Department of **Employment, Economic Development and Innovation**

Enhancing economic input to the CQSS2
Project report

November 2009

Commissioned by the
Fitzroy Basin Association

Queensland Government

On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

Enhancing economic input to the CQSS2

Project report

November 2009

Commissioned by the Fitzroy Basin Association

by Megan Star and Peter Donaghy
Department of Employment, Economic Development and Innovation

Executive summary

The Fitzroy Basin is the second largest catchment area in Australia covering 143,00 km² and is the largest catchment for the Great Barrier Reef lagoon (Karfs et al., 2009).The Great Barrier Reef is the largest reef system in the world; it covers an area of approximately 225,000 km² in the northern Queensland continental shelf. There are approximately 750 reefs that exist within 40 km of the Queensland Coast (Haynes et al., 2007). The prime determinant for the changes in water quality have been attributed to grazing, with beef production the largest single land use industry comprising 90% of the land area (Karfs et al., 2009).

In response to the depletion of water quality in the reef, in 2003 a Reef Water Quality plan was developed by the Australian and Queensland governments. 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 designed includes analysing the costs and benefits of best management practice 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 (FBA) released 'The Fitzroy Basin Water Quality Improvement Plan (Current Version) December 2008'. It is in this report that the FBA sets its long, intermediate and short term outcomes. The report identifies a self management approach to improved water quality focusing on education and extension, and identifies voluntary adoption of best management practices to improve water quality. An objective of this is to encourage the adoption of optimal pasture utilisation rates to improve land condition on land 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)

Enhancing Economics input to the CQSS2 was a project formed under the National Action plan for Salinty and Water Quality and the Natural Heritage Trust extension. The main objectives of the project were as follows.

I. Quantifying the costs of over-utilising available pasture and the resulting sediment leaving a representative farm for four of the regions major land systems and identifying economically optimal utilisation rates.
II. Estimate the cost of reducing pasture utilisation rates below the determined optimal.
III. Using this information to guide the selection of appropriate tools to achieve reduced utilisation rates e.g. extension process' versus incentive payments or combinations of both.
IV. Model the biophysical and economic impacts of altering a grazing system to restore land condition e.g. from 'C' condition to 'B' condition.

In order to meet the project objectives three separate studies were undertaken: a survey of key stake holders to determine current grazing knowledge, a case study into the economics of land regeneration, and the development of a bioeconomic model to determine the trade offs between grazing intensity and sediment exported.

The economics of land regeneration involved a case study approach of two properties, one with brigalow blackbutt and the other with narrow leaved ironbark woodlands. The study explored regeneration from 'D' condition to 'B' condition and 'C' condition to'B' condition. The time periods and capital expenditure assumptions were based on the limited literature available and expert opinion.

Restoring land condition on highly productive land types (e.g. brigalow blackbutt) is a very clever business decision offering land-holders substantial economic returns over a relatively short period of time. A greater extension effort promoting this finding to industry is required.

Targeted extension of this nature is the most efficient means of improving reef water quality outcomes from the more productive land types within the basin.

Restoring land condition on less fertile land types such as narrow-leaved ironbark woodlands is critical to improving reef water quality in the Fitzroy Basin. However the costs to graziers of restoring land condition on these land types was found to be prohibitively high and unlikely to be achieved through extension efforts alone. The use of targeted incentive payments delivered via a competitive tender process is recommended as a means of accelerating investment in land restoration work on less fertile land contributing proportionally higher loads of sediment and nutrients to the reef.

The bioeconomic modelling involved combining the biophysical data with the economic to provide the estimated cost for a tonne of sediment reduced. The modelling explored four different land types, with three different start conditions. It also explored the impact of trees on the sediment exported. The biophysical data was derived from GRASP where 400 years of rainfall, pasture growth, and sediment run-off was modelled (Day et al 1997, Littleboy and McKeon 1997, McKeon et al 2000, Rickert et al 2000). This data was then combined with an economic model to determine the cost of reducing a tonne of sediment.

The land types selected were brigalow blackbutt, coolabah floodplains, narrow-leaved ironbark woodlands and narrow leaved ironbark ranges. The three start conditions were 'A' condition, 'B' condition and 'C' condition. All start conditions were then modelled assuming cleared of trees and then modelled assuming uncleared.

The results lead to the conclusions that land type, land condition and tree basal area are all important determinants of the cost of reducing sediment reaching the reef. For the analysis reported here the cheapest source of sediment reductions will come from uncleared less fertile land types in 'C' or 'D' condition. It is these land types that should be the focus of future investment decisions seeking to maximise sediment reductions at least cost to the public.

Contents

1 Introduction

1.1 Background

The Fitzroy Basin is the second largest catchment area in Australia covering 143,00 km² and is the largest catchment for the Great Barrier Reef lagoon (Karfs et al., 2009). The Great Barrier Reef is the largest reef system in the world; it covers an area of approximately 225,000 km² in the northern Queensland continental shelf. There are approximately 750 reefs that exist within 40 km of the Queensland Coast (Haynes et al., 2007). The prime determinant for the changes in water quality have been attributed to grazing, with beef production the largest single land use industry comprising 90% of the land area (Karfs et al., 2009). The beef industry contributes more than one third of the value of Queensland's primary industries and is the largest agricultural commodity in the State (Karfs et al., 2009).

The Fitzroy Basin has undergone extensive changes though the clearing of brigalow (*Acacia harpophylla*) for the purpose of grazing and cropping (Packett et al., 2009). Catchments with high levels of clearing for cattle grazing and cropping show the largest increases in sediment exported compared with natural conditions (McKergow et al., 2005). It is also recognised that increased ground cover and improved land condition can prevent excessive amounts of sediments entering streams and rivers (Karfs et al., 2009). Excessive sediment loads from grazing lands 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, decreased growth and survival (Haynes et al., 2007).

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 Basin is 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 used 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'. It is in this report that 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).

Land condition changes have often been explained as changes in pasture composition, ecological responses and changes in animal production (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 and McIvor, 2008). The inappropriate management of grazing strategies particularly in response to climatic variability has resulted in the depletion of native grasses and decline in land condition (MacLeod and McIvor, 2007).

Karfs et al. (2009) recognised that there is a positive relationship between improved land condition and ground cover, and the reduction of excessive sediment entering into streams and rivers. There has also been a strong focus on research into sustainable rangelands management both at an environmental level and at an economic level. Stocking numbers and management strategies have been described as the most significant variable affecting productivity and sustainability (Ash and Stafford Smith, 1996).

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), ecological impacts (Ash and Stafford Smith, 1996) and the impact of grazing on pasture species recovery (Orr et al., 2006). These studies have all had a common focus on sustainable management of rangelands.

In order to achieve reductions in the sediment load entering the Great Barrier Reef lagoon, policy and planning are required to use funds efficiently and sustainably. In this instance economic efficiency refers to achieving a desired outcome at minimum cost. 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 National Heritage Trust program have faced criticism due to the absence of a measure for outcomes, lack of prioritisation and for the deficiency to combine biophysical and economic outcomes (Pannell, 2009).

Currently there is limited literature on the relationship between grazing, environmental impacts and subsequent economic outcomes. This paper contributes knowledge on the environmental and economic trade offs that occur in land restoration. In order to address all of the projects objectives this report is broken into three sections:

- Key stake holder grazing knowledge – This investigated stake holders knowledge of land condition, grazing economics, natural resource priorities, and grazing management. The stake holders were land holders, Fitzroy Basin Association and sub catchment extension officers, Fitzroy Basin board members, extension staff, grazing scientists, and policy development officers from the Department of Environment and Resources Management, Environmental Protection Agency, and Queensland Primary Industries and Fisheries.

- Economics of land regeneration – A case study into two land types on the economics of land regeneration for 'D' condition to 'B' condition and 'C' condition to 'B' condition. The analysis provides insight into which land type required incentive payments or extension programs.
- Grazing and sediment trade-offs – This explored the trade-offs between pasture utilisation and sediment run-off for four different land types which were geographically dispersed around the catchment. A dollar value was derived for each land type to reduce a tonne of sediment, and policy and program recommendations are provided.

The implication for policy and limitations of the study are also explored and then the study findings concluded.

2 Project objectives

'Enhancing Input to the CQSS2' was a joint project with the Fitzroy Basin Association and the Queensland Primary Industries and Fisheries. The project was formed under the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust extension. The project objectives were as follows;

- Advance the work of the Fitzroy Basin Association by providing an economic dimension to its decision making and extension processes. In particular the project intends to expand the work undertaken under AGSIP13 (2006) by modelling grazing intensity tradeoffs to cover a range of grazed land types within the Fitzroy Basin and to explore opportunities to link the methodology developed in AGSIP13 with other modelling such as SedNet and FBAs investment in remote sensing of ground cover.
- The major objective is to estimate the economic and environmental trade-offs of altering grazing intensity for a number of grazed land types in the Fitzroy Basin and introducing strategies to restore land condition. The specific outcomes proposed are:

I. Modelling to evaluate the costs and benefits of improving land condition as based on the ABCD framework (Chilcott, Sandral et al.2005).

II. Developing an additional data set based on the optimal economic outcomes to assist in targeting grazing land types and practices.

[1] AGSIP13 was a project exploring the economic and environmental trade-offs under changing stocking rates for grazing lands in the Fitzroy Basin. If it was an avenue to water quality improvements at a low cost was also explored.

III. Quantifying the costs of over-utilising available pasture and the resulting sediment leaving a representative farm for four of the regions major land systems and identifying economically optimal utilisation rates.

IV. Estimate the cost of reducing pasture utilisation rates below the determined optimal.

V. Using this information to guide the selection of appropriate tools to achieve reduced utilisation rates e.g. extension process' versus incentive payments or combinations of both.

VI. Model the biophysical and economic impacts of altering a grazing system to restore land condition e.g. from 'C' condition to 'B' condition.

VII. Examine whether the AgSIP13-developed model can be linked to SedNet to provide indications of economic consequences (e.g. action vs do-nothing) at the catchment scale.

VIII. Generate economic insights that will inform strategic planning in beef extension by exploring options for linking to the CQ *BEEF* project and FBA's Neighbourhood Catchments work via case studies of collaborating property owners.

IX. Working with collaborating landholders, FBA field officers and relevant scientists and economists to validate modelled results and case study scenarios.

In order to meet these objectives a steering committee was formed to provide expert opinion in various areas to ensure that the project parameters were scientifically and economically valid. The steering committee consisted of;

Gavin Peck – Project Leader Fitzroy Basin Association

Peter Donaghy – Principal Project Officer, DEEDI

Professor John Rolfe – CQ University Australia

Joe Scanlan – Principal Scientist , DEEDI

Terry Butell – Senior Scientist (Grazing Lands), DEEDI

Cameron Dougall – Natural Resource Management Officer, DERM

It is from this guidance that it was determined that in order to understand the knowledge of grazing economics held by key stakeholders a survey would be the best method to collect this information. In order to model the economic and biophysical impact of regenerating land case studies were undertaken. Finally it was determined that order 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 central Queensland grazing properties would need to be constructed.

3 Key stakeholder grazing knowledge

3.1 Survey Monkey

In order to determine the current knowledge of stakeholders in the Fitzroy Basin an electronic survey using 'Survey Monkey ' was developed and emailed to participants. The survey explored the respondent's knowledge of land condition, restoration, grazing economics, natural resource priorities and grazing management. From these results it was identified that there was a need for additional grazing economics and land restoration economics to be explored. The stakeholders invited to complete the survey covered land holders, Fitzroy Basin Association and sub catchment extension officers, Fitzroy Basin Association board members, extension staff, grazing scientists, and policy development officers from the Department of Environment and Resource Management, Environmental Protection Agency and Queensland Primary Industries and Fisheries.

Of the 58 participants that completed the survey, 63% believed that there was 'not at all adequate information' or 'limited information' on the economics of grazing management for Central Queensland. In response to the question 'Do you believe that there is adequate information on the impact of sediment run-off on reef water quality due to grazing for Central Queensland's major land types?.' 47% thought that limited information was available and 17.5% selected the response; 'No, not at all', This indicated that there is a clear gap between the information that is available and information received.

In response to ranking why declining land condition occurs, 62% ranked economic factors as a major influence on land condition and 42% believed that economics of grazing would be useful in informing natural resources management and planning. It is foreseen that this project will provide further insight into these key aspects as there is currently limited literature available on grazing economics.

In the section concerning land condition, 44% of land holders who completed the survey identified that they had a vague understanding of the ABCD land condition framework and 22% identified that they had no idea of the land condition framework. Although photo standards were provided for the land condition framework classifications, a lot of questions regarding incentive funding, land regeneration, and land regeneration costs, were specifically related to the ABCD land condition framework. Participants with 'No' or only a 'vague' understanding of the ABCD framework would have found these questions difficult to interpret.

Soil degradation was ranked as the highest priority in 'what is believed to be the natural resource issues facing land holders'. The rankings from highest priority (score of 7) to lowest priority (score of 1) were as follows: soil degradation, erosion, invasive weeds, sediment run-off, feral animals, and salinity. After further statistical analysis, results indicated that the response from land holders as apposed to industry body professionals was not statistically different i.e. they agreed on the rankings.

The major factors influencing land condition were ranked according to whether the participant thought that the reason was a major influence (a ranking of 1) or not an influencing factor at all (a ranking of 7). Economic factors was ranked as a major influence followed by production focused management, beliefs and attitudes, lack of knowledge, inability to identify problems on own property and peer pressure. After completing statistical analysis the responses for 'beliefs and attitudes' had significantly different means. The mean for land holders was 4.67 and the mean for government employees and FBA staff was 3.46. This indicates that the two group have significantly different opinion on the impact of belief and attitudes as a reason for land degradation occurring. Land holders thought that the issues listed were less of an influencing factor on land regeneration than government workers and FBA staff.

In response to the question, 'It is hoped that this research will inform natural resource management planning within the Fitzroy Basin. How useful do you believe understanding the economics of grazing land management in Central Queensland is in informing the following process?' the participants were asked to rank the following options from extremely useful (ranking of 6) to not at all useful (ranking of 1). The options and averaged rankings were indentifying future research needs: 2, targeting incentive funding: 5, informing strategic planning activities: 3, informing future funding applications: 1, informing extension programs across the basin: 4, and understanding economic barriers to changing grazing practices: 6.

Further statistical analysis revealed that there was a significant difference in the mean ranking for economic barriers and targeting incentive funding. Land holders had a mean ranking of 4.67 for targeting incentive funding and government employees and FBA staff had a ranking of 3.45. This indicated that land holders believed that this research will be more useful to inform targeting of incentive funding than government employees and FBA staff.

The mean for understanding the economic barriers to change was also significant with landholders having a mean of 2.44 and government and FBA staff having a mean of 4.68. This indicates that government workers and FBA staff believe that this research will be more useful to inform understanding economic barriers to changing grazing practices than land holders believed.

4 Economics of land regeneration

4.1 Rangeland management and regeneration

In order to determine the assumptions to be made for an economic analysis the biophysical research that has been completed in rangelands was drawn upon. Although only limited research has been completed on land regeneration there is a significant amount of literature on land condition frameworks, grazing management trials and pasture species composition. It is from a combination of this research that the key assumptions underpinning the basis of this economic analysis were formed.

Land condition has been defined by the Grazing Land Management framework (Chilcott et al., 2005) as the capacity of land to respond to rain and produce useful forage and is a measure of how well the grazing ecosystem is functioning. The ABCD land condition framework was developed by Meat and Livestock Australia (MLA) in partnership with the Queensland Department of Primary Industries and Fisheries and was used to classify the condition of land. This classification provides a framework for this project to base biophysical start condition assumptions on. The classification features are as described in Table 4.1.

The land condition that is focused on for the purpose of the case study was 'D' to 'B', and 'D' to 'C' condition. 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). The Grazing Land Management (GLM) workshop notes (Chilcott et al., 2005) suggest that land in 'D' condition requires more than changes in grazing management to restore land condition. The workshop notes quote that in order to restore land in 'D' condition 'it requires a large input of external energy (e.g: mechanical,

Table 4.1 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)

chemical) and even this may be insufficient' (Chilcott et al., 2005). Although the ABCD framework provides a guide there was limited literature identifying actual time frames and practices required to regenerate land condition.

It has been often demonstrated that stocking rate is the most important variable in sustainable grazing management (Ash and Stafford Smith, 1996; Ash et al., 2002; Hamilton et al., 2008). The importance of understanding the different ecological thresholds and the impact of this on carrying capacity of various pasture species is highlighted by (Ash and Smith, 2003). 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 numerous studies into grazing strategies and the impact on rangeland production and biological interaction (Campbell et al., 2006; MacLeod and McIvor, 2008; MacLeod et al., 2004; 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 the implications of animal production. The study concluded that live weight gain on the heavy stocking rate enclosures reduced per head and there were increased costs of drought feeding 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

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

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

(Chilcott et al. 2005)

Figure 4.1 Carrying capacity calculation did not require drought feeding.

Grazing impacts on land condition in tropical woodlands was investigated by Northup et al. (2005). 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 led to less standing crop; and soil properties such as, carbon and nitrogen were more widely dispersed. The results from this study and evidence from Brown and Ash (1996) indicated that for land condition to improve in tropical eucalypt woodlands, time periods required for land regeneration may be economically non-viable.

Orr et al. (2006) explored the recovery of pasture after drought and the composition of pasture species. The study explored pasture recovery to good pasture condition which consists of 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. Orr and Yee et al. (2006) concluded that rainfall was a significant variable in pasture recovery. This conclusion however varied on the results from the ECOGRAZE project.

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.

McIvor (2001) explored regeneration of land in 'D' condition, and 'C' condition for three years with the exclusion of stock as the method of regeneration. 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 impacts of regeneration on both native and sown pasture species and the results indicated that regeneration is dependant on growing conditions as well as the exclusion of stock (McIvor, 2001). In the trial the areas that consisted 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).

As there is limited research in Australian rangelands on the regeneration of land once it has been degraded, assumptions were derived from the results of these various studies and where gaps in the knowledge appeared, a combination of expert opinion and technologies were implemented.

