Final report

Northern Beef Program

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Neighbourhood catchments – Minimising the impact of grazing in the Fitzroy Basin

Abstract

Beef industry members are increasingly aware of the need to demonstrate progression towards improved land management in central Queensland. There is the recognition that barriers exist where producers have not readily adopted new information/technology to support their endeavours. The beef industry has in turn adopted approaches to encourage uptake with little success across the broader cross-section of the industry. This project proposed a new approach linking science and social science methodologies to encourage adoption and change.

Two neighbourhood catchments (80–300 km^2) were established to quantify the impacts of current management and identify environmental & social improvements to reduce the impact of land management practice on the Zamia/Mimosa Catchment (8 585 km^2). We discovered that adoption of specific land management practices at the paddock to catchment scale could improve landscape health and water quality. Three main issues identified to address declining landscape and catchment health included a requirement to Increase year round catchment ground cover, improved land management practices of fragile land types and greater awareness of catchment area impact on gully erosion. However, traditional techniques implemented to extend this information to the producer continued to demonstrate little or no uptake by the intended audience; a new approach was needed.

Through an adaptive management approach, Continuous Improvement & Innovation (CI&I) we encouraged partnerships whereby qualitative data was valued and supported by outcomes from quantitative data. Implementation of producer projects initially supported long unresolved issues which then enabled progression of individuals into examining more complex aspects that dealt with the specific nature of improving land management on a broader scale.

We discovered that using the CI&I approach aids the building of social and human capital for more effective and efficient linking of research and development findings into property management. This encouraged participation by producers that led to evidence of improvements in social systems with potential future economic and landscape health outcomes. CI&I is proving successful in this context for it is involving a broader cross-section of the grazing community implementing a suite of coordinated projects to improve water quality. Through this approach we have developed a better understanding of the social system and have identified the best opportunities for change. We have implemented new methods of building groups and involving people in partnerships and have provided participants with the tools, skills and information to achieve successful outcomes for the sustainability of the grazing industry.

Executive Summary

The grazing industry today is faced with increasing scrutiny in regards to the impact of its practices and management decisions within the broader landscape. Heightened awareness driven by concern for nationally significant natural wonders such as the Great Barrier Reef (GBR) has led to quantifying the role of land based activities in our environment. To understand the impact of human induced decision making at the GBR scale is in principle impossible given the diverse and complex landscapes within its boundaries.

As managed change is essential, at what scale must we (beef producers, scientists, government agencies and environmental bodies) work to encourage better natural resource management that lessens the impact on the environment? How do we improve the adoption of information and technology to assist land owners in continually improving and innovating? This research and development project investigated the interaction of science and social science concepts and challenged some pre-existing notions that have and continue to be ineffective. The project developed three objectives with the aim of answering the above key questions:

1) Determine runoff, soil erosion and pollutant transport at a paddock to neighbourhood catchment scale.
2) Understand the causes and processes that lead to a decline in water quality at a paddock, property and neighbourhood catchment scale, and relate responses to catchment condition.
3) To achieve Continuous Improvement & Innovation (CI&I) with beef producers and other relevant partners to improve water quality in the Southern Mimosa Catchment in the next 12 months.

The completion of this project has demonstrated that working at the property level within a neighbourhood catchment using targeted science and an adaptive management approach designed to achieve change has moved beef producers towards achieving improvement and innovation in a social and environmental context. Supporting evidence has established that critical issues must be addressed at this scale if we are to progress towards improving landscape and catchment health within the Zamia/Mimosa Catchment. These include but are not limited to increased year round ground cover, improved land management practices of fragile land types and greater awareness of catchment area impact on gully erosion. Gully erosion has the potential to adversely impact water quality and within certain land types, is the dominant erosion process. Seasonality of rainfall patterns and resultant impact on runoff and erosion processes is demonstrating an area where large scale change in management practice has the potential for the greatest influence on enhancing landscape and catchment health.

While change at the individual property scale leads to environmental and potentially economic improvement of that enterprise, this project has discovered that development of human and social frameworks are required for continual improvement and innovation within the broader community at a neighbourhood catchment scale. A neighbourhood catchment comprises a group of landholders and relevant partners (6–15 people) within a defined natural drainage catchment working towards improving their enterprises to lessen the impact of their thinking and action on the environment. The present day argument states managed change is essential in order to reverse land degradation and sustain rural communities and businesses. It must be emphasised that change occurs as a result of the thinking and action of people. Change does not occur because of created awareness and delivery of new information and technology.

Removal of resources from bodies administrating and assisting rural communities has necessitated the development of solutions that work at the large landscape and catchment scales. To date, limited evidence exists in the development and implementation of a successful approach that

effectively works with people at this larger scale. Fundamentally, the crucial issue identified in this project is that moving to this scale has removed the ownership of land managers in addressing solutions to declining land productivity and sustainability. Property owners develop a detailed knowledge of their property. When moving outside of their ‘patch of dirt’, their ability to apply their knowledge and skills is lost. The relevance and ownership of what they do is not applicable at larger scales. This project has implemented an approach that has demonstrated how to effectively work with people and science at larger landscape and catchment scales.

This project has further developed a set of concepts and principles enunciated by Clark and Timms *et al*. (2004) using newly established groups at the neighbourhood catchment level within central Queensland. These concepts and principles can be applied beyond the neighbourhood catchment scale to larger landscapes and catchments where change must occur. In essence, if the beef industry wants to improve its image and the progression of its members, our research has found the following needs to be considered:

1) Establishment of new groups (6–15 producers and partners) meeting regularly with a common focus to improve land management within a drainage area.
2) Network of groups within a landscape supporting each other.
3) Skilled facilitator with processes and tools designed to achieve change. Participants are equipped with these processes and tools to build people’s capacity to achieve improvement and innovation.
4) Emphasis placed on the human dimension of land management.
5) Building on and valuing local producer knowledge.
6) Undertaking of producer projects where ownership and action is fostered.
7) Incorporation of local relevant data with high scientific accuracy supporting producer’s issues and project outcomes.
8) Linking qualitative and quantitative information.
9) Efficient and coordinated use of all resources (material & human) within a community.
10) Operating at a systems level. Working with natural resource management and people brings complexity. It is therefore counter productive and false to think that the way forward is with a single solution scenario that does not address and work with this complexity.

The role of people in natural resource management should not be underrated. If change is to result we need to work with industry members, the ‘end-users’ of research and development findings, in networked, resourced, small, facilitated human development groups, regularly, with a specially designed change process that incorporates targeted science and technology. Here also needs to be the articulation of performance that is outcome based and measurable. Using processes and tools that augment thinking and the establishment of outcomes and outputs, which are measurable with on-going support, provide an effective and efficient means of achieving change – continuous improvement and innovation. This project has been clear about differentiating between outcomes and activity. Working with partners, clear specific performance outcomes that matter are generated and measured. Change does not happen by chance with key concepts having to be designed and managed.

This project demonstrates practical and successful methods of achieving the adoption and change needed to improve social, economic and environmental outcomes for graziers by:

1. Increasing return on investment: Approaches that value investment in human infrastructure will achieve real outcomes in the long and short term representing return on investment. With this would also come an improvement in the human resources, knowledge skills and capability to respond and direct the industry into the future.
2. Maximising efficiency in achieving outcomes by making a real impact on the most important issues for the long term and being in a position to track progress.
3. Hastening adoption of research and development findings: Land management improvement will be based on the best information and technology. Relevant specialists in collaboration with producers will generate innovative responses to issues of concern within the rural community.
4. Using highly effective neighbourhood catchment networks/partnerships with proven methods for achieving landscape health and sustainable business.
5. Employing a model, process and tools for innovative and adaptive grazing management that can be applied industry wide.

Effective collaboration with beef producers in neighbourhood catchments requires a social framework and partnerships that support innovation and improvement in achieving change. We have shown that using an adaptive management approach (CI&I) achieves sustained improvement in:

- approaches that value investment in human infrastructure
- the capability of graziers
- adoption of research and development.

The approach also has the potential in the future to improve and promote:

- innovative & adaptive grazing management
- landscape health
- business viability.

Findings from this project will allow the beef industry to make a contribution to the discussion of the health of the GBR through quantifying the impact of management practices at the environmental and social level. More importantly, it will demonstrate an approach to improve the 'triple bottom line' for beef producers that necessitates the encompassing of science and social science methodologies.

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1 Background

1.1 The people

The team comprised:

- Scott Stevens, Jane Gray and Oliver McConnachie (Department of Natural Resources & Mines/MLA project team)
- 15 families from the Zamia/Mimosa Catchment (Figure 1) who formed the steering group and Fish Creek Neighbourhood Catchment (NC)
- Tony Barnes (Brigalow Research Station Manager)
- Michael Walker (Company Property Manager for Central Queensland)
- Felicity Anderson (Fitzroy Basin Association)
- Ray Becker (Dawson Catchment Coordinating Association)
- Six Agforce representatives (Moura and district branch).
- A further nine families in the Kangaroo Creek NC are at early stages of involvement.

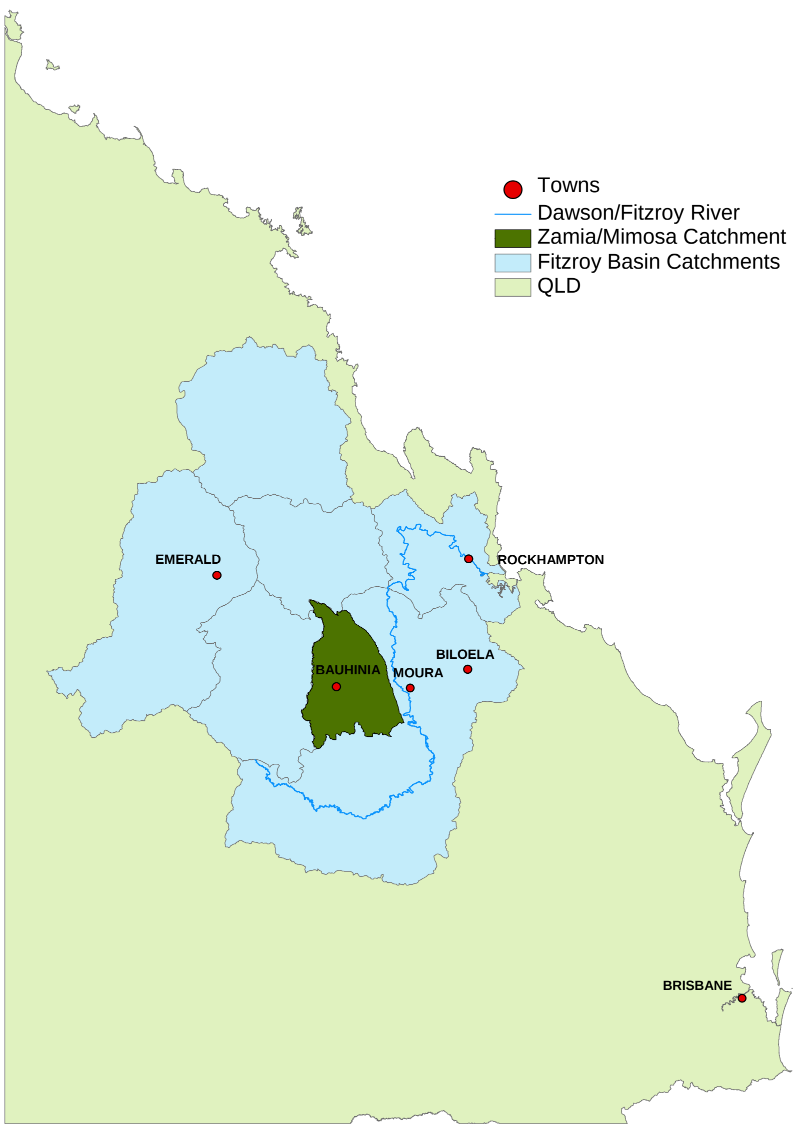


Figure 1: Location of Zamia/Mimosa Catchment in the Fitzroy Basin

1.2 Project direction

1.2.1 Initial project direction – Science and People

Increased attention throughout the wider community is being directed towards land-based industries and their role and resultant impact on the environment. At the forefront of community interest lies the world heritage listed Great Barrier Reef (GBR). Extending over 2 000 km and containing a diversity of plant, animal and marine environments, this natural phenomenon has increasingly been placed under pressure from land-based agricultural and urban activities.

Grazing is the largest industry utilising land based resources within the catchments draining into the GBR. The Fitzroy Basin is the largest coastal catchment in the GBR region, with grazing the predominant land use (>80%). A recent report (Brodie *et al.* 2003) states that over 90% of sediment and nutrient pollutants from the Fitzroy Basin entering the GBR have originated from rangeland beef grazing lands. Evidence suggests that landholders undertaking poor resource management are having a disproportionate impact on catchments and water quality throughout Australia (Prosser, 2001 NLWRA). Approximately 70% of the land-based pollutants from all industries are generated from 20% of the total GBR catchment area (Brodie *et al.* 2003). Concerted efforts are therefore required to identify and reverse this trend within these critical areas as well as targeting the broader cross-section of all industries to reduce the overall impact.

This led us to ask the question, what is the most appropriate scale required to encourage change in natural resource management?

We worked within a naturally bounded catchment that integrated the effects of natural resource management in the quality of its runoff water. The quality of this water then became the focus for improvement of catchment management by its residents, who we formed into a group with a shared goal. Targeted research and development aiding insight into management aspects identified by the group and/or individual property owners was aimed at the relevant parties. This concept of working with people and science at a specific scale to achieve change is an integral part of the neighbourhood catchment philosophy.

This novel neighbourhood catchment philosophy, however, was still underpinned by old and unsuccessful methods of improving natural resource management. Traditional extension and adoption strategies employed to achieve change in the agricultural sector have dealt with landholders who are most ready and able to change. There was the assumption that improvement among ‘early adopters’ will eventually filter down to other industry members.

We employed traditional extension techniques such as field days and individual farm visits to establish whether this ‘filter down’ effect was actually occurring. Presentations detailing improved natural resource management practice from past research and development findings were not common knowledge amongst the producers. We also discovered that provision of information did not lead to adoption of practices. Randomly spaced extension ‘events’ coupled with producers’ reliance of project staff to provide ‘expert’ integration of information into their existing property management strategies was not successful in achieving change. It became evident that adoption of industry-driven research and development using these more traditional extension strategies was not evoking change among the broader cross-section of the community. A fresh approach was needed.

1.2.2 Revised project direction – People and Science

A thorough analysis of the relevant literature showed why traditional extension was not working (Russell *et al*. 1989, Vanclay 1992, Van Beek & Coutts 1992, Woods *et al.* 1993, Buford *et al.* 1995, Clark *et al.* 1999, Timms & Clark 2001). Traditional extension methods have overemphasised the natural environment and technology and underplayed the impact of people on the environment. The natural environment is not just a physical entity on maps; it represents social networks and the ways in which people relate to the land and each other. A more balanced approach is needed, one that recognises and places emphasis on humans, for humans are major change agents and modifiers of the environment.

New approaches based on new thinking have subsequently been developed. This project has immersed natural resource management extension in a research and development paradigm designed to bring about change: Continuous Improvement and Innovation. New approaches have led to a greater understanding and acknowledgement of the complexity producers' work with. Figure 2 demonstrates the increasing complexity of extension situations, moving from technology transfer to human development as complexity increases.

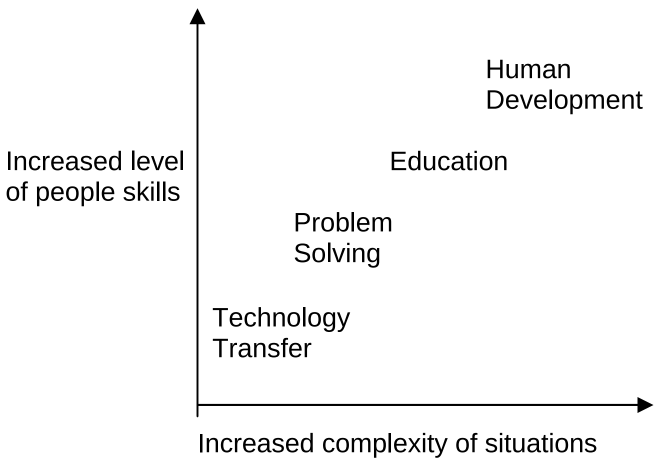


Figure 2: The Extension Spectrum (Van Beek & Coutts 1992, p. 4)

Human development empowers people to realise their potential and better use their capabilities and assures ownership and sustainability of development programs. Human development requires systematic approaches. Continuous Improvement & Innovation (CI&I), is a systematic approach that is designed to bring about sustained improvement.

We believe that to achieve sustained improvement in land management new thinking and action is required. In Thomas Kuhn's book *The Structure of Scientific Revolutions* he shows that almost every significant break through in science required first a break with old ways of thinking and doing, old paradigms. Timms & Clark (2001) state that accompanying new thinking a project needs three components:

1. Supportive human structures such as groups, network of groups and partners.
2. People who are capable.
3. Resources ranging from finances to specialist support and technology.

With this new thinking and action, we asked, "What is the most appropriate scale of science and how do we best work with people (beef producers, scientists, government agencies, environmental bodies etc.) to encourage change in natural resource management?" In this project we proposed the most suitable scale was at a property level within a neighbourhood catchment using targeted science and an extension paradigm using management and improvement processes designed to achieve change.

2 Project Objectives

The aim of the project was to investigate the impacts of adoption of sustainable grazing practices and to demonstrate that improved management lessens the impact on our natural resources. To quantify these outputs and outcome, we developed the following objectives:

1) Determine runoff, soil erosion and pollutant transport at a paddock to neighbourhood catchment scale.
2) Understand the causes and processes that lead to a decline in water quality at a paddock, property and neighbourhood catchment scale, and relate responses to catchment condition.
3) Encourage and show the adoption of sustainable grazing and resource management systems at a property, neighbourhood, sub-catchment and basin scale.

Pollutant is defined as sediment or soil, nutrients or pesticides that are displaced from their point of origin through the action of runoff water.

In the task of undertaking activities associated with these objectives, it became clear to the project team that traditional extension methods adopted to achieve objective 3) were not working. The project was not in a good position to provide learning about resource management systems or have an impact on land management change using such approaches.

Based on the above learning and after consultation with MLA, objective 3) was amended to better reflect the adoption of a new approach, an adaptive management approach to achieve the outcomes of the project. The new objective reads;

3) To achieve Continuous Improvement & Innovation with beef producers and other relevant partners to improve water quality in the Southern Mimosa Catchment in the next 12 months.

The Southern Mimosa Catchment was selected as an area of interest within the Zamia/Mimosa Catchment. Prior attempts to involve producers outside this reference area had failed. With limited timeframes, we have concentrated our efforts on the southern section (Southern Mimosa) of the Zamia/Mimosa Catchment.

This change in direction in the project framework occurred in June 2004 and has therefore been given due attention for a period of 12 months. Outcomes from this revised objective contained within this report will demonstrate that significant learning has occurred within this short period that could benefit the grazing industry now and into the future.

3 Methodology

3.1 Science

3.1.1 Paddock Scale (6–35 ha)

The paddock level was the smallest unit of monitoring area used to gain an insight into the impacts of grazing land management. Hillslope erosion, which is one of the three dominant erosion processes within a landscape, occurs predominantly at this scale. It is the unit of area where the majority of management decisions are made by primary producers and where grazing animals have a large impact. Management at this level affects other erosion processes, so the paddock plays an important role within the broader context of the landscape.

Paddock – History and Location

Paddock-scale monitoring sites (6–35 ha) are located at the property "Cowandilla" (24.41'S, 149.25'E), 25 km east of Bauhinia Downs. Replicated sites in close proximity were established to limit variations in climatic conditions, vegetation and soil types.

The sites were instrumented in June 1999 under a former Natural Heritage Trust (NHT) funded project. These sites were originally selected to investigate primarily cropping management practices reported to retard soil movement, improve water infiltration capabilities and increase production. Identification of applicable sites (both cropped and grazed) for instrumentation was co-ordinated through a combination of local producer knowledge and spatial information developed by the Department of Natural Resources & Mines (NR&M). Sites were selected on land types dominated by brigalow/blackbutt with mostly sodic, texture- contrast soil types (Irvine 1999).

Originally both the cropped pasture (CP) and permanent pasture (PP) trial sites were cropped following the commencement of the Brigalow Scheme in the late 1960s. The PP site continued to be cropped until the mid to late 1980s when improved pastures, namely American buffel (*Cenchrus ciliaris*) was established. The CP site remained under cropping until October 2000 before re-establishment of improved pastures. Management of cropping sequences and grazing strategies was undertaken at the discretion of the property owners.

Equipment

Runoff was measured using eight-foot (2.44 m) parshall flumes located at the outlets of each contoured paddock. Depth of flow through the flume was monitored using a pressure probe connected to a Macquarie logger housed within a rainproof enclosure (Figure 3). Rainfall intensity and volume were measured using an electronic pluviometer supported by a manual raingauge. Runoff was sampled from the outlet of each parshall flume by an ISCO water sampler. Samplers were triggered at pre-determined runoff depths to enable a detailed analysis of soil erosion/runoff relationships across runoff events.

Figure 3: Paddock-scale equipment monitoring runoff (Feb 2000) in CP trial

Erosion Pins

Arrays of erosion pins were installed to measure hillslope erosion on major land types. Early analysis of data suggested that the wetting and drying cycles of some soils led to large inaccuracies in measuring changes in exposed pin height. The shrinking and swelling of these soils caused appreciable movement of the pins and/or surface level of soil with respect to the top of pins. As a result, data from this form of monitoring has not been summarised in this report

Ground Cover

Ground cover was measured using a 1 * 1 m quadrat at randomly selected areas of each paddock following a runoff event. Between five and 10 observations were performed depending on the uniformity of ground cover, with resultant values weighted across the representative areas within each paddock. This information was gathered to provide an insight into cover/runoff relationships as well as validating Landsat images for catchment condition trend analysis.

Brigalow Catchment Study (11–17 ha)

A nationally unique long-term study of the impacts of clearing and developing brigalow forest for cropping and grazing is located on the Department of Primary Industries & Fisheries Brigalow Research Station via Theodore in the Dawson Catchment of the Fitzroy Basin. The base data set includes rainfall and runoff from three adjoining catchments (11.7–16.8 ha) since 1965. Collection of data on soil and productivity changes commenced after clearing two of the catchments in 1982 (one for cropping and one for grazing). The site is representative of the eight million hectares of brigalow bioregions; treatments cover the two major soil types and land uses.

Data storage and analysis

Data recorded from electronic loggers is stored in the HYDSYS state-wide database (Kisters, 2004) supported by NR&M. This information is located on the local Biloela server under w:\hyd. Other landscape data is stored on the local Biloela server under g:\science\neighbourhood_catchments. Analysis of data was performed using various regression and statistical concepts and modelling techniques.

3.1.2 Property scale (~ 3 500 ha)

When determining the impact of grazing management at the property level, gully erosion combined with hillslope erosion processes impact on water quality. Capturing relevant data from an individual property was not appropriate as not all major land systems could be represented. Properties throughout the catchment were used to provide input into erosion processes across land systems and land types. A land type layer for the Zamia/Mimosa Catchment was not available but was deemed essential for greater interaction between science information and producer knowledge. Through the use of local producer knowledge and existing NR&M data layers, property maps depicting land types for the Fish Creek NC were developed. Using a similar methodology but without producer input, a subsequent land type layer for the Zamia/Mimosa Catchment was created.

Property mapping – identifying land types

Property maps were used as a tool to link science information with producer knowledge. Mapping properties within the confines of a neighbourhood catchment helps benchmark current land use and management practice to provide insight into, and quantify their impact on catchment water quality.

Property maps are useful because they can:

- Assist producers with identifying critical areas of learning that could address aspects of land management that need improving.
- Provide a visual means for sharing ideas for improvement with neighbouring producers, the project team and other interested parties.
- Help producers plan and implement individual property projects established as part of the CI&I process.

A survey across Fish Creek NC identified that local graziers tend to formulate grazing strategies with respect to the extent and productivity of land types that occupy a particular paddock. At present however, no land type mapping exists for the Fitzroy Basin. This means that producers generally rely on subjective estimates of land type areas within a paddock. Small-scale (coarse resolution) regional ecosystem and soil data layers are commercially available, but this information can only be used as a guide to what may occur at the paddock level on individual properties.

The survey revealed that adequate data and information integrated at the paddock level would assist producers to better plan and manage their properties. Spatial data sets identified as being essential included: paddock structure and area, topography, land type and drainage information, as well as infrastructure information such as watering point locations.

This information would assist landholders with:

- planning infrastructure, access tracks and land use
- planning watering point placement and pipeline networking
- formulating grazing strategy and estimating stocking rates
- calculating fertiliser and herbicide application rates
- planning erosion control measures such as contour banking.

This information would also adequately meet the requirements of current grazing land education packages, introduced government policies and regulations, and potential financial support from funding bodies.

Property mapping - methodology

None of the members of the Fish Creek NC had any form of property maps at their disposal and their knowledge of current property mapping technology was limited. Most group members were confident in their knowledge of local land types, their extent and location within the landscape.

The information used to create property and land type data sets was drawn from this knowledge and referenced against existing regional ecosystem and land system mapping. In cases where producers were unsure of their property's land types, field verification took place through property visits. Information gathered during these visits provided the project team with a greater understanding of the management units that producers most commonly work with, the land type.

Base maps, consisting of a satellite image (spot_4 panchromatic 10*10 m pixels) and property boundary lines were created from existing data. The average property size (3 500 ha) was pictorially represented on A3 size paper at a scale of 1:25 000. Producers felt this size provided adequate resolution of farm infrastructure, land types etc. and was portable for field based exercises. Producers drew in property infrastructure and land type information on these base maps and the information was entered later into a geographic information system (GIS), Arc View 9.0. Intermediate maps were then created and printed.

Mapping errors were identified and amended by exchanging intermediate maps back and forth between participating producers and the project team. CI&I meetings provided an ideal avenue for this exchange to take place. The process ran over three consecutive CI&I meetings until final property and land type maps were printed, laminated and presented to producers.

A subsequent land type layer for the Zamia/Mimosa Catchment was created by developing relationships between land systems, regional ecosystems and the Fish Creek NC land type layers (Figure 4). Over 100 regional ecosystems classifications and 25 land systems were reclassified into 10 major land types (Table 1). These were consistent with known and already established land types throughout the central west region of Queensland.

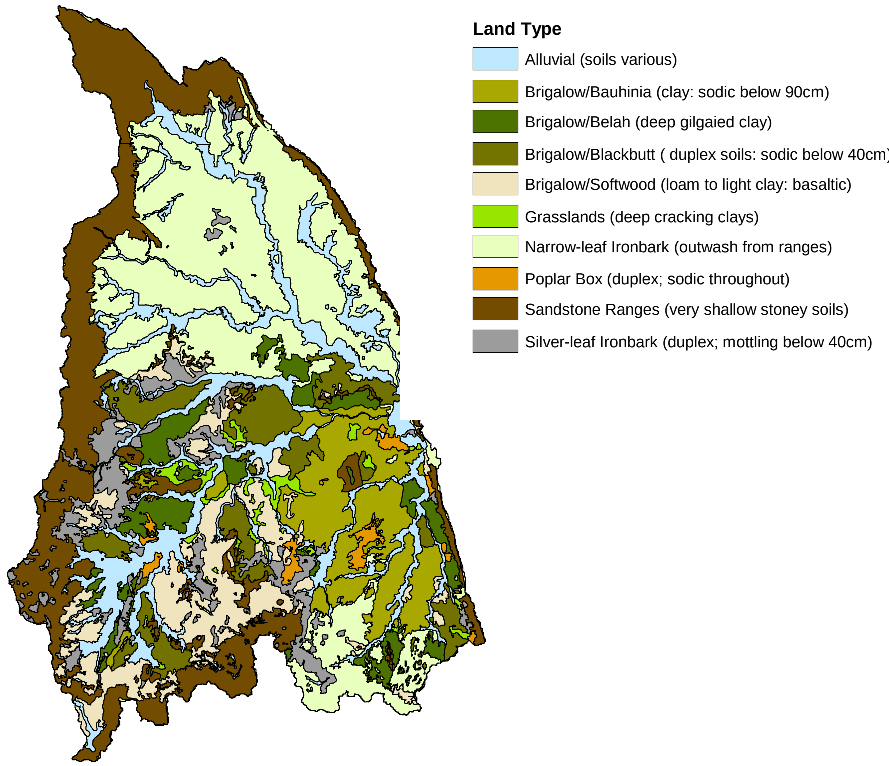


Figure 4: Land type map of the Zamia/Mimosa Catchment

LTC	Land Type	Catchment Area %
1	Sandstone ranges (shallow stony soil)	22
2	Narrow-leaf ironbark (outwash from ranges, stony soil)	25
3	Brigalow/blackbutt (duplex soils, sodic at depth 40cm)	7
4	Alluvial (various soil types)	13
5	Brigalow/belah (gilgaied deep clay)	5
6	Brigalow/softwood (basaltic clay and loam)	10
7	Silver-leaf ironbark (duplex soils, mottling apparent below 40 cm)	7
8	Poplar box (duplex soils, highly sodic throughout)	1
9	Brigalow/bauhinia/blackbutt (cracking clay, sodic at depth 90cm)	9
10	Grasslands (deep cracking clays)	1

Table 1: Ten major land types in the Zamia/Mimosa Catchment

Gully monitoring

Literature review shows that the three main areas of soil movement are through hillslope (largely controlled by ground cover and slope length), stream bank and gully erosion processes. With the exception of fringing mountain ranges and brigalow/softwood hills, over 70% of the catchment consists of undulating country (slope 1–5%), with low relief. Ground cover observations at the catchment level indicate that on average, 85% of the total area is covered by a minimum 40% ground cover all year. Ideally, ground cover under permanent pasture should be in the order of 60% or higher but at 40%, hill slope erosion is generally low under these conditions (Scanlan *et al.* 1996, McIvor *et al.* 1995).

Prosser and Winchester (1996) and Wasson *et al.* 1998 show that erosion from stream and gully banks can generate up to 90% of the total sediment yield from a catchment. Observations made throughout the Zamia/Mimosa Catchment over a period of five years indicate little active erosion is occurring along stream banks. With minimal hillslope and stream bank erosion within the catchment it was assumed that active gully erosion accounts for the majority of observed sediment discharge.

Identification of gully network

Aerial photographs combined with GIS interpretation of land system mapping enabled initial identification of potential areas to monitor the impact of gullies within the landscape. Provision of a land type map would have further refined this process to allow a more detailed analysis of gully erosion at this scale. At the commencement of the project, no land type map existed to establish such a relationship.

Gullies were selected on a range of attributes that included:

- location of gullies within the landscape
- dimension of gully profiles within each land system
- activeness of gully erosion
- relationship between vegetation and permanent grassed pastures.

Five gullied areas across the catchment were selected with aspects of gully development monitored using varying techniques as discussed below.

Gully head

Erosion pins were strategically placed around the head of each gully to establish the rate of gully head advance. Measurement of advance was recorded using a carpenter’s square to establish distance between pin and edge of gully head. Measurement of gully depth established the volume of soil removed on a yearly basis.

Gully edge

Erosion pins were used to measure side slumping of gullies. Similar methods documented to measure volume of soil from gully heads were used to measure gully side slumping.

Gully profile

Gully profiles were measured using surveying techniques (staff and level) along the length of selected sections of representative gullies. Variations in gully profiles could then be attributed to loss or gain of soil from gully heads, side slumping or removal of soil from the gully floor.

Streambank monitoring

Streambank erosion was monitored from June 1999 using visual observations at different locations throughout the catchment. The State of the Rivers report (1995) concluded that bank stability within the Zamia/Mimosa Catchment was "stable to very stable." Visual observations were therefore deemed an appropriate method of measurement technique.

