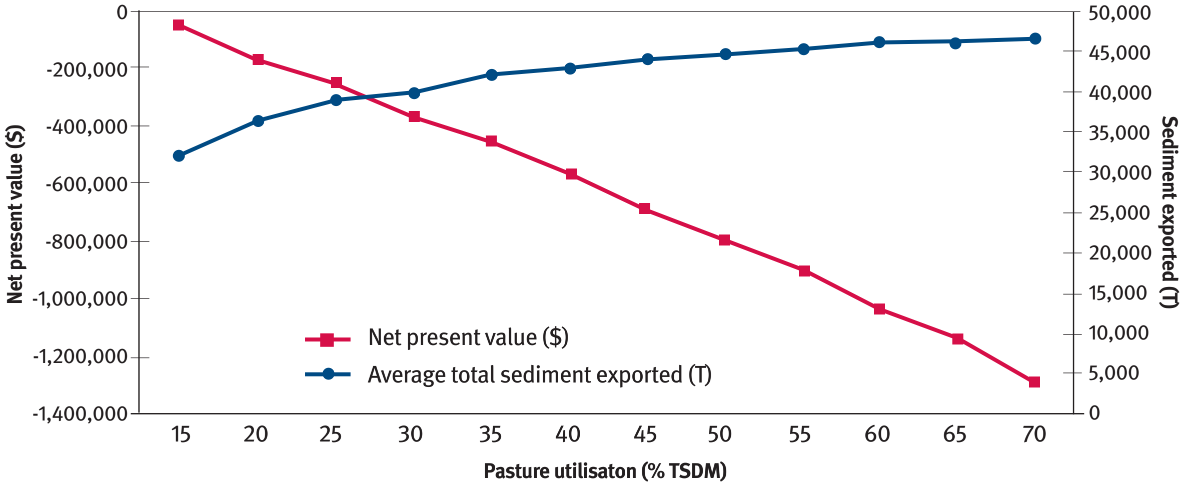

*Figure 22. Silver-leaved ironbark – Springvale, C start condition, 7.5 tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 126 | 138 | 152 | 172 | 176 | 190 | 199 | 211 | 219 | 244 | 238 | 250 |
| Net present value ($) | -196,995 | -296,605 | -383,256 | -486,253 | -569,147 | -670,150 | -796,203 | -891,541 | -989,919 | -1,111,284 | -1,122,125 | -1,364,286 |
| Av total sediment (T) | 31,852 | 36,199 | 38,973 | 39,839 | 42,114 | 42,913 | 44,016 | 44,619 | 45,329 | 45,973 | 46,269 | 46,447 |
| $/T | -6 | -23 | -31 | -119 | -36 | -127 | -114 | -158 | -139 | -191 | -370 | -799 |

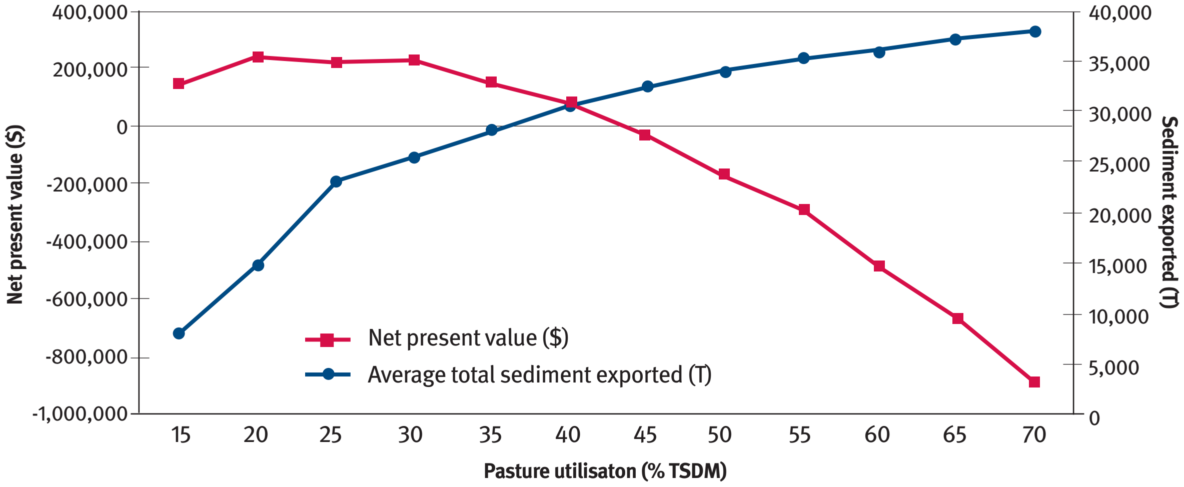

*Figure 23. Silver-leaved ironbark – Springvale, B start condition, zero tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 587 | 582 | 569 | 633 | 680 | 716 | 755 | 801 | 843 | 886 | 933 | 976 |
| Net present value ($) | 134,813 | 241,624 | 216,914 | 226,176 | 144,892 | 77,847 | -39,675 | -172,779 | -292,891 | -487,115 | -664,541 | -901,166 |
| Av total sediment (T) | 7,819 | 14,815 | 22,919 | 25,362 | 27,961 | 30,446 | 32,501 | 33,897 | 35,146 | 35,935 | 37,092 | 37,850 |
| $/T | 17 | 15 | -3 | 4 | -31 | -27 | -57 | -95 | -96 | -246 | -153 | -312 |