5 Methodology

5.1 Land types and regeneration

In order to choose which land types would be modelled an expert panel was formed. The land types were selected on geographical location, percentage of the catchment that consisted of particular land types, decreasing ground cover over the past four years, erosion susceptibility and sedimentation run-off. The land type groups in the area comprise of alluvial, bluegrass downs, brigalow scrubs, coastal, eucalypt woodlands, mountains and ranges, and sand. It was also established that land types should be selected over these particular land type groups. Figure 5.1 illustrates where these land type groups occur in the basin, and

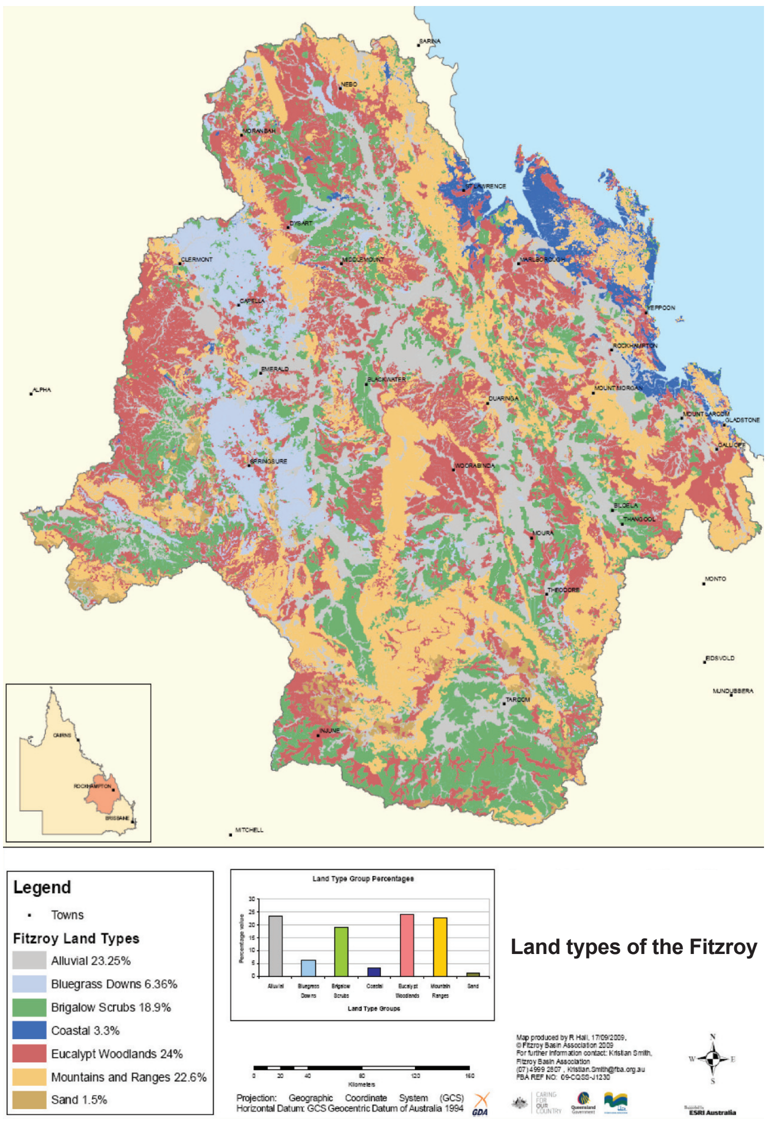


Figure 5.1 Fitzroy Basin land types

the percentage of the basin consisting of the land type.

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 rainfall on average annually (Dougall et al 2008). Due to these factors it was assigned as an area of interest. The predominant land type in this area is narrow leaved ironbark ranges and this land type comprises of 6.61 percent of the catchment. Narrow leaved ironbark was therefore selected to be modelled using the climatic data from the Balaclava Mountains. The Connors region can be seen in Figure 5.2.

Narrow-leaved ironbark ranges can be described as; narrow-leaved ironbark woodlands with a bloodwood and occasional ghost gum. Often found with an understorey of rosewood, red ash, turkey bush, currant bush and hopbush. The preferred pasture composition is black spear grass, kangaroo grass, desert bluegrass, hairy panic grass, tableland couch, forest bluegrass. The soil is described as shallow rocky soils and it can be found on the land form, mountains and ranges (Queensland Government, 2008).

Brigalow blackbutt was the land type selected for the land grouping of brigalow scrubs. The Fitzroy Basin catchment comprises of 7.94 percent of brigalow blackbutt with a high percentage of the land type located in the central area of the catchment. Bare ground index mapping was also implemented in the selection of this land type. Bare ground index mapping demonstrated a downward trend in mean bare ground cover around the Duringa area with the average cover less than 60 percent. It is based on this that the climate

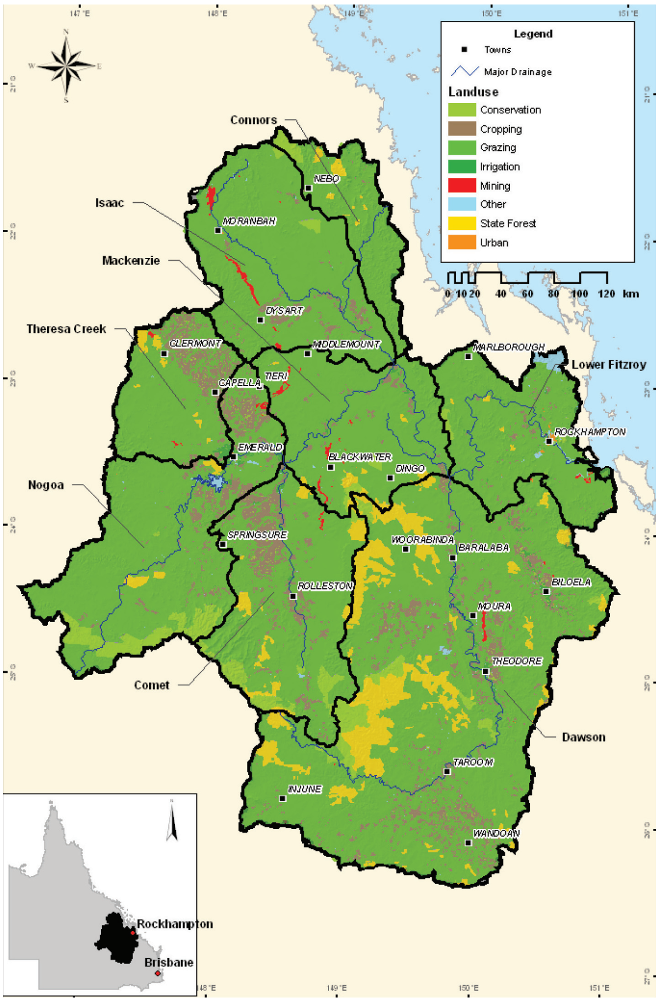


Figure 5.2 Fitzroy Basin sub catchment regions

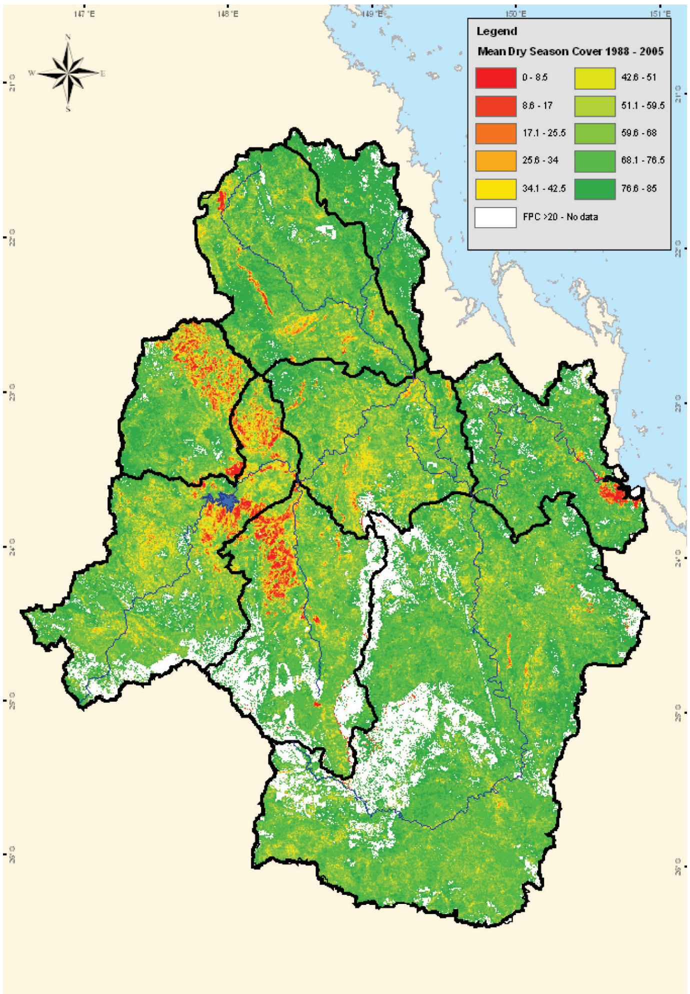


Figure 5.3 Bare ground index map of the Fitzroy Basin

station selected was based on Blackwater the largest town in proximity to Dauringa. The mean bare ground index for the catchment can be seen in Figure 5.3

Brigalow blackbutt is a land type that is described as brigalow scrub with emergent blackbutt or yapunyah with an understorey of false sandalwood, yellowwood or wilga. Preferred pasture composition is Queensland bluegrass, desert bluegrass, forest bluegrass, black speargrass, bull Mitchell grass and kangaroo grass (Queensland Government, 2008). Suitable sown pastures include buffel grass, rhodes grass, leucaena and shrubby stylo (Seca) (Queensland Government, 2008).

Narrow leaved Ironbark woodlands was the third land type chosen. It was selected based on the high percentage of this land type found in the southern part of the region. The basin contains 4.78 percent of narrow leaved ironbark woodlands. The climatic station initially used to undertake the modelling was *Galloway Plains*, a property where a large grazing trial took place. However after receiving non- representative results a second climate station was selected which was Dauringa.

Narrow-leaved ironbark woodlands occur on eucalypt duplex plains and consists of narrow-leaved ironbark, lemon-scented gum, large-fruited bloodwood, pink blood wood, and ghost gum woodland (Queensland Government, 2008). The understorey consists predominantly of paperbark teatree, quinine tree, red ash and heath myrtle. The preferred pasture species composition includes black speargrass, kangaroo grass, desert bluegrass, hairy panic, and forest bluegrass. (Queensland Government, 2008) suggests buffel grass and shrubby stylo as suitable sown pastures.

Finally the fourth land type selected was selected based on a land type in the western part of the catchment. The major land type group of alluvial was also required to ensure that each of the land groupings were represented. It is from these features that coolibah floodplains was selected using the climate station of *Mantum Downs* in the Springsure area.

Coolibah floodplains occur in alluvial plains and consist of coolibah woodland with an understorey of scattered clumps of brigalow and bauhinia. The preferred pasture species is Queensland bluegass, forest bluegrass, silky browntop, bull and curly Mitchell grass, and couch grass. The soil is described as black cracking clay, which is has variable sodic areas (Queensland Government, 2008).

6 Case study

In order to explore the economics of land regeneration a case study for regenerating land from 'D' condition to 'B' condition and 'C' condition to 'B' condition was developed. Brigalow blackbutt and narrow leaved ironbark woodlands were selected as the two land types to perform the case studies on.

6.1 Land types and regeneration

The land condition that both the land types were to be regenerated from initially was D condition. It was defined as D condition due to the large scalds that had occurred over time due to overgrazing.

The initial treatment for both the brigalow blackbutt and the narrow leaved ironbark woodlands was to deep rip and re-seed with buffel grass. This assumption is based on previous work (Queensland Government, 2008) which suggests buffel as a suitable sown pasture. (Campbell et al., 2006) also 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.

Each of the steady state case study scenarios modelled assumed annual average rainfall for the Duaringa area which is 715 mm. 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 the stocking rates where changed to reflect this. Due to differences in fertility between brigalow blackbutt and the narrow-leaved ironbark woodlands, the

Table 6.1 Assumptions for regeneration from 'D' condition to 'B' condition

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

regeneration was assumed to occur over six years. 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 3 to four years was an effective method to maintain 3P grasses. Table 6.1 summarises these assumptions, and the source from which they have been derived.

6.2 Property and capital expenditure

The brigalow blackbutt case study property was based on a 5,000 ha property, and the narrow-leaved ironbark property was based on a 10,000 ha property. Both were located in the central Queensland area of Duaringa. This was done to ensure that the distance to markets, rainfall and production costs would be similar. The enterprises however differed to reflect the productivity of the land type. The brigalow blackbutt turned off Japanese oxen class of animal with a gross margin of $176.04 per adult equivalent and the narrow-leaved ironbark woodlands turned off 18 month old store steers with a gross margin of $149.50 per adult equivalent. These were based on the 'Representative Herd Templates for Northern Australia' (Queensland Primary Industries and Fisheries et al., 2009)

In order to determine the impact of land regeneration over the whole property, the area to regenerate was subtracted from the potential capacity of the whole property which is operating at 'B' condition stocking rate. The carrying capacities were calculated from the pasture growth (kg/ha/yr) and the carrying capacity formula (Chilcott et al., 2005). Table 6-2 summarises the impact of land degradation on the whole property carrying capacity for brigalow blackbutt, and Table 6-3 summarises the impact of land degradation on the whole property carrying capacity for narrow-leaved ironbark woodlands. It can be noted in these tables the percentage of the property that is in declined condition and the reduction in carrying capacity as the area in declined condition increases.

Table 6.2 Property carrying capacity impact as land condition declines in brigalow blackbutt.

Area (ha)	5,000	100	500	1,000	2,000
Percentage of whole property in decline (%)	0	2	10	20	40
'B' condition (1/4.5 ha) – Number of total AEs	1,111	1,111	1,111	1,111	1,111
'C' condition(1/7.5 ha) – Number of total AEs	1,111	1,102	1,066	1,020	930
'D' condition(1/17.38 ha) – Number of total AEs	1,111	1,095	1,029	946	782

Table 6.3 Property carrying capacity as land condition declines in narrow-leaved ironbark.

Area (ha)	10,000	200	500	2,000	4,000
Percentage of whole property in decline (%)	0	2	5	20	40
'B' condition (1/10.73 ha) – Number of total AEs	932	932	932	932	932
'C' condition(1/18.25 ha) – Number of total AEs	932	924	913	855	778
'D' condition(1/36.5 ha) – Number of total AEs	932	919	899	800	669

6.3 Brigalow blackbutt regeneration from 'D'–'B'

Scenario one: Entire paddock declined condition no fencing, no waters installed

- Entire paddock declined condition 'D'
- Entire declined condition area removed from production
- No watering points for any area
- No fencing (apart from 100 ha).

Costs for this scenario in Table 6.4.

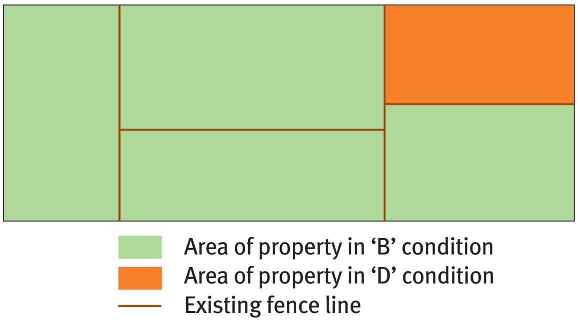


Figure 6.1 Illustration of scenario one

Scenario two: Area declined fenced off from the rest of the paddock, water installed

- Area declined fenced off using a ratio of fencing to area degraded as 1 km:100 ha
- Area declined removed from grazing
- Watering points installed for all areas in declined condition (with the exception of 100 ha).

Costs for this scenario in Table 6.5.

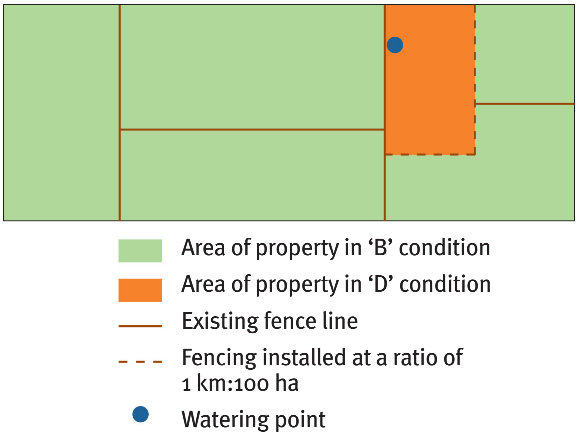


Figure 6.2 Illustration of scenario two

Table 6.4 Scenario one brigalow blackbutt input costs

Land regeneration costs	$/ha/km	'D'– 'B' 100	'D'– 'B' 500	'D'– 'B' 1,000	'D'– 'B' 2,000
Deep ripper $80.46/ha	80.46	8,046	40,230	35,450	70,900
Buffel seed 1.5 kg/ha @$7.00	10.5	1,050	5,250	10,500	21,000
Fencing $5000/km	5,000	5,000	0	0	0
Waters Poly pipe $5000/km	5,000	0	0	0	0
Poly tank	5,000	0	0	0	0
Trough	1,200	0	0	0	0

Table 6.5 Scenario two brigalow blackbutt input costs

Land regeneration costs	$/ha/km	'D'– 'B' 100	'D'– 'B' 500	'D'– 'B' 1,000	'D'– 'B' 2,000
Deep ripper $80.46/ha	80.46	8,046	40,230	35,450	70,900
Buffel seed 1.5 kg/ha @$7.00	10.5	1,050	5,250	10,500	21,000
Fencing $5000/km	5,000	5,000	25,000	50,000	100,000
Waters Poly pipe $5000/km	5,000	0	25,000	50,000	100,000
Poly tank	5,000	0	5,000	10,000	15,000
Trough	1,200	0	1,200	2,400	3,600

Table 6.6 Scenario three brigalow blackbutt input costs

Land regeneration costs	$/ha/km	'D'– 'B' 100	'D'– 'B' 500	'D'– 'B' 1,000	'D'– 'B' 2,000
Deep ripper $80.46/ha	80.46	8,046	40,230	35,450	70,900
Buffel seed 1.5 kg/ha @$7.00	10.5	1,050	5,250	10,500	21,000
Fencing $5000/km	5,000	5,000	0	0	0
Waters Poly pipe $5000/km	5,000	0	0	0	0
Poly tank	5,000	0	0	0	0
Trough	1,200	0	0	0	0

Scenario three: Area declined is a portion of larger paddock. No fencing or watering points

- Portion of a larger paddock is in declined condition 'D'
- Opportunity cost of not being able to utilise the remainder of the paddock for grazing has been included
- Portion of paddock in declined condition as follows;

Table 6.7 Portion of larger paddock declined

Area of entire paddock (ha)	200	1,000	2,000	2,500
Area of paddock in declined condition (ha)	100	500	1,000	2,000

Costs for this scenario in Table 6.6.

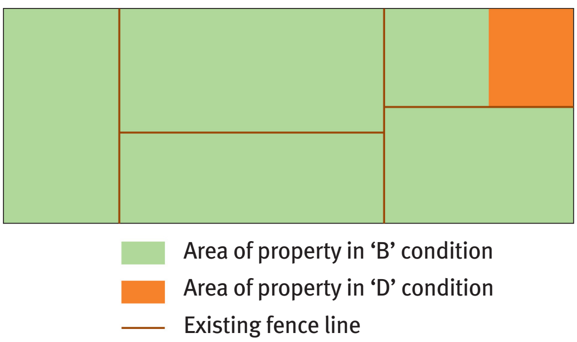


Figure 6.3 Illustration of scenario three

6.4 Narrow-leaved ironbark regeneration from 'D' – 'B'

Scenario one: Entire paddock declined condition no fencing, no waters installed

- Entire paddock declined condition 'D'
- Entire declined condition area removed from production
- No watering points for any area
- No fencing (apart from 200 ha).