3.1.3 Catchment scale (31–8585 km^2)

History and Location

The Zamia/Mimosa Catchment is situated 20 km west of Moura in central Queensland. Bounded by the Dawson Range in the east, Expedition Range in the west, Palmgrove Range in the south and extending into the Blackdown Tablelands in the north, this catchment (8 585 km^2) is approximately 16% of the total area of the Dawson Catchment (Figure 5). Until the mid 1960s, the majority of original vegetation remained until the introduction of the Brigalow Scheme. Broad-scale clearing followed by cropping and increased grazing intensity dramatically altered the landscape. Drought and low commodity prices resulted in the shift back to predominantly a grazing environment during the 1980s and 1990s. Today, the area is dominated by grazing with only 5% still permanent cropped.

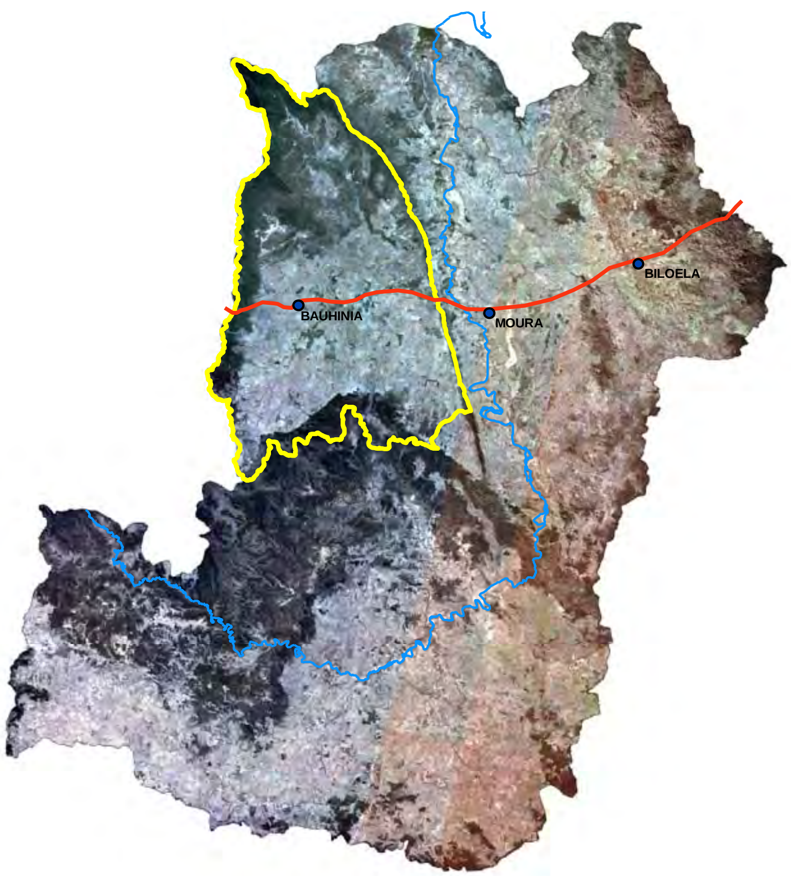


Figure 5: Location of Zamia/Mimosa Catchment (yellow outline) in the larger Dawson Catchment

Three catchments were selected in June 1999 to complement the paddock-scale monitoring sites established on the property, ‘Cowandilla’. Individual catchments dominated by land use and land system characteristics were established within a larger monitored catchment. In January 2003, an additional 16 catchments were selected on the basis of land use, land type and size of contributing area (Figure 6, Table 2). Two of the 16 catchments were electronically instrumented while the remainder have been manually monitored since the commencement of the project.

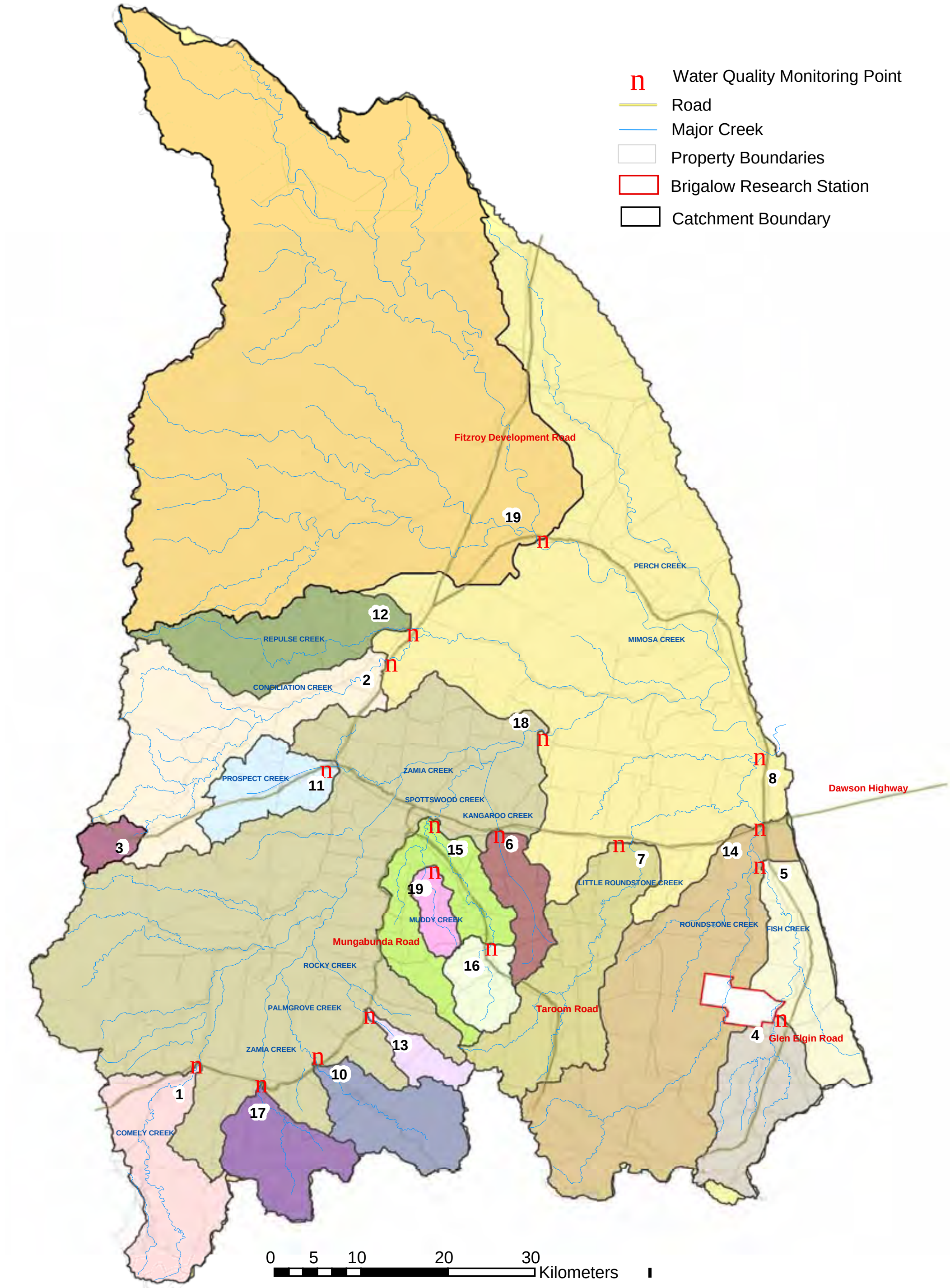


Figure 6: Catchments of the Zamia/Mimosa Catchment (Note: Catchment identification is described in the table below)

Catchment ID	Catchment Creek	Monitoring Location	Total Area (Hectares)	Catchment Area (% of Total Area)
1	Comely	Mungabunda Road	21810	2.5
2	Conciliation	Dawson Highway	40835	4.8
3	Conciliation	Fitzroy Development Road	3135	0.4
4	Fish	Brigalow Research Station	16395	1.9
5	Fish	Napunyah	35571	4.1
6	Kangaroo	Dawson Highway	8323	1.0
7	Little Roundstone	Dawson Highway	28253	3.3
8	Mimosa	Bears Lagoon Road	858550	100.0
9	Muddy	Muddy Creek	3984	0.5
10	Palmgrove	Mungabunda Road	14856	1.7
11	Prospect	Dawson Highway	11317	1.3
12	Repulse	Fitzroy Development Road	21479	2.5
13	Rocky	Mungabunda Road	4108	0.5
14	Roundstone	Dawson Highway	100602	11.7
15	Spottswood	Dawson Highway	28502	3.3
16	Spottswood	Taroom Road	7158	0.8
17	Zamia	Mungabunda Road	13055	1.5
18	Zamia	Oombabeer	255767	29.8
19	Mimosa	Redcliffe Station	241940	28.2

Table 2: Monitored catchments of the Zamia/Mimosa Catchment

Scale

Selecting applicable catchments with varying catchment areas was considered important to assess the role of sediment delivery when moving from a small to larger scale. This approach was adopted for the Spottswood Creek Catchment where two smaller nested catchments were electronically monitored (Taroom Road and Muddy Creek). The Dawson Highway site (Spottswood Creek) allowed objective gauging of the effects of increasing catchment area in respect to sediment delivery.

With the Fitzroy Basin dominated by upland catchments (80% of total area), we investigated the role of such catchments in the landscape. Catchments were selected on the basis of differing components of land use, land types and location within the landscape. Aspects of management within each land use were not quantified owing to the complexity of relating water quality to different management within individual land uses, particularly at the catchment scale and within the timeframes of the project. The location of such catchments however posed some access problems for the project team following rainfall.

Equipment

All electronically monitored catchments were established with equipment designed or recommended by the hydrographical section of NR&M who undertake stream monitoring throughout the state of Queensland. Flow depth, rainfall and water quality were the three main parameters recorded at each monitored catchment site. Flow depth was recorded by a pressure transducer that responds to changes in regulated carbon dioxide (CO_2) pressure when changes in stream height occur. Rainfall intensity and volume were measured using a pluviometer attached to the shed housing the electronic equipment (Figure 7). Water quality samples were extracted using an ISCO sampler triggered by a pre-determined depth of flow.

Figure 7: Catchment scale electronic equipment measuring stream depth, rainfall and water quality.

At the manually monitored catchments, surveying of the profiles of the streams provided an insight into the behaviour of stream discharge during a runoff event. Gauging boards were positioned to record depth of flow and maximum height for each runoff event. Manual water quality samples were taken when project members or producers were passing by the particular stream. Water quality parameters analysed from these catchments were identical to the electronic monitoring catchments.

Water quality

Water quality parameters were selected in relation to their impact on stream habitat, stream plant and animal communities and the Great Barrier Reef. These parameters are also important to the agricultural community as loss of soil and nutrients are a constant concern. The table below (Table 3) summaries the important water quality parameters monitored in the context of this project.

Parameter	Analysis Method	Reference	LRL	Units
Total Suspended Solids	Gravimetric	APHA 2540D	10	mg/L
Turbidity	Nephelometric	APHA 2130B	1	NTU
Total Phosphorus as P	Automated Digestion	APHA 4500-P.H	0.002	mg/L
Total Kjeldahl Nitrogen as N	Persulphate Digestion	APHA 4500-N C	0.02	mg/L

Table 3: Runoff water quality parameters measured in the Zamia/Mimosa Catchment. (Note: LRL – Lower Reporting Limit)

Note: Total Kjeldahl nitrogen (TKN) was analysed in preference to total nitrogen (TN) as this is the preferred method used for water samples containing high sediment loads of refractory origin.

The pesticide family Triazines were analysed in runoff from catchments as they pertain to major chemicals used in broad-scale dryland cropping and grazing in Queensland (Table 4). Throughout the project, random water samples were tested for Organophosphates and Organochlorines with nil detection of either pesticide family.

Substituted Urea Herbicides

Parameter	Analysis Method	Reference	LRL	Units
Herbicide Tot Subs Urea	HPLC/UV Detection/LCMSMS	USEPA 3510	0.01	µg/L
Herbicide Diuron	HPLC/UV Detection/LCMSMS	USEPA 3510	0.01	µg/L
Herbicide Fluometuron	HPLC/UV Detection/LCMSMS	USEPA 3510	0.01	µg/L
Herbicide Tebuthiuron	LCMSMS	In House	0.01	µg/L

Triazine Herbicides

Parameter	Analysis Method	Reference	LRL	Units
Herb. Simazine	GC/NPD/GCMS	USEPA 507	0.1	µg/L
Herb. Tot Triazine	GC/NPD/GCMS	USEPA 507	0.1	µg/L
Herb. Atrazine	GCMS Detection	USEPA 3510/8080	0.02	µg/L
Desisopropyl atrazine	GCMS	In House	0.1	µg/L
Desethylatrazine	GCMS	In House	0.1	µg/L

Table 4: Major chemicals analysed for in runoff water from the Zamia/Mimosa Catchment

Catchment condition – ground cover

Using traditional methods such as quadrat or step point techniques to assess ground cover dynamics at the catchment level is not practical given the scale to undertake such an exercise. The ability of space-borne remote sensing methods to estimate ground cover over such areas has undergone major advancement in recent years and for our project has provided a partial solution to the problem.

Climate Impacts and Natural Resources Systems (CINRS), Natural Resource Sciences, NR&M, Queensland supplied satellite derived ground cover images for the Zamia/Mimosa Catchment. The images were produced by applying a multiple regression bare ground index (MRBGI), developed by the department to scenes captured from the Landsat satellite sensor.

Combining all available Landsat scenes from 1988 through to 2004 then created ground cover mean and trend summary images. The summary images discriminate areas of high (>60%), medium (40–60%) and low (<40%) ground cover and ground cover trend (increasing/no change/decreasing).

Before we could use the mean and trend summary images to assess catchment condition, validation for the use of MRBGI within the Zamia/Mimosa Catchment was necessary. With the exception of brigalow/softwood scrub, containing light-coloured basaltic soils, most of the land types across the catchment have similar properties to those that had undergone prior calibration. For this reason the MRBGI was expected to perform well in our region.

Ground cover estimates derived from traditional quadrat sampling methods completed on 22/12/1999 were compared, using regression analysis, with estimates derived from applying the MRBGI to a Landsat scene captured over the same area on 30/12/99. Information from other dates was available, however, dates that most closely coincided with known rainfall events were chosen for comparison.

Estimates were sorted on the basis of land type and regressions were performed for each land type. Data from land types that did not respond well to the MRBGI were omitted. The remaining data was pooled and a final regression performed. Examples of MRBGI ground cover percentages in comparison to quadrat ground cover percentages are shown in Figure 8.

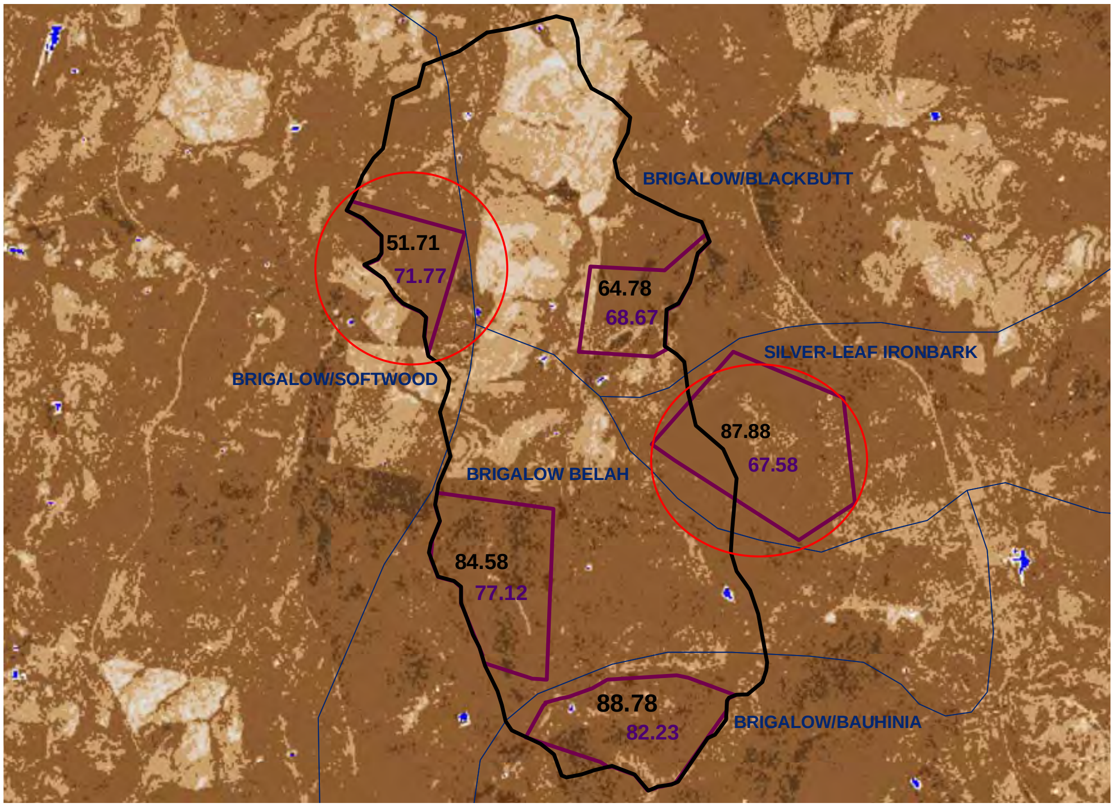


Figure 8: Location of sample points within Muddy Creek Catchment, used to validate the MRBGI across the larger Zamia/Mimosa Catchment. MRBGI groundcover percentages (purple) are shown in comparison with quadrat ground cover percentages (black). Examples of land types that did not respond well to the MRBGI are circled in red.

Gully density

Prior research in the Zamia/Mimosa Catchment concluded that the impact of gully erosion on suspended sediment levels and sediment loads was not well understood or quantified. A first-step approach for gauging the impact of gully erosion was the use of the SedNet modelling software. For the model to make this assessment, spatial data representing gully extent and distribution within the confines of the catchment was required. We sourced the most relevant information available, which was the default national-scale gully density grid developed in 2000 as part of the National Land and Water Resources Audit (NLWRA). The SedNet model was run using audit data where predicted sediment loads from gully sources were low and not at a magnitude to account for observed sediment discharge.

The audit includes the Fitzroy Basin as part of coastal Queensland, one of four national regions that were mapped. Gully density prediction was achieved through the generation of numerical rule-based predictive models using information gathered from only 428 stereo aerial photo pairs.

In comparison to other mapped regions across the nation, gully density predictions for coastal Queensland are among the worst. The authors of the report held the least confidence in their results for this region and cited a lack of available aerial photographs and coarse-scale environmental variables used in the model, as possible reasons for such poor results. It was presumed that the development of a detailed gully density map using information at a finer resolution and increasing the sample size from which data would be extrapolated could yield better results when modelled using SedNet.

Due to time constraints it was not practical to map gully density across the entire Zamia/Mimosa Catchment. Instead a similar approach to that of the NLWRA was developed. Firstly, the physical landscape was analysed and divided into land units based on known environmental attribute values (e.g. land use, soil type, hill slope). This was achieved by intersecting a land type spatial data set (developed in 2005) and land use spatial data set (developed in 2000, Figure 9) within a GIS environment. Ten percent of each land unit was then mapped and the resulting gully density values modelled across that entire land unit.

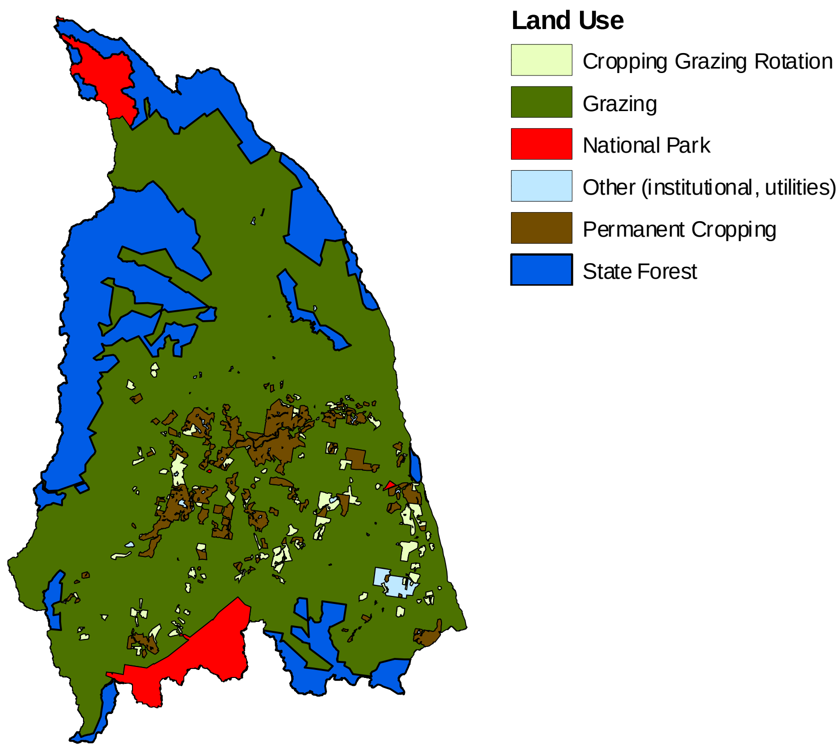


Figure 9: Land use (NLWRA data 2000) within Zamia/Mimosa Catchment

The development of land types information ensured that variability within geology; soil type, hill slope and topographic relief attributes was well represented in the landscape analysis. Annual rainfall values are consistent across the entire catchment, hence this environmental attribute used by NLWRA to develop land units was omitted in our assessment.

Gullies were digitised on screen from scanned aerial photographs (scale 1:40 000) taken in July 2000. A stereoscope was employed to assist with photo interpretation in areas of high tree cover and to help delineate gullies from roads, cattle tracks and natural drainage patterns due to terrain. Gully density was calculated by dividing the length (km) of gullies by their containment area (km^2).

Early evaluation of mapped data revealed that mapped areas less than 10 km^2 produced results that could not be verified. Values generated from such a small sample size were often extremely high or extremely low. The minimum sample size for each land unit thus became 10 km^2. Land units less than 10 km^2 were merged and mapped as a single unit.

To validate the results, manual aerial photograph verification of areas of high, medium and low predicted gully density outside the sample area was carried out. The results from this exercise gave us confidence that the method reasonably predicted areas of actual high, medium and low gully densities.

SedNet

Further understanding of landscape processes at the catchment scale required the use of catchment modelling tools. The SedNet model, developed by CSIRO was considered to meet the needs of the project (Wilkinson *et al.* 2004). Data layers to populate the model were either sourced from NLWA or constructed by the project team (mentioned above in gully density section). Resolution of datasets applicable to the Zamia/Mimosa Catchment scale were used in the SedNet model.

Refinement of the SedNet model to the neighbourhood catchment scale was not undertaken due to a lack of confidence in the accuracy of datasets at this scale. Furthermore, a minimum of 15 years of recorded water quality data is recommended to account for variations in climate patterns. Water quality data gathered even from prior projects at applicable catchment scales only covers a six-year timeframe.

Initial analysis of the SedNet model has been performed during this project. Further refinement of the model could alter the results generated from the Zamia/Mimosa Catchment. Inclusion of data from prior projects could also dramatically alter the final results. It should be used only as a guide to assist in identifying catchments that may demonstrate signs of high levels of pollutant delivery into streams. Ground-truthing is recommended to further clarify the impact of any particular catchment and the erosion processes that could contribute to the current trends in water quality.

Demonstrating link to land management

Two catchments were monitored prior and during the establishment of neighbourhood catchment groups. The aim was to assess changes in land management undertaken by individuals within these groups and corresponding changes in water quality. Formation of these groups (Section 3.2.1) occurred in September 2004. Given the timeframe to the completion of the project, little confidence in results pertaining to change in management can be drawn from one rainfall season. The establishment of other catchment monitoring sites may be used in the future to provide a benchmark for changes in water quality with changes in land management.

3.2 People

Acknowledgement that new thinking and action is required to achieve sustained improvement in land management led to a need to explore what methodology would be most appropriate. An adaptive management methodology: Continuous Improvement & Innovation (CI&I) was chosen for this project because it possesses principles and assumptions that best complement this project’s focus on the human dimension of land management and change.

> *The methods of natural science, extremely productive in enabling external observers to discover the regularities of the natural universe, are exceptionally difficult to apply to human affairs (Checkland 1992, p. 1).*

Because CI&I has a different set of values and hence different aims from natural science and other forms of research, CI&I makes different choices, which lead to different methods. The CI&I approach is emersed in a research and development paradigm that is designed to bring about change. It is important that we are clear about the meaning of research and research & development. Definitions follow:

Research is a series of steps searching through experiences that have already happened in order to gain a clearer understanding. This often leads to new knowledge.

Research & development is a tightly coupled process of research and application of new knowledge by new practices, processes, systems, products and/or services to achieve a specific outcome in the work or market place.

Our new research question, "What is the most appropriate scale of science and how do we best work with people (beef producers, scientists, government agencies, environmental bodies etc.) to encourage change in natural resource management?", clearly requires an approach with a research and development paradigm where change is an outcome.

> *…if the outcome we want is change and innovation in the context of improving economic performance, responsible environmental management and social wellbeing, then we need to purposefully design and implement processes and projects to achieve this. In addition, in these processes and projects we need to use management and improvement processes, techniques and tools that are congruent with human systems-based approaches for change and innovation (Timms & Clark 2001, p. 2).*

In a nutshell the CI&I approach is three-pronged: it is a method of social investigation involving the full participation of the community; it is a capacity building process; and it is a means of taking action for change - improvement and innovation. CI&I moves away from models where people are dependent on a few scientists and innovators.

CI&I involves individuals in teams, networks and partnerships regularly and frequently focusing their thinking and action to achieve improvement and innovation, now and in the future. This approach complements the neighbourhood catchment philosophy, working with people and science at a specific scale to achieve change. It permits the grouping of people in a common area with a shared focus to improve their collective management of the landscape.

CI&I enables people to:

1. Improve the focus of their thinking and action on achieving targets that make a real difference.
2. Identify and use the most effective and efficient tools and technologies to achieve targets.
3. Achieve improvements and innovations in performance, profit, environment, efficiency and wellbeing.
4. Improve and innovate systems, processes, practices, techniques, tools, technologies, products and services.
5. Discover and create new concepts for business and wellbeing.
6. Think and manage creatively in dynamic environments.

Please note a glossary (Appendix 9.10, p. 126) of key terms is included at the end of this report.

3.2.1 People - how we worked

- Initial contact was made with identified leaders within the Zamia/Mimosa Catchment for their input on how the project could best proceed and an invitation to form a project steering group. A survey calling for expressions of interest from local producers in being part of a steering group was distributed throughout the catchment in 2003. The first steering group meeting was in June 2004.
- We also extended an invitation to the local Agforce branch to work in partnership with us to improve water quality.
- Working together we identified people that would make a positive contribution to the project and discussed their location in relation to identified drainage catchments. With their assistance we identified three neighbourhood catchments to initiate establishment of groups. Ideally, catchments had to possess the following criteria:

- presence of a key producer who would take on a leadership role
- naturally bounded catchment
- size of catchment
- social characteristics
- location of monitoring stations
- a dominant land use.

- Producers were invited by a key producer to participate in the new neighbourhood catchment groups. Different strategies to form these groups were used depending on the key producer.
- We aimed at meeting on a monthly basis from June 2004 to June 2005.
- A Six-Step process (Figure 10) was implemented to maximise the involvement of producers in a process, which captured their experience, knowledge, skills, attitudes and perceptions. This process was developed to ensure that the adoption of improved land management would be optimised.

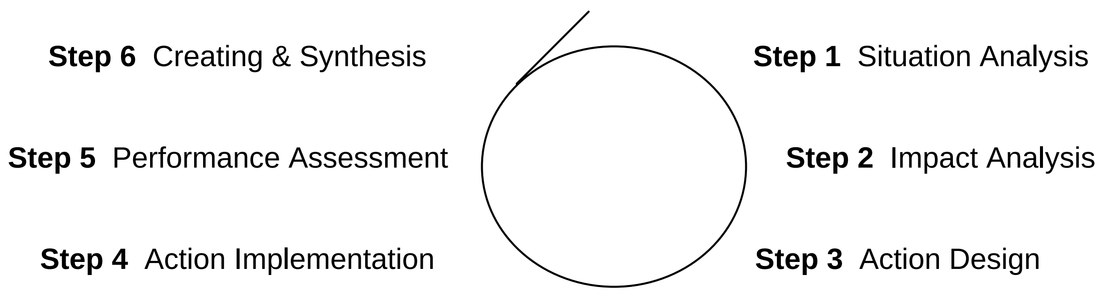


Figure 10: Continuous Improvement & Innovation Six-Step process (Clark *et al.* 2000)

This Six-Step process represents a process of change. For change to be successful, seven features are required:

- pressure for change
- clear shared vision
- actionable first steps
- capacity for change
- models the way
- reinforce/solidify the change
- evaluation and improvement (Cacioppe 1997).

The Six-Step process has incorporated these features into a designed series of steps, (Table 5). Associated with each step are specific questions, outcomes and tools as shown in Table 5. These specific questions, outcomes and tools are required if change is to be achieved.

Step	Question	Outcomes
Step 1 Situation Analysis	What is the current situation? What are opportunities for action to improve the situation? Tool: Focusing Framework	1. Clearly understood opportunities for action. 2. New thinking 3. Confidence in a good start.
Step 2 Impact Analysis	Which opportunities will make a real difference to the situation? What criteria & evidence will I/we use to decide which opportunities to invest in? Tool: Impact Analysis	1. Knowing which opportunities will impact on Focus. 2. Understanding why specific opportunities have high impact.

Step 3 Action Design	For each selected opportunity, what specific actions do I/we need to implement? How will I/we measure the effects of our actions? Tool: SMARTT Focus, Action Design	1. Action designed for impact on performance. 2. Individuals & teams confident in CSFs, KPs and KPIs. 3. Individual & teams committed to improved performance.
Step 4 Action Implementation	What specific actions am I, and others taking? How are we tracking the effects of our actions? Tool: Reporting Framework Observation Question Idea Opportunity	1. High impact actions implemented. 2. Understanding of the effects of the actions.
Step 5 Performance Assessment	What happened as a result of my/our actions? What made a real difference? Why? Tool: Reporting Framework Observation Question Idea Opportunity	1. Performance improvement & impact on focus. 2. Effective & efficient team input in assessing performance. 3. Confidence that performance is being achieved.
Step 6 Creation & Synthesis	What new questions & ideas do I/we have now? What new and different needs and opportunities should I/we focus on next? Tool: Creation & Synthesis	1. New observations, questions & ideas for improvement & innovation. 2. New needs for improvement & innovation.

Table 5: Questions and outcomes for each step. (Note: CSFs – critical success factors, KPs – key practices, KPIs – key performance indicators, CI&I Unit Brisbane).

- There were four types of workshops within the CI&I six-step process. 1) start-up workshop, 2) support thinking & action workshop, 3) assess thinking & action workshop, and 4) assess & celebrate results & re-focus workshop. Figure 11 shows their sequence and devotion of time.