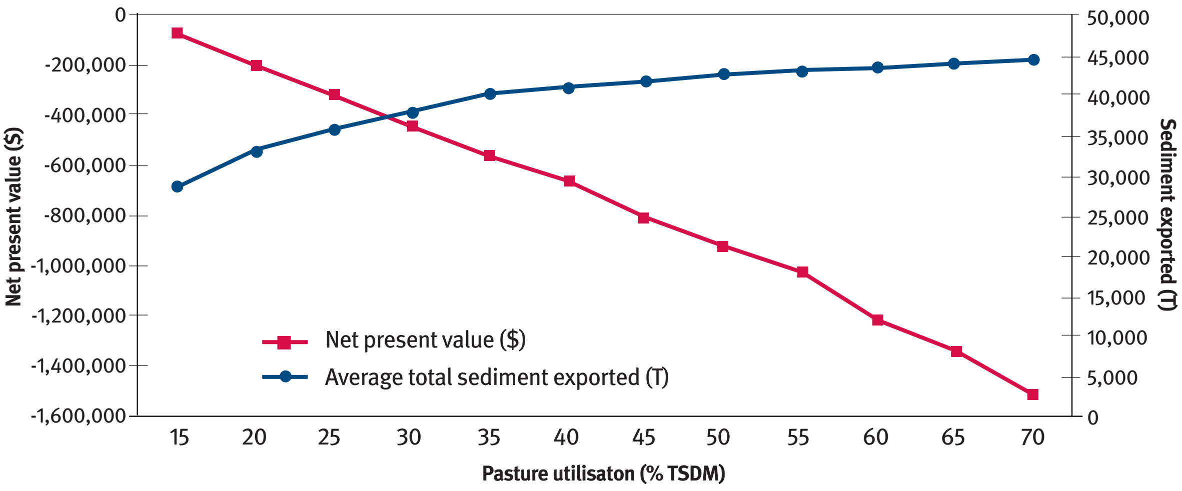

*Figure 24. Silver-leaved ironbark – Springvale, B start condition, 5 tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 146 | 164 | 182 | 197 | 205 | 223 | 239 | 252 | 267 | 297 | 291 | 305 |
| Net present value ($) | -70,526 | -200,985 | -315,877 | -445,474 | -554,334 | -660,434 | -805,077 | -918,420 | -1,029,101 | -1,215,203 | -1,339,027 | -1,517,629 |
| Av total sediment (T) | 28,678 | 33,157 | 35,926 | 37,916 | 40,185 | 40,970 | 41,786 | 42,548 | 43,008 | 43,436 | 44,018 | 44,309 |
| $/T | -2 | -29 | -41 | -65 | -48 | -135 | -177 | -149 | -241 | -453 | -207 | -615 |

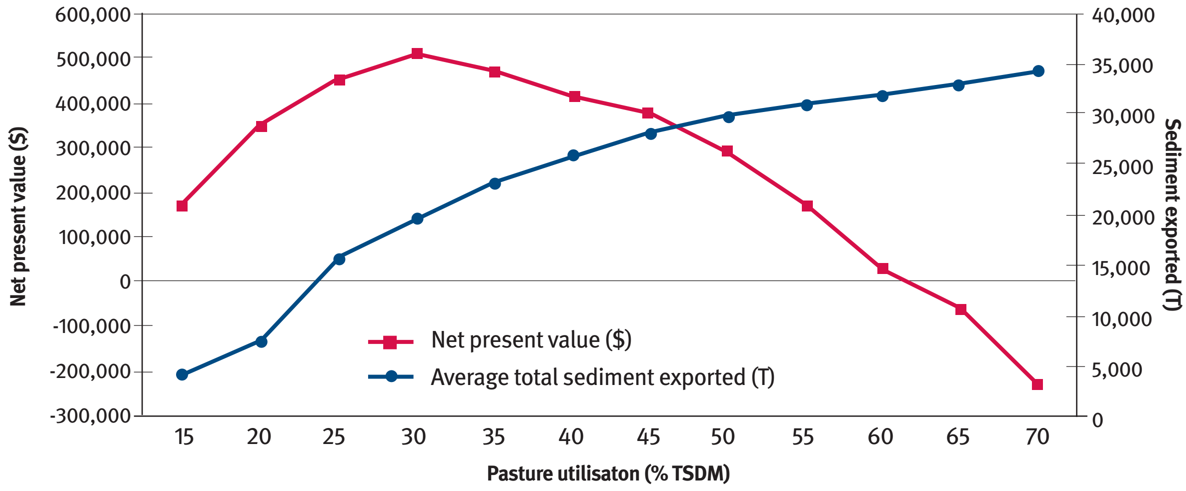

*Figure 25. Silver-leaved ironbark – Springvale, A start condition, zero tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 720 | 804 | 757 | 800 | 831 | 866 | 906 | 954 | 1,008 | 1,036 | 1,100 | 1,137 |
| Net present value ($) | 166,388 | 349,278 | 454,088 | 506,554 | 473,242 | 416,012 | 377,627 | 292,234 | 174,170 | 27,008 | -62,279 | -223,740 |
| Av total sediment (T) | 4,058 | 7,213 | 15,608 | 19,542 | 23,023 | 25,775 | 27,932 | 29,564 | 30,768 | 31,830 | 32,974 | 34,104 |
| $/T | 41 | 58 | 12 | 13 | -10 | -21 | -18 | -52 | -98 | -139 | -78 | -143 |