Costs for this scenario in Table 6.8.

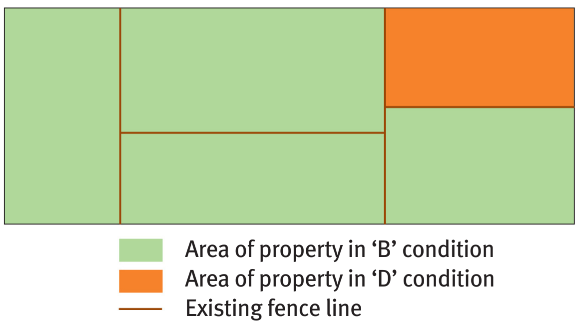


Figure 6.4 Illustration of scenario one

Table 6.8 Scenario one narrow-leaved ironbark input costs

Land regeneration costs	$/ha/km	'D'– 'B' 200	'D'– 'B' 1,000	'D'– 'B' 2,000	'D'– 'B' 4,000
Deep ripper $80.46/ha	80.46	16,092	80,460	160,920	321,840
Buffel seed 1.5 kg/ha @$7.00	10.5	2,100	10,500	21,000	42,000
Fencing $5000/km	5,000	10,000	0	0	0
Waters					
Poly pipe $5000/km	5,000	0	0	0	0
Poly tank	5,000	0	0	0	0
Trough	1,200	0	0	0	0

Table 6.9 Scenario two narrow-leaved ironbark input costs

Land regeneration costs	$/ha/km	'D'– 'B' 200	'D'– 'B' 1,000	'D'– 'B' 2,000	'D'– 'B' 4,000
Deep ripper $80.46/ha	80.46	16,092	80,460	160,920	321,840
Buffel seed 1.5 kg/ha @$7.00	10.5	2,100	10,500	21,000	42,000
Fencing $5000/km	5,000	10,000	50,000	100,000	200,000
Waters					
Poly pipe $5000/km	5,000	0	50,000	100,000	200,000
Poly tank	5,000	0	10,000	15,000	20,000
Trough	1,200	0	2,400	3,600	4,800

Scenario two: Area of land declined fenced off from the rest of the paddock, water installed

- Area declined fenced off using a ratio of fencing to area degraded as 1 km:100 ha
- Area declined removed from grazing
- Watering points installed for all areas in declined condition (with the exception of 200 ha)

Costs for this scenario in Table 6.9.

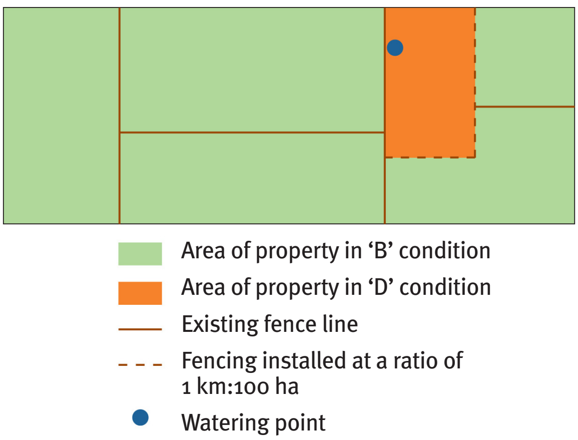


Figure 6.5 Illustration of scenario two

Scenario three: Area of land declined is a portion of larger paddock. No fencing or watering points

- Portion of a larger paddock is in declined condition 'D'
- Opportunity cost of not being able to utilise the remainder of the paddock for grazing has been included
- Portion of paddock in declined condition as follows;

Table 6.10 Portion of larger paddock declined condition

Area of entire paddock (ha)	400	2,000	3,000	5,000
Area of paddock in declined condition (ha)	200	1,000	2,000	4,000

Costs for this scenario in Table 6.11.

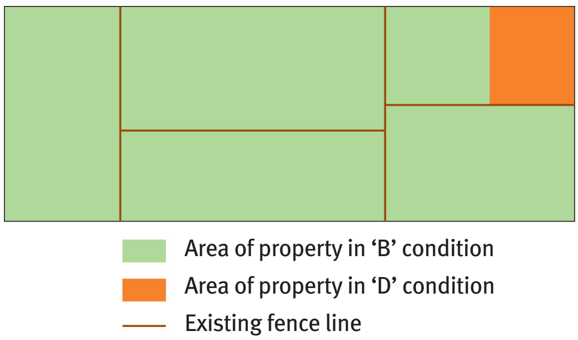


Figure 6.6 Illustration of scenario three

Table 6.11 Scenario three narrow-leaved ironbark input costs

Land regeneration costs	$/ha/km	'D'– 'B' 200	'D'– 'B' 1,000	'D'– 'B' 2,000	'D'– 'B' 4,000
Deep ripper $80.46/ha	80.46	16,092	80,460	160,920	321,840
Buffel seed 1.5 kg/ha @$7.00	10.5	2,100	10,500	21,000	42,000
Fencing $5000/km	5,000	10,000	0	0	0
Waters					
Poly pipe $5000/km	5,000	0	0	0	0
Poly tank	5,000	0	0	0	0
Trough	1,200	0	0	0	0

6.5 Economic analysis results

An economic analysis was undertaken using a cost benefit framework. The investment criterion was taken over 20 years, and a 5% discount rate was applied. Twenty years was the estimated time that one manager or owner will maintain control of the property to reap the benefits or costs of the analysis. A discount rate ensures that the future benefits or costs are translated into today's current dollar value.

6.5.1 Brigalow blackbutt results

The results for the brigalow blackbutt scenarios are presented in Tables 6.12, 6.13, and 6.14 and are illustrated in Figure 6.7

Scenario one:

Table 6.12 presents the results from scenario one. This scenario had the lowest capital costs and all areas that were in declined condition endured positive returns. Table 6.12 can be interpreted as describing that if 100 ha that was in 'D' condition was regenerated to a 'B' condition the land holder would be $13,234 better off in today's dollar value. For the regeneration of 500 ha the land holder would be $91,172 better off. Returns of $226,893 and $481,355 would occur for 1000 ha and 2000 ha respectively. For larger areas although the costs are larger there is also a large production gain from regenerating this land.

Table 6.12 Scenario one results

Area of entire paddock (ha)	100	500	1,000	2,000
Area of paddock in declined condition (ha)	100	500	1,000	2,000
NPV ($)	13,234	91,172	226,893	481,355

Scenario two:

Table 6.13 demonstrates the results of scenario two. Scenario two involved higher capital costs and this therefore resulted in a lower net present value compared to scenario one. This resulted in the returns not been as high as scenario one, however all areas yielded a positive return on investment, indicating that regenerating the land is still financially an attractive option for the land holder involved.

Table 6.13 Scenario two results

Area of entire paddock (ha)	100	500	1,000	2,000
Area of paddock in declined condition (ha)	100	500	1,000	2,000
NPV ($)	13,234	34,972	114,493	262,755

Scenario three:

As this is a portion of a paddock the capital input costs are not as high as scenario two (i.e. no fencing or additional waters) however there is the opportunity cost of not utilising the land in the paddock that is still in 'B' condition. This therefore makes this option not as attractive as scenario one however more attractive than scenario two. The results for scenario three are recorded in Table 6.14.

Figure 6.7 illustrates the three scenarios and the net present value that each scenario returns for the different areas. Scenario one has the greatest return, followed by scenario two and with scenario three having significantly lower net present values across all areas.

Table 6.14 Scenario three results

Area of entire paddock (ha)	200	1,000	2,000	2,500
Area of paddock in declined condition (ha)	100	500	1,000	2,000
NPV ($)	16,960	72,543	189,635	462,726

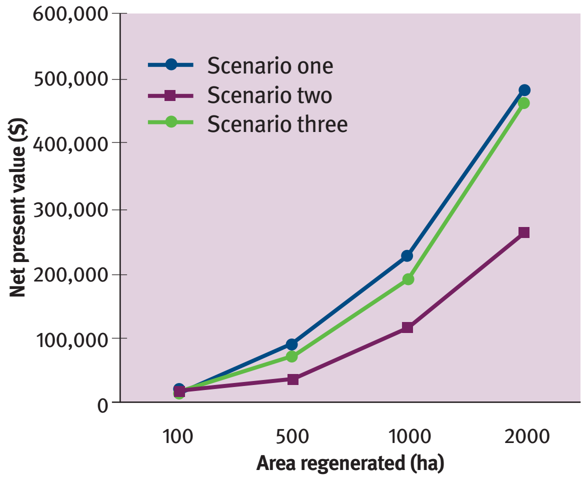


Figure 6.7 Illustrated results for net present value for brigalow blackbutt regeneration from 'D' condition to 'B' condition.

6.5.2 Narrow-leaved ironbark woodlands results

The results for the narrow-leaved ironbark woodlands do not result in any positive returns for any of the areas to be regenerated, for any of the scenarios. This is due to the high investment cost in the regeneration process and the low productivity gains that are achieved. The time taken for the regeneration process to occur also hinders achieving positive returns.

Scenario one:

The results for scenario one are presented in Table 6.15. This yielded the best returns for any of the three scenarios due to its lower capital expenditure required to regenerate. Although this scenario had the best results it is important to note that all results were negative by more than $10,000 and would be a poor investment decision for any land holder to undertake.

Table 6.15 Scenario one results

Entire paddock no fencing over 200 ha, no watering	200	1,000	2,000	4,000
Area of paddock affected	200	1,000	2,000	4,000
NPV ($)	-11,668	-22,660	-27,555	-37,344

Scenario two:

As there were significant costs in fencing and waters to be undertaken, all areas regenerated yielded a negative return. These results are illustrated in Table 6.16. At 4,000 hectares this is a significant portion of the property to be regenerating and a large capital investment to undertake. It cannot be expected that landholders would incur such a large negative return on an investment that had social benefits but no private benefits.

Table 6.16 Scenario two results

Entire paddock fencing and watering	200	1,000	2,000	4,000
Area of paddock affected	200	1,000	2,000	4,000
NPV ($)	-11,668	-135,060	-246,155	-462,144

Scenario three:

This scenario also results in large negative returns and this follows the same reason as scenario one and two. Table 6.17 demonstrates these results. Having the whole paddock out of production also decreased the returns further as the opportunity cost of foregoing income in a lower productivity property impacted on the whole farm cash flow.

Table 6.17 Scenario three results

Area of entire paddock (ha)	400	2,000	3,000	5,000
Area of paddock affected	200	1,000	2,000	4,000
NPV ($)	-14,322	-148,330	-259,425	-475,415

In Figure 6.8 the illustration of regeneration for the narrow-leaved ironbark can be seen. Scenario one having the best option of the three however this scenario still does not yield positive returns. Scenario two and three have similar negative returns and this can be attributed to the similar capital costs that are required for regeneration.

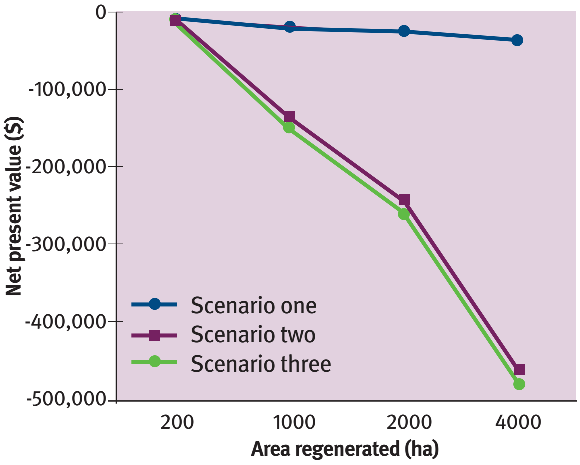


Figure 6.8 Illustrated results for the net present value of regeneration for narrow-leaved ironbark woodlands.

6.6 Land regeneration brigalow blackbutt 'C'–'B'

Assumptions for regenerating land from 'C' to 'B' condition were as follows;

- Declined land would regenerate from 'C' condition to 'B' condition with all stock removed for 12 months.
- It was assumed that every 5 years, for four months of the year all areas (with the exception of 100 ha) practised a lighter wet season stocking rate of 75% of 'B' condition stocking rate.

Scenarios:

Scenarios one and two were again implemented. Scenario three was not implemented as it is assumed that no mechanical or capital infrastructure intervention was required.

Results:

The net present values again indicate that the decision to regenerate land from 'C' to 'B' is economically a viable decision. Figure 6.9 demonstrates that although the costs associated with regenerating land are lower (the opportunity cost of running stock) the production benefits are also lower. Therefore the net present values are not as high as regenerating land from 'D' to 'B' condition, the skew initially is similarly attributed to the wet season spelling rule that does not apply to 100 ha.

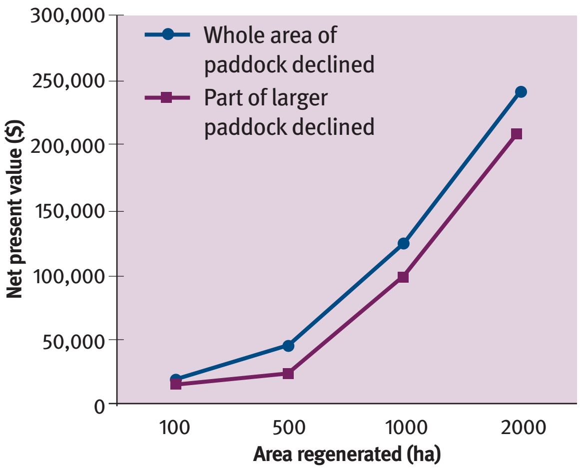


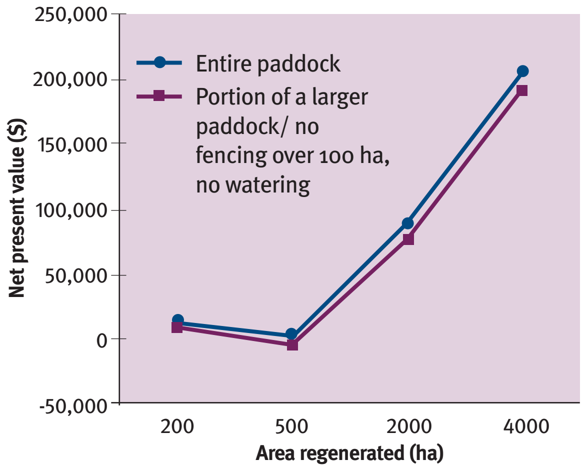
Figure 6.9 Net present values for land regeneration from 'C' to 'B' condition.

6.7 Land regeneration narrow-leaved ironbark woodlands

Regeneration from 'C' to 'B' followed the same assumptions and scenarios as brigalow blackbutt did for regeneration from 'C' to 'B' condition.

Results:

As there were no capital costs assumed and only the opportunity cost of not having stock on the declined area, the net present value for large areas of decline condition were positive. This demonstrates that it is a viable option to regenerate land from 'C' condition to 'B' condition. The reason for the skew in the figure is due to 200 ha not having any wet season spelling. It is assumed at this level that the stock on this 200 ha would be distributed throughout the rest of the property so a wet season spell would occur however there would be no decline in stock numbers.



It can be noted from the results that it is often economically viable to regenerate land without any incentive required. However in some cases there may need to be some incentive required in order for the investment to be a viable option.

6.8 Discussion

The results of this analysis indicate that on a case study basis following the assumptions given in Table 6.1 to regenerate land from 'D' condition to 'B' condition, and 'C' condition to 'B' condition productive land such as brigalow blackbutt is a positive investment. For large areas of narrow-leaved ironbark woodland, regenerating from 'C' condition to 'B' condition

For land regeneration for 'D' condition to 'B' condition in narrow-leaved ironbark woodlands there are further challenges to ensure that it is a viable economic investment, and will not be an attractive investment option for the landholder alone. The methodology of this study also highlights the importance of further scientific work on land restoration, pasture ecology, and restoration practices. Whilst a review of the literature was able to provide most of the assumptions for land regeneration, many more of the assumptions used were based on a group consensus and expert opinion in lieu of land restoration research relevant to the land types analysed.

The results from the brigalow blackbutt case study indicate that land regeneration is a feasible option for landholders. With all six of the scenarios yielding positive returns it indicates that such an investment by a landholder would be economically viable and yield positive returns on all areas required to be regenerated. Particularly where there are large areas that require regeneration, it also reinforces the findings of Ash et al. (1995), Ash et al. (2002) and Hamilton et al. (2008) that place strong emphasis on grazing management.

Whilst knowledge of the ABCD framework was very strong amongst the research, extension and policy makers surveyed (50% indicating they has excellent understanding) 44% of surveyed land holders indicated they only had a vague understanding of the land condition framework. 22% of these indicated that they believed lack of knowledge of land condition was a major influence on declining land condition. Surprisingly only 12% of the research, extension and policy makers surveyed believed that land holders knowledge of land condition was a major influence on rangeland condition. These results suggest that land holders capacity to assess land condition may not be as high as thought by research, extension, and policy makers and this lack of understanding may be a larger contributor to land condition decline than previously thought.

The net present value and payback period for brigalow and restoration works suggests targeting funding towards extension and education activities to increase the awareness and understanding of land restoration economics is likely to achieve the greatest results in sediment movement at least cost to society.

The narrow-leaved ironbark woodlands offer greater financial challenges for the landholder to undertake land restoration under their own initiative. The results of this economic analysis also support Northups et al. (2005) findings that it may not be economically viable to regenerate eucalypt woodlands. However if it is these land types that offer the largest reduction in sediment run-off and greatest ecological gains then this is where incentive funds should be efficiently targeted.

It is important to emphasise the impact of long term sustainable land management. The impact of implementing further infrastructure in the form of watering points and fencing will only yield positive returns if the grazing management practices also change. It should also be acknowledged that implementing such infrastructure may result in further fragmentation if not managed sustainably Stokes et al. (2006).

This economic analysis has given further insight into the economics of land regeneration than previous studies in several areas. The analysis contributes to areas of grazing economics where there has only been limited literature published on the economic options available to land holders. The literature that is available has had a very narrow economic focus and commonly only gross margin changes are reported.

The limitations of the study are recognised. Firstly the difficulty in matching the biophysical information from previous studies with the economic assumptions to complete the analysis has been challenging. The deficiencies in the study are found in the inability to cover all scenarios that occur on properties and the multiple practices in regeneration. It is acknowledged that the proposed methods of regeneration reported here does not fit all classifications of 'D' condition land and that it may not be always possible to undertake the proposed methods to ensure that land regeneration does occur. However with the current scientific studies that have been taken, the assumptions used in the analysis have been matched as closely as possible to the literature to ensure that the regeneration modelling reflects these scientific findings.

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

Finally the constant changes of economic costs, discount rates and time period for analysis all impact significantly on the results and are required to be updated regularly. It must be emphasised that this is a case study and the results are unique to the assumptions and variables used. In order to complete further analysis on other land types in other geographical locations further data collection would be required. It does however provide a scope on the economics of regeneration for brigalow blackbutt and narrow-leaved ironbark woodlands. The study also provides useful insight into the efficient allocation of funding program whether the incentives be offered or extension programs or a combination of both encourage land restoration. This raises interesting questions on when cash incentives as opposed to extension incentives should be offered to reduce sediment and improve water quality.