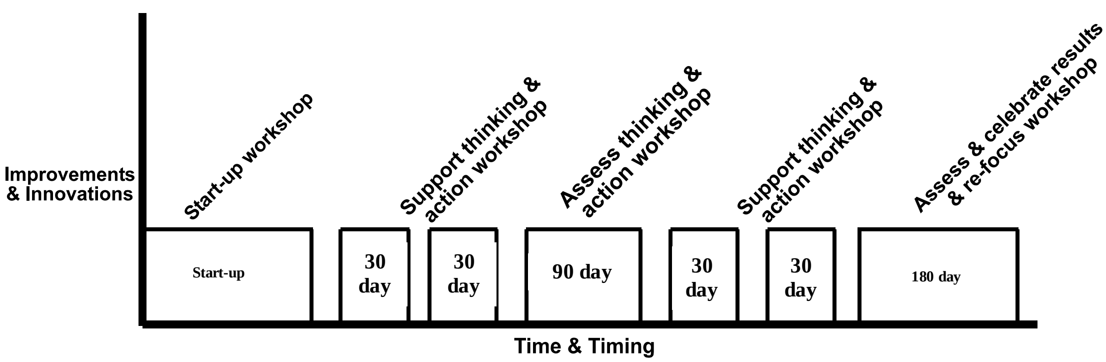


Figure 11: Sequence of workshop types and timing (CI&I Unit 2004)

- The following tools were used. SMARTT[1] Focus, Focusing Framework, Impact Analysis, Action Design, Reporting Framework (Samples in Appendix 9.1, p.101). The purpose of a sequence of these tools is to achieve new thinking and action. Think different things (new ideas and questions); do things differently and do different things; achieve different outcomes and performance.

[1] S specific, M measurable, A achievable, R relevant, T targeted, T timeframed

- The SMARTT Focus and Action Design tools were used to design individual projects that met participant needs and opportunities as well as the groups' outcomes/focus. Each project had key performance indicators (KPIs), which measured people's performance in progressing towards their project outcomes.
- Participants were given the responsibility of carrying out their projects and reporting on progress towards their KPIs.
- Support to achieve outcomes was emphasised. Increased motivation, confidence and enthusiasm were measured for these were qualities that would provide evidence as to the effectiveness of support provided and hence the effectiveness of the CI&I approach.
- Support was provided at workshops by all participants and at one-on-one sessions by project team through feedback on how projects could be improved. Feedback was in the form of observations, questions, ideas and opportunities.
- Regular workshops and support sessions to discuss feedback, and develop and implement strategies to maintain the momentum of the project and individual projects occurred.
- Groups included wife and husbands with group size being 8-17.
- The participants determined their own areas of need for more information.
- Established and maintained partnerships with CSIRO, DPI&F, Fitzroy Basin Association and Brigalow Research Station to provide specialist input in the writing and review of individual projects.
- Data was collected in a systematic, comprehensive and rigorous way; systematic because evaluation occurred throughout the project; comprehensive because different techniques to gather feedback were used and rigorous because the generation of good ideas that emerge out of good understanding is a sign that the project has generated good practical theory (Figure 12). The stronger our theory, the more focused will be our activities, because we will be understanding more deeply why we are doing or valuing (or not valuing) this rather than that, and what the effect has been (Wadsworth 1977).
- Qualitative and quantitative data were collected. This is a strength for the use of a range of data enhances learning. Qualitative data helps us to understand people's perceptions as well as 'hard facts'. It helps to understand situations in which quantitative measures may be misleading. It also helps prevent us overlooking things which may seem obvious, and it may lead researchers to question things others take for granted.
- Data was collected throughout using written evaluations, group and one-on-one discussions, journal entries, CI&I tools, project team observations and written summaries, Local Best Practice technique, and verbal feedback from participants.
- Qualitative evaluation methods were used to assist in the fine-tuning of the CI&I approach for our context and evaluation of the overall project. The technique of triangulation (measurement of phenomena under two or more different perspectives or ways), as recommended by Burgess (1984), and grounded theory Wadsworth (1997) and critical self-reflection, as suggested by Argyris, Putnam and McLain Smith (1985) and Kemmis and McTaggart (1988) were used.

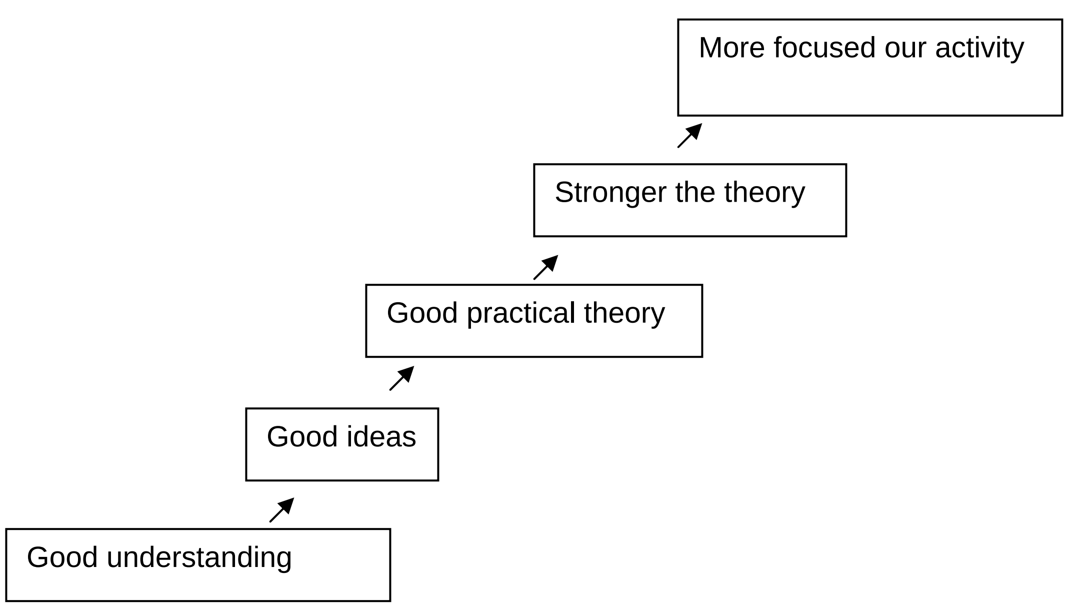


Figure 12: Generating good practical theory and more focused activity

4 Results & Discussion

4.1 Science

The results and discussion section has been written in the following style. As with the methodology section, scale of measurement from the paddock to catchment has been individually reported on within this section. The paddock (4.1.1) and catchment (4.1.3) sections have the same sub headings as follows:

- Rainfall
- Seasonality
- Runoff
- Ground cover/catchment condition
- Soil loss and sediment concentration
- Nutrients
- Pesticides
- Summary.

The catchment section also contains additional sections:

- Rainfall radar technology
- Gully density mapping
- SedNet
- Future work.

The property section (4.1.2) also follows on from the methodology section with detailed sub-headings as follows;

- Property mapping
- Land type mapping
- Gully erosion
- Summary and
- Future Work.

Issue of scale

Research was performed on vastly different scales depending on the issue under study. Scales included *paddocks* (6–35 ha), *properties* (~ 3 500 ha in central Queensland), *catchments* (10 ha–50 500 km^2) and *basins* (Fitzroy Basin is 142 000 km^2).

For the purposes of this project, we define a paddock as a discrete management unit on a property. A property is a discrete economic unit comprised of many paddocks. A catchment is an area of landscape encompassing numerous properties that drain into a single water flow (waterway, creek or tributary). The quality of water leaving a catchment integrates the effects of all activities across that catchment. This means the residents in a neighbourhood catchment are jointly responsible for, and share an interest in, the quality of their runoff water. Catchment water quality affects larger watercourses further downstream and, in the Fitzroy Basin, can ultimately affect the Great Barrier Reef.

This report refers to three levels of scale: paddock, property, and catchment.

4.1.1 Paddock

Prior research into the effects of cropping and grazing at the plot to paddock-scale have documented the aspects that determine the scale and magnitude of runoff water resulting from rainfall. The basic factors determining runoff response include the quality and percentage of total ground cover, size and intensity of rainfall events and soil water deficit. We briefly report on these factors but will devote the interpretation of results to examining the transitional phase of moving from a cropped land use to a permanently grazed pasture.

All results dating from 2001/2002 to 2004/2005 under the cropped pasture (CP) trial relate to the transition of this land use back to a permanent pasture. The permanent pasture (PP) trial has been under the influence of grazing for the last 15 years. Results from changing land use are highly relevant to this catchment given the dramatic increase in grazing in the last 15 years. When viewing catchment-scale results, the reader must be aware that given this transition in land use change, areas deemed as permanent grazed pastures may still be exhibiting signs of a cropping land use in terms of runoff response.

Rainfall

Given that a rainfall year correlates to pasture growth in the northern regions of Australia, rainfall totals were measured from July 1st to June 30th in the following year. Since June 1999, the paddock sites received below average rainfall (<684 mm) for every rainfall year (Figure 13). All months except for August, October and November experienced less than average monthly rainfall totals over the five years. Critically the months of December and March received only 63% and 68% of their long-term monthly rainfall totals respectively.

Rainfall intensity (I30 mm/hr) of events that produced runoff generally occurred at a one in one year recurrence interval. Only 7% of rainfall events had higher intensity recurrence intervals with the highest recorded at a one in 20 year recurrence interval.

Seasonality

As expected, a strong seasonal influence on rainfall and runoff was apparent. Summer produced the highest percentage of runoff-producing rainfall (54%) and actual runoff (65%). The lowest percentages of both variables were recorded during winter (19% and 8% respectively). Spring recorded similar values of runoff-producing rainfall and corresponding runoff (27%).

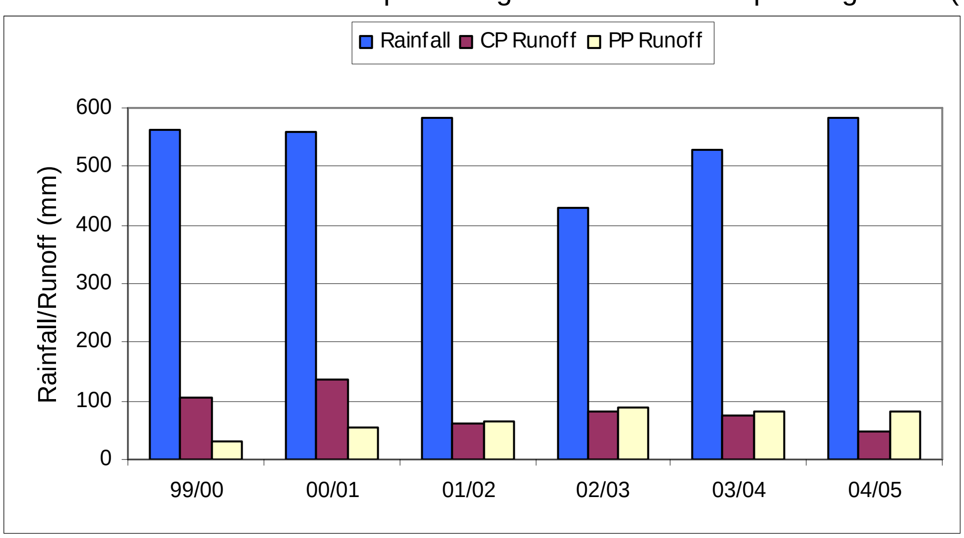


Figure 13: Annual rainfall and corresponding runoff (1999–2005) for the CP and PP trials

Runoff

Approximately 80% of all runoff-producing rainfall events were less than 40 mm (Figure 14). These events produced 38% of all runoff recorded. However, 40% of the total runoff resulted from rainfall events greater than 100 mm, which represented only 6% of the total runoff-producing rainfall events (Figure 15). This was produced from only two storm events (01/2002 and 01/2004), highlighting the effect that large isolated rainfall events can have on resultant runoff totals.

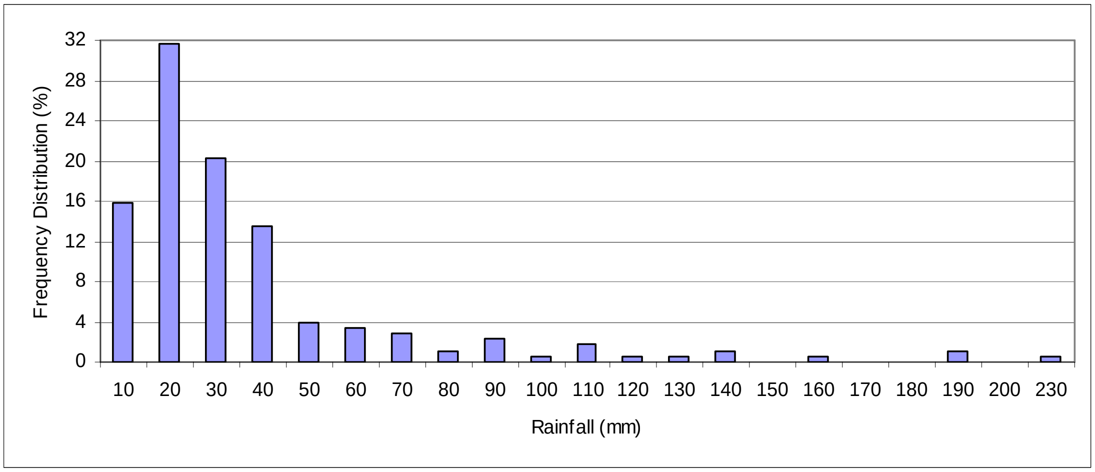


Figure 14: Rainfall event distribution (1999–2005) for all runoff producing events for the CP and PP trials

Significant differences in total runoff occurred between the CP and PP until 2002. Approximately 43% of the total runoff in the CP occurred under a cropped land use in the first two years. Following the transition period from cropping back to pasture, every subsequent year resulted in greater runoff in the PP. Few differences between the CP and PP occurred from 2002 until 2004, however the final year of the trial demonstrated a reduction in runoff in the CP. This can be attributed to one runoff event (130 mm) whereby rainfall intensity recorded in the PP was double that in the CP (26.4 mm/h).

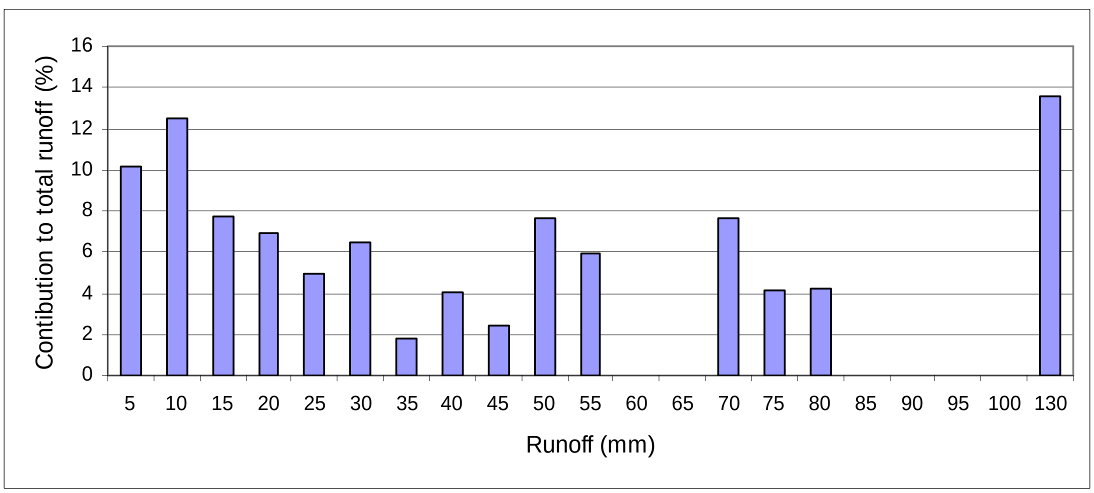


Figure 15: Percentage contribution to the total runoff (1999–2005) for all runoff totals on the CP and PP trials. Note: 5 mm category represents runoff totals of 5 mm or less, 10 mm category represents runoff totals between 5.01 mm and 10 mm. No runoff totals were recorded between 100–125 mm.

Ground cover

Ground cover in the CP demonstrates the transition from cropping to an improved grazed pasture from early 2001 (Figure 16). Little germination and establishment of perennial grass species was evident following the sowing of several improved pasture species. Fluctuations in ground cover during 2001 reflect the life cycle of predominantly annual pasture species. Following the growth of annuals through spring and summer, ground cover dramatically decreased into autumn and winter. From mid October to the end of December 2004, there was an increase establishment of perennial grass species, most probably as a result of high rainfall (>300 mm) during this period.

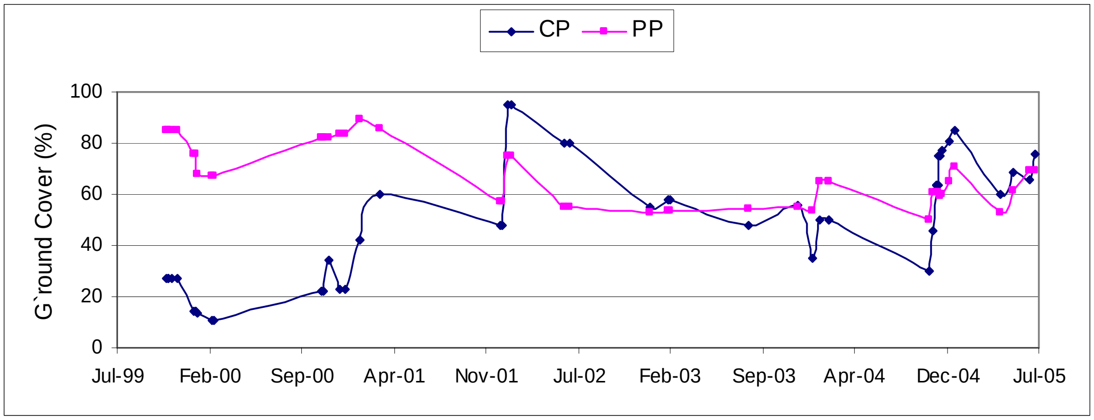


Figure 16: Ground cover assessed at every runoff event (1999–2005) for the CP and PP trials

Rapid decline in ground cover in the PP from March 2001 until January 2002 can be partially attributed to low rainfall (175 mm). Ground cover levels of approximately 55% were sustained from January 2002 until late October 2004. Sudden fluctuations in January 2002 and again in February 2004 were due to rainfall events of 200 mm or more. Only 1 160 mm of rain fell from January 2002 until late October 2004, well below the long-term average of 1 830 mm for the same period.

For two years (2001 and 2003) ground cover should have increased prior to the first major runoff event of the spring/summer season. Between 140–160 mm fell during mid November through to late December 2001 prior to the event in early January 2002. Daily rainfall totals between 19–37 mm fell on four occasions with no runoff recorded. More than 50 mm fell over two consecutive days, two weeks prior to the runoff event in early January 2002. Even then, no appreciable change in ground cover was observed from either the CP or PP. In 2003, 120–160 mm fell from early to mid October through to mid January 2004, the time of the first major runoff event for the season. This rain followed 70 mm in August, with daily rainfall totals in the three months before mid January between 10–26 mm recorded on nine separate occasions. On one occasion, a small runoff event resulted from early rainfall in December 2003.

Soil loss and sediment concentration

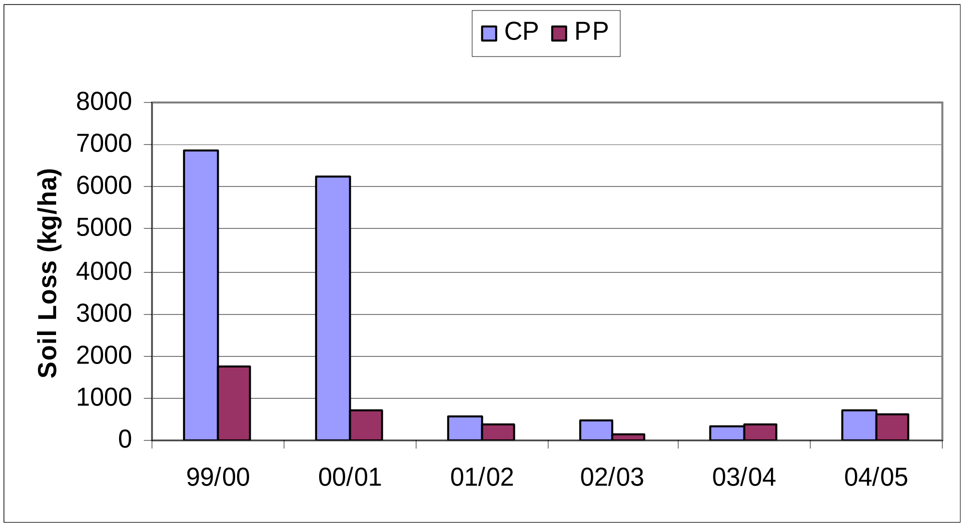


Figure 17: Annual total soil loss (1999–2005) for the CP and PP trials

In 2000 and 2001, the CP was still subject to the effects of cropping management. This resulted in the CP exhibiting significantly higher soil loss than the PP (Figure 17). Dramatic reduction in soil loss from 2002 onwards through changing land use resulted in a closer similarity between CP and PP (Table 6, p. 38). The exception to this trend was in 2002/2003 when soil loss from the PP was considerably lower (by 75%) than from CP. This can be attributed to one event where even though ground cover was similar (58% CP, 54% PP) and total runoff (80.4 mm CP, 87.7 mm PP) slightly greater under PP, significantly higher sediment concentrations in runoff water occurred (730 mg/L CP, 225 mg/L PP).

The critical period for reducing runoff and soil movement was the first runoff-producing rainfall event which generally occurred from late spring to mid summer. A minimum of 50–70% of the total annual soil movement and up to 100% of total annual runoff was recorded from these events. This is most often the period that has the lowest ground cover as perennial grasses have been dormant during the cooler autumn/winter period while cattle have continued to graze. The probability of runoff increases when rain falls in winter which increases the amount of soil water stored in the profile. Because pastures cannot use this soil moisture, less rainfall is required to create a full profile, leading to slower infiltration rates and increasing the potential of runoff. Similar results were obtained in the Brigalow Catchment Study in which October was the month with the largest percentage of annual runoff and soil loss under a grazed permanent pasture.

Soil types within the trials affected runoff through various surface and sub-surface properties. High sodicity levels at the soil surface dramatically reduced infiltration rates through dispersion of clay particles. These particles either seal the surface layer or move through the topsoil, filling air pores and reducing the infiltration capacity of the soil. A reduction in ground cover increases the soil surface exposure to raindrop impact compounding this effect and creating a noticeable hard capped layer. At soil depths of 0.4-0.6m, sodicity dramatically increased to extremely high levels. This in turn would have decreased soil infiltration rates as well as creating a barrier for root development to extract soil moisture below these levels.

Sediment concentration in the runoff water varied for the two trials. The CP had consistently higher sediment concentrations in runoff than the PP. Peak runoff rates were 45% greater under CP than PP. This would increase the potential for not only soil displacement from point of origin but also aid suspension of sediment in runoff. Total runoff was lower from CP over the same corresponding period of time. However, soil loss was greater, indicating the presence of higher sediment concentrations in runoff water. This has downstream implications because on these sodic duplex soil types, once sediment is suspended in runoff water, it continues to remain in suspension for a significant period of time.

Nutrients

Nutrient loss was similar to soil loss where a dramatic reduction in total kjeldahl nitrogen (TKN) and total phosphorus (TP) occurred following the change in land use from cropping to grazing in CP. Application of fertiliser for cereal production resulted in high levels of nitrogen and phosphorus leaving the system in runoff. From 2001/2002 onwards (except for 2002/2003), TKN and TP (kg/ha) for CP was less than PP (Table 6). Soil testing in March 1999 indicated that low to medium levels of nitrogen and low to high levels of phosphorus were present in CP. Given continuous cropping of these soils since the 1960s, nutrient rundown would have occurred as fertiliser application has been minimal. PP although cropped 15 years prior to the June 1999, would have had experienced less nutrient rundown during this period.

The critical period of late spring to mid summer when levels of soil movement are high has similarly high levels of nutrient movement. During 1999/2000, 40–42% of annual total TKN and TP was removed from both CP and PP. This increased to 90-95% of annual totals of both forms of nutrients in 2003/2004 following a major event in mid January 2004. Over the six year period, annual losses of TKN and TP for both trials averaged 75–80% during the critical period of late spring to mid summer.

Even though the patterns of nutrient loss and soil movement were similar, no definitive relationship exists for TSS and TKN or TSS and TP concentrations in water quality samples in CP. Poor correlation existed for TSS and TP prior to (R^2=0.35) and after land use change (R^2=0.46). This can be attributed to the extremely variable nature of event based TSS levels where values ranged from 103–23170 mg/L which were partially a response from the dispersive nature of the sodic, duplex soils. Corresponding levels of TP ranged from 0.05–4.2 µg/L, significantly less due to correspondingly low levels of available TP present within the soils. Initial analysis from the Brigalow Catchment Study (BCS) however demonstrates a good correlation between TSS and TP for cropped land use (R^2=0.76). Land type and associated soil types are not consistent between BCS and this trial but event based TSS levels from BCS (63–1 165 mg/L) were substantially less than our CP. This highlights the importance of land type effect that must be resolved at the larger catchment scale when assessing not only sediment movement but associated relationships with major nutrients.

Paddock	Rainfall	Runoff	Runoff	TSS	Sed load	TKN	TP	TKN	TP
1999/2000	mm	mm	%	mg/l	t/ha	kg/ha	kg/ha	mg/l	mg/l
CP	564	115	20	5520	8.48	13.03	3.41	9.01	2.03
PP	564	34	6	2240	1.59	1.42	0.27	3.97	1.09
2000/2001									
CP	586	142	24	4250	5.87	4.61	0.95	4.02	0.76
PP	539	74	14	830	0.75	1.27	0.13	1.95	0.35
2001/2002									
CP	622	71	11	1180	0.48	0.64	0.14	1.04	0.23
PP	587	59	10	640	0.38	1.03	0.27	1.67	0.44
2002/2003									

CP	412	80	20	500	0.50	1.71	0.26	2.55	0.45
PP	445	95	21	240	0.20	1.01	0.13	1.56	0.23
2003/2004									
CP	533	80	15	650	0.34	0.64	0.20	0.83	0.26
PP	525	94	18	610	0.36	0.91	0.27	1.66	0.46
2004/2005									
CP	677	69	10	2130	0.64	1.24	0.25	7.38	1.60
PP	667	87	13	1140	0.60	1.92	0.48	4.31	1.07

Table 6: Water, sediment and nutrient yields (1999 – 2005) for CP and PP trials

Pesticides

Pesticide analysis was performed in CP only during the period of cropping land use. Evidence of atrazine and associated by-products were detected in water samples following application of the chemical. Further insight into pesticide and herbicide detection was undertaken through an extensive monitoring program within the Zamia/Mimosa Catchment. It is of interest to the grazing fraternity that these results be examined in more detail (Section 4.13, p. 53) as detection products known to be used in the grazing industry occurred throughout the catchment.

Summary

Runoff and soil movement were higher under cropping. Moving through a transitional phase from cropping to a permanently grazed pasture dramatically reduced soil loss and runoff. Runoff continued to decrease in CP in 2004/05 however with higher sediment concentrations in runoff water, overall soil loss was greater in CP than PP. Peak runoff rates were higher under CP than PP which increases the potential for soil movement as well as aiding suspension of sediment particles within the runoff water.

The declining ground cover from March 2001 under both land uses indicates the increased level of attention to management that is required when rainfall is below average. Recovery of ground cover to sustained levels above 70% in mid 2005 would not have occurred except for above average (<300 mm) rainfall from October to December 2004. Re-establishment of perennial pastures in soil types constrained by high levels of sodicity requires a heightened awareness of appropriate management. Local producers suggest that establishment of pastures in sodic soils generally takes a minimum of five years.

Seasonal impact of runoff events are highlighting potential critical periods within the year where change in management by producers can be made. Maintaining a higher ground cover entering into mid spring to early summer would reduce runoff, soil and nutrient loss. Increased infiltration should translate into higher pasture yields and in turn, increased productivity. Where instances of substantial rainfall occurs during winter, soil water increases and is not utilised by current perennial grasses until rainfall occurs in spring. Rainfall through mid to late spring is more often than not associated with storm activity. This form of precipitation combined with high levels of soil moisture entering into this period greatly increases the potential of runoff occurring. It has been highlighted that up to 100% of annual runoff, 50–70% of total soil movement and 75–80% of total nutrient losses have resulted from rainfall in late spring to mid summer.

Ground cover responses to rainfall in PP appear to be limited by factors such as soil surface condition, soil chemical composition and soil biology. Management decisions also contribute to this process; their effect alone may be more significant than the fore-mentioned soil-related factors. The age of the pasture, succession of future populations, pasture composition and trend in pasture health need further understanding to enable a more detailed assessment of the changes in ground cover.

4.1.2 Property

Property mapping

Property and land type maps were created for 10 properties within the Fish Creek NC and two properties owned by members of the Zamia/Mimosa Catchment steering group (Appendix 9.5, p. 120).

These maps add value to planning and management decisions at the paddock to neighbourhood catchment scale. They have provided support for the development of individual producer projects (part of the CI&I process) and eased the transition from thinking at the paddock scale to thinking at the neighbourhood catchment scale.

In addition to the laminated maps, property owners received an A3 size field manual. The manual consists of individual property and land type maps, a neighbourhood catchment map, created by merging all property and land type maps and a ground cover trend map (information supplied by CINRS, Indooroopilly). Several transparent plastic overlay sheets were placed over property maps before the manual was bound. Drawing on these overlays using felt pens could represent changes to property layout and land use.

A digital copy of all information stored on compact disc was provided for producers. The data layers are in various formats corresponding to leading, commercially available property mapping software such as Farm Map, PAM and Auto-Sketch. Free compatible sample mapping software was included on the disc to get producers started.

Producers can use this information as a benchmark from which further property planning and development ideas can be represented by altering data layers digitally using the software. Maps can be printed to any size using any data layer combination. Also included on CD were land type data sheets, a tree and pasture plant identification kit and diagrammatic explanations of simple pH, infiltration and other soil tests and their application in the field.

Land type mapping

Mapping land types within Fish Creek NC led to a better understanding of the relationship between land types, regional ecosystems and land systems within the local region. With this understanding, regional ecosystem classification scheme for the Zamia/Mimosa Catchment was reduced to 10 major land types. The resulting land type data set (Table 1, p. 16) uses the existing 1: 100 000 scale for all regions other than the Fish Creek NC which was mapped at a scale of 1: 15 000.

Analysis of this data set with other data sets (i.e. land use and ground cover data) in a GIS environment has led to a better understanding of landscape processes that occur at the property through to catchment scales. For example, the data set was used to develop land units from which gullies were mapped. The information was also used to validate the use of experimental methods of assessing ground cover mean and trend values via the analysis of Land sat images.

Gully erosion

Initial identification of gullied areas within the Zamia/Mimosa Catchment was conducted using the land systems mapping with selection determined by a range of attributes. A land type map has now permitted the results to be quantified at a more detailed level. Results from three major land systems depicting the major land types are discussed below in detail.

Thomby Land System (brigalow/bauhinia/blackbutt land type)

Gullies within this land system (Figure 18) tend to be on lower slopes and are characterised by shallow depths and small cross-sections (depth 1.0–1.2 m, floor width 1–1.5 m, Figure 19). Meandering in nature, they seldom have significant straight sections before encountering an abrupt change in direction. Side-slumping of edges and gully head advance are the two dominant processes that are occurring at present. Erosion along gully edges was observed with an average loss of 9.25 cm/yr of soil along straight sections and 18.5 cm/yr of soil on gully bends. Soil loss along edges was mainly due to slumping of the side wall from overland flow and natural water movement within the gully profile. Some impact occurs from animal trampling but is generally confined to a localised area in the form of cattle pads when gully depth does not impede cattle traffic to the nearest watering point. However, when gully depth becomes too deep to navigate, cattle tend to walk around the gully head or across the lower slopes where gullies tend to fan out with a reduced cross-sectional depth.