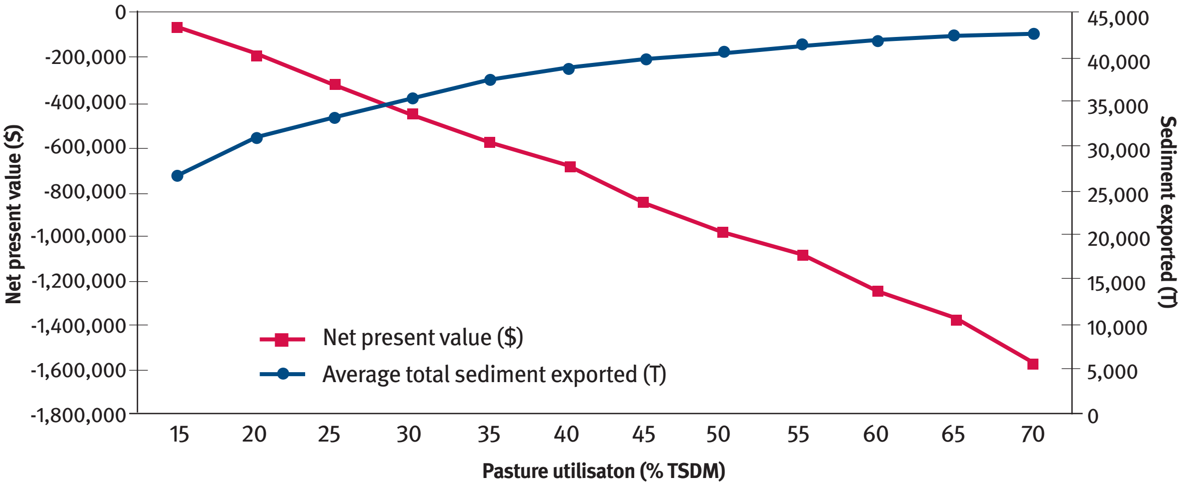

*Figure 26. Silver-leaved ironbark – Springvale , A start condition, 5 tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 161 | 183 | 208 | 224 | 238 | 253 | 267 | 283 | 300 | 325 | 324 | 339 |
| Net present value ($) | -69,929 | -188,554 | -313,410 | -456,809 | -579,046 | -690,297 | -854,748 | -975,427 | -1,085,773 | -1,248,996 | -1,373,339 | -1,567,808 |
| Av total sediment (T) | 26,638 | 30,999 | 33,336 | 35,490 | 37,560 | 38,891 | 39,957 | 40,661 | 41,190 | 42,065 | 42,440 | 42,753 |
| $/T | -3 | -27 | -53 | -67 | -59 | -84 | -154 | -172 | -209 | -231 | -229 | -621 |

## Spotted gum

The spotted gums inherit low productivity was reflected in the bioeconomic modelling results with negative results for C, B and A starting land condition. This is due to the low productivity of the land and the low degradation thresholds. This land type however exported significant amounts of sediment with the average for 20% pasture utilisation over the three start conditions being 59,123 tonnes. In A condition at 20% pasture utilisation 57,215 tonnes of sediment (figure 29) was exported in comparison to the 61,016 tonnes exported in C condition, therefore the land type characteristics particularly the soil characteristics are susceptible to erosion even in A condition.

The sediment curve for each start condition follows a similar trend with a jump from 15% TSDM to 20% TSDN and then a flattening of the curve. It must be kept in mind that the land type is heavily treed (11 TBA) and therefore this jump may be attributed to the tree and leaf litter that would be initially exported in a rain event, and the initial loss of top soil.

This is a land type which has a relatively low level of inherit productivity and one property is unlikely to exist with only spotted gum on it. The Fitzroy Basin consists of 13,066 km$^2$ of spotted gum and this is a land type that if it is being grazed presents a very affordable option for large sediment reductions.

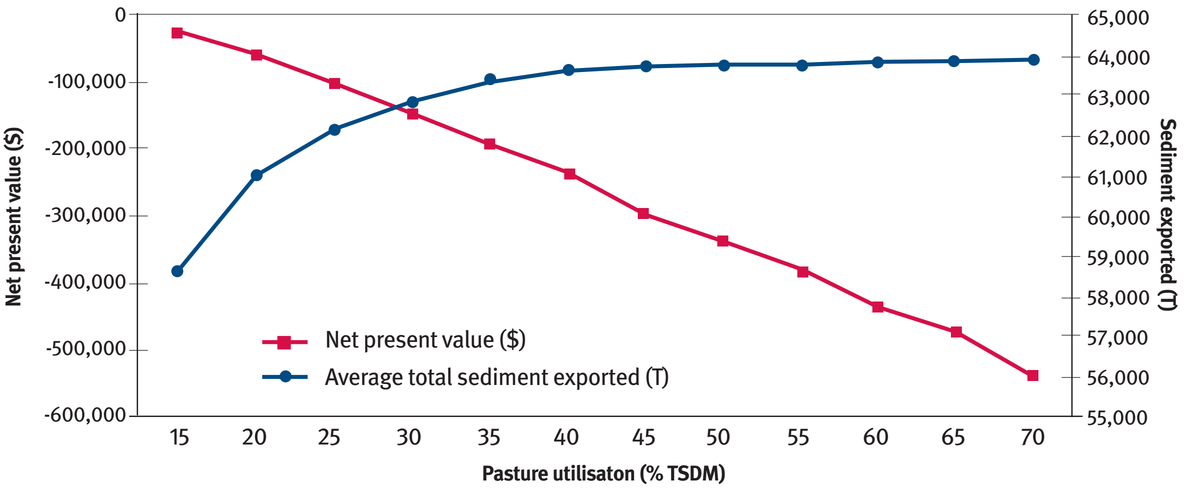

*Figure 27. Spotted gum – Duaringa, C start condition, 11 tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 48 | 52 | 58 | 65 | 71 | 78 | 85 | 92 | 100 | 105 | 113 | 120 |
| Net present value ($) | -24,166 | -60,449 | -100,674 | -150,144 | -193,028 | -237,349 | -295,582 | -336,212 | -378,140 | -438,204 | -477,195 | -542,702 |
| Av total sediment (T) | 58,576 | 61,016 | 62,140 | 62,792 | 63,279 | 63,597 | 63,662 | 63,728 | 63,770 | 63,777 | 63,821 | 63,857 |
| $/T | 0 | -15 | -36 | -76 | -88 | -139 | -895 | -614 | -997 | -9,422 | -882 | -1,839 |