7 Environmental economics

7.1 Bioeconomic modelling

In order 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 process'. Bioeconomics is a relatively new method in economics. Oriade and Dillion suggested in 1997 that it was a growing area and was described as relatively novel in 1971 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 biological system can be encompassed into different types of economic models. It is the economic model that interacts with the biological model at different level depending on what the problem is that is been analysed. It is this economic link that makes available the connection between the market and the production system (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'.

Some of the possible uses given by (Cacho, 1997) include:

- Integration of existing data and concepts
- Evaluation of policy
- Identification of gaps in research
- Interpretation and evaluation of experimental results

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). It is due to these attributes that bioeconomic modelling was used to complete the analysis.

Bioeconomic modelling has been implemented for natural resource outcomes 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 reduce 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 would not increase further and the crop production could be continued (Cacho et al., 2001).

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

Recently in the United States of America 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 and Huffacker, 1997). The evaluation of natural resource policies and mechanisms have been explored by Haffaker et al (1990) who determined the trade-offs between the policy for controlling wild horse populations and the impact on the western livestock industry. The results concluded that the policy was possibly economically inefficient (Huffaker R. G, 1990).

Bioeconomic modelling enables a complete analysis of the economic and environmental trade offs of reducing a tonne of sediment into the Great Barrier Reef Lagoon. Bioeconomic modelling provides a strong platform to encompass both the biophysical stimulation data and the economic model to allow an analysis of the outcomes.

In order to ensure that the correct figures were used from the biophysical model a bioeconomic model was designed to import the biophysical data into the economic model. It is from this integration that assumptions are derived and ensured that the model combined correctly the biophysical elements with the economic methodology.

7.2 Biophysical modelling

In order to model the biological interactions that occur with the impacts of climate, land and pasture condition, and grazing pressure a pasture simulation model was used called GRASP. GRASP was developed for semi-arid and tropical grasslands using point based native pasture simulations (Day et al 1997, Littleboy and McKeon 1997, McKeon et al 2000, Rickert et al 2000).

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 the average time in which management is held by one particular party.

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

1896	1917	1942	1962
1902	1924	1945	1967
1904	1929	1949	1971
1912	1936	1956	1981
1915	1941	1960	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 descried as the meters squared in one hectare that tress 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 all of the land types a simulation with zero m^2/ha was also included. Table 7.1 demonstrates the tree basal area simulated for each of the land types.

Table 7.1 Tree basal area

Land type	Tree basal area (m^2 /ha)
Brigalow blackbutt (Dawson's gum)	3
Narrow-leaved ironbark on mountains and ranges	15
Narrow-leaved ironbark woodlands	9
Coolibah floodplains	6

Three initial start condition of the pasture were also simulated. This 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.

Table 7.2 Start condition for land types

Land type	Start condition (% perennials)		
	'C' condition	'B' condition	'A' condition
Brigalow blackbutt (Dawson's gum)	20	70	88
Narrow-leaved ironbark on mountains and ranges	20	70	80
Narrow-leaved ironbark woodlands	20	70	80
Coolibah floodplains	20	70	88

The start conditions selected were reflective of an 'A' condition, 'B' condition and 'C' condition pasture species composition and total standing dry matter (TSDM). The start conditions selected are demonstrated in Table 7.2.

On order 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%

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 to live weight 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.

7.3 Economic model

In order to combine the biophysical results into an economic model the GRASP data was fed into an economic model that was designed to explore the economic implications of different pasture utilisation rates for the four land types. This also enabled the dollar cost of reducing a tonne of sediment to be estimated for each land type for a range of pasture conditions.

The GRASP simulation provided much of the production data assumptions and the soil loss to determine the economic and environmental implications. The variables that provided the most information were the head per square kilometre, live weight gain per head and run-off.

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.

The economic model comprised of many assumptions regarding operation parameters, and these were as follows;

- The property size was 5000 ha. It was assumed to be a homogenous block of one land type, although it is acknowledged that does not reflect reality but was required to undertake the modelling.
- The enterprises selected were Japanese oxen for coolibah floodplains and brigalow blackbutt, and trade store steers for narrow-leaved ironbark woodlands and narrow-leaved ironbark ranges. This was done to reflect local production in the area.
- Mortality was calculated both for the dry herd and for the breading herd. This was dependent on the live weight gain and 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 maximum of 20% for mortality rates. The equation was

calculated as a function of live weight gain.

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

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:

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 MacLoed 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 2 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 7.3.

Table 7.3 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 AEs determined by GRASP the base herd was multiplied across all animal classes or divided across all animal classes to adjust stock numbers up or 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 however in order to account for the difference in turn-off age Japanese oxen were held for 2 years and the trade steers were turned off at the yearling age group. The percentage sales and the price per kilo are listed below in Table 7.4.

Table 7.4 Percentage herd sales and price

Animal class	Percentage of base herd sold (%)		
	Japanese Oxen	Trade store steers	Price $/kg
Calves	0	0	0
Heifer weaners	30	30	1.69
Steer weaners	0	0	0
Heifers 1 yr	42	42	1.57
Steers 1 yr	0	100	1.90
Heifers 2 yrs	42	42	1.35
Steers 2 yrs	100	0	1.90
Cows 3–9 yrs	42	42	1.35
Cows 10 yrs	100	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 penalty price penalty in incurred on the cattle sold.
- 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 hectare 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)

8 Results

The results will be presented in 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.

8.1 'A' start condition zero tree basal area

For the brigalow blackbutt with an initial start condition of 88% perennials indicates that it was 'A' condition classification, and the 0 tree basal area is defined as a cleared area. The most profitable pasture utilisation rate is at 55% pasture utilisation (TSDM) where the net present value is $904,210. At this level of pasture utilisation there are 1,895 adult equivalents stocked on the 5,000 ha property.

At 55% pasture utilisation the total sediment load leaving the paddock over 20 years is 3,730 tonnes. If the pasture utilisation rate is decreased to 50% in an attempt to reduce sediment movement the cost per tonne of sediment would be $360.92, if the land-holder was then to reduce pasture utilisation a further 5% to 45% the cost per tonne of sediment reduced is $604.87.

At 60% pasture utilisation the grazier is operating past the most economically viable point and has forgone $91,787 in income. At this level of pasture utilisation there is also an increase of 2,806 tonnes of sediment getting exported over the 20 year period. An illustration of the results can be found in Figure 8.1 and tabulated results are presented in Table 8.1.

For the coolibah floodplains the economically optimal pasture utilisation rate is lower than that of the brigalow blackbutt. This is attributed to two variables, the impact of climatic data and the productivity of the land type. The most economical optimal pasture utilisation rate for coolibah flood plains is 30 percent of TSDM. At this level the net present value is $530,235 and the sediment exported is 1,836 tonnes over a 20 year period or 91 tonnes annually. The results are illustrated in Figure 8.2 and tabulated in Table 8.2

The narrow-leaved ironbark woodlands has an economically optimal point at 40 percent pasture utilisation. At this level the net present value is $366,975 and 292 tonnes of sediment are exported annually. The results are illustrated in Figure 8.3 and tabulated in Table 8.3.

Narrow-leaved ironbark ranges with an A start condition has an optimal utilisation rate of 50 percent of total standing dry matter. At this level of utilisation net present value is $359,703 there is 56,415 tonnes of sediment exported over the twenty year period. In order to reduce a tonne of sediment exported at this utilisation rate the cost to the grazier would be $6.40.

For this particular scenario the range in cost to reduce the tonne of sediment for the different utilisation had little variation with a maximum cost of $7.80 per tonnes and a minimum cost of $4.00. Figure 8.4 illustrates the exported sediment and net present value for narrow leaved ironbark ranges, with the results tabulated on Table 8.4

Net present value, and tonnes of sediment exported directly correlated to cost per tonne of sediment. Land types with the highest optimal net present value, and a relatively low total sediment exported are the most expensive to reduce a tonne of sediment from. Where there are negative costs associated with the reduction of a tonne of sediment the land holder is not operating at an economically viable pasture utilisation rate (i.e. the land-holder is over grazing to the point of costing themselves forgone income as a result of degraded land and lost production.

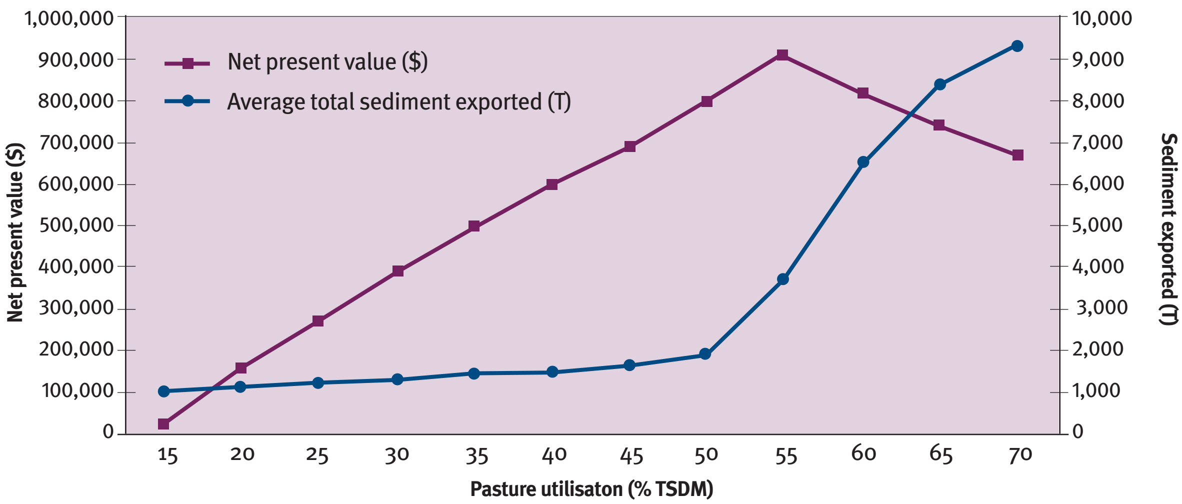


Figure 8.1 Brigalow blackbutt 'A' start condition zero tree basal area

Table 8.1 Brigalow blackbutt '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	706	914	1,110	1,294	1,468	1,639	1,791	1,915	1,895	1,789	1,772	1,805
Net present value ($)	22,779	152,026	275,490	387,591	494,878	597,549	691,702	796,955	904,211	812,423	737,105	669,458
Av total sediment exported (T)	1,055	1,146	1,240	1,342	1,445	1,511	1,666	1,958	3,730	6,536	8,377	9,336
$/T	21.58	1421.27	1321.80	1096.34	1036.91	1572.00	604.87	360.92	60.52	-32.71	-40.92	-70.50

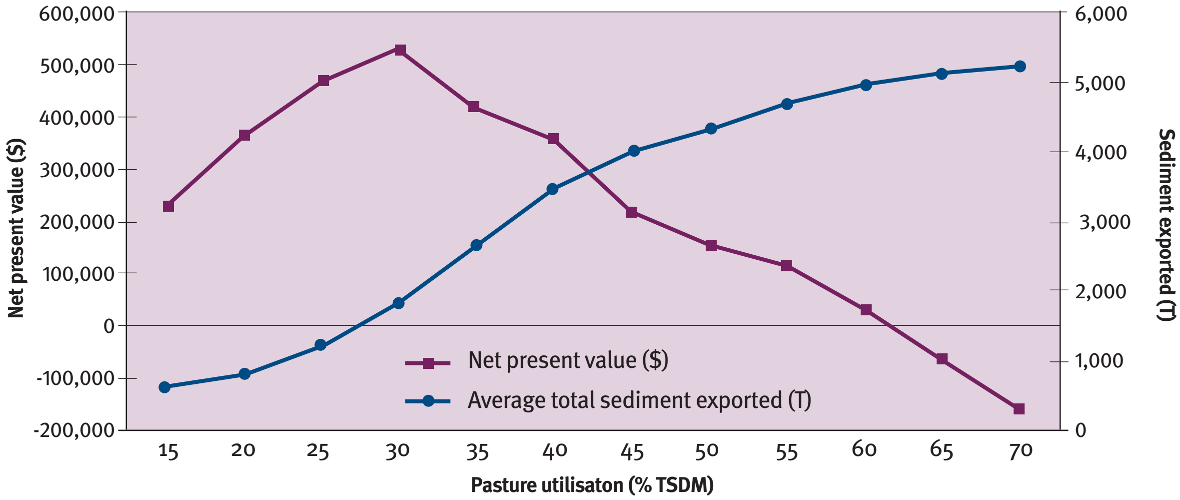


Figure 8.2 Coolibah floodplains 'A' start condition zero tree basal area

Table 8.2 Coolibah floodplains '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	661	831	953	1,023	1,020	1,046	1,086	1,146	1,198	1,261	1,316	1,387
Net present value ($)	223,727	361,210	467,508	530,235	417,689	355,668	216,237	154,556	113,277	32,307	-65,121	-161,452
Av total sediment exported (T)	663	824	1,237	1,836	2,673	3,488	3,988	4,339	4,661	4,937	5,124	5,229
$/T	337.6	850.96	257.71	104.71	-134.38	-76.164	-278.91	-175.73	-127.9	-293.6	-522.16	-915.8

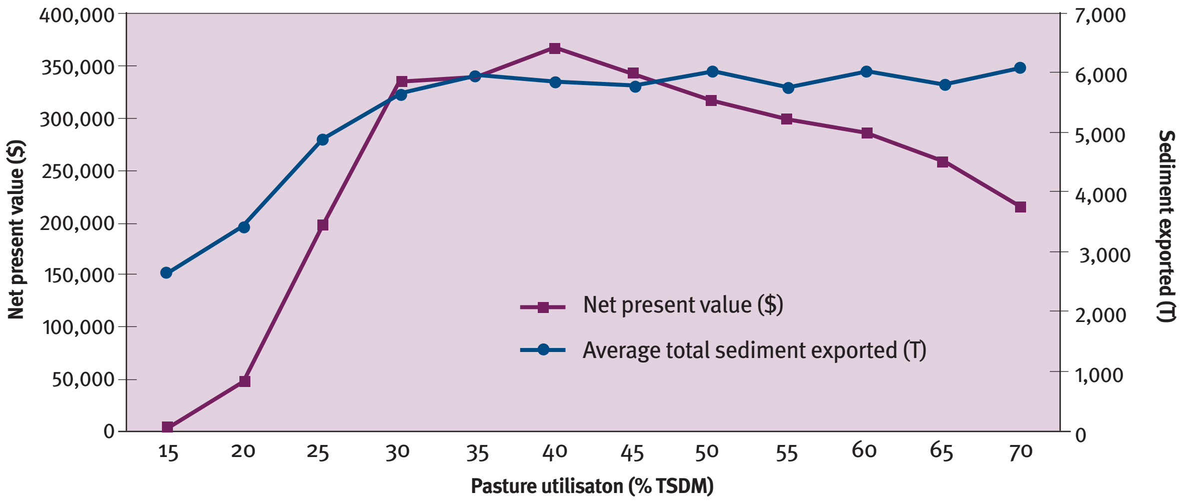


Figure 8.3 Narrow-leaved ironbark woodlands 'A' start condition zero tree basal area

Table 8.3 Narrow-leaved ironbark woodlands '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	723	895	914	827	883	950	1,026	1,100	1,165	1,230	1,296	1,359
Net present value ($)	1,805	47,050	193,120	331,668	337,874	366,975	341,126	317,696	298,671	286,076	257,308	212,905
Av total sediment exported (T)	2,669	3,422	4,893	5,694	5,933	5,845	5,782	6,015	5,764	6,040	5,837	6,052
$/T	0.68	60.07	99.27	173.12	25.94	-331.28	-406.68	-100.55	-75.84	-45.57	-141.25	-205.98

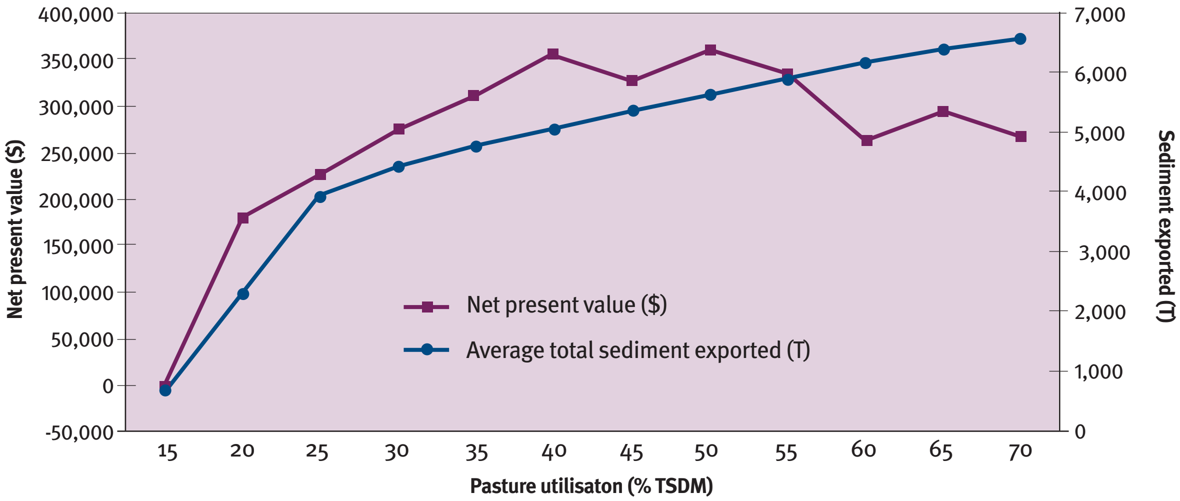


Figure 8.4 Narrow-leaved ironbark ranges 'A' start condition zero tree basal area

Table 8.4 Narrow-leaved ironbark ranges '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	706	914	1,110	1,294	1,468	1,639	1,791	1,915	1,895	1,789	1,772	1,805
Net present value ($)	-1446	180,027	226,635	274,795	311,843	356,166	326,801	359,703	334,617	264,622	293,681	266,478
Av total sediment exported (T)	6,518	23,312	39,376	44,476	47,692	50,822	53,697	56,416	59,007	61,636	63,863	65,813
$/T	-0.22	7.72	5.76	6.18	6.54	7.01	6.10	6.38	5.67	4.29	4.60	4.05

8.2 'A' start condition tree basal area

As trees compete with grasses for nutrients and water the impact of the tree on the sediment runoff and the economically optimal point is significant. The brigalow blackbutt results demonstrate this impact with a decrease in the optimal pasture utilisation from 55% to 45%. The impact was particularly noted at the higher levels of pasture utilisation.

For brigalow blackbutt, 45 percent is the economically optimal point and the net present value is $558,925 at this level the total sediment exported is 3,021 tonnes. There is a slight reduction ($1,877) in net present value from 45% to 50% utilisation and an increase of 830 tonnes of sediment exported. However from 55% utilisation to 60% utilisation there is a decrease in net present value of $208,937 and an increase of sediment of 3,361 tonnes. It is this particular type of scenario that can achieve reductions through extension and education. These results are depicted in Figure 8.4 and tabulated in Table 8.4.