Figure 18: Representative gully within brigalow/bauhinia/blackbutt land type

Gully head erosion was more pronounced (visually) than side-slumping of gully edges. Where gully head erosion was most significant was at the very apex of the gully head and the surrounding area. This area typically receives the longest duration of runoff water as it lies at the lowest section of the upstream drainage line. Due to greater rates of advance in upstream movement of gully head's than first perceived by project staff, estimates of total increases in length and soil loss have only been established recently. Gully head advance averaged 40 cm/yr with some areas experiencing in excess of 70 cm/yr. Soil loss was between 2.0–2.5 m^3/yr at the gully head. The majority of soil from the gully head appears to have moved beyond its place of origin to be deposited further down the gully or suspended in runoff water.

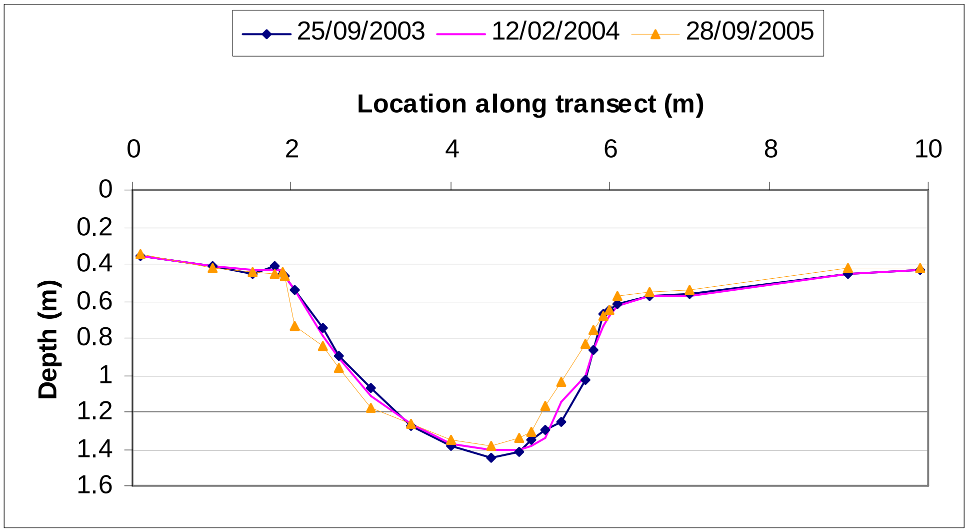


Figure 19: Cross-section of gully within brigalow/bauhinia/blackbutt land type

Calculating the impact of gullies within this land type across the broader Zamia/Mimosa Catchment yields some interesting results. The brigalow/bauhinia/blackbutt representing 9% of the total catchment area and having a projected gully density of 0.505 km/km^2, equates to 380 km of total gully length. Total soil movement from place of origin within the gully profile using the average gully edge advance of 9 cm/yr and gully depth of 0.4 m is estimated at 30 000 t of soil. Cross-sectional profiles indicate that approximately 0.4 m of gully depth is affected by gully edge advance. Assuming soil movement is evenly distributed along the total length of gullies using an average gully floor width of 1.25 m, a decrease in depth of 6 cm/yr (accumulation of material) would occur. Our findings indicate that on average 9 cm is deposited per year, suggesting that additional sources of sediment are accumulating within the gully profiles.

Redcliffe Land System (cypress pine/popular box/narrow-leaf ironbark land type)

Gullies located within this land system (Figure 20) tend to be deeply incised channels with steep sided walls. Typically cross-sectional profiles indicate depths of 1.2–1.8 m with floor widths of 2.5–6.75 m. Significant branching of new gullies from the main gully tends to occur with loss of ground cover a contributing factor. Erosion tends to be confined to side slumping of gully edges and tunnelling from overland flow entering adjacent to gully edges through visible cracking in the surface soil layers. The dispersive nature of the sodic soil types is conducive to underground tunnelling that decreases the stability of large areas of gully walls with significant slumping of material deposited on the gully floor.

Figure 20: Representative gully within cypress pine/popular box/narrow-leaf ironbark land type

Annual erosion of 8 cm/yr along gully edges and 12 cm/yr from gully head advance was observed. The rate of gully head erosion around the gully head itself was variable with no relationship between location and soil loss established. Gully head advance varied from no change to 34 cm/yr with estimated soil loss of between 1.5– 2.5 m^3/yr. Concentrating flow around the apex of the gully heads did not translate to an increase in head advance when compared to surrounding areas of the gully head itself. Effects such as tunnelling, tree and grass/ground cover impact were factors that led to no discernable patterns of gully head advance within this land type.

The impact of these results across the broader Zamia/Mimosa Catchment and in particular the narrow-leaf ironbark land type (25% of the total catchment area) are described using a similar approach as documented under the previous land system of Thomby. A projected gully density of 0.366 km/km^2 equates to 770 km of total gully length within the catchment. Erosion of gully edges at 8 cm/yr at an average gully depth of 0.9 m would translate to 110 990 t of soil movement. Assuming that soil is evenly distributed along the length of the gully network using an average gully floor width of 3.6 m, an accumulation of 4 cm/yr would occur across the gully floor. Our results indicate that on average 12 cm/yr is deposited from gully erosion which could indicate accumulation of external sources of sediment remain with the gully profile. Given the development of new gullies branching from the main gully, appreciate soil movement from these gullies could be adding to the accumulation of sediment.

Highworth Land System (brigalow/belah land type)

Gullies within this land system (Figure 21) proved hard to identify using the standardised methods employed. Although projected gully density for the brigalow/belah land type is 0.528 km/km^2, the size of the gullies provided the project team with difficulties in establishing representative areas across the catchment. One area where gullies appeared to form within this land type was from concentration of cattle movement along cattle pads. Where there was a break in slope, cattle padding had provided the ideal conditions for a break-away gully to form, slowly advancing back up the slope along the path of a cattle pad. Although this incidence is not confined to this land type, it did provide the project with a viewpoint of the impact of cattle and their role in the formation and development of gullies.

Figure 21: Representative gully within brigalow/belah land type

Erosion along gully edges was either negligible or quite pronounced depending on the gully profile. Where incised gullies were forming from recent erosion processes along cattle pads, gully edge and side slumping was very active. Where gullies had formed from an earlier cattle pad, the profile suggested that the gully had reached an equilibrium state of natural erosion. Annual erosion along gully edges of active gullies was 20 cm/yr. Gully head advance was extremely difficult to measure given the impact of cattle and the impact of erosion related to concentrating runoff water along the cattle pads. Small changes were noted but significant change did not occur within the timeframe of the project.

When assessing gully profiles further down the slope within this land type, they tended to flatten out and decrease in depth. Little evidence of erosion was observed apart from smaller rills that developed in the gully floor from pedestalling of tussock perennial grasses such as buffel. Accumulation of material from upslope was more apparent with an average depth of 5 cm/yr recorded. Using the projected gully density of 0.528 km/km^2 across the catchment, 220 km of gully length would produce 33 000 t of soil movement using an average of 10 cm/yr of gully edge erosion at a depth of 0.75 m. With a gully floor width of 2 m, this would equate to a deposition of 8 cm/yr along the entire gully length. Our results indicate that 5 cm/yr is deposited from gully erosion which may signify removal of sediment is occurring in the form of suspended sediment.

Summary

Gully erosion studies within this catchment relate to approximately 40% of the total catchment area. Representative areas were initially selected from the land systems map with the major landforms identified and monitored during the course of the project. The scope of this work was to assess the impact of gullies on landscape erosion process and relate response to water quality. Gully assessment across the three land systems has identified that significant movement of soil from gully erosion could occur on a yearly basis. Most gullies had active edge erosion (8-20 cm/yr) which increased where directional changes in gullies impeded the natural flow of runoff water (doubled the rate of edge erosion).

Gully head soil loss has been omitted from this analysis due to negligible overall impact on total soil displacement along the entire length of the gully. Some land types, particularly those with more dispersive soils demonstrated significant gully head advance of 70 cm/yr. Gully advance could be slowed by reducing the direct impact of cattle and increasing ground cover and retardant structures but the effort would lead to minimal improvements at the larger scale. Management impacts across the catchment area draining to the gully would yield greater improvements in minimising gully erosion over the longer term. Impacts of catchment areas above gullies have not been taken into account with the generation of these results but could greatly influence the role of gully erosion within the landscape.

Accumulation of sediment (additional to gully erosion processes) within the gully profiles would suggest that the catchment area above gullies is influencing these results. Given the less than average annual rainfall experienced over the course of the project, deposition within the gully may not have encountered significant flow to move heavier sediment particles. Evolution of gullies could be occurring whereby the gully cross-sectional reaches a state of equilibrium through natural processes.

Gully erosion has the potential to play a significant role in annual sediment loss and water quality within the Zamia/Mimosa Catchment. Using an example from a neighbourhood catchment (30 000 ha) within the Zamia/Mimosa Catchment, annual soil loss through suspended sediments was approximately 7 000 t over five years of monitoring. Hillslope erosion from paddock-scale monitoring generated 0.45 t/ha for grazing pastures over the same period. It is estimated that only 10% of sediment from hillslope erosion is transported through the stream network (Prosser *et al.* 2001) therefore total soil loss from this process monitored at the end of the neighbourhood catchment would equate to 1 350 t/yr. Given that streambank erosion is relatively minor within this catchment, 5 650 t/yr of sediment could be generated through gully erosion which equates to over 80% of the total soil loss.

Using a value of 0.510 km/km^2 for gully density with gully edge erosion of 10 cm/yr and an average depth of 0.7 m, gully soil displacement would equate to 21 500 t/yr. This figure is four times the value of 5 650 t/yr estimated to occur from gully erosion at the end of the catchment. Our findings indicate accumulation of sediment is occurring in gullies even though significant soil displacement is occurring from erosion along gully edges. Location of gullies to stream networks and impact of catchment areas requires further understanding to assess the impact of gullies. As all gullies do not empty into streams, a further percentage of soil movement from gullies would not be transported through to the stream networks. Long term studies are required to generate more definitive answers to impact of variations in climatic patterns that may transport deposited material from within gullies. Initial modelled results from SedNet demonstrates gully erosion has a significant role in sediment movement across the Zamia/Mimosa Catchment.

Future work - active *vs*. non-active gullies

Gully age across the Zamia/Mimosa Catchment varies in accordance to land type and major land use change. Gullies that have formed prior to broad-scale clearing in the 1960s appear to have not significantly increased in size in particular land types. These gullies could be classed as being non-active, are relatively stable and not significantly impacted by runoff associated with overland flow. In contrast, the clearing of vegetation followed by cropping or grazing practices has resulted in the formation of gullies in certain land types. Development of gullies increased quite rapidly, most probably as a result of low ground cover and aided by the dispersive nature of some soil types.

It is difficult to asses whether such gullies remain as active today with ground cover at or above critical levels. Producer experience has shown that low ground cover mostly through land use change in the last five years has caused significant gully erosion. We have also demonstrated that gully erosion may not be solely linked to ground cover but may be related more closely to soil properties. Given the trend in decreasing ground cover within the catchment, land types may be approaching the conditions where gully erosion becomes more prominent in the future. Identification of such areas is needed with monitoring over time to quantify the impact of gully erosion within these critical land types.

Radio-nuclei testing of sediment (both suspended and bed load) within the gully profile could indicate place of origin of soil particles. This would establish the direct impact of gully erosion on water quality throughout the catchment by determining if soil particles are originating from the soil surface or at various depths throughout the soil profile. Refinement of monitoring at gullies by analysing water quality and flow rates immediately prior to entry into the gully and the exit could allow further verification of gully processes. Results generated would allow further refinement of catchment water quality models as present gully erosion documentation is extremely limited. Assessment of catchment areas above gullies and management strategies employed by producers would provide greater insight into the role producers can play in minimising both hillslope and gully erosion.

4.1.3 Catchment

Results at the catchment scale have been analysed on the pretext that runoff and soil loss occurred evenly across the entire catchment. Our understanding of rainfall patterns however suggests otherwise given the extreme variations in spatial and temporal patterns experienced. Data from June 1999 to July 2002 has been omitted as land use change was occurring in the three of the four monitored catchments (Taroom Road, Muddy Creek and Spottswood Creek at Dawson Highway) during this period. Results from July 2002 reflect a more stable land use pattern although residual impacts from previous land use could impact on runoff and soil loss from these catchments (Table 7). Selected catchments throughout the Zamia/Mimosa Catchment are included within this results section and commencement of monitoring occurring in February 2003. Only water quality data (TSS, TKN and TP) are reported although measurements of stream height, ground cover trends and land types are some components that have been incorporated into the analysis of these catchments. The Roundstone Catchment was included as the fourth monitored catchment as the Fish Creek NC group is located within its natural drainage area.

Rainfall

Rainfall totals throughout all catchments within the Zamia/Mimosa Catchment were highly variable in both spatial and temporal patterns. Differences in totals of more than 50 mm within 1 km were not uncommon for single monitored events. The Bureau of Meteorology radar service was accessed to assist in determining the spatial and temporal patterns of rainfall as often the raingauge network failed to capture some events. Results from monitored stations indicated that higher than average annual rainfall totals occurred at three stations during the 2004/2005 season. During the same year, a producer’s record from the Roundstone Catchment totalled 1 135 mm (793 mm at Roundstone Creek), highlighting the variable nature of the rainfall experienced in the catchment.

Rainfall intensity (I30 mm/hr) of events that produced runoff at the catchment scale sites were generally of the nature that you would expect to occur on average every year (one in one year occurrence interval). Only 7% of rainfall events fell at higher intensity recurrence intervals with the highest recorded at a one in 20 year recurrence interval. Typifying the variable nature of rainfall, events that fell at higher frequencies than a one in one year occurrence were not recorded at more than one catchment site for any individual runoff event.

Rainfall radar technology

The Bureau of Meteorology radar imagery became commercially available during the latter half of 2004. Accessibility has allowed greater interpretation of catchment events through the spatial and temporal patterns of rainfall activity. For this report, an example of the use of such technology is described below. Further interpolation of images for other rainfall events will occur when accuracy of rainfall patterns are correlated with pluviometer and manual raingauge recordings. Inaccuracies in the generated images are well documented on the Bureau of Meteorology website (www.bom.gov.au) hence the need for further validation before reporting in detail can occur.

The Bureau of Meteorology radar imagery provided a valuable insight into the June 2005 event for the Roundstone Catchment. Rainfall patterns were concentrated on the upper part of the catchment across approximately 40% of the catchment area. Only four land types were influenced by this event enabling resultant water quality and runoff characteristics to be associated with these land types. Catchment lumped results show that water yield was only 2% as rainfall recorded was between 11 and 18 mm. Flow was measured at greater than 2.5 m indicating significant runoff had been generated from this rainfall event. Suspended sediment concentrations averaged near 5 000 mg/L, nearly double the average concentration for this catchment. If available, through remote sensing of catchment ground cover condition, further conclusions could have been drawn about the localised impact from this rainfall event.

Seasonality

As expected, a strong seasonal influence on rainfall and runoff was apparent. Summer produced the highest percentage of runoff producing rainfall (37%) and actual runoff (61%). Spring recorded similar values of runoff producing rainfall and corresponding runoff (33% and 32% respectively). The lowest percentages of both variables were recording during winter through a combination of low rainfall totals and low rainfall intensities. Seasonal relationships between the paddock and catchment sites were similar except for summer runoff producing rainfall which was significantly higher at the paddock scale than the catchment scale. It is not uncommon in the summer season to experience multiple rainfall events in a short period of time across different areas of the catchment. At the paddock scale, these are generally recorded as individual responses but at the catchment scale, given a larger area of influence, overlap between events occur that results in a net response at the end of the catchment. The total amount of rainfall in the catchment will also govern whether a response occurs at the larger catchment scale.

Runoff

Runoff patterns throughout the four monitored catchments reflect the inconsistent nature of the rainfall patterns experienced. In 2002/2003, the lowest rainfall year, the highest annual runoff percentage or catchment yield was recorded for each catchment (Taroom Road was slightly higher in 2004/2005, Table 7). February rainfall for that year accounted for 60% of the annual total (ex-cyclone Beni) with corresponding runoff high due to prevailing dry conditions (80–90 mm of rainfall since July 2002) and the nature of rainfall activity associated with a tropical low system (low intensity, high volume). All significant runoff recorded for 2002/2003 occurred in the month of February.

In 2003/2004, all catchments demonstrated a reduction in runoff percentage which can be attributed to a more normal rainfall pattern. Annual rainfall totals were still significantly less than the long-term average due partially to extremely low rainfall in the months of May and June. The majority of runoff was recorded in January following a wetter than normal month of December, both months having above average rainfall. In 2004/2005, unusually high late spring/early summer rainfall patterns produced significant runoff. Between 75–88% of catchment yield was recorded through November and December. Late autumn and winter rainfall (170–200 mm) in May and June produced a response for each catchment although corresponding soil loss was less than 20% of the annual totals.

One aspect of interest is the continual reduction in catchment runoff yield in the Muddy Creek Catchment. Rainfall patterns indicate that this catchment has received on average less rainfall than the other three catchments since 2002. Rainfall may indeed then be a contributing factor however, this catchment has reduced cropping land use by 45% since early 2001. Cropping land use has been returned to permanent pasture in the majority of cases although establishment of pastures has been a slow process. The paddock scale results for the CP trial highlight a similar trend from 2002/2003 where runoff has decreased but soil loss after a dramatic reduction from a cropping to pasture environment has begun to increase with the return of more normal rainfall patterns.

Catchment 2002/2003	Rainfall mm	Runoff mm	Runoff %	TSS mg/l	Sed load t/ha	TKN mg/l	TKN kg/ha	TP mg/l	TP kg/ha
Taroom	463	12	3	440	0.05	2.13	0.22	0.69	0.09
Muddy	452	23	5	1580	0.37	1.13	0.33	0.20	0.05
Spottswood	461	46	10	550	0.22	1.00	0.79	0.24	0.10
Roundstone	551	45	8	750	0.04	1.20	0.06	0.27	0.01
2003/2004									
Taroom	584	5	1	290	0.03	1.28	0.06	0.63	0.03
Muddy	535	18	3	1960	0.23	1.43	0.25	0.37	0.07
Spottswood	555	39	7	440	0.16	1.60	0.53	0.42	0.15
Roundstone	566	9	2	2220	0.17	2.80	0.70	1.23	0.31
2004/2005									
Taroom	736	22	3	320	0.12	1.81	0.40	0.78	0.19
Muddy	650	16	2	1610	0.30	2.66	0.49	0.79	0.14
Spottswood	686	29	4	1070	0.41	1.93	0.80	0.67	0.31
Roundstone	793	29	4	2120	0.53	2.98	1.17	1.15	0.44

Table 7: Water, sediment and nutrient yields (2002 – 2005) for four monitored catchments within the Zamia/Mimosa Catchment. (Note: Roundstone Catchment water quality data is incomplete for 2002/2003 due to establishment of monitoring equipment following an early runoff event).

Catchment condition - ground cover

Validating the use of the MRBGI for the Zamia/Mimosa Catchment

Traditional ground cover measuring techniques were not suitable for assessing ground cover at the catchment scale. In partnership with CINRS, Indooroopilly a multiple regression bare ground index (MRBGI) was developed for the Zamia/Mimosa Catchment. A good correlation (r>0.66) between actual cover and MRBGI was achieved for all land types except brigalow/softwood (r=0.39), occupying 10% of the catchment and silver-leaf ironbark (r=0.23), which occupies about 7%. Data from these land types was omitted and the results from the final analysis are shown in Figure 22.

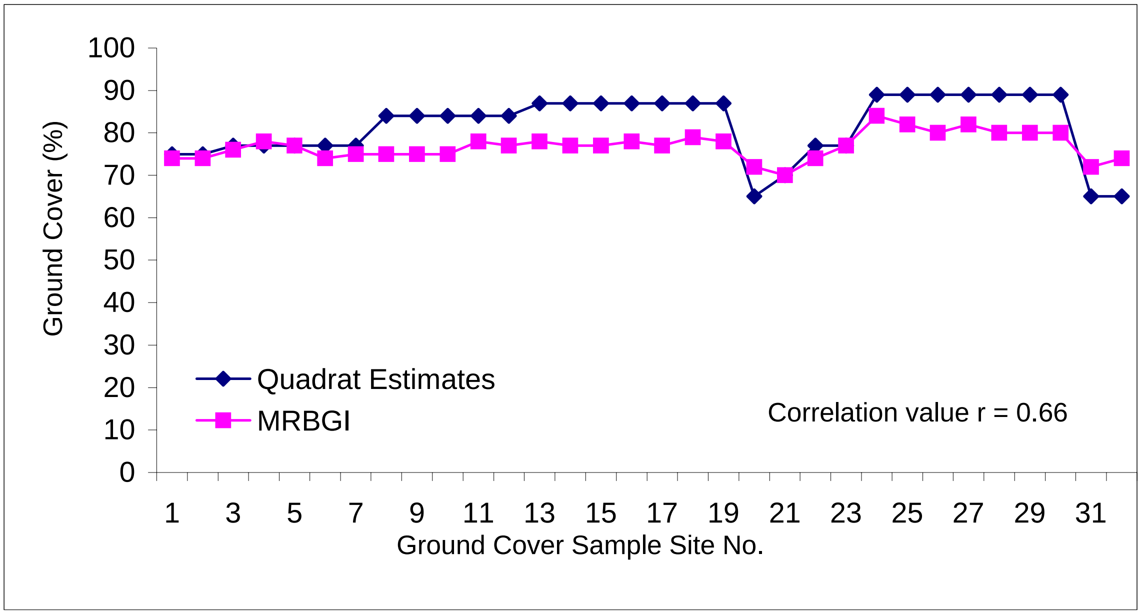


Figure 22: Comparison of MRBGI ground cover estimates with field based observations

The final regression analysis shows a strong agreement between both sets of ground cover estimates. The level of correlation achieved (r=0.66) is similar to that achieved for other regions in similar validation exercises undertaken by CINRS. The MRBGI produces sensible results for the direction and magnitude of change in ground cover for all land types, excluding areas of brigalow/softwood and silver-leaf ironbark land types.

This assessment has with confirmation from local producers, led to the identification of four critical land types within the catchment. The ground cover mean and trend images were analysed for each monitored catchment to help identify potential areas of increased risk of erosion. At the Zamia/Mimosa Catchment level, average annual ground cover figures are greater than 60%. Seasonal differences in 2001 and 2004 depict ground cover between 75 – 90% in summer but through winter this drops to 35-50% with the catchment average closer to 45%. Visual observations support this finding throughout monitored catchments, where it was rare that ground cover levels fell below 50% for permanent pastures.

Nearly two-thirds (63%) of the Zamia/Mimosa Catchment has signs of decreasing ground cover since 1988 (Figure 23). At the catchment level, all land types have greater than 85% of their total area covered by at least 40% ground cover. Medium (40%–60%) and high (>60%) ground cover levels represent 50% and 38% respectively of the total catchment area. Field observations from the last five years support these findings. Generally it was rare for ground cover to drop below 50% in grazed pastures. While this indicates ground cover was maintained above the critical level (40%), analysis of the ground cover trends shows a decline in ground cover on all land types from 1988.

The four critical land types displaying downward trends in ground cover across significant areas are brigalow/belah (80% of total area), brigalow/bauhinia/blackbutt (77%), brigalow/blackbutt and brigalow/softwood (74%). Within these land types, the medium cover level is displaying the greatest tendency to decline. Ground cover is moving towards the critical threshold level where one can expect an increase in runoff and soil movement to occur. The critical ground cover level for grazing on most land types lies between 40 and 60%. However evidence suggests that this figure is greater than 60% for the more fragile land types. Below the 40% ground cover level, there is an increased likelihood of runoff and soil movement as a result of reduced infiltration.

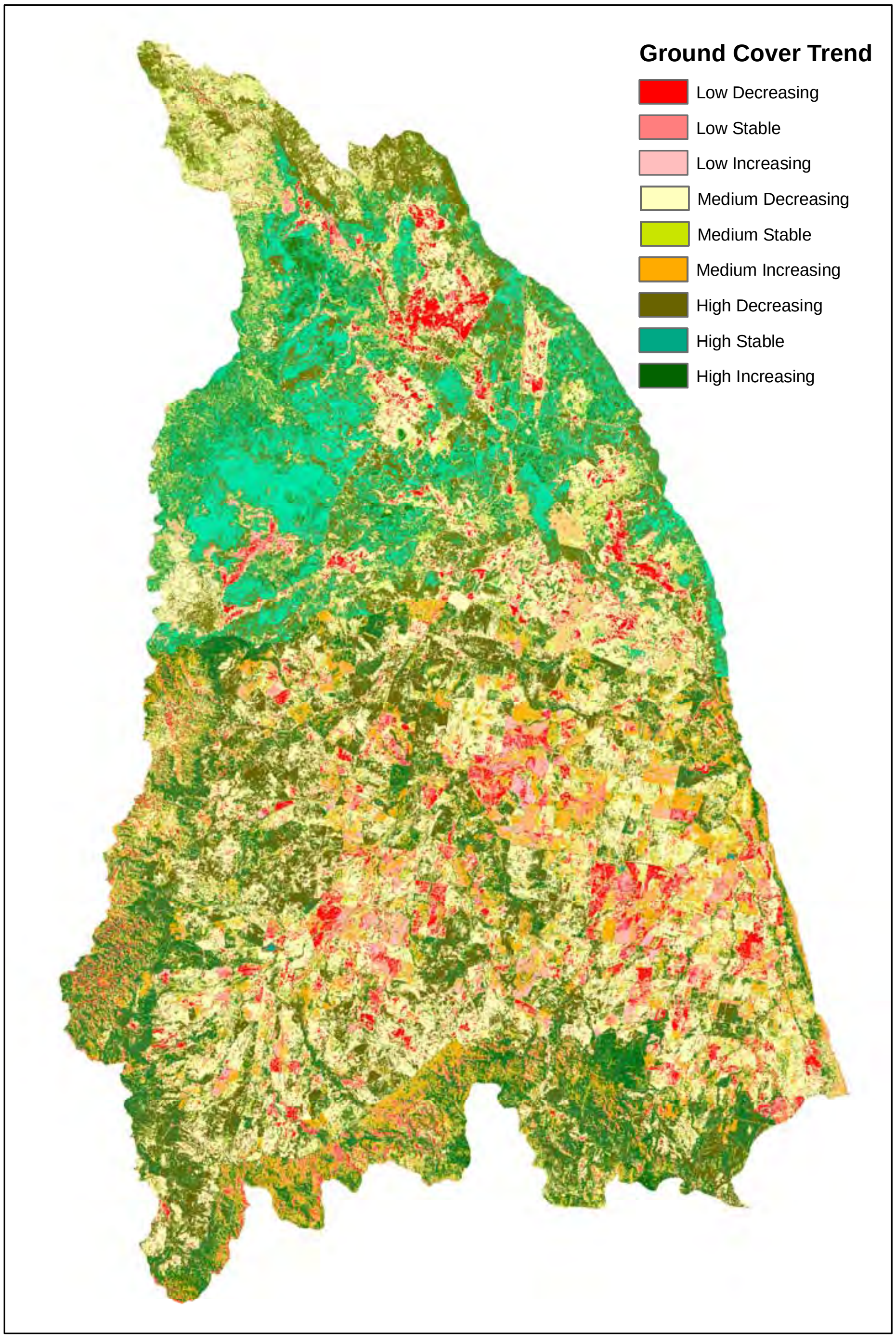


Figure 23: Ground cover trends across Zamia/Mimosa Catchment (1988–2004)

Soil loss and sediment concentration

Soil movement was lowest in the catchment dominated by grazing land use (Taroom) and highly variable in the largest catchment (Roundstone) with all ten major land types represented within its boundaries. The highest annual sediment loads were recorded in 2004/2005 for each catchment. Higher than average rainfall totals contributed to the generation of a significant number of runoff events in 2004/2005 which equated to over 50% of the total number of events from 2002/2003. The majority of soil movement in 2004/2005 resulted from late spring rainfall events when ground cover was at its lowest throughout the year.

Soil movement was restricted to the month of February in 2002/2003 from the impact of the ex-cyclone Beni. Very little beneficial rain fell prior to February (80-90mm from June 2002) resulting in ground cover levels dropping below 50% across areas of the four catchments. In 2003/2004, higher rainfall totals did not correspond to an increase in soil movement apart from the Roundstone Catchment.

There is a good correlation between runoff (mm) and soil loss (t/ha) for the Taroom Road, Muddy Creek and Spottswood Creek Catchments. Further insights through data interpretation are needed to define this conclusion given the variability in rainfall, catchment characteristics (apart from Taroom and Muddy being catchments within the broader Spottswood Catchment) including land types, topography, land use, origin of sediment sources, ground cover and grazing management strategies. One could assume that given their location within the landscape and small catchment area, factors that influence catchment response including rainfall and land type variability are reduced at this scale. The Roundstone Catchment which is considerably larger in area can be greatly influenced by the spatial and temporal rainfall patterns as mentioned in the rainfall summary. In combination with representation of the 10 main land types within its boundaries, this catchment is displaying significant variations in soil movement. Because of no defined pattern in soil movement within the Roundstone Catchment, no correlation exists between runoff (mm) and soil loss (t/ha).

To achieve a greater understanding of the factors influencing water quality within the Zamia/Mimosa Catchment, catchments with various aspects of topography, land use and land type were monitored from February 2003 to June 2005. Four of the top five catchments exhibiting high levels of suspended sediment are located at the upper reaches of the Zamia/Mimosa Catchment (Appendix 9.7, p. 123). Each catchment is influenced by topographic effects ranging from high slopes, shallow stony soils and large incised gullies. These factors are characteristic of the range land type and are dominated by National Parks or State Forest land use. Due to accessibility, ground-truthing of this land type did not occur during the project. Aerial photography was used instead to examine the development of gullies as gully development is most likely impacted through soil type, slope or effect of catchment drainage area to the gully. The study concluded that this land type appeared to be quite stable however ground-truthing is needed to quantify this finding. The Muddy Creek Catchment with the highest ratio of cropping land use to catchment area recorded the second highest average sediment concentration.

Apart from November 2004, the catchments recorded higher average concentrations than the paddock scale monitoring sites. Fine sediment particles once removed from point of origin within the landscape have a tendency to remain suspended within runoff. Sediment movement from gully erosion would be increasing sediment concentration at the catchment scale even though findings indicate accumulation of sediment is occurring within gully profiles. Finer sediment particles from dispersive sodic soils would never the less be transported from existing gully networks.

A good correlation exists between catchment and paddock-scale sediment concentrations (R^2=0.93) which could reflect the uniformity of a dominant land use (grazing) even though a seven fold increase exists between the lowest and highest sediment concentrations across the catchments monitored. The dominant land use may also indicate the good correlation between catchment TSS and TKN (R^2=0.91) and catchment TSS and TP (R^2=0.94). A poor correlation resulted from catchment and paddock relationships between TSS and TKN (R^2=0.31) and TSS and TP (R^2=0.44). A similar finding was established where relationships between TSS, TKN and TP demonstrated poor correlation at the paddock-scale.

No relationship existed between sediment concentration and total area of the four critical land types within individual catchments. Catchments that had a greater representation of critical land types did not demonstrate higher levels of TSS, TKN and TP. Three of the top five catchments with high TSS levels are located where range land type is adjacent to brigalow/softwood. Location of catchments within the landscape had a greater impact than size of critical land types within each catchment.

Nutrients

Highest nutrient exports were recorded in 2004/2005 for each of the four monitored catchments (Table 7, p. 49). Rainfall activity experienced was greater than long-term averages in 2004/2005 and appreciably higher than 2002/2003 and 2003/2004. Seasonality of runoff events continued to be the dominant process in nutrient exports from the monitored catchments. At least 80% of annual TKN and TP exports occurred from initial events in late spring to mid summer.