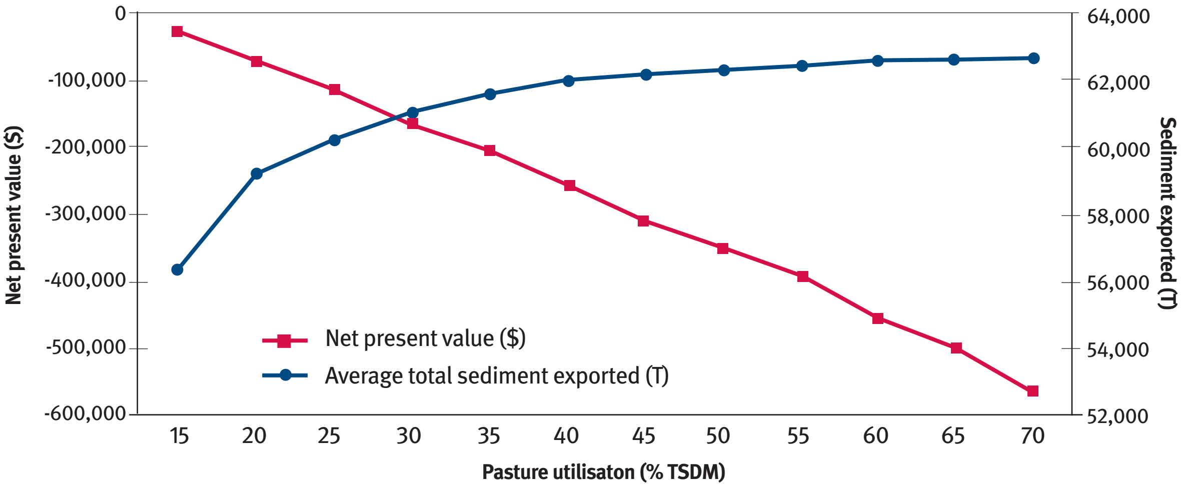

*Figure 28. Spotted gum – Duaringa, B start condition, 11 tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 61 | 66 | 75 | 82 | 90 | 97 | 105 | 113 | 121 | 126 | 135 | 142 |
| Net present value ($) | -28,102 | -71,676 | -114,118 | -165,644 | -207,844 | -255,691 | -311,253 | -352,025 | -393,967 | -454,949 | -498,065 | -568,624 |
| Av total sediment (T) | 56,116 | 59,138 | 60,170 | 61,073 | 61,574 | 62,029 | 62,164 | 62,303 | 62,419 | 62,501 | 62,546 | 62,598 |
| $/T | -1 | -14 | -41 | -57 | -84 | -105 | -413 | -292 | -364 | -737 | -960 | -1,352 |

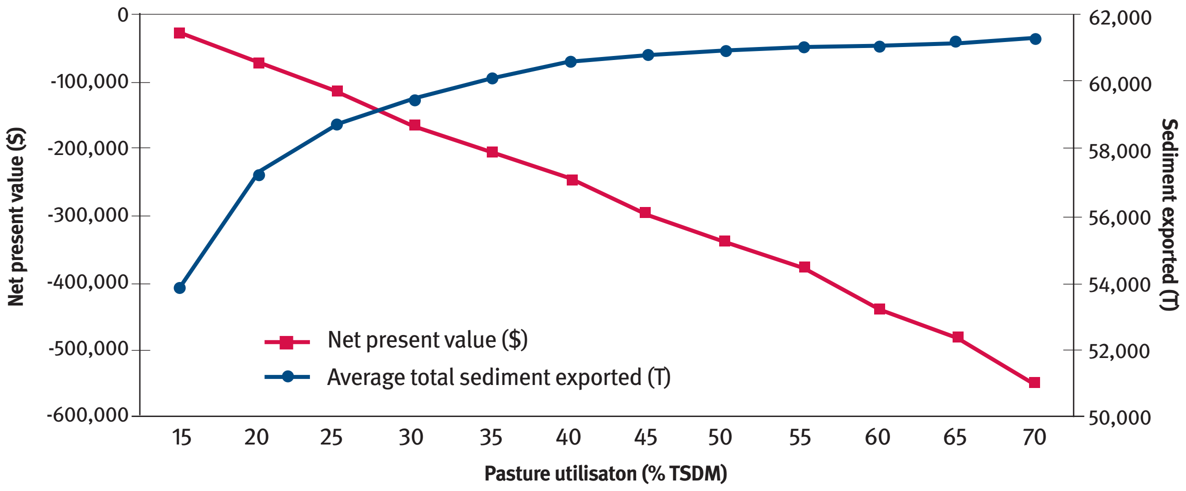

*Figure 29. Spotted gum – Duaringa, A start condition, 11 tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 72 | 76 | 84 | 94 | 103 | 111 | 120 | 129 | 137 | 143 | 152 | 159 |
| Net present value ($) | -12,231 | -56,475 | -94,788 | -138,255 | -177,941 | -218,033 | -268,079 | -307,044 | -342,472 | -400,939 | -445,482 | -510,593 |
| Av total sediment (T) | 53,757 | 57,216 | 58,700 | 59,457 | 60,067 | 60,569 | 60,745 | 60,905 | 60,987 | 61,077 | 61,149 | 61,243 |
| $/T | 0 | -13 | -26 | -57 | -65 | -80 | -285 | -244 | -433 | -645 | -618 | -695 |