The impact of tree basal area on coolibah floodplains is also highly significant. The reason for the larger tree basal area is attributed to the tree species found on this particular land type. The economically optimal point of production is 20% pasture utilisation with a net present value of $117,017. To reduce a tonne of sediment at this pasture utilisation rate it would cost $224 per tonne. This scenario is represented in Figure 8.5 and in Table 8.5.

Although the narrow leaved ironbark woodlands demonstrated an economically optimum with o tree basal area, when there was a tree basal area of 9 there were no positive returns made at any level of pasture utilisation. This particular scenario also yielded vey high sediment loads. At 15 percent utilisation there is 787 tonnes of sediment exported annually, this is eight times as much sediment as what is exported from brigalow blackbutt at the same pasture utilisation rate. The results of this scenario are illustrated in Figure 8.6 and are recorded in Table 8.6.

The results of the narrow-leaved ironbark modelling demonstrate the challenges to receiving an economic return from heavily timbered land systems. The higher tree basal results in a decreased amount of nutrients able to be utilised by pasture species. This scenario also yielded very high sediment exports. The results of this scenario are illustrated in Figure 8.7 and Table 8.7.

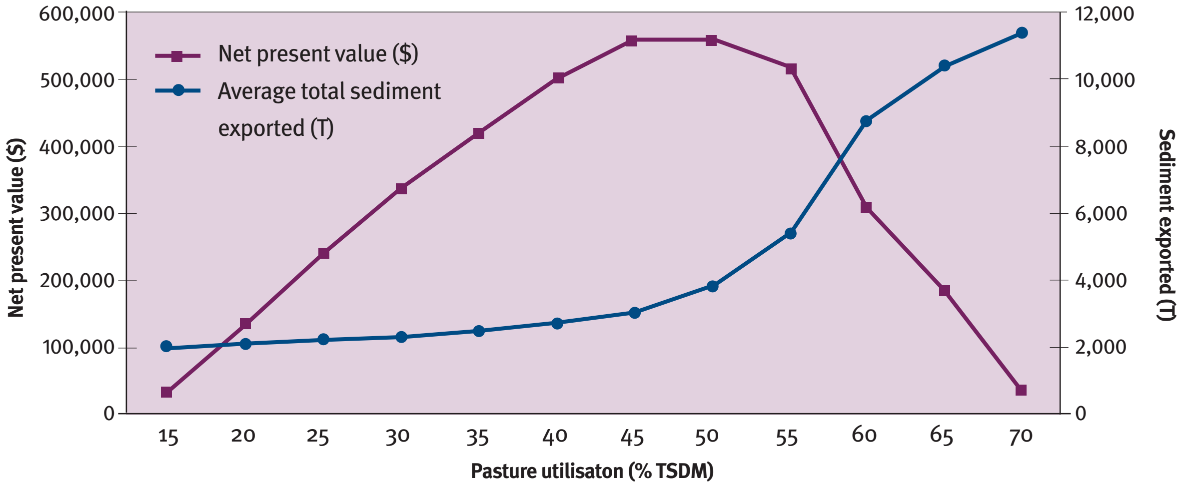


Figure 8.5 Brigalow blackbutt 'A' start condition three tree basal area

Table 8.5 Brigalow blackbutt 'A' start condition three tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	562	727	886	1,039	1,182	1,312	1,432	1,520	1,537	1,449	1,441	1,478
Net present value ($)	32,403	134,490	238,876	335,135	419,981	499,472	558,925	557,047	517,121	308,185	183,621	33,375
Av total sediment exported (T)	1,972	2,106	2,206	2,323	2,485	2,732	3,021	3,851	5,394	8,755	10,403	11,356
$/T	16.43	761.67	1,043.21	824.49	523.54	321.01	206.08	-2.26	-25.87	-62.16	-75.60	-157.59

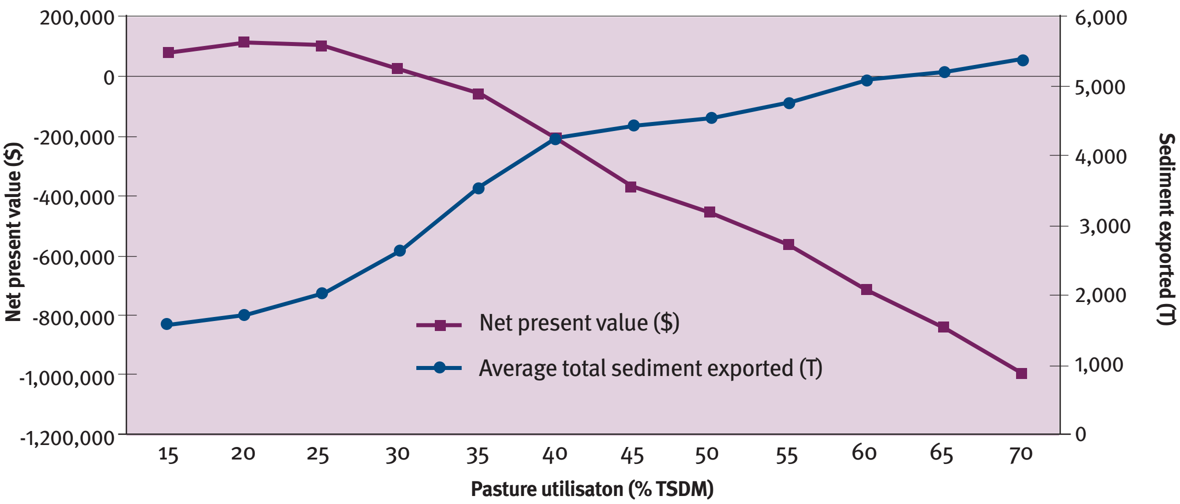


Figure 8.6 Coolibah floodplains 'A' start condition six tree basal area

Table 8.6 Coolibah floodplains 'A' start condition six tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	361	460	537	580	592	611	652	702	734	763	796	829
Net present value ($)	82,889	117,018	108,878	33,049	-57,373	-206,028	-367,888	-452,809	-561,654	-720,087	-838,467	-996,278
Av total sediment exported (T)	1,587	1,739	2,033	2,610	3,554	4,274	4,433	4,563	4,773	5,109	5,228	5,374
$/T	52.23	223.93	-27.72	-131.36	-95.77	-206.60	-1016.19	-656.08	-516.70	-471.90	-998.84	-1077.21

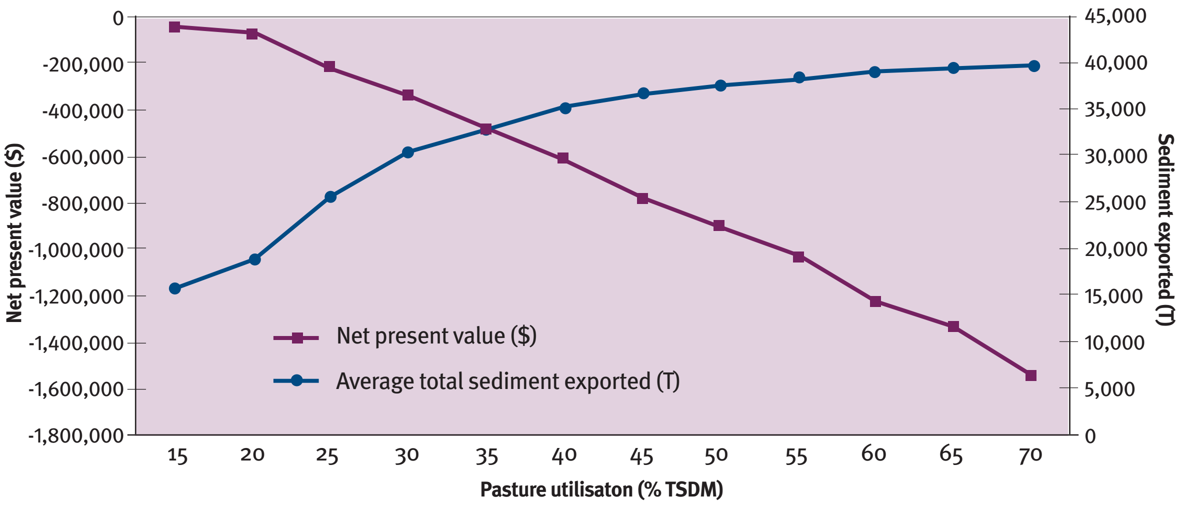


Figure 8.7 Narrow-leaved ironbark woodlands 'A' start condition nine tree basal area

Table 8.7 Narrow-leaved ironbark woodlands 'A' start condition nine tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	242	297	317	332	359	375	397	422	446	466	497	518
Net present value ($)	-45,571	-76,168	-224,219	-343,295	-479,461	-617,478	-787,776	-914,979	-1,039,129	-1,237,361	-1,341,518	-1,550,043
Av total sediment exported (T)	15,741	18,827	25,631	30,334	32,774	35,174	36,499	37,478	38,268	38,902	39,231	39,692
$/T	0.68	60.07	99.27	173.12	25.94	-331.28	-406.68	-100.55	-75.84	-45.57	-141.25	-205.98

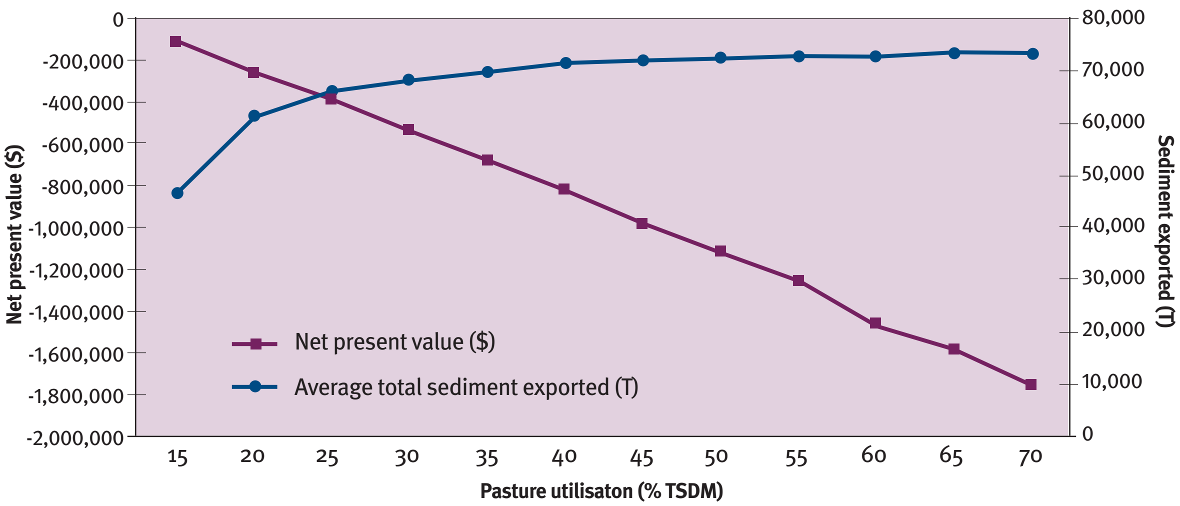


Figure 8.8 Narrow-leaved ironbark rangers 'A' start condition 15 tree basal area

Table 8.8 Narrow-leaved ironbark rangers 'A' start condition 15 tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	178	188	210	235	257	277	298	319	340	358	376	518
Net present value ($)	-108,032	-258,833	-385,077	-532,736	-676,209	-819,077	-988,603	-1,120,318	-1,252,420	-1,458,685	-1,581,114	-1,550,043
Av total sediment exported (T)	46,664	61,306	65,736	68,045	69,824	71,200	71,910	72,352	72,662	72,805	73,228	39,692
$/T	-2.32	-10.30	-28.50	-63.95	-80.63	-103.85	-238.65	-298.31	-425.75	-1444.46	-288.95	-205.98

8.3 'B' start condition and zero tree basal area

The 'B' start condition and tree basal area reflect the same findings as the 'A' condition scenarios with tree basal area, however for each land type the economically optimal peak has decreased by 5% pasture utilisation and the sediment exported has also slightly increased.

The results for the brigalow blackbutt in an initial 'B' start condition have the highest net present value achieved at 50% utilisation. At this level of utilisation the net present value is $740,729 and the tonnes of sediment exported are 4,015 on average over a twenty year period. The results of this scenario are represented in Figure 8.9 and Table 8.9.

The results of the coolibah flood plain in a 'B' start condition highlights the importance of ensuring that the correct program of policy is developed to achieve reductions. Land holders who are operating between 25% and 40% utilisation are past the economically optimal point. In this instance they require targeted extension and education to inform them of the income forgone and motivate them to move back to the economically optimal position. This will result in significant sediment reductions. Producers operating between 40% and 70% are economically unviable and will also require extension and education to move back toward the profit maximising position of 20%. These results are depicted in Figure 8.10 and Table 8.10.

The results for the narrow-leaved ironbark woodlands demonstrate a decrease in the optimal pasture utilisation, and an increase in sediment exported. The optimal economic pasture utilisation rate is at 35 percent and at this level of pasture utilisation the net present value is $295,472. The sediment export starts at 29,511 tonnes exported over the 20 year period on average. The results for this land type is represented in Figure 8.11 and Table 8.11.

For the narrow-leaved ironbark ranges the profit maximising utilisation rate was at 45% pasture utilisation with a NPV of $212,015. There is very little difference in NPV between 35% and 25% pasture utilisation, and an increase of 7,576 tonnes per hectare over the twenty year time period. In order to make this sediment reduction it would cost in total $23,691 over 20 years. A representation of the sediment exported and net present value can be seen in Figure 8.12 and Table 8.12.

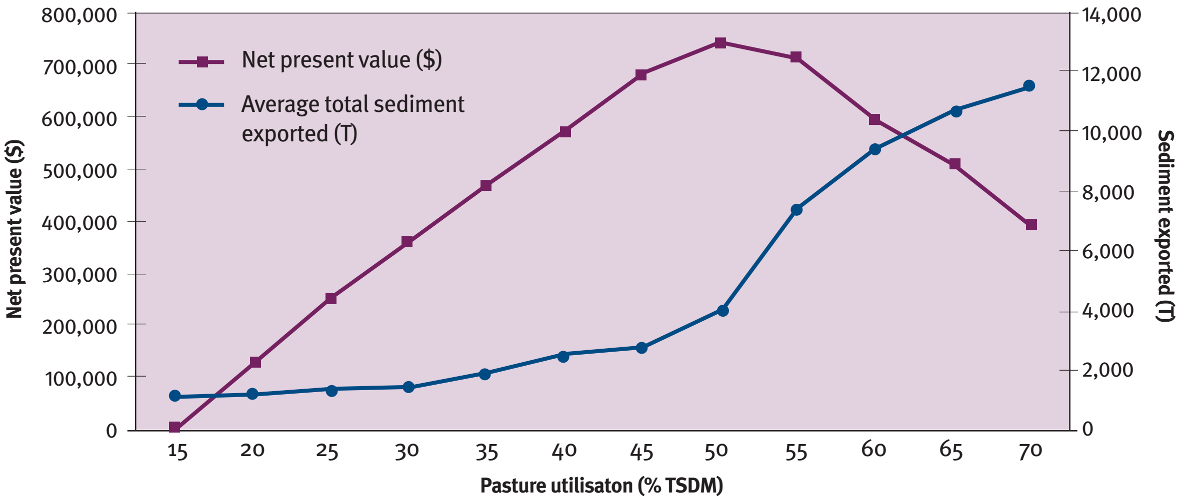


Figure 8.9 Brigalow blackbutt 'B' start condition zero tree basal area

Table 8.9 Brigalow blackbutt '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	700	907	1,099	1,276	1,404	1,513	1,639	1,677	1,552	1,538	1,551	1,591
Net present value ($)	2,483	130,743	252,742	360,564	467,899	570,014	679,887	740,730	712,465	590,631	505,921	390,422
Av total sediment exported (T)	1,109	1,205	1,316	1,454	1,867	2,414	2,735	4,015	7,383	9,357	10,649	11,511
$/T	2.24	1,337.78	1,103.44	781.67	259.87	186.64	342.55	47.51	-8.39	-61.73	-65.55	-134.02

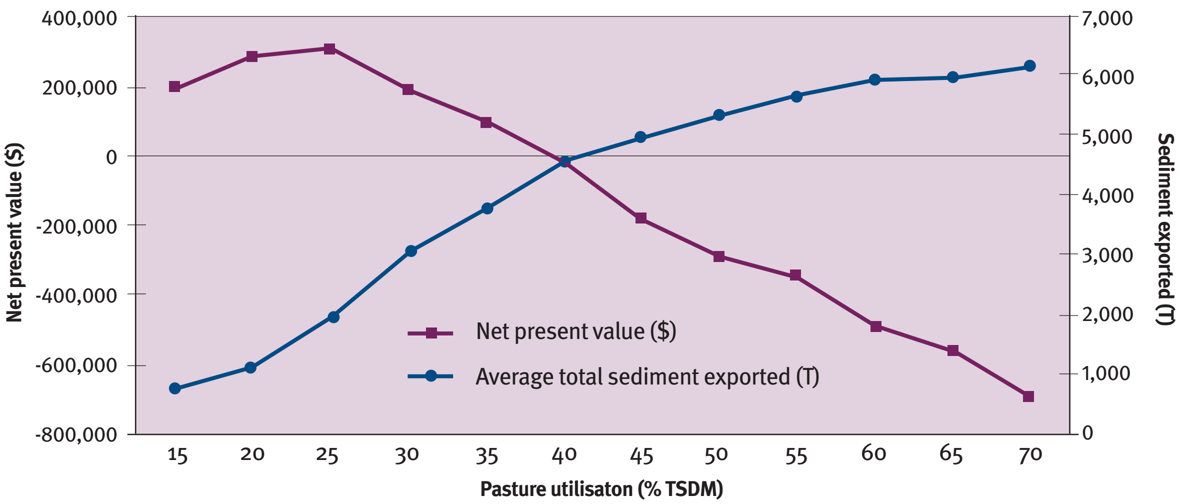


Figure 8.10 Coolibah floodplains 'B' start condition zero tree basal area

Table 8.10 Coolibah floodplains '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	635	771	811	818	838	861	909	957	1,011	1,068	1,124	11,84
Net present value ($)	199,631	283,071	302,730	187,498	93,113	-20,042	-187,495	-293,344	-348,551	-496,070	-565,850	-695,522
Av total sediment exported (T)	788	1,100	1,961	3,050	3,805	4,572	4,983	5,353	5,663	5,918	5,990	6,152
$/T	253.36	267.68	22.84	-105.75	-125.13	-147.40	-407.80	-286.08	-177.98	-577.85	-970.57	-801.06