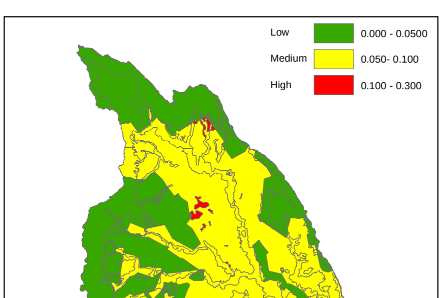
A good correlation between catchment TSS and TKN (R^2=0.91) and catchment TSS and TP (R^2=0.94) was evident across all monitored catchments. Investigation into the top five catchments with elevated levels of TKN (Appendix 9.8, p. 124) and TP (Appendix 9.9, p. 125) demonstrated the same four catchments earlier depicted as possessing high levels of TSS were present. This was partially expected given the good correlation between TSS, TKN and TP. Location of catchments within the landscape therefore plays a vital role in nutrient concentrations in runoff within the Zamia/Mimosa Catchment. Upland catchments featuring components of range land type adjacent to critical land types are displaying potential sources for soil and nutrient mobilisation.

Pesticides

The two main pesticides detected at the catchment level were Atrazine (and associated by-products) and Tebuthiuron (Graslan). Atrazine and Tebuthiuron are activated by rainfall activity and hence have greater potential for moving off site through runoff. Both chemicals are classed as residual herbicides so have the potential to last longer in the system depending on application rate, soil types, rainfall activity and time of application. For the period of monitoring from December 2003 (first recorded events) until May 2005, Atrazine was detected 45 times with only eight samples recording above the trigger level one for freshwater (0.05 µg/L). Tebuthiuron was detected on 25 occasions with only four samples recording higher than trigger level one for freshwater (1.0 µg/L). Trigger levels are only proposed water quality guidelines established by Australian and New Zealand Environment Conservation Council (ANZECC). Current pesticide detection would indicate that producers are demonstrating safe and acceptable application of chemical use throughout the catchment.

Gully density mapping

Figure 25 shows the gully density map produced by the project team. Gully density is expressed as kilometres of gully length per square kilometre of area (km/km^2). The map depicts a single value for each land unit. Figure 24 shows the resultant map where land units remain the same, but gully density values are extracted from NLWRA sources. Project data predicts a far greater magnitude of gully density for the catchment than the audit data does. Average gully density is 0.425 km/km^2 using project data and 0.101 km/km^2 using audit data across the Zamia/Mimosa Catchment.



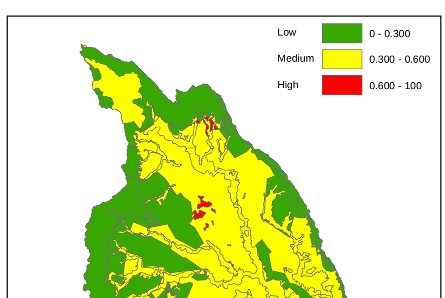


Figure 24: Gully density map (audit)

Figure 25: Gully density map (project)

The audit classed all National Park and State Forest areas as having negligible gully development. The exception was on Land Type Code (LTC) 6 where high gully density was predicted. These areas were located adjacent to range country where visual observations through aerial photo assessment concluded a similar finding. Field and aerial photo assessment were employed to examine more closely the audit findings for National Park and State Forest areas (Table 8). Re-mapping National Park areas has resulted in values changing from low to the medium range. For State Forest however, values have remained in the lower range for LTC 1 and LTC 2, increased from low to medium range for LTC 4 and increased from low to high range for LTC 7. LTC 6 remained in the high range for both audit and project generated gully density maps (Note: LTC are described in Table 1 p. 16).

LAND USE	LTC	Gully Density (NLWRA)	Gully Density (Project)
Cropping Pasture Rotation	7	0.191	0.511
"	5	0.160	0.792
"	9	0.159	0.829
"	4	0.147	0.843
"	6	0.168	0.854
"	8	0.139	0.874
"	3	0.186	0.931

Grazing	1	0.091	0.129
"	6	0.146	0.426
"	9	0.157	0.443
"	4	0.117	0.477
"	2	0.084	0.492
"	10	0.164	0.501
"	5	0.141	0.510
"	3	0.145	0.679
"	7	0.177	0.714
"	8	0.171	0.872

LAND USE	LTC	Gully Density (NLWRA)	Gully Density (Project)
Permanent Cropping	10	0.181	0.563
"	5	0.163	0.629
"	6	0.176	0.733
"	4	0.160	0.791
"	7	0.185	0.808
"	9	0.132	0.819
"	3	0.180	0.828
"	8	0.120	0.927

State Forest	1	0.004	0.132
"	2	0.009	0.184
"	4	0.016	0.477
"	7	0.014	0.627
"	6	0.250	0.833
National Park	1	0.001	0.368
"	6	0.004	0.737
Other	1	0.124	0.220

Table 8: Comparison between audit and project gully density (km/km^2) for major land uses and land types within the Zamia/Mimosa Catchment.

When interpreting aerial photographs, significant over-storey tree cover can obscure gullies to the point where they may be under represented or even undetected. Such was the case for a majority of National Park and State Forest areas within the catchment. Although not confirmed through field verification, it may be assumed that gully development is underrepresented in these areas.

Particularly in the southern parts of the catchment, remapping gully density has resulted in obvious changes from predicted medium values. Changes in land use since the audit's completion may account for this. For example, predicted gully density is generally higher for cropping than grazing land use. Remapping areas that have shifted from cropping to grazing since the audit has resulted in those areas now receiving a higher value corresponding to cropping land use. The opposite scenario would of course produce the opposite result.

Gully density - land type

Poplar box land type (Table 9) has the highest gully density (0.786 km/km^2). This land type only constitutes 1% of the catchment so may not contribute significantly to overall sediment loads. Sandstone ranges and narrow-leaf ironbark land types in contrast have the lowest values but constitute almost 50% of catchment area. Brigalow/blackbutt and silver-leaf ironbark land types have high gully density values and also constitute a considerable area (just under 15% of the catchment). Reducing soil loss in these land types may significantly reduce total sediment discharge from the catchment.

LTC	Land type	Catchment area (% of total)	Mean gully density (km/km^2)
1	Sandstone ranges (shallow stony soil)	22	0.168
2	Ironbark (outwash from ranges, stony soil)	25	0.366
6	Brigalow/softwood (basaltic clay and loam)	10	0.474
4	Alluvial (various soil types)	13	0.503
9	Brigalow/bauhinia/blackbutt (cracking clay, sodic at depth 90cm)	10	0.506
10	Grasslands (cracking clay)	1	0.515
5	Brigalow/belah (gilgaied deep clay)	5	0.528
7	Silver-leaf ironbark (duplex soils, mottling apparent below 40 cm)	6	0.624
3	Brigalow/blackbutt (duplex soils, sodic at depth 40cm)	7	0.694
8	Poplar box (duplex soils, highly sodic throughout)	1	0.806

Table 9: Gully density (low to high values) for 10 major land types within the Zamia/Mimosa Catchment

Gully density - land use

Land use 'Cropping Pasture Rotation' has the highest gully density (0.814 km/km^2); higher than permanent cropping (0.707 km/km^2) and approximately twice as high as land use 'Grazing' (pastures alone), which is 0.462 km/km^2 (Table 10). Although possibly yielding high sediment loads, the area it occupies (2.5% of the catchment) is small compared to grazing (87% of the Zamia/Mimosa Catchment). This might imply that compared to grazing, 'Cropping Pasture Rotation' contributes insignificantly to overall sediment discharge.

Land use	Catchment area (% of total)	Mean gully density (km/ km^2)
State Forest (grazed)	20	0.174
Other	0.5	0.220
Grazing	67	0.462
National Park	5	0.524
Permanent Cropping	5	0.707
Cropping Pasture Rotation	2.5	0.814

Table 10: Gully density for major land uses within the Zamia/Mimosa Catchment

Gully density - combined effects of land type and land use

Areas of high gully density tend to be on duplex and sodium-dominated soil profiles of undulating terrain, low relief and under cropping and cropping pasture rotational land uses. These areas are concentrated in the southern half of the Zamia/Mimosa Catchment.
Sandstone orientated land types to the north of the catchment and along the ranges dominated by State Forest show minimal gully development. This result could be skewed by high over-storey tree cover obscuring gullies. National Park areas show development of large incised gullies (easily detected even under high tree cover), however the inspection of historical aerial photography show most of the gullies had developed.

Permanent cropping and/or cropping pasture rotation appear to elevate predicted gully density significantly in pre 1960s fragile land types. This is particularly true for brigalow/bauhinia/blackbutt land type (Table 9). This land type is dominated by soils that increase in sodicity as they increase in depth. Traditional cropping systems such as tilling/ploughing destroy soil structure and exposes the sodic sub soils to surface erosion processes where their dispersive nature renders them especially prone to gully development. Minimum disturbance is needed in these soils for them to retain reasonable stability.

Rotation of cropping with grazing land use seems to exacerbate gully development beyond the effect of cropping alone. This is the case, particularly for brigalow/bauhinia/blackbutt, brigalow/blackbutt and brigalow/softwood land types. Rotating cropping land use with grazing may leave large areas of the landscape with very low ground cover for extended periods as pastures develop.

Gilgai formation on grassland and brigalow/belah land types may impede overland flow and hence limit erosion even when ground cover is low. This may explain why these land types do not show the same trend towards increased gully development under cropping and cropping grazing rotation land uses. These land types are also dominated by more stable, non-sodic soil profiles, which would also reduce their erosion potential.

SedNet

The audit data layers in combination with historical local stream flow were used for initial assessment of SedNet outputs across the Zamia/Mimosa Catchment. The improved gully density grid was then re-modelled using SedNet without altering any other data layer. A comparison of results is tabled below (Table 11). Although exports from the catchment remain relatively similar, sediment supply from gullies has increased from 127 kt/yr to 323.6 kt/y (150%). The model has compensated the increase in sediment supply from gullies by increasing deposition in the floodplain and channels of streams.

Sediment supply (kt/yr)	Audit gully density grid	Project gully density grid
Gully	**127.1**	**323.6**
Bank	10.2	10.2
Hillslope	94.3	94.3
Total	**231.5**	**428.0**
Exports (kt/yr		
Bedload	48.0	55.7
Suspended Sediment	3.4	5.1

Table 11: Comparison between audit and project gully density grid on sediment supply to stream networks throughout the Zamia/Mimosa Catchment.

Verification into the accuracy of resultant outputs from this modelling exercise did not occur. This exercise was used to demonstrate the enormous variability in modelled outputs that can be generated from the changing of one data layer. Without highly accurate information to populate these models, resultant outputs can be extremely inaccurate. The use of such models would provide a greater insight into critical areas or potential erosion processes within catchments that could cause disproportional impacts at the catchment level.

Summary

Hillslope and gully erosion are the two main erosion processes that occur at the paddock, property and catchment scale within the Zamia/Mimosa Catchment. While visual observations generally do not detect soil movement at the hillslope scale in a grazed environment, one can infer this process occurring when viewing the development of gullies within the landscape. Gullies across the catchment are demonstrating signs of accumulation of sediment, hence impacted by upland areas within the landscape where additional runoff water enters into the lower regions. Soils with high levels of sodicity either at the surface or at depth throughout the profile lend themselves to increased potential for accelerated gully development from storm activity.

All catchments that border the southern boundary of the Zamia/Mimosa Catchment have mature (>50 years) gullies in brigalow land types adjacent to range country. The range land type is made up of predominantly sandstone ridges leading to lower escapements. Evidence suggests that this land type generates significant runoff from storm activity by the development of gullies along major drainage lines. These drainage lines extend into the brigalow land types and gullies formed have not shown a dramatic increase in size since broad scale clearing (1960s).

Brigalow/softwood is the most common brigalow land type adjacent to the range. Characterised by high slopes, declining ground cover and fragile soils, this land type is most susceptible to increased runoff and erosion activity. Gully density within this land type across the Zamia/Mimosa Catchment is the lowest of the four critical land types. When brigalow/softwood meets with the range, gully density is double the average of the same land type across the entire Zamia/Mimosa Catchment.

It is too early to establish the direct cause for why this has occurred within this land type. Certainly, the topographic effects (steeper slopes) play a role as does hydrology and soil characteristics. The assumption is that hillslope erosion does occur at a moderate level with gully development characterised by location to the range and on-going hillslope erosion. Activeness of gully erosion within this land type is unknown at present but would relate more to increased depth of gully rather than side slumping or gully head advance.

The brigalow/blackbutt land type is clearly demonstrating high levels of hillslope and gully erosion. Comparisons between paddock-scale findings between this land type and Brigalow Catchment Study show a four fold increase in hillslope erosion when compared to the brigalow/belah land type.

Active gully erosion is occurring within this land type with declining ground cover and sodic soils aiding in the development of gully head advance, significant side slumping and increased cross-sectional depth. Localised effects within catchments containing this land type are common throughout the Zamia/Mimosa Catchment. Critically, the ground cover trends are indicating that the majority of this land type is declining in both high and medium cover levels.
Brigalow/bauhinia/blackbutt land type was heavily utilised under cropping management when selectively cleared following the Brigalow Scheme. Implementation of erosion control methods i.e. contour banks and waterways have occurred on significant areas within this land type. These structures still remain in place today but where they were not effective or implemented, development of gullies occurred. Gully density within brigalow/bauhinia/blackbutt is the highest of all four critical land types. Development of gullies resulted mainly from the clearing of vegetation, low ground cover and high sodic levels in surface and sub-surface soil layers.

Due to its low sloping aspects and gilgaied surface, hillslope erosion is considered by landholders to be negligible in the brigalow/bauhinia/blackbutt land type. Soil type is characterised by deeper clay, self-mulching and cracking given it good infiltration properties. However, when ground cover is reduced below critical thresholds, surface runoff does increase and tends to aid gully development. Evidence of hillslope soil movement is not apparent even though runoff increases with lower ground cover. Gullies can rapidly increase in size within a rainfall season if ground cover levels remain below the critical level. The fact that ground cover levels within this land type are decreasing, concern for increased soil erosion is justified for the brigalow/bauhinia/blackbutt land type.

The brigalow/belah land type represents the smallest area of all four critical land types within the Zamia/Mimosa Catchment. A lack of available data on this land type to date has allowed only general assumptions to be drawn. Visually, evidence of gully erosion is apparent but the timing of such development is unknown. Most aspects of erosion processes would be similar to the brigalow/bauhinia/blackbutt land type. Decreasing ground cover (80% of total area) within this land type is cause for concern for its future long-term sustainability.

When we get beyond the paddock/property, the level of resolution of data at our disposal is greatly compromised. The accuracy therefore to assist in clarifying impact from land types/management therefore is made with a degree of caution. The SedNet results highlight the need for increased accuracy of information when moving in the opposite direction from a larger to smaller catchment scales. Refinement of one data layer dramatically altered the resultant outputs causing a heightened awareness in the role of water quality models in predicting impacts from either terrestrial features or changes in management practices.

Above all, when moving beyond the paddock, we need involvement of producers to understand the implications of management practices on the health of the landscape. Working at this level is required if we are to firstly demonstrate the impact of current management and secondly, change practise where it is required.

Future work – ground cover

CINRS, are currently refining the Landsat MRBGI for application over the entire Fitzroy Basin. Strategically placed study sites are being established across the basin to collect calibration data for all soil types. Calibration data collected in this project has assisted with identifying two land types that do not respond well to the MRBGI. These land types need additional calibration data collected to further refine the index.

A maximum of 16 Landsat scenes can be captured in a single year. It is unlikely therefore, that rainfall events will correspond to capture dates. Using Landsat images for accurately assessing short-term responses in ground cover due to rainfall events is therefore not possible. This may be overcome in the near future with Modis TERRA_1 satellite platform (Modis) launched in 1999.

Modis has the ability to capture scenes from the same area of the earth’s surface at intervals of approximately six days. The remote sensing team at CINRS are working on a MRBGI that can be applied to Modis scenes to generate ground cover estimates. The increased temporal resolution of available scenes means assessing short-term responses in ground cover due to rainfall events will become possible.

A similar index to the MRBGI is also being developed at present that aims at assessing trends in biomass as opposed to simply ground cover. This advancement would offer the opportunity for producers and researchers to assess pasture utilisation remotely over large areas. Other areas of application might include assessing pasture productivity recovery after drought, fire or alteration of grazing management strategies.

Objective up-to-date ground cover information can be used by producers to support more sustainable management for improved productivity and reduced impact on land condition. The information provides producers with a base line against which future changes can be compared and a tool to assessing past management decisions and aiding future ones. It can be used objectively to assess if similar (same land type) areas across a property are equally impacted due to management decisions or whether other factors that may be also be amended through changes in management.

The effect that existing property infrastructure has on ground cover and subsequent land condition can be easily undertaken by using the ground cover information. More heavily impacted areas can be readily identified and infrastructure altered (adding of watering points or restructuring their access points, repositioning lane ways, fence lines, etc) or changes in management practice implemented to minimise the effect and achieve more even pasture utilisation.

Further work – gully density

This assessment of gully density and distribution across the Zamia/Mimosa Catchment has improved on previously available data. Additional input data such as ground cover trend data and more detailed land type data may improve predicted gully density values in some instances. Further verification in the form of field and or aerial photo analysis is also required to further validate results and improve predicted gully density, particularly within areas with significant over-storey tree cover.

Gully erosion typically occurs as a protracted pulse of activity. Initially sediment yields are high as the gully forms, but then they decline, leaving a fully developed gully as evidence of the total erosion. Again further field and photo analysis is needed to assess the activity of gullies in terms of gully head development and side slumping before the gully density map can be used to accurately predict sediment discharge from the catchment.

4.2 People

Data was collected throughout the project using: written evaluations, group and one-on-one discussions, journal entries, Continuous Improvement & Innovation (CI&I) tools, project team observations and written summaries and Local Best Practice technique. All participant quotes appear in italics and have been recorded verbatim.

Data and associated discussions have been organised under headings that represent project achievements in relation to CI&I. These achievements are:

1) improved understanding of and by producer participants
2) motivated people involved in taking regular focused action for improvement
3) positive response to CI&I
4) effective support
5) change resulting from individual projects.

Within each achievement section are the sub-headings outcomes/outputs and what we learned about the approach of the project and participants. The key learnings appear as a summary at the end of this results and discussion section.

Achievements

4.2.1 Improved understanding of and by producer participants

Who we worked with

Most properties in the Zamia/Mimosa Catchment are managed by family enterprises. These families have a genuine interest in handing down their properties to their children in the best possible condition. The majority of families have lived in the catchment since the commencement of the Brigalow Scheme in the 1960s. A high percentage of families are multiple property owners with properties often outside of the Zamia/Mimosa Catchment. There is an increase in the number of properties that are run by managers for corporations or owned by family enterprises from other areas.

Working with the newly formed Fish Creek Neighbourhood Catchment (NC) we collectively wrote a land management report using the Local Best Practice technique. This report provides guidelines for a beef property typical for their area in 2004. This document contains a description of land types, vegetation, topography, soils, pastures, production capacity and condition. Also described are suitable enterprises, cattle management and grazing land management. Sustainable production has been defined as production that optimises profit with minimal degradation of the natural resources. A short exert from this report follows, the full report can be found in Appendix 9.2, p. 105.

Enterprise

Cattle breeding and finishing are the main enterprises. Cattle breeding occurs mainly on land type 2. Open forest, while finishing occurs on the best paddocks in land types 2. Open forest on alluvial flats, 3. Brigalow/blackbutt, 5. Brigalow/belah/bauhinia and 6. Softwood scrub with associated brigalow.

The majority of producers incorporate both breeding and finishing into their enterprises. Buying in cattle is time consuming, requires a big outlay of capital and there is more risk involved as well as no financial advantage. Some producers buy cattle in to ‘top up’ if the season is good.

Property size depended on the amount of land type 1. Range country and land type 2. Open forest included in the block under the original Brigalow Scheme. Properties in this area range in size from 3 035 ha to 3 844 ha with land types 1. Range country, 2. Open forest, 3. Brigalow/blackbutt, and 4. Open forest on alluvial flats, down to 1 619 ha with only land types 5. Brigalow/belah/bauhinia and 6. Softwood scrub with associated brigalow.

Approximately 1 500 head of cattle with everything weaned, which equates to 500–600 breeders should be able to support one family once cash flow is operational and equity increases. Increased economic pressure is being placed on families with three levels of education to finance for their children.

Social description of catchment

The Bauhinia Landcare group folded in the late 1990s. Those involved with this group expressed their experience with the conundrum of getting people involved. From the outset they stressed the importance of creating a "social environment" within the project.

There has been a lot of social change in the Zamia/Mimosa Catchment in the last five years. For example eight families have been 'lost' resulting in decreasing opportunity for people to socialise. Agforce is the only functioning group in the catchment outside of sporting groups that is supporting people technically and socially. In response to this the local Moura and district Agforce branch is developing "Know Your Neighbour" project that encourages social interaction.

People have had negative experiences with government employees initiating projects where they have positioned themselves as 'experts'. They were offended by the assumption that they were incompetent and/or do not understand contemporary issues.

People are frightened and cynical with some experiencing economic pressure. There was concern about the issue of extrapolating information, the weaknesses associated with this and the government 'getting hold' of the information to use against them. There needed to be clarification about ownership of the information gathered and generated by this project and its future use. Nevertheless there were people willing and keen to participate in our project in order to represent their industry proactively and to demonstrate that, "*Our house is in order*".

Producer's perspective of the future

The steering group were asked to identify trends in the community that would have an affect on the beef industry, these trends can be found in Appendix 9.3, p. 114. They also created a vision of what they thought the catchment would be like in 5–10 years based on these trends (Table 12).

Social	Environment	Production/Economics
• Aging community with an average age of 70, there will be a large turnover when these people retire. • Less young people with rural skills. • Fewer people • The next generation will be more proactive, with their "get up and go" attitude; rural towns will be revived. • Less opportunity for the younger generation. • Increase in leasing and hence absentee landholders. • People will have more balanced life styles; they will have interests hobbies outside of work. • We will be influenced by the electronic age. • More difficult to easily obtain skilled labour. • Increase in the standard of living. • Increase in private consultants.	• Runoff less turbid • Increased occurrence of Giant Rats Tail. • Country more timbered	• Decrease rate of return • Increase in supplementary feeding. • Grazing still the main land use. • Other protein producing animals such as camels, kangaroos etc. • More feedlots • Increased ecotourism for example farm stays. • Increase use of electric fencing and watering points. • Less cropping • Economic squeeze • More mining of coal and gas. Questioned use of coal? • NLIS in place • More leuceana • Property size will be larger. • Harvesting of lime bush and wait-a- while. • Families relying on off farm employment for income. • Bookkeeping requirements have increased.

Table 12: Future vision of Zamia/Mimosa Catchment identified by the steering group

Producer's perspective on water quality

Water quality was not perceived as an issue of concern. This could be due to the history within the catchment, where enterprises have moved from cropping to grazing. They witnessed significant soil movement during the cropping phase. As grazing land use increased, water quality appeared to have improved.

The steering group were not aware of the extent that the wider community, particularly the Great Barrier Reef Marine Park Authority (GBRMPA), was targeting the beef industry in respect to their role and resultant impact on the environment. Their response was to take up the challenge of representing their industry in a positive light and to demonstrate with the use of science and social science the impact of their practice on water quality.

I was not aware of the problems with the reef being affected and the concentration on grazing.

Wanted to show people that we understand what we need to do. That we want to be part of this issue. That we can think rationally about the topic.

Water quality is going to be a big issue. If we don't get involved bureaucrats will tell us what to do. It's about having a voice.

Assisting producers in targeting water quality

Using a CI&I tool (Focusing Framework), both Fish Creek NC and the steering group were asked how water quality could be improved. Focusing Frameworks use words and diagrams to help people identify all components within a situation; these are represented by a flow diagram to improve thinking. This then enables people to select and focus on one component or a pathway of components to improve their action and in turn improving water quality. The steering group Focusing Framework (Figure 26) and the Fish Creek NC Focusing Framework (Figure 27) also helped to achieve a shared mental model of the project, which in turn fostered ownership.

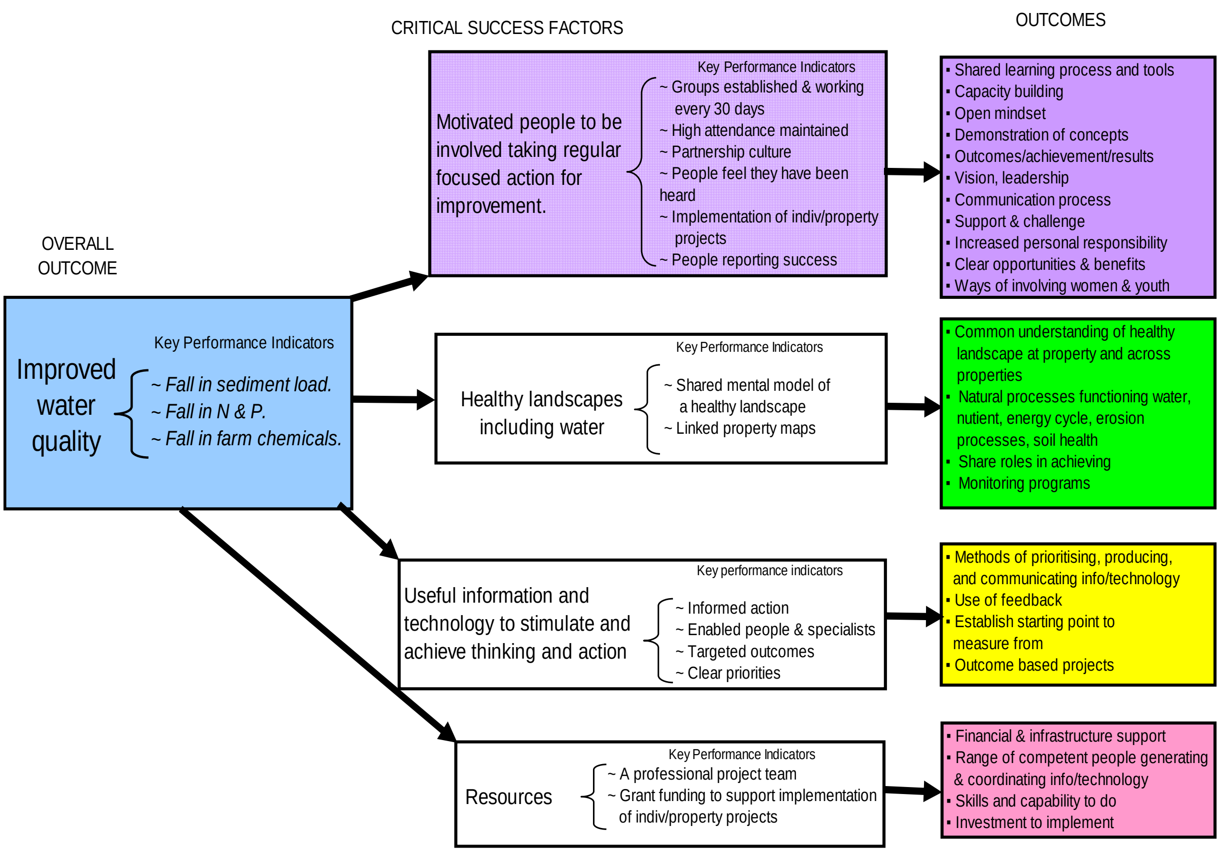


Figure 26: The steering group's Focusing Framework

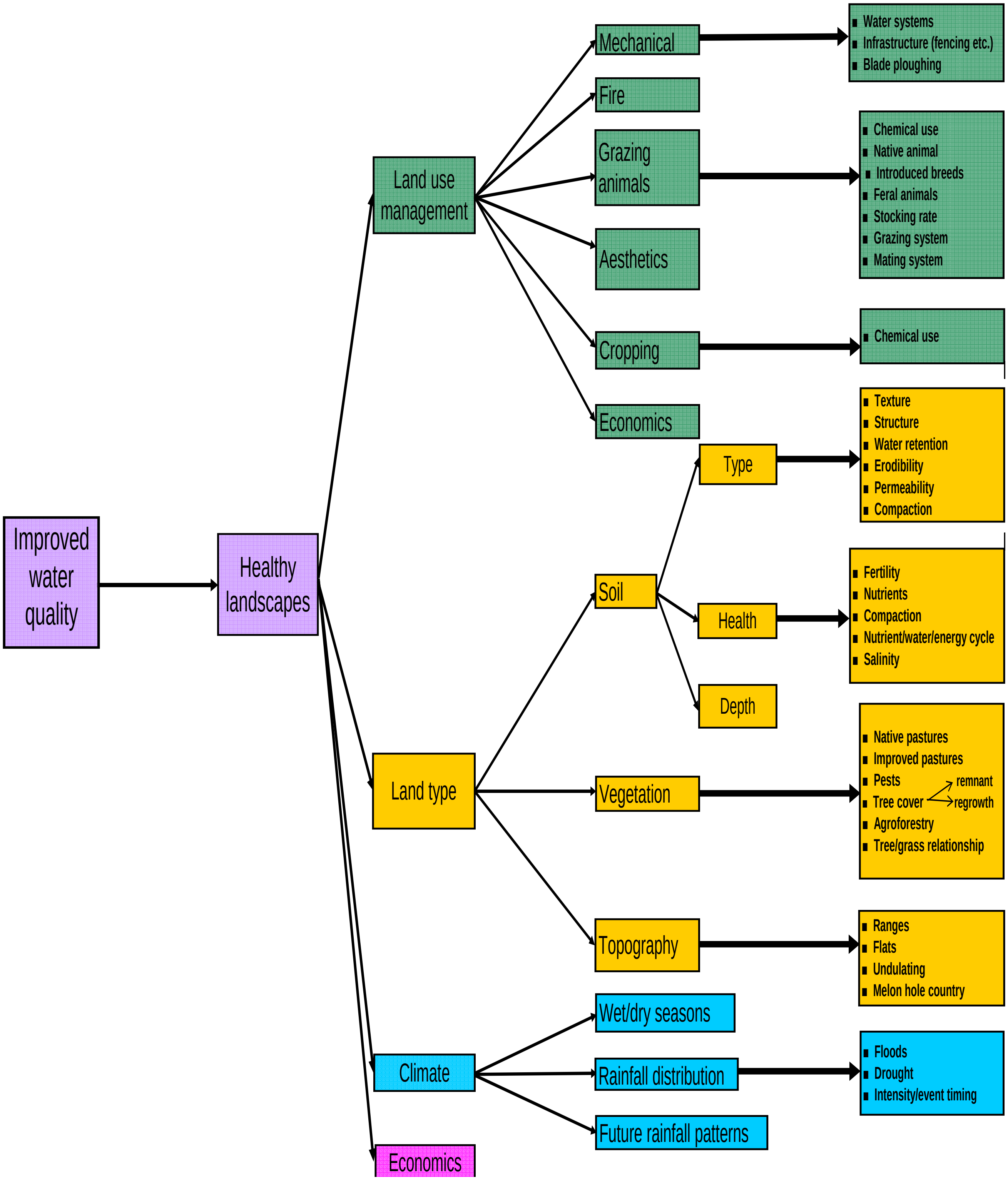


Figure 27: Fish Creek NC Focusing Framework

With the use of the Focusing Framework participants are in a good position to develop opportunities for action to improve water quality. Opportunities developed by the steering group and Fish Creek NC are shown in Table 13.

Using the Focusing Framework and list of opportunities in conjunction with another CI&I tool, SMARTT Focus, people wrote a Focus for their group as well as for their individual projects. Key concepts, words and assumptions are clarified and negotiated during this task. The Focus represents a clear statement of what is to be achieved and the resulting outcomes.