## Goldfields

The goldfield's results demonstrate the influence of starting land condition and the stronger influence tree basal area has on the economically optimal point for pasture utilisation. As land condition improves from C to B with a zero tree basal area the optimal pasture utilisation rate increases from 15% TSDM in C condition where the net present value is $81,693 and 15,358 tonnes of sediment is exported (figure 30) to 25% TSDM in B condition with an NPV of $205,958 and 12,524 tonnes of sediment. For A condition with a zero tree basal area (figure 34) the economically optimal pasture utilisation rate is achieved at 25% where the net present value is $354,141 and 7777 tonnes of sediment are exported.

Tree basal area impacts more significantly on the sediment exported due to the competition between pasture species and the trees, this also has cumulative impacts on the net present value. At B condition with a tree basal area of zero the economically optimal pasture utilisation rate is 25%, for B start condition with a tree basal area of 3 $m^2$ at 20% pasture utilisation the NPV is -$570,263 and 21,998 tonnes of sediment is exported. This results in 9474 extra tonnes of sediment exported over the 20 year period, and highlights the importance of taking into account both land type, start condition and tree basal area in designing programs for sediment reductions

The goldfields results demonstrate that the land type is more productive than the spotted gum and the silver-leaved ironbark at Springvale however was less productive than the silver-leaved ironbark at Nebo. It is these comparisons that allow funding to be targeted more efficiently.

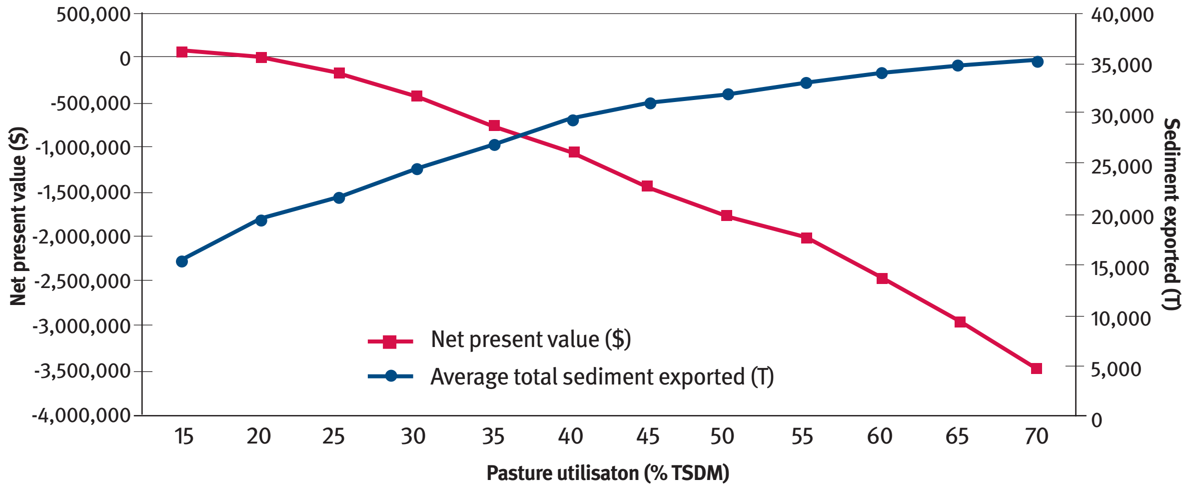

*Figure 30. Goldfields – Charters Towers, C start condition, zero tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 600 | 692 | 813 | 895 | 971 | 1,033 | 1,117 | 1,199 | 1,280 | 1,357 | 1,435 | 1,512 |
| Net present value ($) | 81,693 | 20,172 | -155,783 | -432,525 | -753,650 | -1,051,633 | -1,428,518 | -1,741,390 | -2,017,823 | -2,458,369 | -2,938,422 | -3,486,411 |
| Av total sediment (T) | 15,358 | 19,333 | 21,547 | 24,356 | 26,907 | 29,478 | 30,958 | 32,047 | 33,055 | 34,044 | 34,762 | 35,381 |
| $/T | 5 | -15 | -79 | -99 | -126 | -116 | -255 | -287 | -274 | -445 | -669 | -885 |