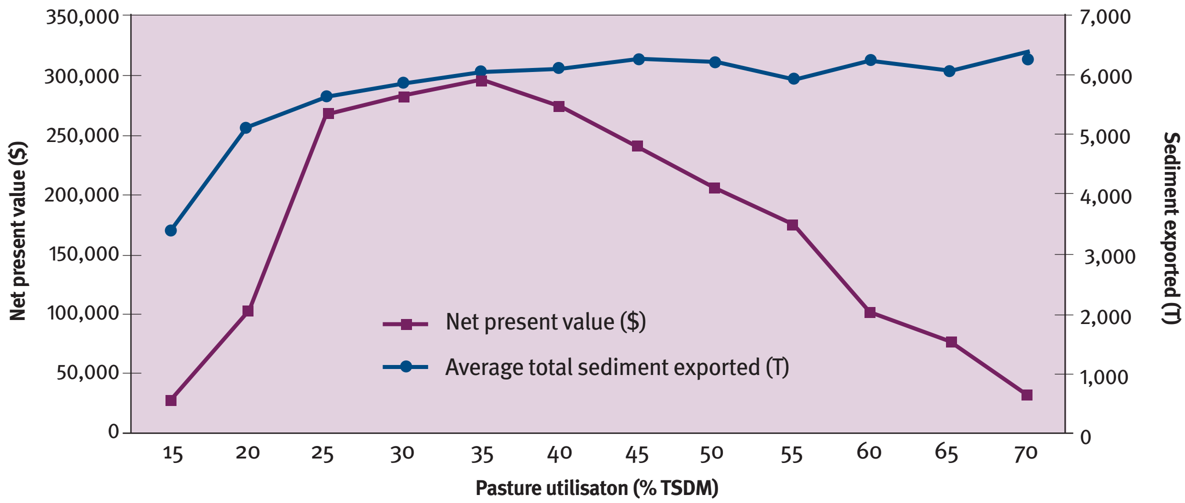


Figure 8.11 Narrow-leaved ironbark woodlands 'B' start condition zero tree basal area

Table 8.11 Narrow-leaved ironbark woodlands '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	684	767	713	701	757	837	907	974	1,036	1,097	1,161	1,216
Net present value ($)	26,083	101,442	267,836	281,469	295,472	274,015	239,773	204,366	174,182	99,471	76,439	31,502
Av total sediment exported (T)	3,400	5,110	5,633	5,875	6,031	6,102	6,257	6,203	5,923	6,243	6,086	6,362
$/T	7.67	44.07	318.23	56.32	89.71	-303.54	-221.05	-660.26	-107.51	-233.09	146.35	-162.63

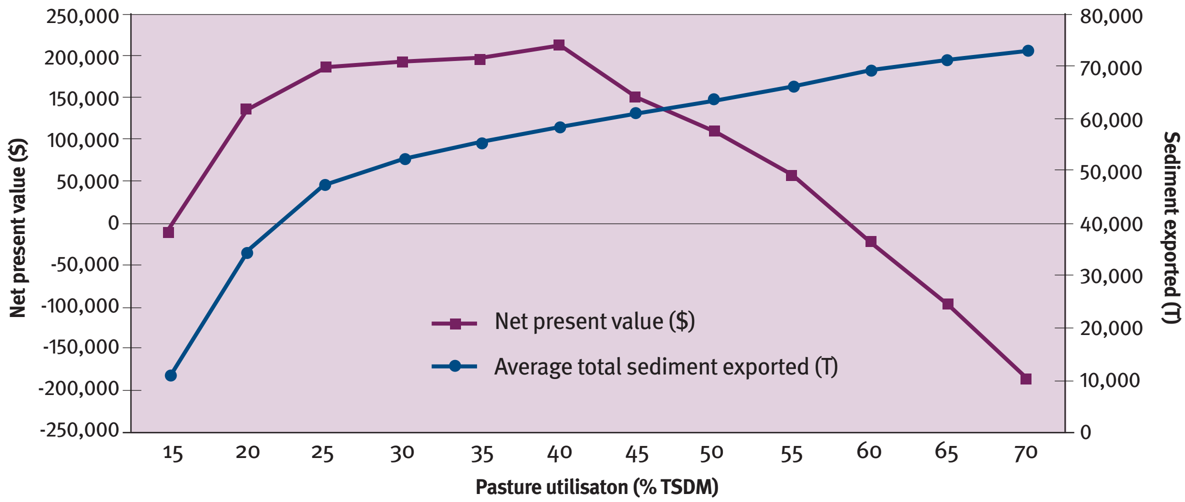


Figure 8.12 Narrow-leaved ironbark ranges 'B' start condition zero tree basal area

Table 8.12 Narrow-leaved ironbark ranges '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	684	632	675	763	852	932	1,008	1,079	1,145	1,202	1,256	1,314
Net present value ($)	-10,038	135,109	185,671	191,326	194,292	212,015	148,225	108,395	56,371	-23,126	-97,599	-186,323
Av total sediment exported (T)	10,719	34,259	47,719	52,039	55,295	58,265	61,011	63,547	65,886	68,900	71,176	73,061
$/T	-0.94	6.17	3.76	1.31	0.91	5.97	-23.23	-15.71	-22.24	-26.38	-32.72	-47.08

8.4 'B' start condition with a tree basal area

The results of this particular scenario demonstrate the interaction of decreased land condition and an increase in tree basal area on sediment movement and economic trade-offs.

The results across all land types demonstrated increased sediment exported and decreased net present values when compared to 'B' condition with zero tree basal area. This indicates that it is a cheaper option to reduce sediment exported from land with a tree basal area. Concluding that tree basal area has a significant impact on the result.

To isolate the impact of decreased land condition on brigalow blackbutt when compared to the 'A' condition simulation the optimal pasture utilisation rate decreases by 5% utilisation from 45% to 40% and the net present value also decreases by $153,399.

The implications from tree basal area can also be observed in the comparison with the B start condition and a zero tree basal area for the brigalow blackbutt. With a zero tree basal area the economically optimal point of pasture utilisation rate is at 50% pasture utilisation. At this level the net present value is $740,730 however with a tree basal area of 3m^2/ha the optiaml pasture utilisation drops 10%, to 40% and the net present value drops to $405,526, a decrease of $335,204. This demonstrates that the impact of trees on optimal pasture utilisation rate and net present value is greater than the impact of decreased land condition alone.

The results for brigalow blackbutt in 'B' condition with a tree basal area of 3m^2/ha can be found in Figure 8.13 and the tabulate results in Table 8.13. The results for coolibah flood plains can be observed in Figure 8.14 and Table 8.14. The impact of tree basal area is more prominent for the narrow-leaved ironbark woodlands and narrow-leaved ironbark ranges which are heavily wooded. The results of the narrow-leaved ironbark woodlands are depicted in Figure 8.15 and Table 8.15. The results of the narrow-leaved ironbark ranges are recorded in Figure 8.16 and Table 8.16.

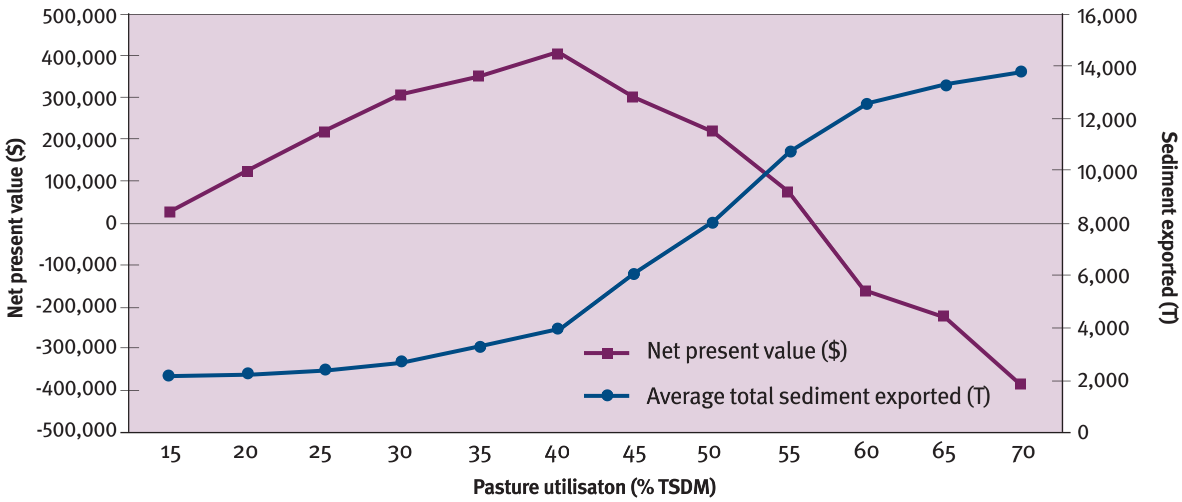


Figure 8.13 Brigalow blackbutt 'B' start condition three tree basal area

Table 8.13 Brigalow blackbutt 'B' start condition three tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	558	722	878	1,022	1,135	1,237	1,255	1,251	1,208	1,213	1,257	1,307
Net present value ($)	23,855	123,907	218,316	308,791	352,076	405,526	303,916	225,548	74,446	-165,623	-222,173	-388,652
Av total sediment exported (T)	2,066	2,215	2,345	2,605	3,261	3,940	6,110	8,025	10,767	12,602	13,246	13,823
$/T	11.54	671.07	727.28	348.23	66.01	78.71	-46.83	-40.91	-55.11	-130.86	-87.75	-288.29

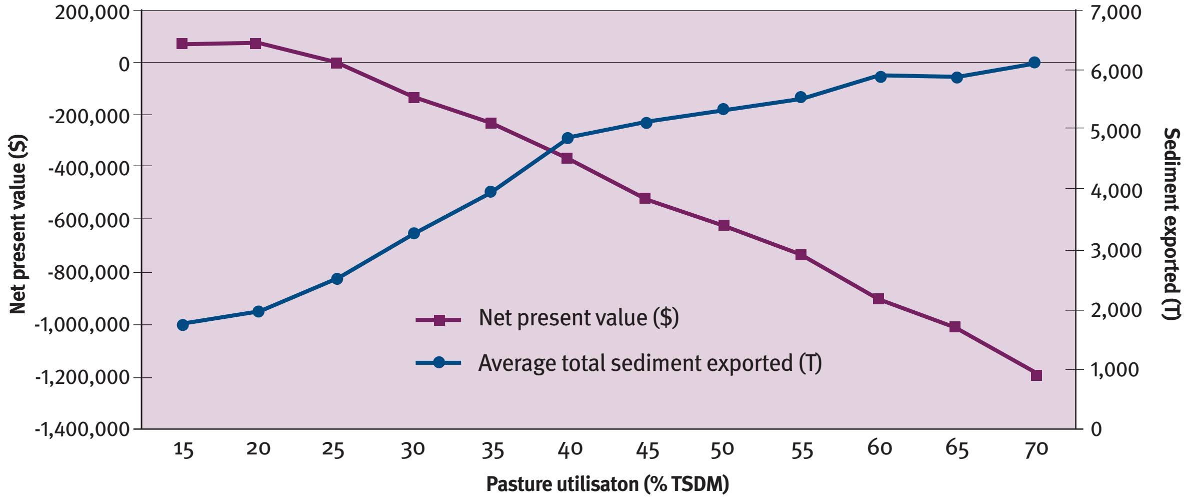


Figure 8.14 Coolibah floodplains 'B' start condition six tree basal area

Table 8.14 Coolibah floodplains 'B' start condition six tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	348	434	483	504	529	544	568	605	632	662	698	723
Net present value ($)	65,556	73,439	2,578	-134,929	-233,497	-373,058	-524,989	-625,205	-739,486	-911,256	-1,012,574	-1,182,952
Av total sediment exported (T)	1,729	1,961	2,507	3,241	3,932	4,866	5,118	5,310	5,523	5,857	5,867	6,105
$/T	37.92	37.45	1.03	-41.63	-59.39	-76.67	-102.58	-117.73	-133.90	-155.58	-172.60	-193.77

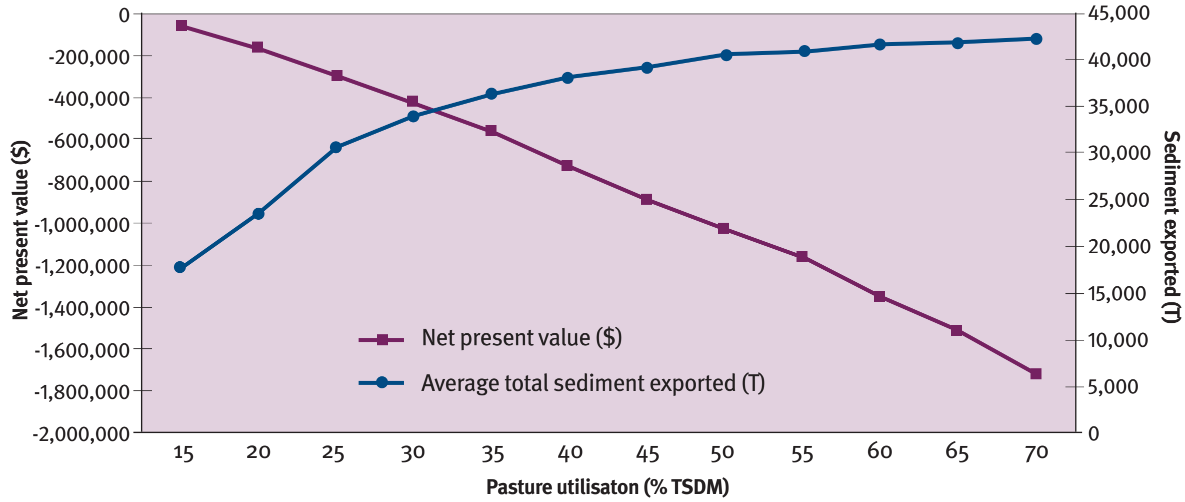


Figure 8.15 Narrow-leaved ironbark woodlands 'B' start condition nine tree basal area

Table 8.15 Narrow-leaved ironbark woodlands 'B' start condition nine tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	233	267	278	299	322	339	362	379	404	424	452	474
Net present value ($)	-61,706	-166,047	-311,421	-429,215	-565,922	-725,516	-887,754	-1,026,497	-1,153,649	-1,347,174	-1,511,432	-1,718,048
Av total sediment exported (T)	17,635	23,535	30,625	33,907	36,305	38,150	39,143	40,393	40,942	41,461	41,770	42,110
$/T	-3.50	-17.68	-20.51	-35.89	-56.99	-86.50	-163.51	-110.99	-231.67	-372.65	-531.82	-607.53

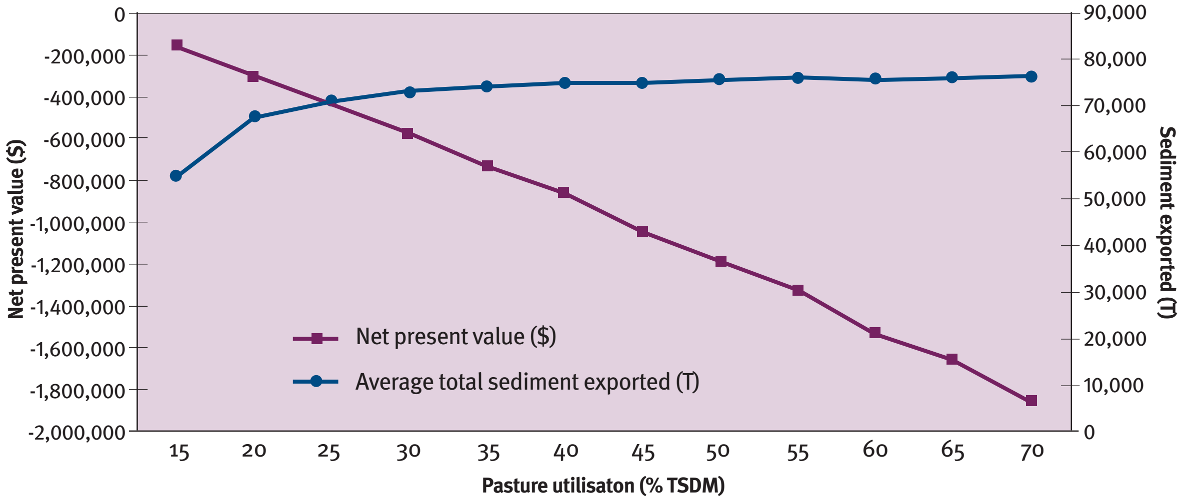


Figure 8.16 Narrow-leaved ironbark ranges 'B' start condition 15 tree basal area

Table 8.16 Narrow-leaved ironbark ranges 'B' start condition 15 tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	154	165	186	207	227	248	269	289	307	326	343	362
Net present value ($)	-144,538	-296,964	-422,608	-573,477	-720,501	-859,318	-1,041,706	-1,184,875	-1,323,482	-1,530,664	-1,654,290	-1,854,165
Av total sediment exported (T)	55,434	67,778	71,525	73,274	74,564	75,202	75,497	75,846	76,201	76,215	76,480	76,437
$/T	-2.61	-12.35	-33.53	-86.27	-114.00	-217.40	-618.13	-410.26	-390.06	-15,692.90	-466.54	-4,716.82

8.5 'C' condition zero tree basal area

Land that is in 'C' condition provides the cheapest option to reduce sediment exported as there is a substantially decreased net present value. There is also an increased sediment load leaving land in declined condition.

As land condition declines the economically optimal pasture utilisation decreases and the sediment exported increases. As a consequence of this finding it is more cost effective to reduce a tonne of sediment from land that is in declined condition ('C' condition) than that of a higher start condition ('A' or 'B' condition).

The results for brigalow blackbutt and coolibah flood plains in a C start condition with zero m^2/ha tree basal area can be found in Figure 8.17, Table 8.17 and Figure 8.18 and Table 8.18 respectively. The results for narrow leaved ironbark woodlands and narrow leaved ironbark ranges are represented in Figure 8.19, Table 8.19 and Figure 8.20 and Table 8.20.