Steering group's list of opportunities	Fish Creek NC list of opportunities
Group Focus: To achieve continuous improvement and innovation with beef producers and other relevant partners to improve water quality in the Southern Mimosa Catchment in the next 10 months.	**Group Focus:** To improve water quality by 10% in the Fish Creek Catchment in the next 10 months.
1. Need to deal with water quality not being an average concern. Need to take a focused and proactive stance. 2. Quantify what effect we have on land and water. 3. Make use of results generated by other agencies. 4. Engage and maintain producer participation. 5. Demonstrate the opportunity to improve financial and environmental benefits to individual landholders. 6. Make a real difference to natural resources. 7. Introduce technical information and technology. Technology – mapping, GIS, automation systems, remote sensing, modelling. Technical information – improved pastures, ecology. 8. Produce guidelines of practices to improve water quality. 9. Attract funding. 10. Producers to take a proactive stance.	1. Set up monitoring site on our place that measures quantity and quality of runoff. 2. Monitor erosion source after intense rainfall event. 3. Continue to do Grass check to keep an overview of groundcover. 4. Use other systems to increase animals' ability to exhibit maximum potential (spike feeding) with the outcome of increased ground cover with animals being removed earlier. 5. Maintain existing infrastructure contour banks, waterways, no grazing of cropped areas to slow water flow and increase ground cover. 6. Explore the rate of recovery of country to changes in management. 7. Make use of climate forecasting for specific activities e.g. chemical application. 8. Slow overland flow to encourage water penetration and retention with the use of blade ploughing. 9. Use of chemicals to control regrowth to minimise soil disturbance. 10. Plan infrastructure within land types.

Table 13: Opportunities for action to improve water quality

An example of an individual project Focus was: To achieve an improvement in the productivity of land (improved soil health & better pastures) by 40-50% by implementing two methods of regrowth control (Graslan & blade ploughing) on two soil types (popular box & brigalow) until July 2005.

Project outcomes**:**

- better pastures (increase in types of grass, water infiltration and number of grasses)
- improve stock management
- increased stocking rate (kg/ha)
- improve water quality.

Figure 28 and 29 show (from participant's perspective) what level of impact implementing the opportunities will have on improving water quality and their personal ability to contribute to achieving these opportunities. Participants gave a score between 1–10 for the impact and influence of each opportunity. Each point represents an opportunity and the average score calculated from participants' scores. For instance, point 4 in Figure 28 is the steering group's opportunity number 4. Engage and maintain producer participation (Table 13).

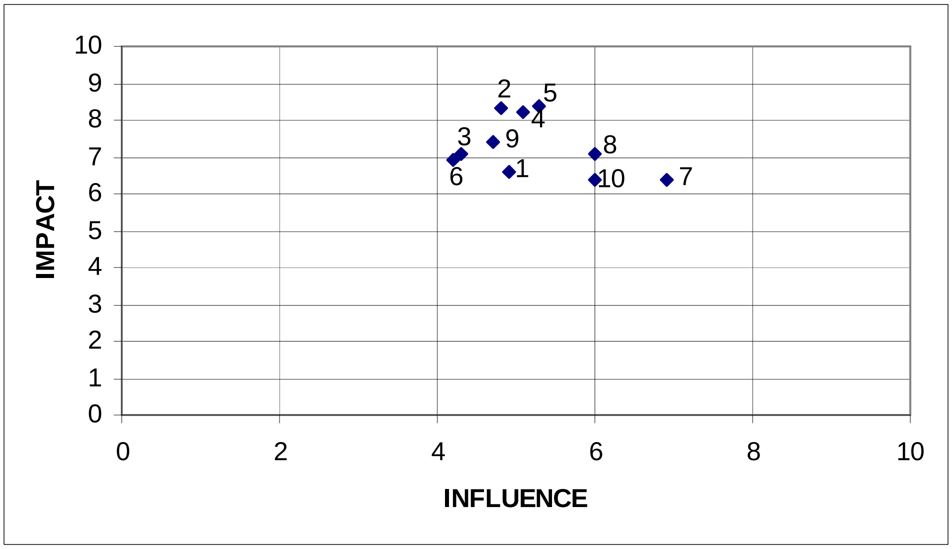


Figure 28: Impact of and personal influence on opportunities for the steering group

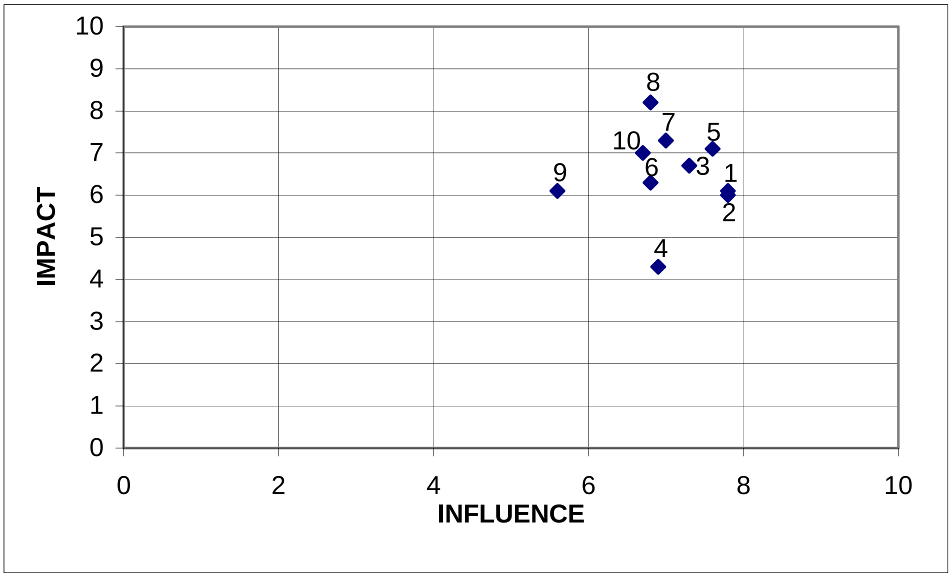


Figure 29: Impact of and personal influence on opportunities for Fish Creek NC

Both groups felt that they had the ability to influence the opportunities with Fish Creek NC feeling more influential. The majority of the opportunities identified would have an impact on improving water quality with the steering group scoring their opportunities for higher impact. <u>There was no single course of action that they all agreed on for improving water quality.</u>

Opportunities with high impact and influence for improvement of water quality were:

- introduction of technical information and technology

- demonstrating the opportunity to improve financial and environmental benefits to individual landholders
- setting up monitoring sites, monitoring erosion source after intense rainfall event
- slow overland flow to encourage water penetration and retention with the use of blade ploughing.

Outcomes/outputs of improved understanding of and by producer participants

Local Best Practice document of current management of grazing lands in Fish Creek NC 2004.

Shared mental project model of what is crucial to have in order to improve water quality.

New thinking and action on how to improve water quality from a producers' perspective. This producer perspective was developed with the support of project partners.

List of opportunities for action to improve water quality, action that involved a number of different ways of tackling the issue.

A greater number of people working together to improve water quality having an impact at a property and catchment scale.

An approach for producers that will improve the image of the beef industry.

A new working relationship with project participants that this project is calling a partnership.

A better understanding of producers' situation and perceptive. The project is in a position to be more beneficial to participants.

What we learned from an improved understanding of and by producer participants

Natural resource management projects need to accommodate the many and varied ways people tackle land management. The individual project key performance indicators (KPIs) provided participants with the scope to make their own connection with water quality.

For collaborative work to be successful it is imperative to develop a shared mental model of a project at its commencement.

Producers provided excellent suggestions on how to improve both science and social science practice of the project.

The data shows that we are working with a diverse group of people with a broad range of skills, knowledge and interests. Projects/programs need to accommodate this diversity and allow for a range of people to become involved, taking and retaining action and ownership of the issue(s).

There is high diversity within our communities. Developing programs where one size fits all, don't go there anymore.

Issues not forced upon us, encouraged to be proactive rather than reactive.

Even in an untrusting and cautious climate resulting from recent vegetation management legislation, producers are willing to volunteer their time and resources to natural resource management activities with government agencies.

Producers are eager to represent their industry in a positive light. They have the mindset that we must and need to work together.

This is what we're facing how can we best demonstrate that our house is in order? Take a proactive stance, being positive about it.

We have to work with the whole community. Creating an us and them feeling is not healthy.

Knowing the people, knowing their setting and their values, recognising their existing knowledge and their fears are prerequisites to establishing a solid working partnership.

4.2.2 Motivated people involved in taking regular focused action for improvement

Participation

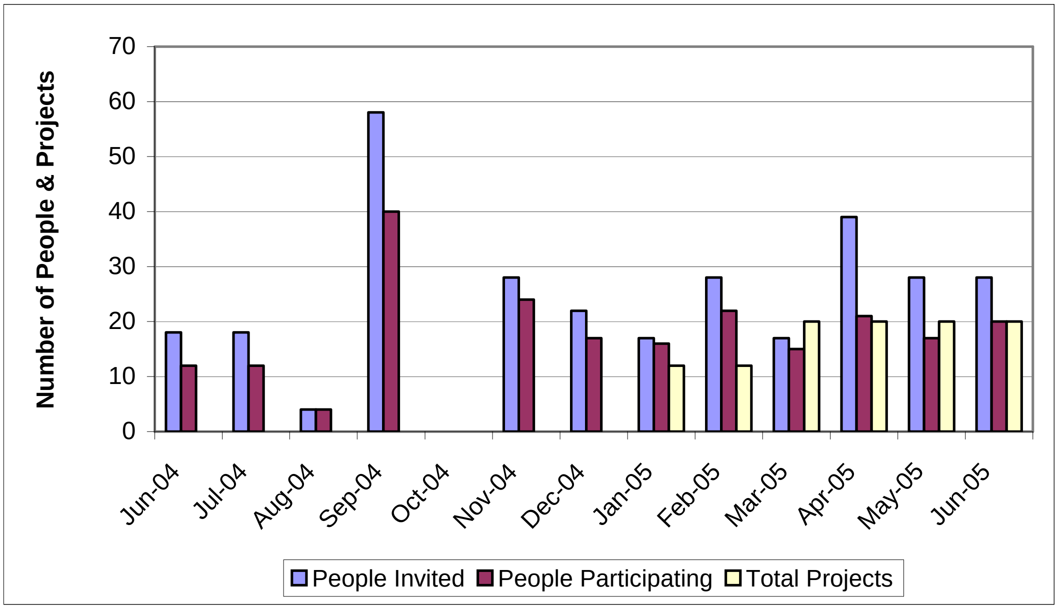


Figure 30: Participation of people through the 12 month CI&I approach

Emphasis was initially placed on forming and working with the steering group and Fish Creek NC. In late 2004, with increased confidence we decided to form another neighbourhood catchment, Kangaroo Creek. This catchment's social characteristics were quite different from Fish Creek NC with the majority of properties being managed by absentee landholders/managers. With the absenteeism characteristic it became evident that more time was required when establishing a group.

The greatest difference between people invited and people participating occurred in Sept 04 and April 05 (Figure 30). In September 04 this higher difference was due to Fish Creek NC meeting twice that month and in April 05 all three groups were to meet that month, but Kangaroo Creek NC workshop was cancelled. Overall, we achieved a participation rate of 49% to 100% with an average participation rate of 70%. What stopped people from participating included rain, work with outside contractors e.g. helicopter hire, cattle trucking etc., monthly meeting came around too fast, lack of skilled labour, struggle with reporting, lack of project future and travel time to attend meetings.

The steering group came together nine times over 12 months with workshop length averaging 4.5 hours (1/2 day). We gathered at private residences, Bauhinia community hall and Brigalow Research Station. We also worked with single families within this group when developing property maps and supporting the writing of individual projects (Action Designs). In total we spent approximately six days contact time per family during the twelve-month period.

Fish Creek NC met 10 times over 10 months again with average workshop length 4.5 hours (1/2 day). We initially met at the key producers home them moved to the Brigalow Research Station.

Work with single families in this group involved the production of property maps and support with CI&I tools as well as establishing monitoring sites relevant to their projects. In total we spent approximately seven days contact time per family during a ten-month period.

In total this project was supported by a core of 28 producers plus five partners who remained committed to the project. Monthly meeting times and location were set by each group early on. In addition to the monthly meetings producers committed their own time and resources at the various stages of the project process.

Outcomes/outputs of participation

Formation of two new groups and the establishment of the groundwork to form a third.

Eighteen individual projects working towards improving water quality. A full list of these projects is in Appendix 9.4, p. 115. Eight of these projects have been completed. The following list gives an indication of the topics of some individual projects':

- reduce soil loss (two projects)
- fence off creek and land types (one project)
- improve how land management was monitored (two projects)
- improve ground cover (four projects).

Good working partnership that is still evolving. Steering group acting as advocates for the project.

The project, because of the methodology it has chosen, has acquired quality data on what is currently happening and what strategies to best employ to achieve the project outcomes. If a similar project did not proceed the data collected would provide a rich picture of what factors led to the non-completion of the project.

Producers who are participating represent a cross-section of the industry. Some have not and would most likely not participate in extension/natural resource management programs/projects.

Ongoing involvement of current participants includes:

- the steering group co-writing submission for refunding
- co-presenting the project at MLA final report meeting
- Fish Creek NC is still functioning under their own initiative. On October 17th & 18th 2005 Fish Creek NC held a grazing education course (Cattle & Catchment). They plan to meet in the future to hold field days that feature their individual projects.

What we learned about participation

CI&I is an approach that is based on mutual respect in a non-judgemental environment. Building different working relationships is important for this type of approach to be successful.

Everyone needs to go in this direction for growth. Need to do things for growth, look at different ideas, improving the way you run everything or you won't prosper and grow.

If any form of change, in this project's case improvement and innovation, is to be achieved project activities need to be part of a specifically designed process as opposed to irregular, *ad hoc* activity that is primarily about the communication of research outputs.

Introducing tools and a process to generate better thinking, results that we could apply and the idea that you could achieve an outcome; if this happens we can build on that.

We did something different, I now see I'm sick of the same learning processes. We caught people by the unique way we did things. Like the CI&I game, the coloured sheets, working with the six-step cycle. The method of thinking and the flowing process were unique.

The regular practice of improvement and innovation is essential. Regular workshops were established to build the groups and identify and implement actions that supported individual projects.

A way of motivating me to get my project completed. Meeting monthly to check people's progress.

Meeting monthly keeps the project in your mind.

We drift along with work; coming to this meeting has put me back on track.

It is imperative to persistently evaluate how the approach is progressing to adapt and improve how we work together, thus maintaining interest and people's involvement. Two examples of how the project approach was adapted follows:

- Most participants struggled with reporting their projects using the designed Reporting Framework. With a redesign of the framework the reporting of projects improved.
- Fish Creek NC found monthly meetings difficult to maintain and put up the solution of meeting as a group every second month with monthly support from the project team. They also wanted to incorporate field visits to each other's projects.

Adaptive processes such as CI&I are flexible and robust enough to be a long-term proposition for a community, not just another project that comes and goes.

With the apparent trend of increasing absenteeism projects need to consider this feature when mapping group formation milestones.

Working with small-facilitated groups (6-15 people) intensely is the most productive course of action if change is an outcome. For these groups are easier to manage, more versatile in the type and format of information that can be handled and participants have more of a chance to contribute leading to more effective action and outcomes. Constraints with these groups include, special skills are required to manage project processes and finding a conducive environment within which to meet can be difficult.

There are two kinds of groups; one-off group meetings and ongoing groups. Ongoing groups and the associated on-going evaluation with small groups allows for a building process enhancing thinking and action.

Small groups work best when:

- people are focused on outcomes that can be implemented and give results
- people can participate for this is the key to developing ownership
- there is the expectation that people involved with any enterprise need access to training to develop skills and knowledge
- mutual trust has been established
- there is in place an agreed on process to work together.

Project outcomes will improve with more emphasis being placed on participation. This involves including the wider community as partners, recognising producer knowledge, integrating information into projects across disciplines and institutions and increasing self-directed action.

A facilitator can work with one to three groups if the type of group you are working with is an on-going learning and improvement group that is not yet self-managing. A facilitator needs to consider the likely needs of the group based on its type and maturity, but also how many different foci of individual projects that can be managed when considering facilitator/group ratios.

A facilitator needs the ability to show empathy, initiative and to develop trust.

Levels of collaboration from lowest to highest involvement are: liaison, coordination, cooperation, partnership, consortium and corporation. Within our project collaboration is at the partnership level. Partnerships ask for a higher level of participation with each participant having a role and a contribution to make.
I am very keen to see the project continue as I believe it has a lot of potential in increasing awareness of what can be achieved through working together to achieve environmental improvements and highlights the importance of a community approach to overall catchment improvements. It also engenders enthusiasm and a healthy community spirit about working together, on both productive and environmental projects, to achieve improvements that are simply not achievable by one enterprise working alone. The social benefits and overall wellbeing from this interaction should not be underestimated.

Advantages of truly collaborative partnerships are:
- more perspectives strengthens action taken
- increased commitment
- work with a larger range of skills
- promotes confidence
- captures those who would normally not participate.

We've never had Sam come along before. He is keen to do something about erosion on one of his blocks.

Fred has never phoned me to have a chat before. This is the first time he has shown his hand. He's got it all but can't get it together. He needs support, organising and a focus.

This approach included women and the younger generation.

4.2.3 Positive response to CI&I

Understanding of CI&I

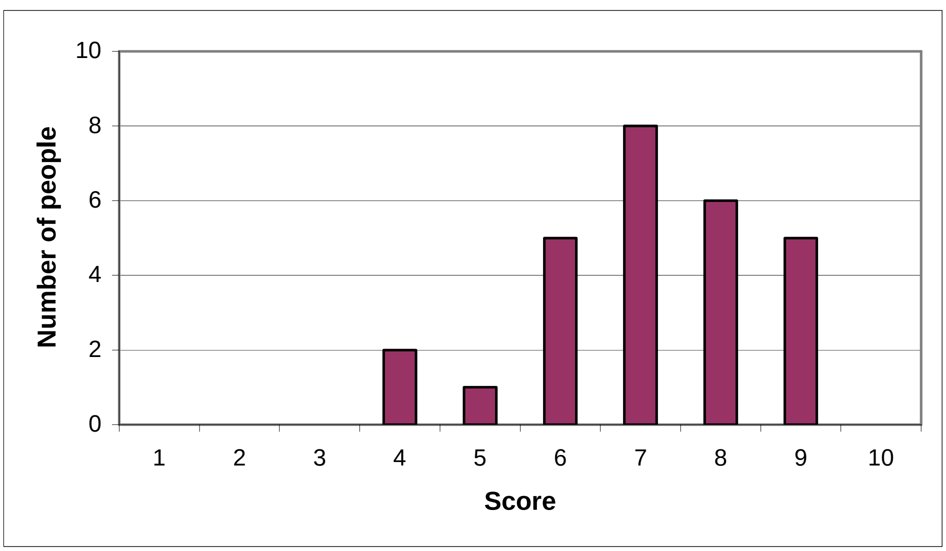


Figure 31: Understanding of CI&I, with a modal score of 7 and an average score of 7.11

This was the first exposure participants' have had to an adaptive management approach such as CI&I. Through their involvement with the project they developed an understanding of CI&I (Figure 31).

Outcomes/outputs of an understanding of CI&I

Increased capacity of participants to use the processes and tools of CI&I to assist in the identification of projects, their construction and taking action to achieve outcomes.

Stimulated shared thinking and action.

Building knowledge and confidence in the CI&I approach, their projects and themselves.

You allowed the group to work within their own level while trying to encourage them to improve and become confident with what they are doing.

What we learned

Rural communities need outside skills and expertise (research, facilitation, project and data management) to initiate and maintain involvement and direction in natural resource management projects.

We need a facilitator someone to drive the process – provide leadership and management of project.

Good organisation and facilitation, need it to motivate.

Adaptive processes are more effective at fitting in with people's busy life styles.

Oh no time is good at the moment, I'm trying to get a lot done while the kids are home. I'll make the time if it's going to happen.

Focusing on outcomes, not activities is essential. People confuse activities with outcomes and as a result many people rarely set or achieve outcomes that matter.

We worked with a structured project reporting technique that makes outcomes easy to evaluate in terms of progress and learning. Your restructuring of the process whilst keeping the basic principles intact, has made the whole concept more digestible for producers and their learning style.

We understood what we were doing and our outcomes. We enjoyed the meetings.

Where a project places its emphasis will affect the project's results. If emphasis is placed on packaging information you will end up with a package, if emphasis is placed on plans you will end up with plans. We placed emphasis on improvement and innovation - change.

I was lost until it finally twigged. It eventually fell into place. It's a bit of a different way to get where we want to go. It was about challenging my thinking and thinking outside the square.

Haven't been to a meeting before where people have had to present. It was a real education for me.

Determine what's to be done, how to look after what's there and how to improve what is there.

Skills developed during the project are transferable to community situations.

There were two people from Fish Creek that would never have attended a community meeting and they did last night.

The language of CI&I was a barrier for some.

Found it hard to get my head around it. There seems to be a gap. We've been trained differently to you. Doing things how you wanted us to do them and fitting them into what you want I found difficult. It may be what something is called like outcomes – this put me off straight away. I found the words you used difficult. Explaining them on the day was good but being left to fill in the sheets I'm stuck. I'm not use to doing those sorts of things. It was hard to grasp the whole thing.

The likelihood of participants using the results of research and development is higher with participative approaches such as CI&I.

The systematic collection of data coming back and our job is to see the data and the bigger picture and get direction from it. Having a conversation with one another. It's about not being closed minded we need to look at all the information. Look at all points of view put them on the table and pool our knowledge and work out what to do next.

We grew up with a lot of influence on this is the way to go. We listen to our elders. Learning to maintain country the best way. These projects and the monitoring ask you to think about these ideas. Looking at the grass roots of ideas.

Land management is more about managing self.

CI&I tools were well received

Outcomes/outputs of CI&I tools being well received

87.5% of people found the Focusing Framework tool helpful.

Brings the group together so they can act as a whole and achieve an 'ultimate' goal more effectively.

I tend to get lost in the big picture stuff and so found the focusing framework very useful to bring me back into focus.

I felt that the Focusing Framework was quite a good exercise to go through, as it probably made people focus on their action and reinforced, and quantified what they subconsciously do every day in a mental way.

We had to work out all the directions of getting there, most only look at one way. Look at all possibilities this tool helped us do that.

100% of people found the Action Design tool useful.

It provides clear direction and time for thought/reflection plus a clear structure to work within.

Due to my scatterbrain I need something to focus on. It is an excellent way to promote progress, as you can see what you are achieving and spend more time on things that need attention i.e. spread your efforts evenly instead of just doing what you enjoy and neglecting other issues.

Focusing things, the thing is to get as much information as possible and work out direction. I thought the project was an interesting and vital one.

Helps with the planning process, concentrate on the critical issues and makes best use of resources available to us. It makes you focus on what you want to do and how to improve.

Participants responded favourably to the CI&I tools primarily because these tools helped to establish a shared understanding of what the project wanted to achieve and how we were to work together. This resulted in participants being clear about what was expected of them.

I found all the tools helpful and useful. They're guidelines that provide steps – get conclusions and results at end. When George doesn't follow through and gets two thirds of the way through a project he tends to deviate. I can use the tool to say this is where we're supposed to be.

What we learned

The quality of a Focusing Framework is improved with the involvement of a cross-section of participants.

Establishing an individual project (Action Design) ensures participants are actively involved in seeking relevant information and support that will make a difference to their action.

When people have clear, outcome based action with articulated performance measures they know how to choose, conduct, evaluate and modify activities and information/technology to achieve.

Improved knowledge & skills

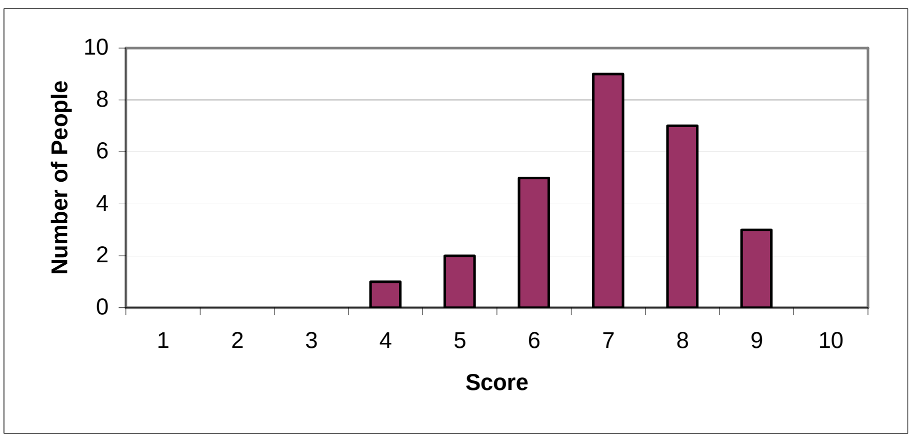


Figure 32: Improved knowledge and skills with a modal score of 7 and an average score of 7.04

Outcomes/outputs of improved knowledge & skills

The majority of participants thought their knowledge and skills had improved (Figure 32).

My knowledge did improve I don't know about my skills. It also enforced our knowledge and made us concentrate on it.

We didn't know we had the number of different grasses that we had.

Having mapping skills is important because I see it as an important tool for future structures and it forces Fred to put his knowledge down to share with the family.

Collection and analysis of data by producers and project team has resulted in changes in land management such as:

- knowing pasture quality and quantity to achieve reduced soil movement
- role of fire
- improved contour banking
- monitoring more closely
- incorporation of trees
- fencing to reduce paddock size
- improved cooperation between neighbours
- the use of management tools that minimise disturbance of the soil.

What we learned

Most participants struggled with the ‘paper work’ side of the approach. Most struggled when they were asked to use reading and writing skills due to low literacy levels.

Providing there is no paper work.

Lack of confidence to tackle things that we’re uncomfortable with such as paper work. X is really resistant to change; he does things as his grandfather did them.

It was the gap with the paper work, having to do the paper work after meetings was a big bugbear.

We would need one-on-one support to be more confident with the paper work.

Participants though, saw the value of thinking through and writing their individual projects in the format asked for by the Action Design tool.

Tools for burning haven’t changed but the tools of monitoring the paddock and project have because of our involvement in the project. We now see that you need to put a project on paper and look at the data. We could track our progress.

Low literacy skills have ramifications on confidence levels, how they perceive themselves and their ability to assess information outside their communities. Projects such as ours that are based on measurable outcomes allows people to identify what skills they need to develop in order to improve their actions.

Most people required and saw the value in developing skills such as documenting individual projects and data management.

We would not have thought of putting the project on paper and looking at data. It made us look at the paddock and what it’s produced. We will keep doing that if we simplify the data. Doing the project has made us look at the paddock much sooner by two years.

Producers realised the importance of performance measurement to review their practice and to identify opportunities for improvement. Developing the skills to collect their own data to ascertain whether they needed to change management direction appealed greatly and did result in change in management.

The positive is that I have collected hard data regarding weight gain per hectare over the trial period. I will continue this for 12 months minimum. It must be noted however that to me as a manager and cattleman I could see the positives and negatives, but the data put a definite figure on the experiment. The next two collections of data will hold great interest in regards to results.

I could see the change but the extent was not clear. (The data showed me that) I could have kept on that track and I could have been in trouble.

I'm going to put a report together after 12 months. Photograph monthly and data on rainfall and kg/ha. I could see my mistakes and finding quantifying it is really interesting and useful.

We had reached the stage where people were starting to review their practice.

One of the most interesting presentations we've had in awhile. Some thought that through ripping they were doing all these wonderful things when in fact they could be damaging their soils.

Individual projects involved family members not attending workshops.

Being part of a small group has provided the support and motivation to seek further education opportunities collectively and in a way that best benefits them.

Monitoring programs – interesting and creating a desire to learn more about grass check and monitoring in general.

Is the RCS course set in concrete, can we adapt it to meet our needs?

We would consider doing a course if financial support was offered.

Timely support and the timely provision of information/technology are essential.

Individual projects provided a structure into which research and development findings could be incorporated. Research and development findings were discussed and applied to individual projects. This information then becomes more meaningful and individuals are challenged to think more widely, deeply and creatively in a practical way.

It is not information on its own that actually makes for better practice. It is how the person relates to that information, how the information fits in with existing knowledge, how practical and useful it is perceived to be and whether it can be readily implemented.

Happy with the whole project. I hit the wall I got going at the start but knew I was going to get data the give us direction.

All participants need to be equipped with the necessary capacity in order to achieve. The range of knowledge and skills needed for CI&I are not currently taught. While people are achieving improvement and innovation during this project the relevant knowledge, skills and tools were acquired.

Improved implementation of individual projects

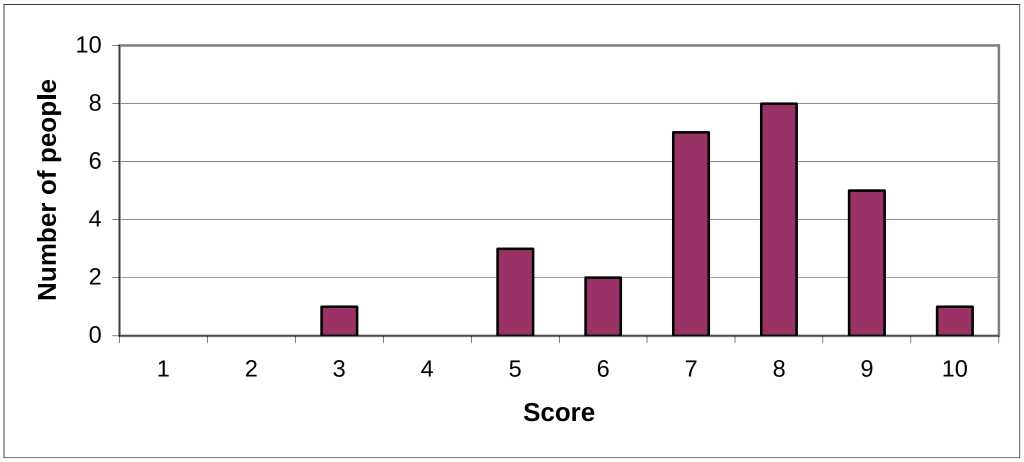


Figure 33: Improved implementation of individual projects with a modal score of 8 and an average score of 6.74

Individual projects regularly measured and recorded their achievements, which has improved implementation as shown in Figure 33.

Outcomes/outputs of improved implementation of individual projects

Outcome based targets were developed rather than activity based targets. Establishing outcomes greatly improved the implementation of individual projects. This research project made a clear distinction between outcomes and activities for many get caught in the 'activity trap' where people have little idea of what is to be achieved let alone how to assess whether they have been successful in achieving.

Greater awareness of critical success factors (CSFs), key practices (KPs) and key performance indicators (KPIs) to improve water quality.

Better coordination of effort that recognises and uses the skills of all participants.

Participants staying on track and moving towards improved performance.

Participants are more focused on what they want to achieve in their businesses.

Participants recognise that there is a possibility of thinking differently about their situation.

What we learned

Implementation of projects was improved with regular measurement of KPIs that were linked to individual project outcomes and Focus. The measuring of performance has a strong influence on what is achieved and the rate of this achievement for measurement drives behaviour and behaviour change (Francis 1992).

We have seen it (our project) through further. The tools that we're learnt we wouldn't have thought of, putting effort into this project has done this.

It challenges your excuse making and areas that you are not comfortable in.

We like the opportunity to try things out and decide for ourselves. We need to action things out.

Participants had control over the content of their individual projects within a prescribed process. This resulted in the investigation of a diverse range of topics all working towards improving water quality.

The CI&I principles and tools allow for the recognition of success. People feel rewarded and confidence and motivation increased.

The project provided an opportunity for people to implement projects that would never have been implemented by them.

This project helped 99% with getting our project going. It was a job that wasn't going to ever get done. If it doesn't made money right away tends to go on the back burner. We're in a position now to go.

When action is focused where impact is greatest greater return on investment results.

Producers were willing to invest their own resources into the implementation of their projects, evidence that they were committed to achieving them.