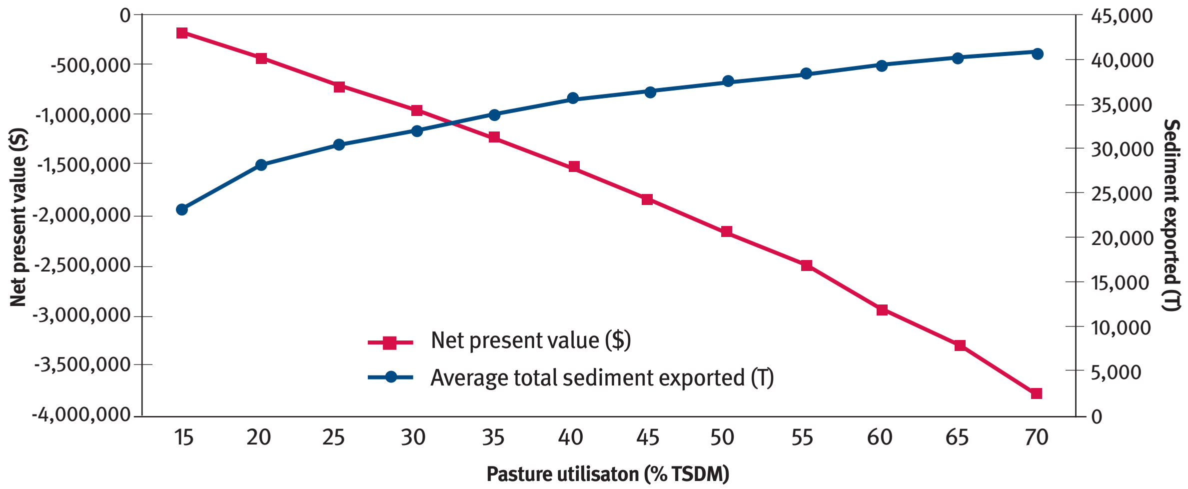

*Figure 31. Goldfields – Charters Towers, C start condition, 3 tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 367 | 403 | 464 | 523 | 571 | 612 | 664 | 712 | 756 | 799 | 846 | 888 |
| Net present value ($) | -186,151 | -418,186 | -682,764 | -978,820 | -1,246,945 | -1,521,958 | -1,877,852 | -2,175,705 | -2,487,645 | -2,964,791 | -3,308,169 | -3,798,971 |
| Av total sediment (T) | 23,151 | 28,213 | 30,440 | 32,173 | 33,798 | 35,436 | 36,469 | 37,422 | 38,494 | 39,391 | 40,114 | 40,830 |
| $/T | -8 | -46 | -119 | -171 | -165 | -168 | -344 | -313 | -291 | -532 | -475 | -685 |

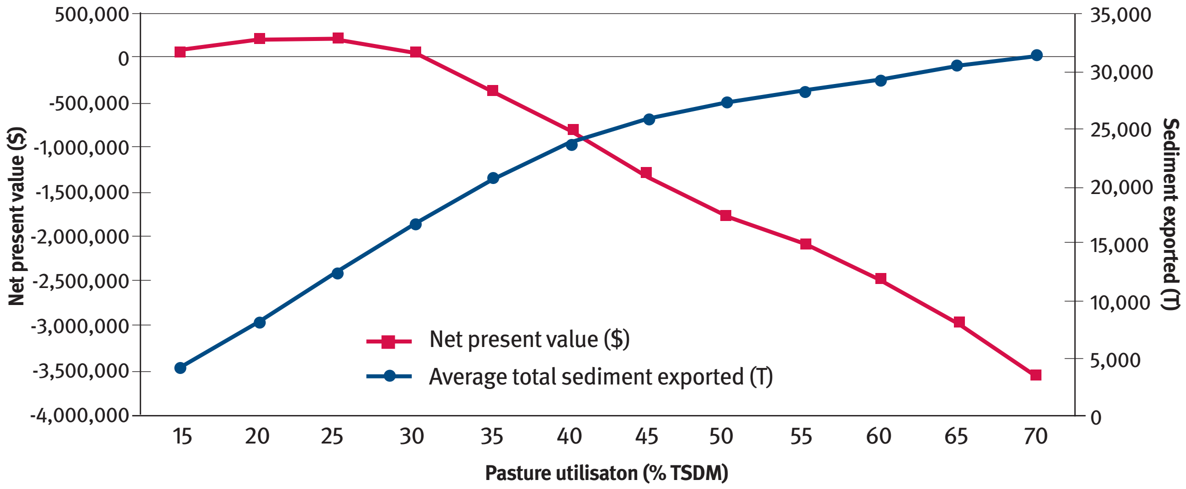

*Figure 32. Goldfields – Charters Towers, B start condition, zero tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 1,020 | 1,085 | 1,159 | 1,221 | 1,253 | 1,316 | 1,395 | 1,480 | 1,570 | 1,664 | 1,739 | 1,832 |
| Net present value ($) | 76,617 | 205,943 | 205,958 | 67,789 | -366,795 | -805,318 | -1,322,347 | -1,742,847 | -2,058,271 | -2,487,369 | -2,967,895 | -3,555,111 |
| Av total sediment (T) | 4,102 | 8,385 | 12,524 | 16,679 | 20,770 | 23,799 | 25,938 | 27,297 | 28,363 | 29,280 | 30,438 | 31,326 |
| $/T | 19 | 30 | 0 | -33 | -106 | -145 | -242 | -309 | -296 | -468 | -415 | -661 |