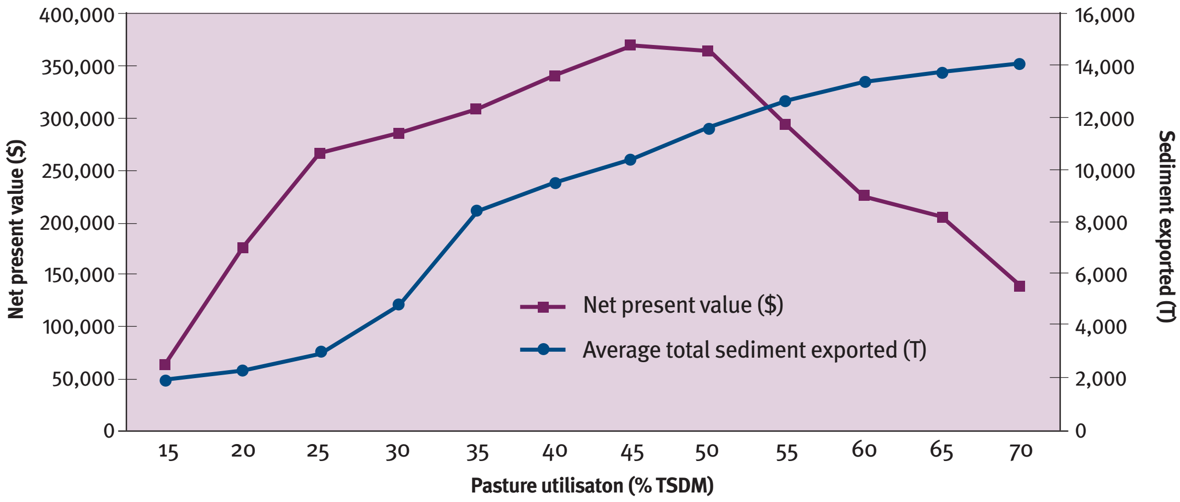


Figure 8.17 Brigalow blackbutt 'C' start condition zero tree basal area

Table 8.17 Brigalow blackbutt '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	664	846	1,000	1,048	976	1,047	1,126	1,173	1,217	1,284	1,354	1,425
Net present value ($)	60,800	174,074	265,813	283,675	309,006	339,332	368,736	362,720	291,547	223,812	203,576	138,486
Av total sediment exported (T)	1,905	2,263	2,918	4,771	8,369	9,440	10,398	11,592	12,644	13,309	13,721	14,020
$/T	31.91	316.44	140.08	9.64	7.04	28.31	30.70	-5.04	-67.68	-101.86	-49.13	-217.47

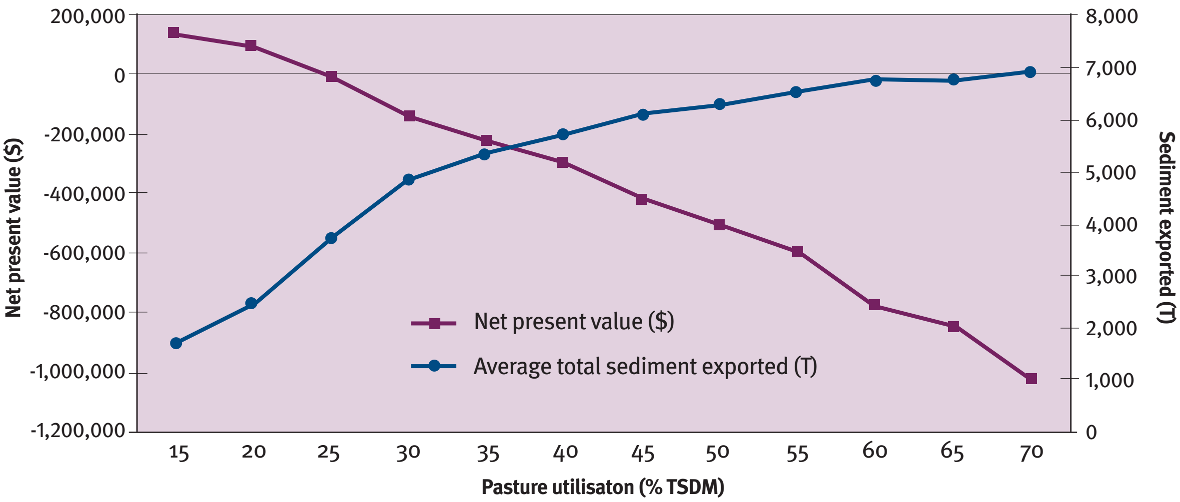


Figure 8.18 Coolibah floodplains 'C' start condition zero tree basal area

Table 8.18 Coolibah floodplains '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	543	609	602	607	657	711	764	823	878	928	986	1,036
Net present value ($)	135,907	101,617	-4,970	-146,486	-222,674	-288,255	-416,214	-506,196	-592,709	-785,236	-845,253	-1,027,258
Av total sediment exported (T)	1,703	2,441	3,709	4,830	5,369	5,709	6,095	6,286	6,492	6,732	6,780	6,913
$/T	79.79	-46.49	-84.04	-126.24	-141.56	-192.46	-331.90	-469.50	-421.05	-802.63	-1,253.48	-1,360.79

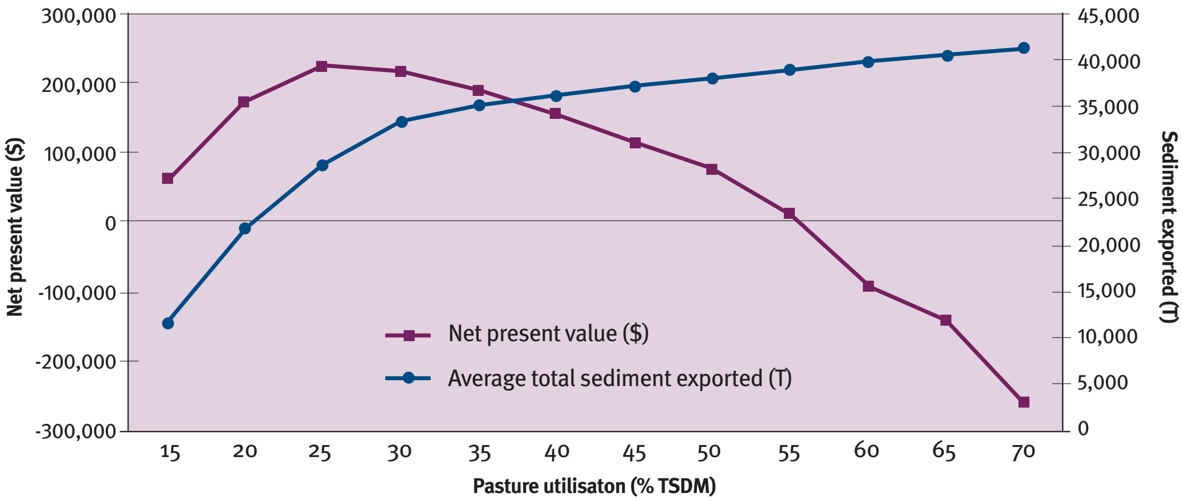


Figure 8.19 Narrow-leaved ironbark woodlands 'C' start condition zero tree basal area

Table 8.19 Narrow-leaved ironbark woodlands '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	545	518	553	603	671	742	808	871	932	985	1,044	1,096
Net present value ($)	59,957	173,156	225,144	215,422	189,592	155,303	114,023	75,399	12,755	-92,324	-141,033	-260,490
Av total sediment exported (T)	11,694	21,858	28,695	33,350	34,963	36,049	37,086	38,032	38,857	39,864	40,524	41,234
$/T	5.13	11.14	7.60	-2.09	-16.01	-31.57	-39.80	-40.85	-75.90	-104.38	-73.74	-168.23

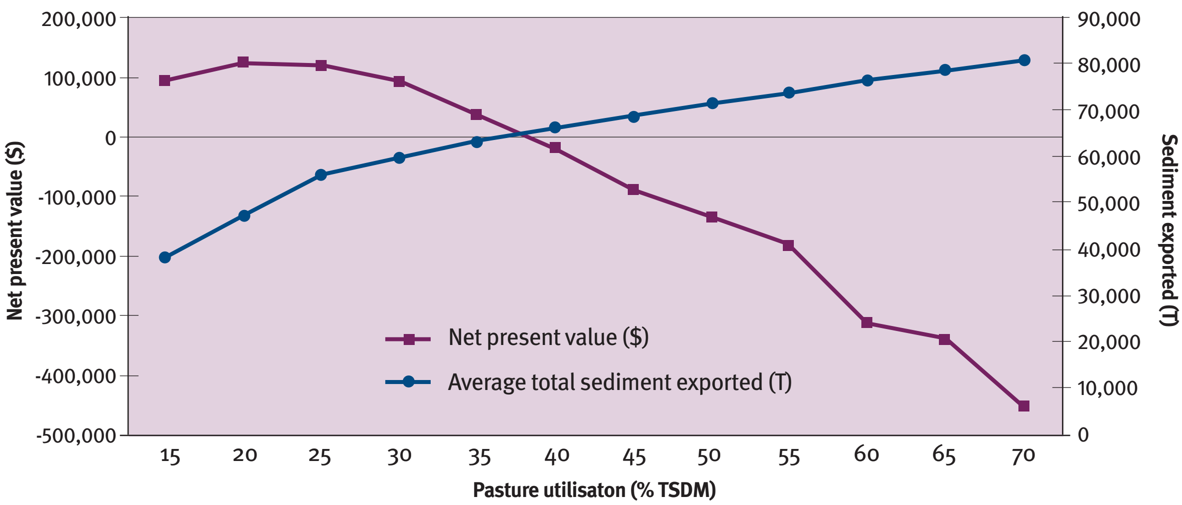


Figure 8.20 Narrow-leaved ironbark ranges 'C' start condition zero tree basal area

Table 8.20 Narrow-leaved ironbark ranges '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	441	530	600	687	767	842	914	978	1,039	1,096	1,148	1,197
Net present value ($)	91,973	121,966	118,727	91,112	37,640	-20,939	-88,439	-134,477	-181,060	-310,671	-338,852	-446,944
Av total sediment exported (T)	38,463	47,441	56,292	59,950	63,225	66,249	68,523	71,096	73,619	76,235	78,303	80,448
$/T	2.39	2.57	2.11	1.52	0.60	-0.32	-1.29	-1.89	-2.46	-4.08	-4.33	-5.56

8.6 'C' start condition and tree basal areas

The declined start condition combined with tree basal areas has a significant impact on all scenarios with the sediment exported increasing significantly and the profit maximising point of pasture utilisation decreasing along with net present values.

For all land types, land that is in 'C' condition and has a tree basal area offers the cheapest sediment reductions. This is due to decreased net present values and increased sediment exported resulting from poor land condition and the impact of trees.

The results for brigalow blackbutt and coolibah flood plains are depicted in Figure 8.21 and Table 8.21, and Figure 8.22 and Table 8.22. The results for the narrow-leaved ironbark woodlands and narrow-leaved ironbark ranges are represented Figure 8.23 and Table 8.23, and Figure 8.24 and Table 8.24.

The results of the narrow-leaved ironbark ranges dramatically demonstrates the impact of increasing sediment exported as land condition declines particularly with a tree basal area of 15. There is a 20,573 tonne increase in sediment exported over a twenty year period from land that is in 'A' condition to land that is in 'C' condition with a tree basal of 15 m^2/ha. The table below demonstrates the increase in sediment exported on average over a twenty year period. The simulation results can are depicted in Figure 8.21 and Table 8.21.

Sediment exported for 15% pasture utilisation

Start condition and tree basal area	Tonnes of sediment exported (T)
'A' start condition zero tree basal	6,518
'A' start condition 15 tree basal	46,664
'B' start condition zero tree basal	10,719
'B' start condition 15 tree basal	55,434
'C' start condition zero tree basal	38,463
'C' start condition 15 tree basal	67,237

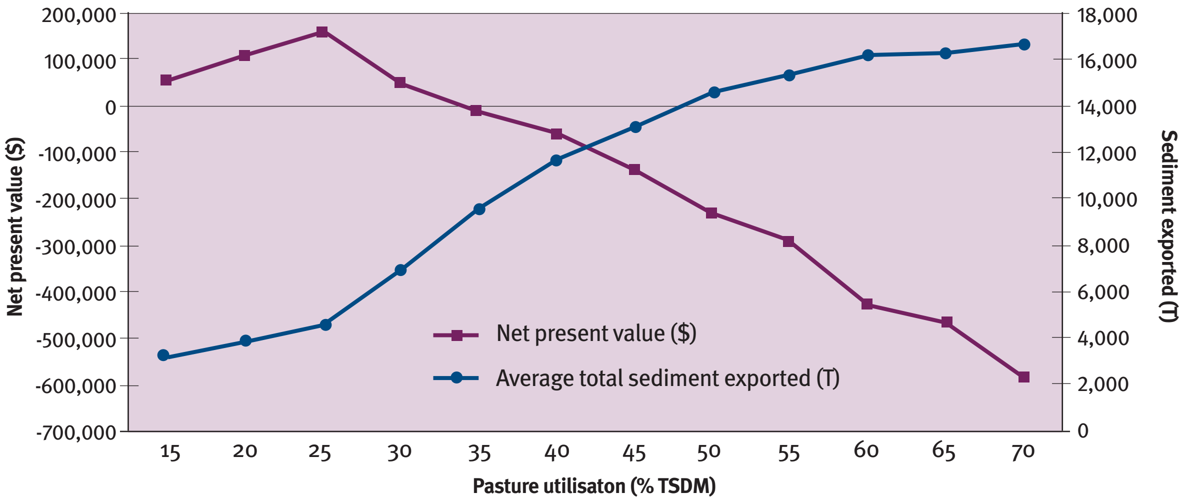


Figure 8.21 Brigalow blackbutt 'C' start condition three tree basal area

Table 8.21 Brigalow blackbutt 'C' start condition three tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	527	670	795	825	834	868	908	941	980	1,022	1,083	1,138
Net present value ($)	54,989	109,396	156,224	47,849	-14,151	-62,022	-138,641	-233,558	-293,614	-429,070	-466,716	-586,195
Av total sediment exported (T)	3,193	3,846	4,539	6,916	9,601	11,747	13,165	14,567	15,361	16,169	16,311	16,663
$/T	17.22	83.37	67.59	-45.58	-23.10	-22.30	-54.06	-67.66	-75.71	-167.60	-265.89	-338.95

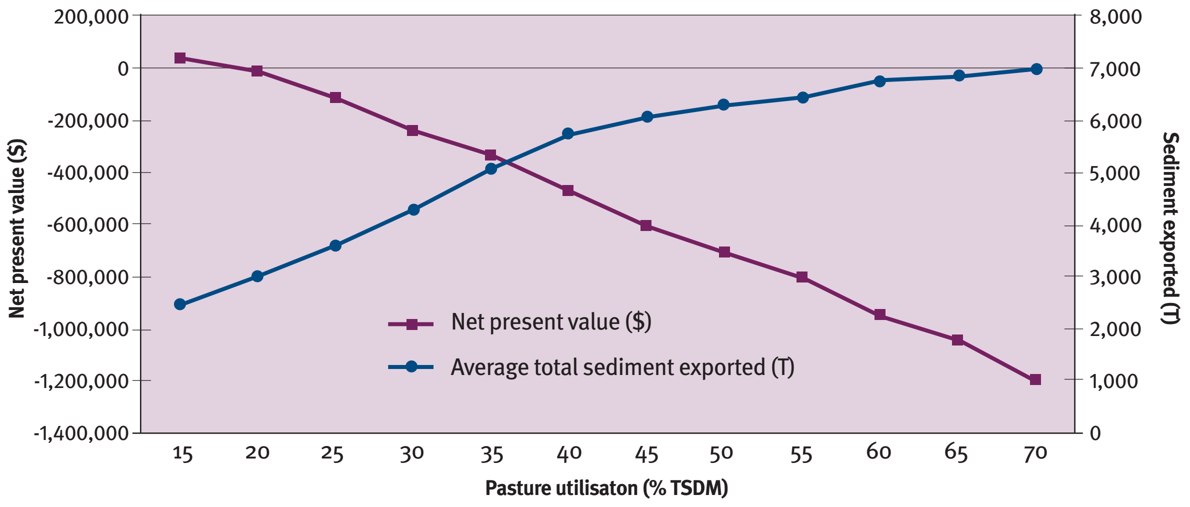


Figure 8.22 Coolibah floodplains 'C' start condition six tree basal area

Table 8.22 Coolibah floodplains 'C' start condition six tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	305	364	401	418	435	451	472	503	532	563	592	620
Net present value ($)	36,884	-13,135	-119,074	-242,603	-338,484	-470,583	-608,038	-707,670	-803,764	-950,316	-1,045,696	-1,198,820
Av total sediment exported (T)	2,472	2,993	3,608	4,311	5,060	5,737	6,040	6,288	6,456	6,760	6,851	6,952
$/T	14.92	-96.11	-172.27	-175.76	-127.90	-195.11	-453.65	-402.65	-569.87	-483.36	-1,043.21	-1,523.16

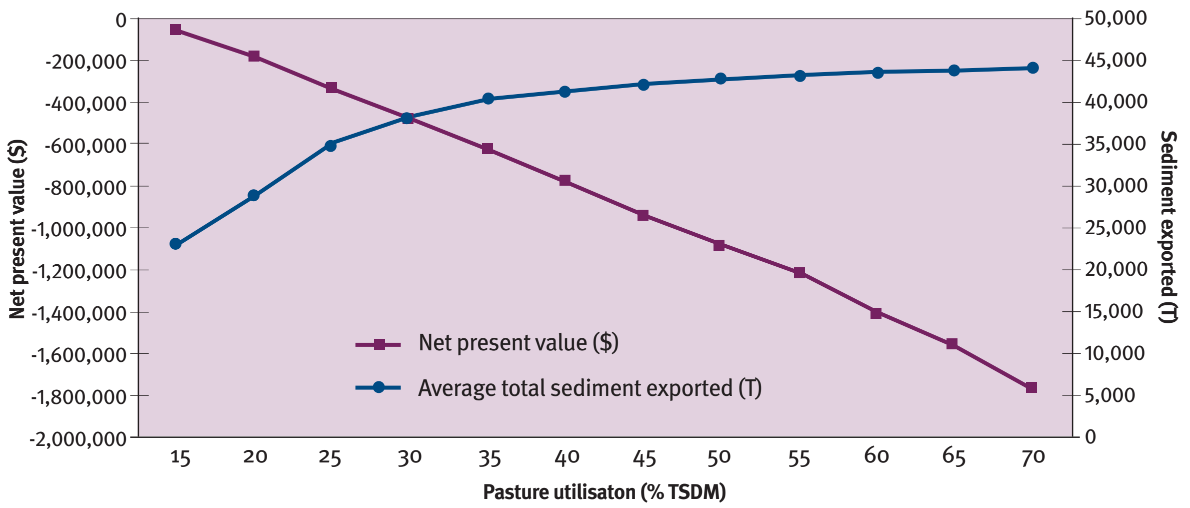


Figure 8.23 Narrow-leaved ironbark woodlands 'C' start condition nine tree basal area

Table 8.23 Narrow-leaved ironbark woodlands 'C' start condition nine tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	204	230	243	258	277	298	317	340	363	381	406	427
Net present value ($)	-45,149	-172,718	-321,767	-482,382	-625,546	-771,683	-943,036	-1,087,202	-1,223,215	-1,409,696	-1,556,839	-1,769,331
Av total sediment exported (T)	23,127	28,984	35,091	38,352	40,301	41,378	42,391	43,015	43,396	43,796	43,982	44,252
$/T	-1.95	-21.78	-24.41	-49.25	-73.45	-135.70	-169.12	-231.31	-356.90	-465.97	-788.87	-787.92

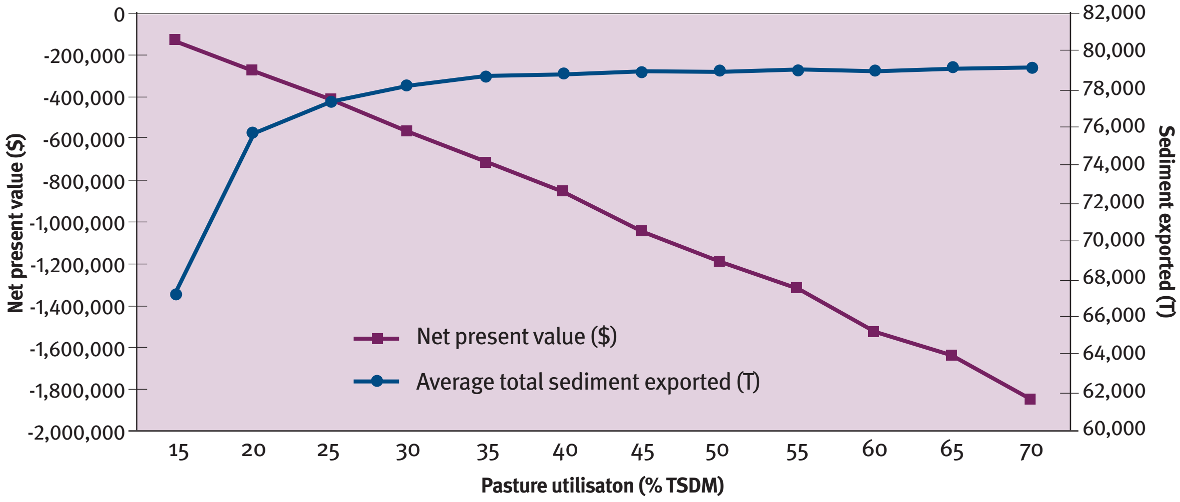


Figure 8.24 Narrow-leaved ironbark ranges 'C' start condition 15 tree basal area

Table 8.24 Narrow-leaved ironbark ranges 'C' start condition 15 tree basal area

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	123	137	160	181	201	223	243	262	280	297	314	330
Net present value ($)	-121,261	-275,304	-407,063	-572,101	-712,955	-852,427	-1,050,035	-1,188,290	-1,319,928	-1,525,750	-1,645,866	-1,856,152
Av total sediment exported (T)	67,237	75,707	77,271	78,184	78,688	78,823	78,914	78,972	79,005	78,987	79,108	79,136
$/T	-1.80	-18.19	-84.23	-180.79	-279.51	-1,037.94	-2,150.83	-2,400.51	-3,992.82	-11,354.66	-995.25	-7,274.76

9 Discussion

The results demonstrate that the more productive land types such as coolibah floodplains and brigalow blackbutt are expensive to reduce a tonne of sediment from, due to the productivity of the land and the relatively low amount of sediment exported. These are also the land types that incur the highest opportunity cost for reducing pasture utilisation below the economically optimal point. In contrast lower productivity land types such as narrow-leaved ironbark woodlands and narrow-leaved ironbark ranges, which are less productive, provide a less expensive alternative to reduce sediment loads due to the high quantity of sediment exported and the low income that is generated from these land types.