My biggest problem is that I have a fair bit on my plate. The project I worked on is deep to my heart and time is very valuable. I need to delegate so I have more time for this project.

They are now more aware of organisations and networks that could support them.

Increased confidence and enthusiasm

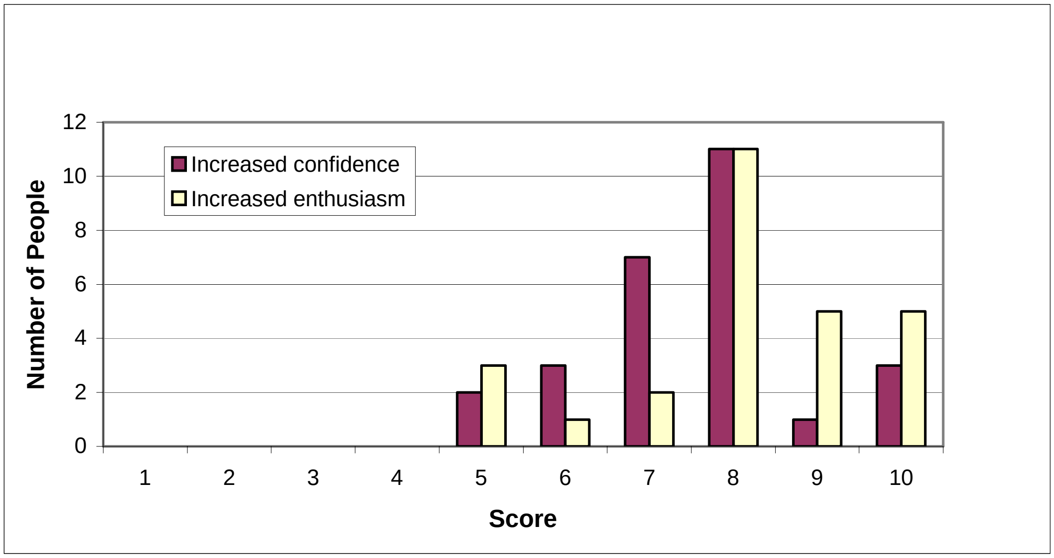


Figure 34: Increased confidence and enthusiasm; confidence with a modal score of 8 and an average score of 7.56; enthusiasm with a modal score of 8 and an average score of 8.07.

Outcomes/outputs of increased confidence & enthusiasm

Improved confidence, enthusiasm and skills (Figure 34) in the effectiveness of CI&I, documenting projects and managing data.

Just continue on a positive path and stay focused. Remember to use the step-by-step process and not jump back and forth, this will help to quantify and recognise my achievements and give me confidence to continue improving.

Improves my confidence - believe that I can understand things.

What we learned

Feedback was an element of the project that people valued.

Feedback has improved my confidence in putting data together. My data helped influence other people. It gave me a lot of self-esteem when presenting my booklet. The project has given me confidence.

I would want to continue as the process gives me confidence and will to achieve. The feedback I have received has boosted my feeling of worth and purpose. The overall support has lifted me to perceive things in a more positive light and has reduced my frustrations when I have set backs, others fail and have set backs too.

The project is worthwhile because I do believe until we get feedback, back and forwards and match our observations with old knowledgeable producers who have experience over a longer period of time we won't move forward.

Participants worked well together and benefited from each other's projects.
This project kicked us along and gave me direction to get it done. It was good to have other people interested in what you where doing.

Getting the ideas from others in the group on how you might do things better was good.

Enjoyed the project, it was a bit of a challenge to get it done – the push along sort of a thing was good. People in the group had knowledge that we knew nothing about.

People's confidence with putting projects on paper did improve.

The paper work side, the project has put it together. This project has given me the confidence putting the project together on paper to tackle it.

I'm going to keep going with graphs and collecting data.

People were starting to add complexity to their projects.

We'd like to improve the project by adding cattle, soils and pastures as opposed to just land. We now have experience with vegetation identification, photography monitoring, tree measurements & tree counts and have learnt how to better construct a project to achieve a measured result.

This project makes you look; take more notice of what's going on in the paddock.

Participants enjoyed the project

Outcomes/outputs of enjoyment

The majority of participants gave a score of eight and above to the support they received (Figure 35 & 36). They enjoyed the materials provided (Figure 37), the social aspect of the project (Figure 38), the organisation (Figure 39) and our meeting place (Figure 40). Overall enjoyment of the project had a modal score of eight and an average score of 8.37 (Figure 41).

The social side was good. You could live next door to people for years and never see them. You're that tied up these days. We see and meet people at clearing sales and we play tennis other wise we don't do much else. We run our places as a family. The project was a way of changing our lives a little.

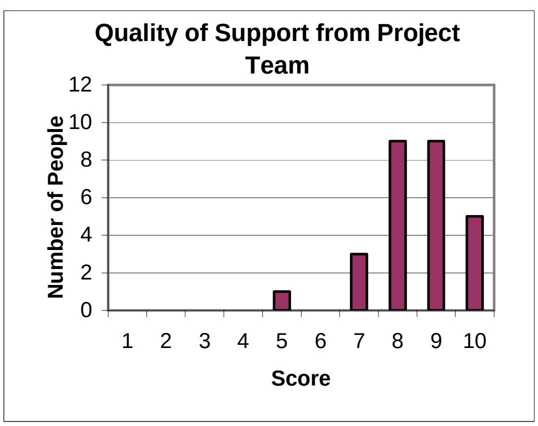


Figure 35: Quality of support from project team with modal score 8/9 & average 8.48

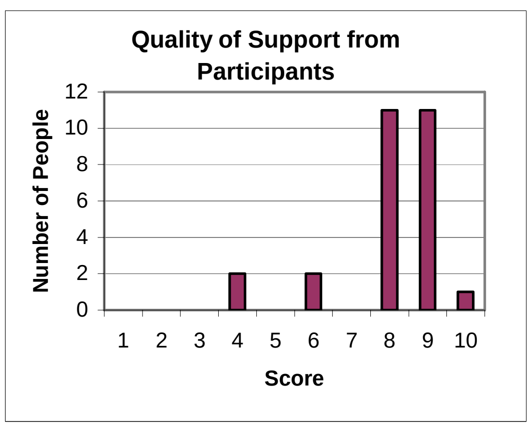
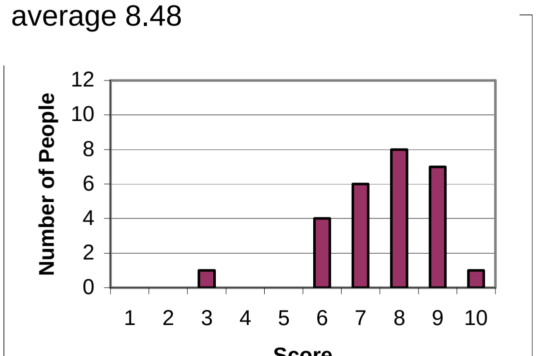


Figure 36: Quality of support from participants with modal score 8/9 & average 8.04



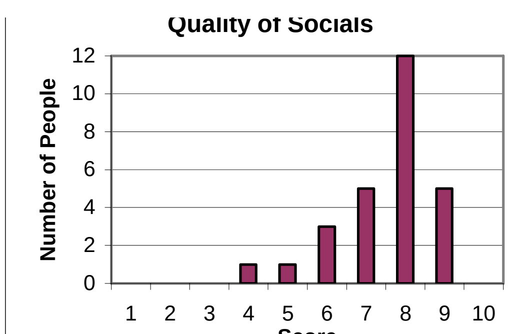


Figure 37: Quality of materials with modal score 8/9 & average score 8.04

Figure 38: Quality of socials with modal score 8 & average score 7.52

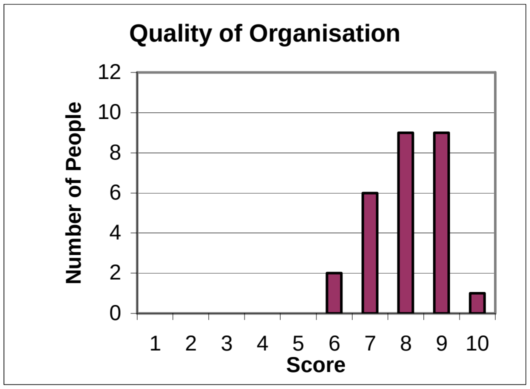


Figure 39: Quality of organisation with modal score 8/9 & average score 8.04

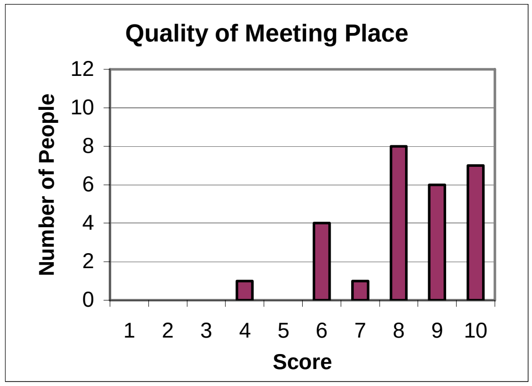


Figure 40: Quality of meeting place with modal score 8 & average score 8.26

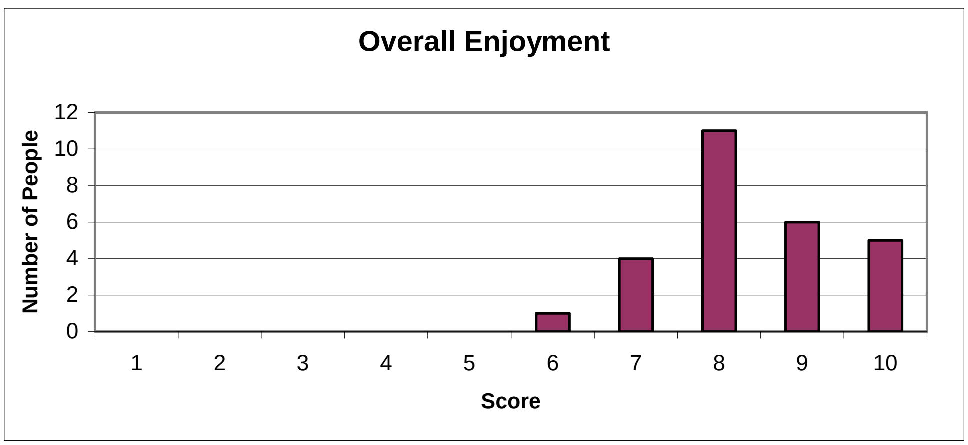


Figure 41: Overall enjoyment with modal score 8 & average score 8.37

What we learned

People do their best work in a supportive environment.

Inspiring being involved in a project with such specific targets, attainable means to get there and the motivation of the group to do so.

It is crucial to continually evaluate people's feedback and make improvements to project content and process based on this feedback.

We had a good group and how we interacted was good. If we do it again start with a full day then spread the meetings out with farm visits to people's projects.

4.2.4 Effective support

96% of participants rated the quality of support with a score of seven and above (Figure 42). The support provided during the project resulted in participants' feeling positive about their work and improved implementation of individual projects (Figure 43).

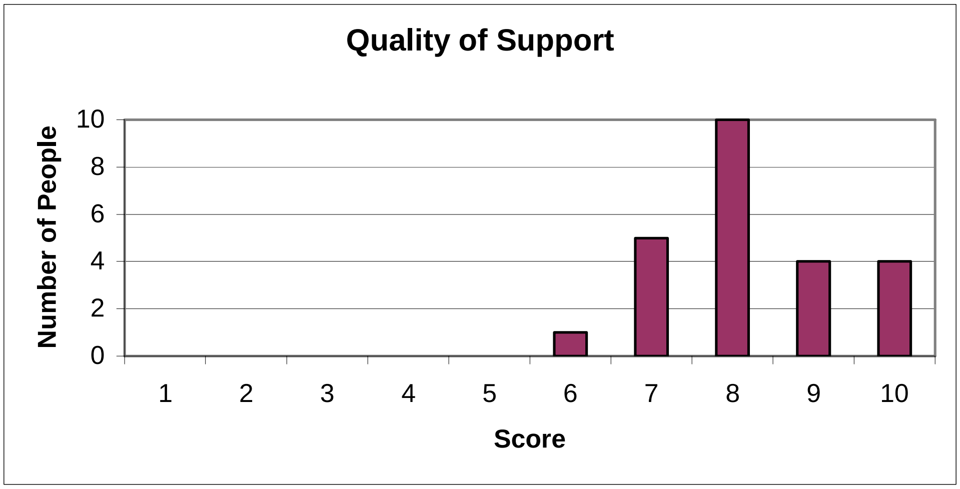


Figure 42: Quality of support with a modal score of 8 and an average score of 8.21

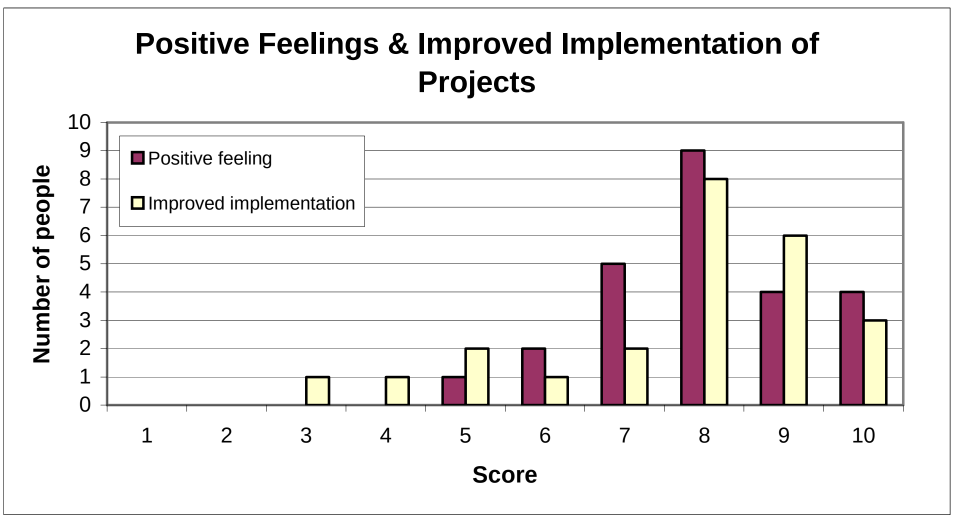


Figure 43: Positive feelings & improved implementation of individual projects, positive feeling with a modal score of 8 and an average score of 8, improved implementation of projects with a modal score of 8 and an average score of 7.71.

The following table (Table 14) relates to the support thinking & action workshops. During these workshops the listed outputs and outcomes in the table were monitored. The data shows that support sessions were successful in achieving their outputs and outcomes.

Outcomes	February	May
Increased understanding of other projects	100%	100%
Improved thinking & action	78%	71%
Creation of new observations, questions and ideas	100%	100%

Identification of new opportunities for action	67%	86%
Increased confidence & enthusiasm for action	89%	100%
Increased understanding of CI&I	78%	100%
Outputs	**February**	**May**
Contributions by participants in support of individual projects (Observations, Questions, Ideas and Opportunities)	O=12 Q=30 I =9 O=2	O= 13 Q= 23 I = 4 O= 0
Scores of confidence and enthusiasm	C 6.9 E 7.8	C 8.3 E 8.4

Table 14: Outcomes & outputs of support sessions

Outcomes/outputs of effective support

All participants were offered support every 30 days in improving and implementing their projects. Specialist support was also provided.

New observations, questions and ideas on how to improve.

Participants rated the support received as high.

We got a lot of support at meetings.

The day I had in Bilo with you all really kicked it along really well.

I was a bit apprehensive at first. I found it good. I've always been quiet and reserved the project helped to take you outside of yourself.

Participants supported each other in the designing and implementation of individual projects.

There was a totally different atmosphere – you giving support and we in turn gave you support.

People felt positive about their work and the implementation of individual projects improved.

I'm interested in the project because I can see the benefits to us as a community. We are working together, getting to know our neighbours, improving communication between ourselves for we do affect each other. We get pulled in so many directions; we need organisational support to keep us on track and moving. Without the support that this projects provides we would lose interest and would get lost in our paddocks.

What we learned

Achieving early results is paramount.

CI&I provides a framework that supports people in managing projects rigorously.

The quality of support is influenced by the skills of participants in asking for and providing support as well as the tools used.

The need and desire for support varies with participants. Is meeting monthly the right timing for participants? One group suggested the opportunity of meeting every two months as a group with support offered monthly using another means of communication.

There needs to be more research on what happens to the intensity of support through time. Do people require less support as they continue to participate?

They appreciate and value feedback on what they are doing when it is presented in a culture that is supportive and positive. People enjoyed giving support to others. The support they provided each other was excellent. Peers often are best at providing support that is challenging.

Leading an isolated group into self-sufficiency will not work. Single groups need to be part of a network of groups to support project initiatives for the long term. Groups need financial and technical support as well as human resources to succeed in the long term.

4.2.5 Change resulting from individual projects

The following figures demonstrate specifically what outputs and outcomes (changes) that have been achieved by individual projects for the steering group members (Figure 44) and the Fish Creek NC (Figure 45). Each stack represents an individual project. This research and development project is using the following definitions for output and outcome.

Output
The interim results, the activities, products, and services designed to contribute to achieving outcomes.

Outcome
The end result (impact) of activities, products and/or services, i.e. what is actually achieved in terms of measurable change as a result of activities.

Project Status

Outcome	thin border
Output	thick border

Palatable grasses	Building knowledge	Producer involvement	Mapping	Environ. Management systems	Positive stories	Utilisation & quality	Better soil health
On-going	**On-going**	**Completed**	**Completed**	**On-going**	**Stalled**	**Completed**	**Stalled**
		Support of grazing community					
		Established network of leaders					
		Maturing partnerships	Management tool to support improved family decision making				
	Improved rapport with producers	Improved understanding of who we are working with	Family involvement	Improved local contacts			
Family support	Improved producer understanding of technical information	**Fish Ck NC & steering group**	Facilitated software support with program supplier	Trees planted			
Clarification of direction	**Technical information to support projects**	**Measure of projects progress**	**Two property maps**	**EMS manual**		**Family involvement**	
Independently sought technical support	**Specialist contact list**	**CI&I workbook**	**Mapping software**	**Draft EMS**		**Accessed FBA funding**	
Fencing design	**Soils presentation**	**Producer involvment process design**	**Satellite imagery**	**Monitoring photos**	**Media contacts**	**Photographic records**	**Data tables**
Budget	**Knowledge gaps identified within producer projects**	**18 working projects**	**FBA funding application**	**EMS Guidelines**	**Facts & figures to support accurate reporting**	**Sketch of plan**	**Monitoring sites**

Figure 44: Steering group individual project outputs & outcomes

	Body weight	Improve pasture health	Reduce soil movement	Better maps	Regrowth control	Use of fire	Red tape/soil loss	Motivation & support	Reduce erosion	Reduce soil runoff
Project Status	**On-going**	**On-going**	**Completed**	**Completed**	**On-going**	**Completed**	**Completed**	**Completed**	**On-going**	**On-going**
Outcome				Improved management within current infrastructure				Improved working partnerships		
Output				Linkage to educational packages		Continuing to monitoring burnt plots vs. unburnt plots		Coordinated ground work to improve water quality		Increased desire to understand impact of management
Level 3				Improved resolution of data sets		Improved data collection & analysis		Producer request for additional R&D findings		Involvement of son
Level 4			Reduce soil loss	Linking to computer mapping packages	Son involved	Improved computer skills		Increased confidence & enthusiasm	Improved understanding of landuse, runoff and soil relationships	Improved understanding of linking cattle pasture & soil
Level 5	Continue monitoring of cattle weight & grass recovery	Desire to develop skills	Reconstructed waterways & modified contours	Improved understanding of land types	Maps supported application of Graslan	Improved grass identification	Cooperative management of drainage issue with neighbour	Participants wanting to continue	Awareness of improved contour bank design	Completed ripping program
Level 6	Expressed interest in more comprehensive monitoring	Involvement of son	**Management records**	**Maps utilised for CI&I projects**	Improved understanding of tree pasture relationships	**Plant specimens**	Involvement of son	Supportive environment	Involvement of son/daughter	Family support
Level 7	Increased data support in decision making	**Erosion sites mapped**	**Photographic records**	**Improved quality & relevance of maps**	**Photographic records**	**Monitoring sites**	**Photographic record**	**Support strategies**	Improved participation	**Monitoring data**
Level 8	**Monitoring of cattle, climate and time**	**Monitoring program & records**	**Contour & waterway design**	**Map package**	**Recorded rainfall**	**Rain chart**	**Contour bank & waterway design**	**Improved CI&I tools**	**Remediation of waterways**	**Photographic records**
Project	**Data management system**	**Fencing in progress**	**Project plan**	**Property mapping process**	**Monitoring program & records**	**Stocking records**	**Signed off soil conservation plan**	**Measure of people's response to CI&I**	**Rainfall records**	**Plan of attack**

Figure 45: Fish Creek NC individual project outputs & outcomes

Key learning

If change in land management practice and improved natural resource health is to result we need to work in partnership with industry members, the ‘end-users’ of research and development findings. We need to work in resourced, networked, small-facilitated human development groups, regularly, using targeted science/technology and a specially designed change process. The most effective people landscape relationship in the Zamia/Mimosa Catchment is a small group (6-15) in a neighbourhood catchment (~300 km^2). To extrapolate to a larger geographic area increasing the size of a group is not the answer. The most effective direction is to establish human infrastructure such as supportive networks of small groups that equip people to improve and innovate.

Participants responded positively to an adaptive management approach (CI&I) using a structured collective focus to achieve outcomes that would benefit individuals, water quality and the health of their neighbourhood catchment. These outcomes were achieved for participants’ knowledge and skills improved in relation to seeking and implementing research and development findings on property through learning from group-based activities in development of individual projects. Also implementation of individual projects was improved with regular measurement of KPIs that were linked to individual project outcomes and the group Focus. The measuring of performance has a strong influence on what is achieved and the rate of this achievement for measurement drives behaviour and behaviour change (Francis 1992).

An outcome of the project has been an improved understanding of project participants, which has led us to new thinking and action in regards to improving water quality, how to work effectively together and how to link research and development findings into property management. Creating partnerships where people have clear roles and responsibilities, relate to each other professionally and have common outcomes is also enhanced through a better understanding of whom you are working with.

CI&I is proving successful in this research context for it is involving a broader cross-section of the grazing community implementing a suite of coordinated projects to improve water quality. Local relevant data both qualitative and quantitative was used to identify and refine the management of natural resources requiring greater awareness and improvement. As well, monitoring tools that enabled measurement of performance from implementation of producer projects allowing analysis of management practice.

Participants have been equipped with a process of change and tools to improve their thinking and action collectively and individually. As well support strategies have been developed with regular measurement of results both of which have improved enthusiasm, confidence, thinking and action. Support strategies provided such as CI&I tools, property maps, one-on-one sessions, participant feedback, specialist information/technology and regular meetings were effective in initiating and managing change.

Through this approach we have developed a better understanding of the social system and have identified the best opportunities for change. We have implemented new methods of building groups and involving people in partnerships. The project has provided participants with tools, skills and information to achieve, all of which will support the sustainability of the grazing industry.

Adaptive approaches such as CI&I present themselves as long-term propositions for participating communities. Because they ask for a constant review of project content and process that monitors the results of actions and integrates this new learning, they are able to adapt actions as necessary. They are therefore flexible enough to ‘fit into’ producers’ time frames where climate, time of year, family and financial commitments may require immediate responses. If managed well they are not yet another project that comes and goes. This long-term outlook matches the long-term commitment of most beef producers.

The maturity of groups, the demographic characteristics of neighbourhood catchments, subsequent repeated completion of the Six-Step process, response to support over time, content and increased complexity of individual projects and impact of forming networks of neighbourhood catchments need further understanding to enable a more detailed assessment of CI&I within the beef industry.

5 Success in Achieving Objectives

5.1 Objective 1&2: Science

1) Determine runoff, soil erosion and pollutant transport at a paddock to neighbourhood catchment scale.

Runoff, soil erosion and pollutant transport from the paddock to catchment scale was rigorously monitored using applied scientific techniques. The critical issue where targeted research was warranted examined the change of cropping land use back to permanent pasture. At the paddock scale, the project highlighted how the transition in land use affected runoff response and soil movement (p. 34–36). Moving from a cropped land use back to permanent pasture reduced runoff and soil loss by 37% and 93% respectively. Within two years of returning to pasture, runoff and soil erosion behaved in a similar manner to a permanently grazed pasture of 15 or more years establishment (p. 38). Seasonal rainfall patterns were instrumental in determining critical periods of the year (late spring to mid summer) where increased runoff, soil erosion and pollutant transport occurred (p. 39).

Change of land use and seasonality of rainfall patterns contributed to runoff and soil erosion response at the neighbourhood catchment level (p. 48, 52). Highly erratic spatial and temporal rainfall patterns restricted analysis of monitored results to a generalised level. Establishment of electronically monitored catchments at a neighbourhood catchment level demonstrated the role of land use and land types in controlling runoff and soil movement (p. 52).

When moving from the paddock to catchment scale, one can assume that pollutant transport levels (TSS, TKN and TP) generally decrease as catchment size increases. This project clearly demonstrated that this relationship does not necessarily relate to conditions experienced within the broader Zamia/Mimosa Catchment (p. 121–123). This suggests that a greater understanding of other causes and processes that lead to a decline in water quality at all scales is required to further investigate the role of people and rainfall response within diverse landscapes.

2) Understand the causes and processes that lead to a decline in water quality at a paddock, property and neighbourhood catchment scale, and relate responses to catchment condition.

The dominant erosion processes occurring within the Zamia/Mimosa Catchment are restricted to the hillslope and gully areas within the landscape. At the hillslope scale, ground cover is an important factor in improving runoff water quality. When critical ground cover levels are reached, resultant impact of rainfall across all scales leads to a decline in water quality. This catchment is experiencing a general decrease in ground cover that is cause for concern for land holders now and in the future (p. 50).

Gully erosion appears to be the dominant erosion process at the property and neighbourhood catchment scale both pre and post clearing of vegetation. Significant gully erosion is occurring but short-term response has seen an accumulation of soil movement in gullies rather than removal through runoff water (p. 42–43). Ground cover may not however retard future gully erosion in land types dominated by soils with high surface or sub-surface levels of sodicity.

This project has provided an insight into the erosion processes occurring in major land types across the Zamia/Mimosa Catchment. Detailed analysis has permitted the identification of four critical land types that are influencing decline of water quality throughout the catchment (p. 50–51). Producer information allowed the initial identification of such land types known to the project team. Catchment water quality and rainfall event distribution combined with ground cover trends have highlighted the importance of such land types within the landscape.

Brigalow dominated land types are displaying moderate to high levels of both hillslope and gully forms of erosion and an increase in the trend of decreasing ground cover (p. 50–51). Location of such land types within the Zamia/Mimosa Catchment is critical to water quality, with a higher impact when they are directly influenced by the range land type. Upland catchments dominated by range land type with adjacent brigalow land types are demonstrating high levels of TSS, TKN and TP (p. 121–123). Critical areas within the broader Zamia/Mimosa Catchment have been identified, through science investigation, where resources and management practices could be implemented in future to improve water quality and overall landscape health.

5.2 Objective 3: People

3) To achieve Continuous Improvement and Innovation (CI&I) with beef producers and other relevant partners to improve water quality in the Southern Mimosa Catchment in the next 12 months.

The development of this new objective placed importance on the human dimension of land management. The processes we have used have looked towards gaining a greater understanding of the people involved in the project and their land management practices (p. 61–69). Participants knowledge was valued which fostered a stronger working relationship and motivated people in taking regular focused action for improvement.

Evidence of motivated people can be found in the participation section (p. 69–73). In total the project was supported by a core of 28 producers plus five partners who remained committed to the project. These participants formed three new groups; a steering group, Fish and Kangaroo Creek Neighbourhood Catchments (NC). In addition to monthly meetings participants committed their own time and resources to the 18 individual projects that collectively worked towards improving water quality.

The success of the approach can be attributed to the use of small-facilitated groups. The creation of a supportive ongoing group environment that targeted issues of relevance also contributed to the success of this objective (p. 84–86). The fact that participant involvement is still ongoing post project demonstrates the approach has created an avenue for producers to collectively learn and improve their current approaches to land management. This is highlighted by the Fish Creek NC members requesting and completing a grazing education course on their own initiative following completion of the project.

Rigorous evaluation of the approach occurred throughout the project. Data on how CI&I tools were received was collected and concluded that CI&I tools were well received by participants (p. 75–76). Establishing individual projects with the use of CI&I tools ensured participants were actively involved in seeking relevant information and support that would make a difference to their action. This was further supported with findings in relation to improved knowledge and skills (p. 76–79), improved implementation of individual projects (p. 79–80), increased confidence and enthusiasm (p. 81–82) and enjoyment of the project (p. 82–84). A vital aspect of individual projects was the measurement of performance. Each project had articulated key performance indicators that provided the evidence of people's progression. Some participants were starting to add complexity to their projects illustrating that the process of continual improvement had been instilled.

In the short time in which the approach was implemented it was shown to be effective in fostering cultural change for the majority of participants. Continuous Improvement and Innovation has been accepted and improved by all participants. The approach has demonstrated its ability to create change (improvement and innovation), this change is demonstrated by the outputs and outcomes of individual project (p. 86–88).

6 Impact on Meat and Livestock Industry – now & in five years time

The grazing industry will inevitably be faced with the prospect of either self-administered change or regulated enforcement to decrease the impact of land management on the environment. Beef producers involved with this project have demonstrated a strong desire to lead industry in an approach to improve their current thinking and action, in turn leading to increased productivity and sustainability of enterprises and communities. This project provided the framework, tools and support in aiding producers to not only learn, adopt and apply new information to improve land management but also to identify opportunities that would have greatest impact, design individual projects, measure performance and celebrate achievement.

If we are to change and improve land management, we must look to approaches that value the human dimension of land management and that develop human and social capital. Too often, approaches are based on technical solutions using delivery mechanisms that create only awareness and/or understanding. Evidence suggests that this technical focused approach has been unsuccessful given that producers are still facing the same issues today. This project implemented a new approach that used a science and social science methodology in engaging people and directing attention to the real issues producers are currently encountering in relation to the bigger natural resource management issues such as water quality. The demise of the local land care group (Bauhinia Landcare) in the late 1990s shows that producers also have been frustrated with the conundrum of getting people involved. From the outset of the project the steering group set about developing ways of involving all producers in the study catchment. The experience of the project approach gave them confidence in the fact that our new approach had great potential with engaging producers.

And it is this engagement that is required to rectify the current situation involving particular land types and ‘hot spots’ within the Zamia/Mimosa Catchment. The monitoring methodology employed to examine water quality and landscape processes quickly established where attention is required to improve water quality. More concentrated efforts within these areas could significantly alter the present situation of high levels of sediment and associated nutrients exported from these catchments. There is also evidence to suggest that it may not be solely the action of beef producers that is contributing to this outcome, hence the need to involve all land managers.

Concentrated efforts within a small catchment of the Fitzroy Basin will not ultimately affect the water quality at the Dawson Catchment, let alone that entering the Great Barrier Reef. For real change to occur, it must be delivered at an industry wide level. The project approach of creating neighbourhood catchments that use targeted science and an extension paradigm that uses management and improvement processes designed to achieve change provides a way forward on an issue that has long stopped the progression of the beef industry. Establishment of networks of neighbourhood catchments across the landscape is the solution to encouraging change at a larger scale. It would require adequate resourcing or redirection of resources from ineffective activities and research programs that have no affiliation with beef producers. This action by the beef industry would be viewed in a positive manner by all members in light of the feedback this project has received from engaging a small but motivated group of beef producers from a cross-section of the industry.