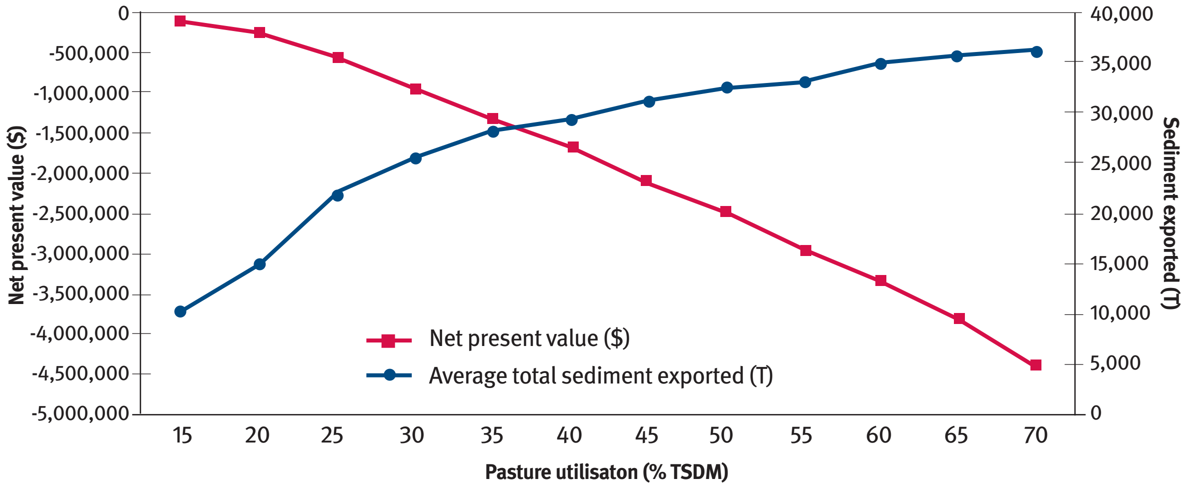

*Figure 33. Goldfields – Charters Towers, B start condition, 3 tree basal area*

| Pasture utilisation (%TSDM) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 610 | 680 | 669 | 709 | 757 | 822 | 863 | 921 | 978 | 1,008 | 1066 | 1116 |
| Net present value ($) | -93,881 | -266,397 | -570,263 | -961,902 | -1,338,152 | -1,675,291 | -2,115,906 | -2,494,846 | -2,955,845 | -3,353,871 | -3,807,132 | -4,399,970 |
| Av total sediment (T) | 10,151 | 14,835 | 21,998 | 25,555 | 28,215 | 29,315 | 31,255 | 32,382 | 33,202 | 34,721 | 35,467 | 36,244 |
| $/T | -9 | -37 | -42 | -110 | -141 | -307 | -227 | -336 | -562 | -262 | -608 | -762 |

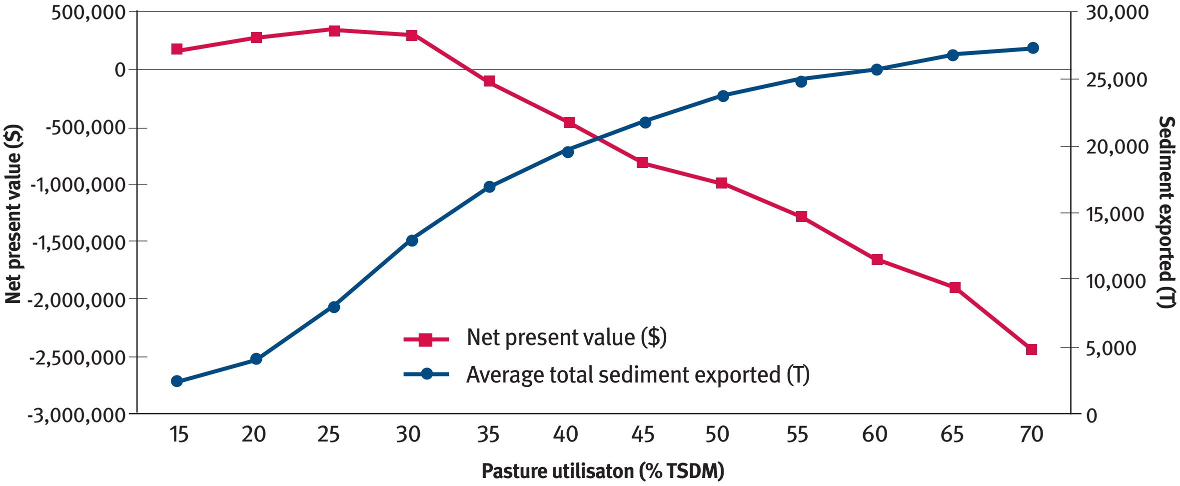

*Figure 34. Goldfields – Charters Towers, A start condition, zero tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 1,181 | 1,388 | 1,455 | 1,462 | 1,499 | 1,575 | 1,647 | 1,717 | 1,813 | 1,923 | 2,029 | 2,128 |
| Net present value ($) | 153,426 | 285,215 | 354,141 | 297,940 | -80,267 | -445,459 | -828,560 | -990,381 | -1,285,572 | -1,643,521 | -1,894,407 | -2,435,896 |
| Av total sediment (T) | 2,247 | 3,862 | 7,777 | 12,802 | 16,674 | 19,536 | 21,842 | 23,710 | 24,954 | 25,808 | 26,712 | 27,397 |
| $/T | 68 | 82 | 18 | -11 | -98 | -128 | -166 | -87 | -237 | -419 | -278 | -791 |