The bioeconomic modelling results validate the results from the land regeneration case study for regeneration which demonstrated that the lower productivity land types provide the most cost effective method to reduce sediment entering into the Great Barrier Reef lagoon. The most effective policy or program for brigalow blackbutt or coolibah floodplains is extension. Education and extension will ensure that people understand the economic benefits of restoring land condition and maintaining sustainable grazing pressure.

For all scenarios where an economically optimal pasture utilisatiton rate was identified it would be expected that landholders 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 less than the optimal a financial incentive may be required.

If the land holder is operating already to the left of the economically optimal point (e.g. below 55% pasture utilisation in Figure 8.1) 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.

The results of the modelled land types indicated that the narrow leaved ironbark ranges and narrow leaved ironbark woodlands have high sediment exports at a low cost per tonne of sediment that is reduced. This indicates that these are the most cost effective land types to reduce sediment exported and provide an insight into which land types should be initially targeted. These land types often had negative net present values when tree basal area was incorporated indicating that there are significant challenges to being economically viable and sustainable in the long term on these land types.

The coolibah flood plains and brigalow blackbutt present a more expensive solution in terms of policy and programs. These land types have different soil types and pasture species that ensure greater returns and net present value. They are also much less undulated and have lower sediment exported in comparison to the narrow-leaved ironbark ranges and the narrow leaved ironbark woodlands with tree basal area. The cost per tonne of sediment reduced from these land types is much higher due to the opportunity costs that the landholder incurs in reducing production. With this in mind it is recommended that resources directed to reducing sediment from these land types should be constrained to targeted extension. Raising land holders awareness of the economic returns achievable from restoring land condition from these land types as well as providing land restoration advice should be all that is required.

The starting land condition was also an important determinant of the cost of reducing a tonne of sediment exported. For land that starts in good condition, the net present value is higher at all pasture utilisation rates and this translates into a higher cost to reduce a tonne of sediment. The implication of this is that it is more cost effective to reduce a tonne of sediment from land that is initially in poor condition than it is for land that is in the higher land classifications of 'B' or 'A'.

In order to examine the impact of the climate station chosen on the results the narrow leaved ironbark woodlands with a start condition of 'B' and 0 tree basal area was then remodelled using two climate stations. The results in Figure 9.1 demonstrate the significant impact that the biophysical modelling has on the results and the importance of validating modelled results with grazing trial data and property case studies.

Live weight gain is calculated from a multiple linear regression using percentage of utilisation of growth and the percentage of green days. A green day is when the product of the temperature index, soil water index and radiation index is greater than 0.5. The percentage of green days is largely driven by climate, but grazing does have an effect. If grazing pressure is high, then cover is reduced and so there are fewer 'green days'.

When the narrow leaved ironbark woodlands were initially modelled using the climate station of *Galloway Plains* there was an unusually high number of green days, that is days where there is nutritious new growth of pasture, contributing to higher live weight

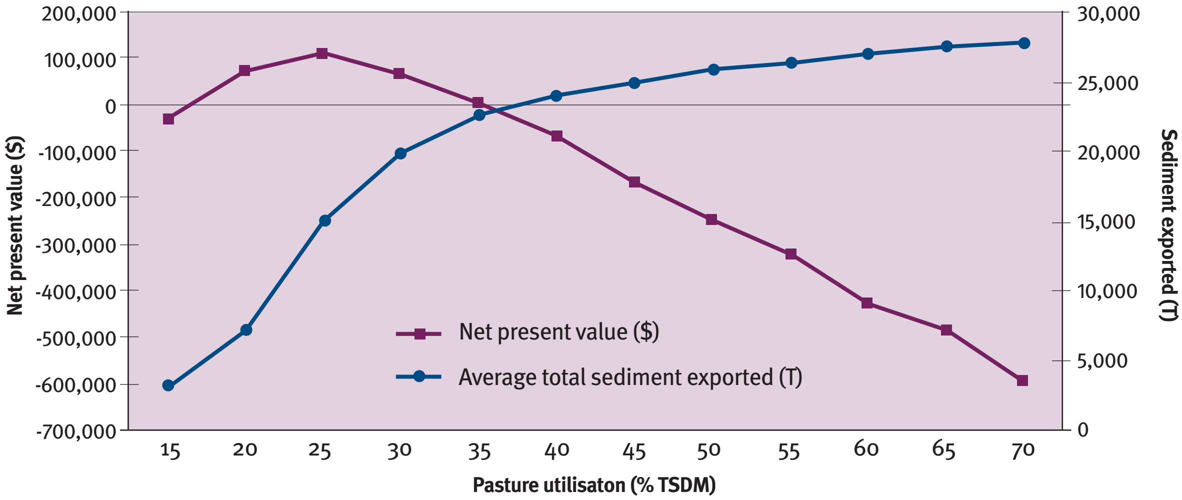


Figure 9.1 Narrow-leaved ronbark woodland 'B' start condition zero tree basal area—Blackwater climate station

Table 9.1 Narrow-leaved ronbark woodland 'B' start condition zero tree basal area—Blackwater climate station

Pasture utilisation (%TSDM)	15	20	25	30	35	40	45	50	55	60	65	70
Actual AEs for 5000 ha	656	599	616	655	709	763	814	867	918	966	1,013	1,481
Net present value ($)	-28,830	76,663	110,869	68,015	5,164	-64,368	-167,514	-244,327	-321,239	-428,594	-483,943	-594,262
Av total sediment exported (T)	3,174	7,111	15,051	19,926	22,698	24,011	24,980	25,846	26,421	27,161	27,550	28,051
$/T	-9.08	10.78	7.37	3.41	0.23	-2.68	-6.71	-9.45	-12.16	-15.78	-17.57	-21.18

gains. When modelled for the Blackwater climate station over the same period, due to the decrease in green days and therefore a decrease in live weight gain, there was an increase in the number of days drought feeding. The peak of the net present value curve was at 25% pasture utilisation with a value of $110,896 for the Blackwater climate station. When modelled using the *Galloway Plains* climate station there was an unusually high number of green days which translated into the net present value curve not peaking and falling (i.e. continuously increasing economic returns from an increasing stocking rate). This highlights the impact that climate station and the biophysical data have on the modelled result. The results from the narrow-leaved ironbark land types modelled using climate data from Blackwater are illustrated in Figure 9.1.

10 Conclusion and recommendations

The results of the case study and the bioeconomic modelling have given insight into achieving water quality outcomes at least cost to society. The results of the study have resulted in three key findings to further inform policy decisions.

Firstly, land type, land condition and tree basal area are all important determinants of the cost of reducing sediment reaching the reef. For the analysis reported here the cheapest source of sediment reductions will come from less fertile uncleared land types in 'C' or 'D' condition. These land types should be the focus of future investment decisions seeking to maximise sediment reductions at least cost to the public.

Secondly, restoring land condition on highly productive land types (e.g. brigalow blackbutt) is a very clever business decision offering land-holders substantial economic returns over a relatively short period of time. A greater extension effort promoting this finding to industry is required. Targeted extension of this nature is the most efficient means of improving reef water quality outcomes from the more productive land types within the Fitzroy Basin.

Finally, restoring land condition on less fertile land types such as narrow-leaved ironbark woodlands is critical to improving reef water quality in the Fitzroy Basin. However the costs to graziers of restoring land condition on these land types is prohibitively high and unlikely to be achieved through extension efforts alone. The use of targeted incentive payments delivered via a competitive tender process is recommended as a means of accelerating investment in land restoration work on less fertile land contributing proportionally higher loads of sediment and nutrients to the reef.

Further recommendations include:

- Land types that are generally less productive should be targeted initially as this is where the largest sediment reductions can be made at least cost to society.

- Further bioeconomic modelling of land types and climate station data should be undertaken to ensure that the most accurate information can be utilised in further decision making.
- Incentive payments should only be made to those land holders that are operating in land types that are less fertile (e.g. narrow-leaved ironbark woodlands) or those that are already operating to the right of the economical optimal point if further reductions are sort from fertile land types. The most efficient method to achieve this is through a competitive tender process.
- Those land holders who are operating past the economical optimal point should be offered extension and education to improve viability and to better demonstrate the social implications of over grazing.
- Additional modelling be undertaken on sediment export rates from different land types at a paddock scale to ensure that modelling can be the most accurate for the particular land type.

References

Ash, A.J., and D.M. Stafford Smith. 1996. Evaluating stocking rate impacts in rangelands: animals don't practice what we preach. *The Rangelands Journal* 18:216-243.

Ash, A.J., and M.S. Smith. 2003. Pastoralism in Tropical Rangelands:Seizing the Opportunity to Change. *Australian Rangelands Journal* 25:113-127.

Ash, A.J., J.P. Corfield, and T. Ksiksi. 2002. *The Ecograze Project: Developing guidlines to better manage grazing country* CSIRO.

Ash, A.J., J.G. McIvor, J.P. Corfield, and W.H. Winter. 1995. How land condition alters plant-animal relationships in Australia's tropical rangelands. *Agriculture, Ecosystems & Environment* 56:77-92.

Bennett, J. 2005. Australasian environmental economics:contributions, conflicts and 'cop-outs'. *The Australian Journal of Agriculture and Resource Economics* 49:243-261.

Brown, J., and A. Ash. 1996. Pastures for prosperity: 4 . Moving from sustainable yield to sustainability in tropical rangelands. *Tropical Grasslands* 30:47-57.

Cacho, O.J. 1997. Systems modelling and bioeconomic modelling in aquaculture. *Aquaculture Economics and Management* 1:45-64.

Cacho, O.J., R. Greiner, and L. Fulloon. 2001. An economic analysis of farm forestry as a means of controlling dryland salinity. *Australian Journal of Agricultural and Resource Economics* 45:233-256.

Campbell, B., I. Gordon, M. Luckert, L. Petheram, and S. Vetter. 2006. In search of optimal stocking regimes in semi-arid grazing lands: One size does not fit all. *Ecological Economics* 60:75-85.

Chilcott, C.R., C.J. Sandral, J.L. Aisthorpe, C.J. Paton, and B.S. McCallum. 2005. *Grazing Land Management - Fitzroy Basin Version Workshop Notes*. Meat and Livestock Australia.

Cooper, K., and R. Huffacker. 1997. The long-term bioeconomic impacts of grazing on plan succession in a rangeland ecosystem. *Ecological Modelling* 97:59-73.

Day KA, McKeon GM and Carter JO (1997). Evaluating the risks of pasture and land degradation in native pastures in Queensland. DAQ – 124A. *Final report for the Rural Industries Research and Development Corporation.* Queensland Department of Primary Industries and Fisheries, Brisbane.

Dougall, C., C. Carrol, M. Herring, R. Trevithick, S. Neilson, and P. Burger. 2008. *Enhanced sediment and nutrient modelling and target setting in the Fitzroy Basin*. Department of Natural Resources and Water.

Finnoff, D., A. Strong, and J. Tschirhart. 2008. A bioeconomic Model of Cattle Stocking on Rangeland Threatened by Invasive Plants and Nitrogen Deposition. *American Journal of Agricultural Economics* 90:1074-1090.

Fitzroy Basin Association. 2008. *Fitzroy Basin Water Quality Improvement Report*. Fitzroy Basin Association, Rockhampton.

Hamilton, J., C. Chilcott, and D. Savage. 2008. Contemporary livestock carrying capacities for pastoral properties in Northern Australia: a methodology for intergrating objective data on pasture growth and condition. *Australian Journal of Experimental Agriculture* 48:735-740.

Haynes, D., J. Brodie, J. Waterhouse, Z. Bainbridge, D. Bass, and B. Hart. 2007. Assessment of the Water Quality and Ecosystem Health of the Great Barrier Reef (Australia): Conceptual Models. *Environmental Management* 40:993-1003.

Huffaker R. G, W.J., E. Gardner B D. 1990. A bioeconomic Livestock/Wild Horse Trade-Off Mechanism for Conserving Public Rangeland Vegetation. *Western Journal of Agricultural Economics* 15:73-82.

Karfs, R.A., B.N. Abbott, P.F. Scarth, and J.F. Wallace. 2009. Land condition monitoring information for reef catchments: a new era. *The Rangeland Journal* 31:69-86.

Laurence, G., C. Richards, and L. Cheshire. 2004. The Environmental Enigma: Why Do Producers Professing Stewardship Continue to Practice Poor Natural Resource Management? *Journal of Environmental Policy and Planning* 6:251-270.

Littleboy M and McKeon GM (1997). Subrouting GRASP: Grass production model. Documentation of the Marcoola version of Subroutine GRASP. Appendix 2 of Evaluating the risks of pasture and land degradation in native pasture in Queensland. *Final Report for Rural Industries and research Development Corporation project DAQ124A*.

MacLeod, N.D., and J.G. McIvor. 2007. Quantifying production-environmental tradeoffs for grazing land management-A case example from the Australian Rangelands. *Ecological Economics* 65:488-497.

MacLeod, N.D., and J.G. McIvor. 2008. Quantifying production-environment tradeoffs for grazing land management -- A case example from the Australian rangelands. *Ecological Economics* 65:488-497.

MacLeod, N.D., A.J. Ash, and J.G. McIvor. 2004. An Economic Assessment of the Impact of Grazing Land Condition on Livestock Performance in Tropical Woodlands. *Australian Rangelands Journal* 26:49-71.

McIvor, J.G. 2001. Pasture management in semi-arid tropical woodlands: regeneration of degraded pastures protected from grazing. *Australian Journal of Experimental Agriculture* 41:487-496.

McIvor, J.G., and R. Monypenny. 1995. Evaluation of Pasture Management Systems for Beef Production in the Semi-arid Tropics: Model Development. *Agricultural Systems* 49:45-67.

McKeon G, Ash A, Hall W and Stafford Smith M (2000). Simulation of grazing strategies for beef production in north-east Queensland. *In Applications of seasonal climate forecasting in agricultural and natural ecosystems – the Australian experience*. Editors GL Hammer, N Nicholls and C. Mitchell. Pp 27-252.

McKergow, L.A., I.P. Prosser, A. Hughes, O., and J. Brodie. 2005. Sources of Sediment to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin* 51:200-211.

Northup, B.K., J.R. Brown, and A.J. Ash. 2005. Grazing impacts on spatial distribution of soil and herbaceous characteristics in an Australian tropical woodland. *Agoforesrty System* 65:137-150.

O'Reagain, P., J. Bushell, C. Holloway, and A. Reid. 2009. Managing for rainfall variability: effect of grazing strategy on cattle production in a dry tropical savanna. *Animal Production Science* 49:85-99.

Orr, D.M., M.C. Yee, and D.J. Myles. 2006. Impact of short-term exclosure from grazing on pasture recovery from drought in Six Queensland pasture communities. *Tropical Grasslands* 40:202-212.

Packett, R., C. Dougall, K. Rohde, and R. Noble. 2009. Agricultural lands are hot-spots for annual runoff polluting the southern Great Barrier Reef lagoon. *Marine Pollution Bulletin* 58:976-986.

Pannell, D. 2009. Australian environmental and natural resource policy-from the Natural Heritage Trust to Caring for our Country, pp. 1-11 AARES 2009, 53rd Annual Conference of the Australian Agricultural and Resource Economics Society, Cairns.

Queensland Government. 2008. *Land types of Queensland* ; Fitzroy, In Department of Primary Industries and Fisheries, et al., (eds.), Brisbane.

Queensland Primary Industries and Fisheries, Beef CRC, Northern Territory Government, and Western Australian Department of Agriculture and Food. 2009. *Representative Herd Templates for Northern Australia*, In H. W.E, (ed.), 1.00 ed. Queensland Government, Brisbane.

Rickert KG, Stuth JW and McKeon GM (2000). Modelling pasture and animal production. In Field and Laboratory Methods for Grassland and Animal Production research. Eds L 'tMannetje and RM Jones. Pp 29-66. CABI publishing New York.

Stokes, C.J., R.R. McAlliser, and A.J. Ash. 2006. Fragmentation of Australia rangelands: processes, benefits and risks of changing patterns of land use. *The Rangeland Journal* 28:83-96.

The State of Queensland and Commonwealth of Australia. 2003. *Reef Water Quality Protection Plan; for catchments adjacent to the Great Barrier Reef World Heritage Area*, In Queensland Department of Premier and Cabinet, (ed.), Brisbane.