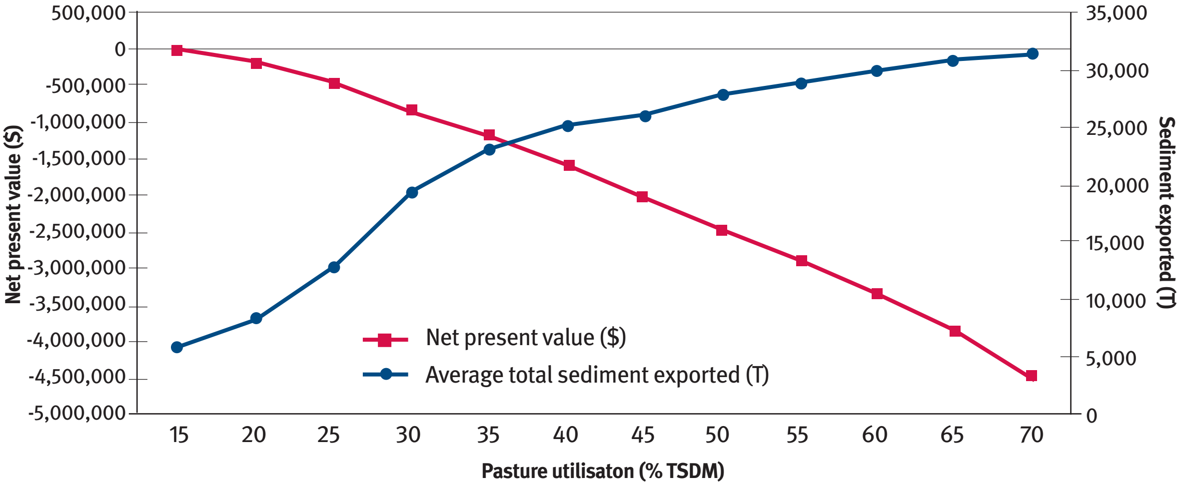

*Figure 35. Goldfields – Charters Towers, A start condition, 3 tree basal area*

| **Pasture utilisation (%TSDM)** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual AEs for 5000 ha | 732 | 874 | 940 | 907 | 926 | 976 | 1,055 | 1,107 | 1,161 | 1,225 | 1,282 | 1,346 |
| Net present value ($) | 3,315 | -173,025 | -439,079 | -856,711 | -1,180,129 | -1,578,011 | -2,041,281 | -2,465,344 | -2,859,285 | -3,342,675 | -3,843,146 | -4,498,485 |
| Av total sediment (T) | 6,001 | 8,288 | 12,637 | 19,222 | 23,171 | 25,212 | 26,167 | 27,888 | 28,979 | 30,025 | 30,887 | 31,441 |
| $/T | 1 | -77 | -61 | -63 | -82 | -195 | -485 | -246 | -361 | -462 | -581 | -1,181 |

# 13 Discussion

The results highlight the complexity of achieving sediment reductions from grazing lands for improved water quality outcomes, and the importance of informed decision making. The key aspects of this research identifies that the three key variables to consider when targeting sediment reduction investment are tree basal area, land condition land type.

In the economics of land regeneration the impact of tree basal area significantly alters the economic viability of regenerating land, and the results of the bioeconomic modelling. In areas which are treed for all land types in this analysis, incentives are required to reduce pasture utilisation rates and sediment exported. This is due to the reduced productivity of the land when trees are competing with pasture species for nutrients and water. The large sediment export rates in the bioeconomic model also reflect that at low pasture utilisation rates there will be increased leaf matter that initially will be exported.

Starting land condition also needs to be consideration when determining which policy or program is most effective for sediment reduction. Land initially in C condition which was cleared indicated that regeneration would be a viable investment for the land holder to undertake alone particularly for the more productive land types such as silver leaved ironbark at Nebo. It also presents the cheapest option in all cases to reduce sediment loss.

The land types with increased inherit productivity (e.g silver-leaved ironbark at Nebo) in some instances regeneration works were economically viable for the landholder to undertake alone. In some cases extension programs are recommended to reduce pasture utilisation back to the economically optimal levels. For land types which demonstrate low productivity and high sediment rates such as spotted gun and silver leaved ironbark at Springvale, it does not appear that regeneration is economically viable when in D condition. However these land types and present cheap options for sediment reduction through decreased pasture utilisation. This presents a case for significant reductions in sediment movement through incentives for land holders not to graze these land types.

For all scenarios where an economically optimal pasture utilisation rate was identified it would be expected that land-holders would want to operate at this level. However it must be understood that the bioeconomic model has perfect knowledge at the start of the season regarding growth and pasture availability. Therefore it should be recommended that land holders operate at a lower utilisation level (e.g. 5% lower than the modelled optimal) to ensure that risk associated with this lack of perfect knowledge is accounted for. In order to achieve sediment reductions and to get land holders to further decrease the level of pasture utilisation below the economically optimal level a financial incentive may be required.

If the land holder is operating already to the left of the economically optimal point then the cost of reducing a tonne of sediment further is increased, as the opportunity cost of not utilising the pasture increases. However if the landholder is operating to the right of the economically optimal point, then sediment reductions are most effectively dealt with through the implemented of extension and education activities.

There are some deficiencies in such an extensive modelling process and interactions between both the GRASP pasture modelling and the economic modelling. In all of the modelling perfect knowledge has been obtained and in reality this is impossible for landholders to achieve, especially for extended periods of time into the future. It must also be noted that the economic model maintains the AEs derived from GRASP and this involves trading cattle and drought feeding. The economic parameters are based on an ‘average’ property however it is acknowledged that some landholders may have derivations of this.

# 14 Conclusion

It has been expressed that 'environmental problems are often technically complex and uncertain'. Robust decisions about their management need to be based on good knowledge about the degree of threat or damage to environmental assets at risk, and the extent to which this threat or damage can be reduced by particular changes in management. In many cases, generic knowledge is not sufficient- we need locally specific knowledge (Pannell 2009).

The findings of this report support this statement and indicate that further biophysical work is required on land regeneration time frames and methods of achieving sediment reductions through decreased pasture utilisation. NRM agents need to understand the impact of tree basal area, initial start land condition and the land type informing policies and programs.

The report highlights the need for NRM groups, on ground delivery agents and policy officers to have a comprehensive understanding of the land type's productivity, biophysical elements and current landholder management practices before funding can be targeted efficiently to reduce sediment. It also provided insights into the most efficient allocation of funds between extension, education and incentives to allow for the largest sediment reduction to occur at least cost to graziers and the broader community.

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