Finally, this project is unable to clarify the impact of the beef industry now and into the future beyond the Zamia/Mimosa Catchment. Significant resources have previously been allocated to undertaking water quality monitoring with little or no co-ordination and a lack of strategic direction regarding the location and analytical requirements to report on land management by industry members throughout the Fitzroy Basin. This project has placed emphasis on working with producers at the level required to assess the impact of their actions, the individual property scale. The project timeframe has not permitted changes in biophysical evidence to occur but has demonstrated an approach that supports beef producers from a cross- section of the industry in achieving improved land management in the key parameters influencing water quality.

7 Conclusions and Recommendations

7.1 Conclusions – Science and People

If the beef industry's aim is to improve current land management practices resulting in an improvement of landscape health and the establishment of stronger communities and businesses, findings from this project provide an approach to achieve these outcomes from the property to basin scales. To encourage change in natural resource management, the most suitable scale is a property within a neighbourhood catchment using targeted science and an extension paradigm that uses management and improvement processes designed to achieve change. Establishing networks of neighbourhood catchments across the landscape will ultimately demonstrate positive changes in social, economic and environmental outcomes.

The role of science must support the learning from adoption of improved practices, using tools such as monitoring to evaluate the effect of change. Results indicate that if we improved ground cover at critical times of the year and across more fragile land types, then we could improve water quality. Seasonality of rainfall patterns and resultant impact on runoff and erosion processes is demonstrating an area where large scale change in management practice has the potential for the greatest influence on enhancing landscape and catchment health. Erosion processes vary in magnitude between land types with findings indicating that gully erosion may in fact be the dominant process across the Zamia/Mimosa Catchment. Preventive measures to minimise this process relate more to the immediate catchment area rather then remedial activities within the gully itself.

However, if we extend this information gathered in isolation to the producer, the 'end user', and ask them to apply it at a level beyond their influence, we will not achieve change. Every producer is unique in their management style, and how they incorporate new practices will result in different outcomes on individual properties. Science must therefore be flexible enough to incorporate quantitative information with individual producer knowledge (qualitative) to achieve the desired outcomes of improving property and landscape health.

Neighbourhood catchment and larger catchment scale assessment requires a longer-term commitment than 12 months to establish whether change at the property scale translates to improvement at the landscape and catchment level. Natural factors and land type processes that impact on the health of the landscape need to be examined in unison with the adoption of improved practices. Working at this scale will also allow for identification of critical areas within a catchment that may cause disproportional impacts across the greater landscape and catchment level.

Scale is also an issue that relates to the social dimension of the project. The most effective grouping of people is 6–15. The most effective people landscape relationship is a small group (6–15) in a drainage catchment (~300 km^2) for the Zamia/Mimosa Catchment, which this project has called a neighbourhood catchment. Increasing the size of a group when extrapolating to a larger geographic area is not the answer if change is an outcome. The most effective direction is to establish supported networks of neighbourhood catchments that are equipping people to improve and innovate. The number of networks of groups would depend on the geographic area.

The role of people in natural resource management should not be underrated. If change is to result we need to work with industry members, the ‘end-users’ of research and development findings, in networked, resourced, small-facilitated human development groups, on a regular basis, with a specially designed change process that incorporates targeted science and technology. Performance that is outcome based and measurable needs to be determined. Using processes and tools that augment thinking and the establishment of outcomes and outputs which are measurable with on-going support, provides an effective and efficient means of achieving change – continuous improvement and innovation. This project has been clear about differentiating between outcomes and activity. Working with partners, clear specific performance outcomes that matter are generated. Change does not happen by chance with key concepts having to be designed and managed.

There is tremendous potential for other paradigms/methodologies to play a role in improving natural resource management and progressing agricultural industries. The predominant use of empirical research methodologies has served the industry well. But with the increasing complexity of natural resource management and the push to report on outcomes as opposed to outputs, the opportunity for the inclusion of other paradigms of research such as critical research methodologies (adaptive management) has emerged. Adaptive management best fits research and development projects that are about achieving change and that are inclusive of the human dimension of land management.

To work most effectively with beef producers in neighbourhood catchments requires the building of a social partnership and framework that supports the implementation of innovation and improvement in achieving change. We have shown that using an adaptive management approach (CI&I) has demonstrated sustained improvement in:

- approaches that value investment in human infrastructure
- the capability of industry members
- adoption of research and development.

It also has the potential in the future to improve and promote:

- innovation & adaptive grazing management
- healthy landscapes and
- sustainable businesses.

CI&I has greater potential to create long lasting change as more producers become familiar with the CI&I process and the associated tools and techniques. In the short time that we have been working with CI&I, producers have identified that they are tired of the traditional ways in which research bodies, natural resource management bodies and government agencies approach them. Producers and partners have clearly understood the principles and concepts of CI&I to the extent of moving out of personal comfort zones to develop necessary skills for improvement and innovation and some have started to introduce complexity into their individual projects by working at a systems level. CI&I represents a practical model of the key components that need to be included in the design and management of research and development projects to ensure change is achieved as part of the project.

7.2 Recommendations – People and Science

1. Research and development organizations need the support of producers to improve research information and improve how information, technology and adoption are approached. The working relationship between producers, extension staff and researchers needs to be significantly improved.

2. View producers as agents of change not barriers.

3. Work on the ground in partnership with science and a change process for this results in the best improvements and innovations.

4. Today's issues are more complex, requiring comprehensive institutional and cultural change to address problems such as resource use. The implementation of research and development projects that use management and improvement processes that are congruent with human systems-based approaches for change and innovation are imperative.

5. Reduce the reliance on government and research and development corporations through the stimulation of cultural change by the development of human and social capital. The building of better human infrastructure for best practice in achieving, leading and managing continuous improvement and innovation initiatives.
6. Approaches that target the selection and adoption of relevant technology and information for achieving targeted outcomes will engage people in local/regional/industry/community to achieve change.

7. Provide graziers with an opportunity to participate in having an influence on what future initiatives might be introduced into their communities.

8. Move to collaborative adaptation and development of new information/technology as opposed to technology driven activity.

9. Projects/programs that strive to engage a broader cross-section of rural communities need to accommodate low literacy levels.

10. This approach represents a model, process and tools for innovative and adaptive grazing management for MLA to use in a broader context with application from and across the beef industry.

11. For the industry to recognise that expertise and resources need to be placed into outcome-based research and development that places more emphasis on the human dimension of land management.

12. That the grazing industry in general play a greater role in demonstrating that its members are accountable for their actions and willing to challenge and improve the utilisation of resources for the long-term benefit of improved landscape and catchment health.

13. An honest and critical assessment of research and extension paradigms/methodologies within the grazing industry needs to occur if adoption and change are the desired result. There needs to be clarification as to what industry bodies mean by research and research and development. What do industry bodies want to achieve and importantly how are future researchers to improve their practice? Projects have struggled with these issues but have continued to do the same thing and achieved the same result. The timing is right for this assessment, with funding bodies now having to demonstrate that research findings are being adopted throughout the broader community. The way forward is to explore alternative paradigms/methodologies that are demonstrating progress towards the goal of adoption and change. Bring together and back the people with a real desire to support the endeavours of our landholders to continue improving and implementing innovation. The public and landholders recognise the timing is now, let's hope that the industry listens and responds in a positive manner to this exciting challenge.

Future work into areas of current research has been documented throughout this report. A summary of these follows:

1. Moving projects up to operating at a systems level, both in their design and implementation. This project has primarily been operating at the practice and process level.

Improvement and innovation is usually possible and needed at all these levels, however we have found that often the great leverage for change comes from supporting people to work at the systems level (Clark & Timms, 2001 p1)

Natural resource management is about managing a complex system. For us to be most effective we need to consider the relationships between the elements of a system in order to be assured that the perceived solution is in fact not causing harm. There needs to be the development of ways to effectively work at this level for the scientific method has made choices that does not allow it to work with complexity.

2. Multiply advances of the CI&I Six-Step process. During this project participants only had the opportunity of completing one cycle of the Six-Step process. They are now familiar with the concepts and principles of CI&I and the type of thinking and action required. They have increased confidence in themselves and the approach as well as a feeling of success and achievement. Researching the impact of multiply advances would contribute greatly to our understanding of the impact of this process.

3. More effective and efficient linking of research and development findings into property management. There can be improvement made to the developed platform and partnerships for integrating research and development information/technology into producer projects.

4. Establishing human infrastructure. Improved groups/teams/partners and networks that are motivated, committed and equipped to continuously achieve improved landscape health and sustainable business represents the human infrastructure that needs to be established and researched.

The ability to achieve our goals, fulfil our missions, and make contributions to the world depends as much on the resources available in and through our networks (our social capital) as it does on our individual knowledge, expertise and experience (our human capital) (Baker 2000).

Getting this aspect of a project right will support the application of this approach in other locations within Australia as well as within the Fitzroy Basin.

There needs to be recognition of the changing social nature of rural areas. People, families are leaving the industry with properties being purchased by neighbouring families, families outside the local area or corporations. This leaves the question, how effective is CI&I in a catchment where the number of absentee landholders is high?

5. Improved involvement of women and youth. This project was inclusive of the perspective of all participants, which did include women and youth. The acknowledgement and incorporation of the perspectives of women and youth improved the quality of individual projects as well as their implementation. The principles of the approach seemed to naturally allow for there participation to occur. More in-depth research on this would be beneficial.

6. Explore the use of other research paradigms and methodologies. An improved matching of the strengths and weaknesses of research methodologies to the research outcomes and/or outputs will improve return on investment.

7. Improved remote sensing capabilities of ground cover to allow rapid assessment of catchment condition to allow researchers and producers the ability to investigate the role of management at the paddock, land type and catchment level.

8. Improved confidence in the Bureau of Meteorology radar imagery to gain a further insight into rainfall spatial and temporal patterns and their effect on critical land types/areas with catchments.

9. Exploring in greater depth the role and interaction between qualitative data (producer knowledge) and quantitative data (locally relevant science findings) in aiding future improvements and innovation in grazing strategies to improve landscape health.

10. The role of gullies in the landscape, active *vs*. non-active gullies, critical land type relationships investigating soil properties and contributing area relationships with gully development.

11. Role of change in management at the property level translating to an improvement in catchment water quality and overall landscape health.

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9 Appendices

9.1 Appendix 1 – CI&I tool worksheets

SMARTT Focus Tool

Area of Attention:
……
……………………………………………………………

Need/Opportunity:
……
……………………………………………………………………………………………

Draft Focus:

……
……
……………………………………

SMARTT your Focus:

Specific? **……………………………………………………………………………………**
Measurable? **………………………………………………………………………………**
Achievable? **………………………………………………………………………………**
Relevant? **…………………………………………………………………………………**
Targeted? **…………………………………………………………………………………**
Timelined? **………………………………………………………………………………**

SMARTTer Focus:

……
…………………………………………………………………………………

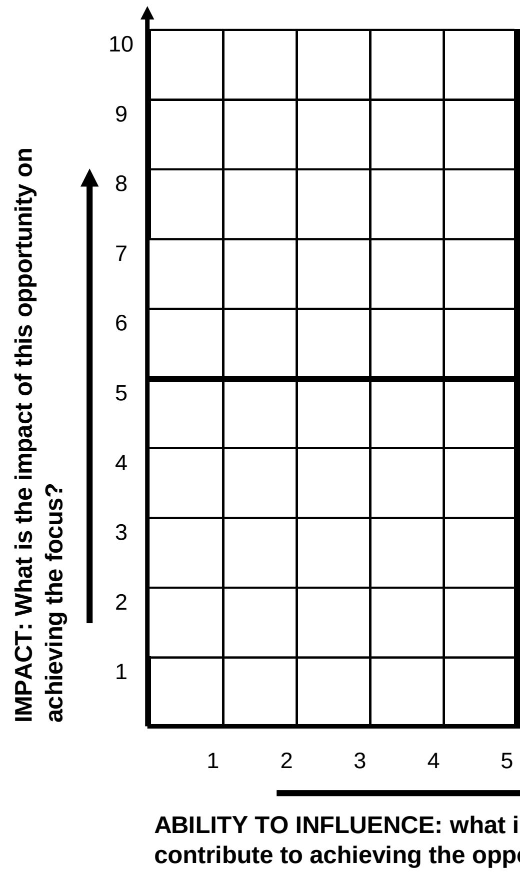
Target Outcomes	**Target Outputs**

Key Principles and Assumptions Underpinning the Focus & Target Outcomes & Outputs:
……
………………………………………………………………

Impact and Influence Tool

Focus:

No.	Opportunities for action to achieve the Focus	Impact	Influence
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			



Action Design Framework

Focus: A Focus should state clearly what you want to achieve; Be SMARTT (Specific, Measurable, Achievable, Relevant, Time-bounded and Targeted); Indicate boundaries and scale of Focus.		
CSFs Critical Success Factors **To achieve the focus it is critical to have …… (state as outcomes)**	**KPs** Key Practices **To ensure the CSF is in place it is necessary *to do* these steps. KPs start with an active verb eg list, negotiate, send, develop etc.**	**KPIs** Key Performance Indicators **To assess the level of achievement of the CSF it is necessary to have these measures of performance.**
1.		
2.		
3.		
4.		
5.		

Reporting Framework

Focus:

Target Outcomes of Reporting	Target Outputs of Reporting
1.	1.
2.	2.
3.	3.
4.	4.

CSF	KPI	What actions I have completed over the last 30 days	What blocks or problems have arisen?	How I/we are tracking the effects of our actions	Support Needed to continue AD

9.2 Appendix 2 – Local Best Practice Report for Fish Creek Neighbourhood Catchment

Local Best Practice Report

Introduction

This report contains management guidelines for a beef property typical in the Fish Creek Catchment.

This document contains a description of land types in the catchment, their vegetation, topography, soils, pastures, production capacity and condition. The report also describes suitable enterprises, cattle management and grazing land management. The management guidelines support sustainable production and has been defined as production which optimises profit with minimal degradation of the natural resources.

The Fish Creek Neighbourhood Catchment group consisted of eight families and the manager of the Brigalow Research Station. This group was formed in 2004 as part of an MLA funded project, Neighbourhood catchments – Minimising the environmental impacts of grazing in the Fitzroy catchment.

The production of this report is the first step in a process to work with producers to increase our collective understanding of land management and water quality.

Land types

There are six main land types in Fish Creek Catchment.

1. Range country

Range country consists of an elevated plateau that, at places, has an escarpment face. The soils are red sedimentary sandstone, which support a mixed eucalypt forest of spotted gum, lancewood, iron bark, wattle and bloodwood. The pasture is native.

This area has not been cleared because of the steep nature of the country. It is very rocky and if it is cleared inferior grasses such as kerosene grass tend to appear as well as heavy regrowth. Cattle use this land type in winter for grazing and shelter.

Producers considered this country to be fragile. It is very erosive and gullies can form. If rain falls after a hot fire, significant soil movement can result.

One producer, who had better quality country with less rock, grazes in the summer and reported this land type was more useful for cattle production in summer than winter. Also grazing in the summer lightens the fuel load, reducing the fire potential. He is also investigating silviculture where he thins out the less desirable trees and leaves the better ones to mature.

2. Open forest

Open forest country consists of scattered spotted gum, poplar box and narrow-leaved iron bark on grey duplex sandy soils.

Within Fish Creek Catchment, half of this land type has been cleared. There was discussion as to whether this land type should be cleared or not. Some producers think there is production gain from clearing this country. Regrowth is controlled by burning and blade ploughing. This practice may cause erosion.

Those who have not cleared thought that the country was too fragile and the timber represented a valuable resource which some harvest. Native grasses survive better under tree cover and seca stylo can be introduced.

The final recommendation is to selectively clear and/or clear open forest in waterways, which does not create erosion problems.

This land type is quick to respond to rain and is considered reasonable for winter grazing. Most use this land type for running breeders. It has a lighter carrying capacity compared to other land types. There is not much point in building dams in this land type, as they do not fill.

This land type was considered to be in good condition with some gully erosion due to fire.

Carbon credits, silviculture and selective timber harvesting were seen as opportunities in this land type.

3. Brigalow/blackbutt

This land type is one of the two dominant land types in this catchment. This land type is gently sloping country with predominantly brigalow and blackbutt with softwood scrub patches throughout. Softwood scrub patches tend to be found on the ridges running down from the range country. There are a large variety of soils in this land type that are clay based. This may explain the variety in the types of softwood scrub found.

This country was typically pulled two ways and then burnt. This land type is considered expensive to maintain. It requires clearing of regrowth every 8-10 years depending on the run of dry years. Blade ploughing is used to control regrowth and improve infiltration. Chemical control with Pellet was another option but more expensive. A run of good seasons makes the country ‘soften up’ and produces good pasture.

Most of the softwood scrub patches have been cleared. Some two–four acre patches have been left. Softwood scrub produces the best pasture.

Pastures in this land type are mainly buffel with some native grasses and urochloa. The best native grass is blue grass. Pasture needs to be managed well to prevent erosion and control the spread of parthenium. Minimising the level of disturbance is important.

Originally the country was cleared in strips leaving shade lines about 100 m wide. These shade lines have disappeared because of fire not long after initial clearing. Land was used for grain production mainly forage and oats with aerial seeding. Land use changed to cattle due to improved prices in 1978.

This land type tolerates change in land use. It was thought that moving from grazing to cropping invigorated the country. With cropping it is essential to have contour banks. The move from one enterprise to the other was related to commodity prices.
This land type was considered to be in reasonable condition by some and not so good by others in some areas. It is at a plateau stage and could go either way. The right conditions are needed for it to be productive.

Good breeder country that offers opportunities for it is seen as versatile country.

4. Open forest on alluvial flats

The vegetation is brigalow with mixed eucalypt including blue gum, moreton bay ash and poplar box. Alluvial loam soils with patches of land type 2 and 3 soils. This land type is closely associated with the creek.

It was found that native grasses would disappear if over grazed. Producers recommend increasing groundcover to minimise/prevent erosion.

This land type is useful for watering. Watering points (bores) are found along the creek. Fencing the creeks would not be practical because of the convoluted nature of the creeks. Fencing would cause problems with small sized paddocks and odd shapes that could trap cattle. A solution is to create laneways approximately 500 m along the creeks that run into the yards.

There needs to be more timber throughout as cattle tend to camp on creeks which causes erosion due to padding.

Flora and fauna are preserved in this area because the timbered waterways attract wildlife.

This land type was thought to be in healthy condition but parthenium is encroaching.

5. Brigalow/belah/bauhinia

This is the other dominant land type in the catchment. Its vegetation consists of brigalow, belah and bauhinia and has deeper clay self-mulching, cracking, gilgaied soils. It is very flat country with some old drainage lines running north south that eventually feed into the creek.

This land type is considered the best producing land type. Pastures in this land type need to be managed well by minimising the level of disturbance to control the spread of parthenium.

Gullies are left undeveloped as buffers around creeks and drainage lines with grass cover being maintained. It can be fenced to soil types for management. It is also good for cropping. Dams are used for watering points. Otherwise this land type is primarily managed as land type 2.
There was no sheet erosion on this land type because of the gilgaied surface and good infiltration.

6. Softwood scrub with associated brigalow

This is their best country for it has deeper, more fertile soils, which is predominantly of one type. This land type encompasses the second creek and has been cleared.

This land type is managed much the same as land types 3 and 5. Land use is dictated by commodity prices. Large areas are used for cultivation because it is more profitable. If grazed, this land type is used for seasonal mating. Dams are used for watering points.
There is an opportunity to practice agro forestry on this land type. One producer is growing Chinchilla whitegum.

This land type is in excellent condition.

Enterprises

Cattle breeding and finishing are the main enterprises. Cattle breeding occurs mainly on land type 2 while finishing occurs on the best paddocks in land types 3, 4, 5 and 6.

Producers think it makes more sense to do both breeding and finishing. Buying in cattle is time consuming, requires a big outlay of capital and there is more risk involved as well as no financial advantage. Some producers buy cattle in to 'top up' if the season is good.

Crop production is another enterprise option.

Cattle management

Herd size is adjusted to seasons. Everyone backgrounds cattle and pregnancy testing is common. In enterprises that focus on cattle production everyone weans. Many producers breed on light country and finish on better country.

The change from hereford-based herds to brahman-based herds typically led to the differences seen in today's management strategies. Some things are a hangover from previous experience. There is no wrong management strategy regarding seasonal versus continuous mating. It is simply what best suits an individual operation.

Cattle are cross breeds. Mostly brahman crossed cattle to gain hybrid vigour and gain a level of tick resistance.

Fence lines run perpendicular to the first creek on the eastern side. A paddock will therefore encompass land type 1 to 4. This is to allow for grazing of less productive land types.

One producer has removed all original fences and has fenced according to soil type to better support their enterprise of cropping and grazing.

Bulls

Bulls are usually stocked at a 3% bull to cow ratio for brahman bulls.

Bull prices fluctuate heavily; some participants stated that price is a poor criteria for a bull. Some use the following list of criteria to judge a bull: eye muscle area, heavy boned, good length, like the animal, good temperament and good reputation of stud. A bull must be able to improve the herd, not just maintain status quo. Some producers use statistical evidence – unit actual criteria.

Bulls are culled at five years.

Cows

Cross-bred cattle based on the personal preference of individual landholders. Cull cows at six to eight years of age. One producer is keeping cows to ten years to increase the size of the herd. Culled cows have become important because their market value has improved.

Mating

A producers' mating objective is for every cow to successfully calve and wean each year.

Different mating systems are used in this catchment. Producers felt that there was no right or wrong way of mating depending on what market you supply to and personal preferences in regard to management style. Producers felt that having a variety of mating systems was positive because cattle supplies are distributed throughout the year, flooding the market does not occur.

Seasonal mating
When brahmans were introduced handling of cattle decreased, which resulted in management becoming seasonal, and weaning became more difficult.

Cows typically cycle seasonally due to feed quality and nutrient requirements and availability. This results in 80-90% of the herd calving at the one time, it makes sense to have 100% of the herd calving at the one time.

With seasonal mating calving takes place from September to November. Bulls are put in six weeks following calving.

It is useful for planning labour requirements to know when calving, branding, weaning etc will occur.

Continuous mating
Bulls are left in all year round. This system of mating produces three to four mobs a year allowing supply to lot feeding and European Union (EU) markets. This method suits some markets such as EU and feedlot as cattle are always coming on to sale readiness.

Calving rates are comparable with seasonal mating.

Reproduction rates

Ninety to 92% of cows mated return a positive pregnancy test (not including first mated heifers). Negative pregnancy tested cows are culled.

Weaning

In an enterprise that is into full cattle production, weaning always occurs. Weaning varies due to seasonal conditions. In June calves range from five to eight months of age. Weaning occurs mostly in May, June and July. Weaning tends to happen in batches.

Cattle are locked in yards for a couple of weeks. One producer puts weaners in yards for only one night. The weaners are then put with the older cattle and moved to another property. Weaning quietens cattle down, wild cattle are culled.

Supplementary feeding

Participants supplement to keep fertility and reproduction rates up. Survival feeding does not occur, cattle are sold before survival feeding is required. This was considered to be cheaper in the long run and would result in less cattle deaths. Urea and molasses supplementation is provided at the end of winter. Weaners are fed in yards.

Weaners go on a protein supplement for the first year and first calf heifers are supplemented.
It was thought by some that cutting cattle numbers was easier than supplementary feeding. Some apply the principle of only feeding cattle that will be sold. If cattle

needed to be supplementary fed in this country it could be attributed to bad genetics or too many cattle.

Markets

Producers in this catchment cover all markets – domestic market for Woolworths and Coles, grinding market to USA, Jap Ox, Korean, saleyards, EU and live market. It is personal preference as to what market is chosen.

EU is a good market at present because a lack of accredited producers means this market is not fully supplied. Once NLIS is implemented this may change as it will mean producers are two-thirds of the way accredited for the EU market.

Herd health

Vaccinations
Cattle are usually vaccinated at weaning for both 7 in 1 and 5 in 1 vaccination. Producers vaccinate for three-day sickness.

Internal parasites
Not many producers dip or worm regularly. Store cattle purchased elsewhere are wormed on arrival. Weaners are also wormed.

External parasites
Ticks can be a problem and are treated with Acatack. Blood for tick fever for losses can be big when it occurs. Lice may be an immerging problem caused by dry weather.

Deaths
Generally quite low at < 1%.

Grazing land management

Breeding operations occur on land type 1 to 3, fattening operations occur on land types 3 to 6.

Stocking rates

Stocking rates vary with different types of country. Participants consider an adult equivalent (AE) to be 600 kg.

The stocking rate for land types 3, 5, and 6 is one AE/seven acres. On land types 1 and 2 the stocking rate is reduced to one AE/10 acres. This should give 200-240 kg of growth a year on better country and 180-200 kg on lighter country. This production would increase with a suitable legume.
The lowest stocking period is the end of winter until spring rain. Stocking rates are adjusted according to seasonal conditions and are usually assessed late summer.

Pasture management

The size of paddocks varies. Producers talked about manageable areas and use the following criteria to determine paddock size: mustering technique, horse or helicopter; soil types; shape of block; location of yards, lanes and water; and position of the road.
Blade ploughing is good for infiltration and nutrient cycling but not good for recovery of grass unless good seasons follow. Producers do not plough across gullies because the risk of erosion is too great if rain soon follows.

The legume seca stylo is introduced in lighter country. Leuceana is planted as it puts nitrogen back in the soil and is good cattle feed but it is a plant that needs to be managed.

Dry season management

Numbers of stock are cut as soon as possible with oncoming drought. Producers start to lighten stocking rates in February. Producers recommended weaning earlier and dropping adult numbers down to one AE/15 acres. If summer rain did not occur numbers are continually dropped.

It was thought by a producer that this area could be described as 'safe country'. Cattle generally do not die here. There is plenty of water however feed shortages could be a problem. The grass holds nutrition better than a lot of areas. Eight in 10 animals will put on weight every day.

Tree and woody weed management

Regrowth is typically managed with blade ploughing. Gullies should be left untouched.

Sally wattle survives blade ploughing and it has been observed to return after cultivation. It is best to control it with chemicals.

Lime bush is also considered a weed.

Compaction

Compaction can be a problem. Producers recommend lighter stocking to allow regeneration and/or rotational grazing.

Fire

Burn at the first spring rain. Some burning occurs after good spring rain, burning does not occur every year.

Fences and water

Land types 1 to 3 on the eastern side of the first creek are watered from creek bores and are fenced across land types to allow access to watering points.

Land types 5 and 6 are watered with the use of dams and fenced in north south direction. One producer has fenced according to land types in this area.

Weeds

Parthenium is in all land types except for land type 1. Parthenium becomes a problem when the ground cover is reduced because of the removal of competition. Blade ploughing can cause parthenium to explode for it can take up to three years for a good cover of buffel to return.

Pests

Dingo numbers are under control. The number of grey kangaroos has increased three fold. It is thought that these two issues are related. Destroying dog populations has resulted in the increase in kangaroo populations. Kangaroos move to the green patches and follow the rain.
Pigs can also be a problem.

Erosion

Erosion is more of a problem in cultivated areas. Many use zero till to reduce erosion. Producers thought it was not a major problem with small areas found in each property within the catchment. Maintaining good ground cover was thought to be important.

Erosion can be a problem in land type 4 with grazing under timber in riparian areas.

Contour banks can cause more severe erosion for water backs up behind contour banks and break during big storms.

Trends

Land types 1 and 2 are stable, while land types 3 and 5 suffer declining fertility and to a lesser extent in land types 4 and 6. Declining fertility is measured with soil testing and visually through pasture productivity.

Generally soil compaction is occurring in all land types, which is thought to lead to pasture decline. There is not much opportunity for legume improvements in clay soils. Legumes that are used include dolly cross and *seca stylo*.

Leuceana has been planted in land types 5 and 6. Some landholders were concerned about the ability of this plant to spread. The benefits of leuceana include keeping the water table down and increasing production during dry periods and winter.

There has been an increase in adoption of minimum and zero tillage systems. Swapping from cropping to grazing may result in parthenium and other weed problems.

One producer has been soil testing for the past 15 years with results indicating seven to eight years of peak fertility after clearing then a drop of over 10 –15 years and then a plateau period, which we are in now.

Soil infiltration problems in duplex sodic soils.

Social

Producers felt there were a number of social trends that were not supporting them. They identified a change in their work patterns, an increase in work and decrease in social activities. Book keeping requirements have increased as well as families relying on off farm employment for income.

The age structure is changing with an increase in the average age of people in the area.

It is also becoming more difficult to obtain skilled labour. There is a requirement for multi-skilled reliable staff.

Constraints

"Government red tape" including the erosion of property rights and the constant shifting of the goal posts. Freehold land is no longer given any additional "bundle of rights" over leasehold land.
There is no benefit from the original costs associated with freeholding land.

9.3 Appendix 3 – Future community trends for the beef industry

Community trends

What are trends in the general community that are moving into the future and will have an effect on the beef industry?

- Clean and green foods, increase in food safety and providing proof
- Accountability – quality assurance, transparency of how they manage. The market is consumer focused.
- Increase in global tourism
- A more health conscious community
- Increase in standard of living of developed nations such as Asia and Brazil
- Decreased consumption of beef in western countries
- New cooking appliances lowering standards of beef
- There is a public perception that the beef industry is being supported by government funds, for example drought fund.
- Media creating a negative response to rural issues
- Media portrayal that the larger beef enterprises are using 'ordinary' land and cattle practices. The industry in not progressing.
- Declining voting power, hence political influence due to demographics, less rural electorates.
- General community having less attachment to agriculture
- More high protein diets
- Increase call for pieces of paper – 'bureaucratic b-----it'
- More people wanting to control land management
- Move towards catchment focused natural resource management. Working as a community rather than as individuals.
- People in this industry need to consider supporting voluntary lobby organisations like Agforce. Government authorities are requiring industry bodies like Agforce to make recommendations and the requests for information is increasing.
- Increased documentation eg planning
- Decrease in tonnage of fish protein from the oceans
- Increased global terrorism, sabotage of food chain eg food & mouth disease
- Government finances going into health, education and police.

9.4 Appendix 4 – Producer projects

Fish Creek Neighbourhood Catchment

Group Focus: To improve water quality by 10% in the Fish Creek Catchment in the next 10 months.

Individual Projects:

1. **Focus:** To achieve more kg/h and enhance pasture (pasture composition, bulk, ground cover) by maintaining a relative constant body weight (up to 450 kg) of cattle grazing Cattle Creek paddock until July 2005.
   Outcomes:
   - improve kg/h (economic) and pasture composition, groundcover (environment)
   - improve environmental health and property value.
2. **Focus:** To achieve an improvement in pasture health (types of grass, ground cover & less cow pads), weed control and creek bank stability by fencing Beeswing Paddock into three (two high paddocks and one creek) to improve cattle handling (rotating, spelling and mating) and pasture usage until July 2005.
   Outcomes:
   - good grass coverage of desirable plants
   - better understanding of whether the project helped control erosion and is it worth applying elsewhere on our property
   - improve control of parthenium.

3. **Focus:** To achieve a 50% reduction in soil movement by redesigning and refurbishing waterways and contour banks and monitor potential contamination due to chemical runoff in two dry land cropped paddocks, D and J, by July 2005.
   Outcomes:
   - stop soil erosion
   - slow water entry into the waterway
   - redesign and repair existing damage to waterways
   - initiate a chemical monitoring system for atrazine, 24D, metasuphuron.

   Outputs:
   - measured what soil has been lost tonnes/ha
   - ordered engineering equipment, Reno- mattress
   - set up monitoring points for soil loss.

4. **Focus:** To achieve a better understanding of the usefulness of cartographic products by testing the effectiveness and efficiency of mapping procedures and packages designed to support sustainable grazing land management by July 2005.
   Outcomes:
   - scores on how effective maps were in supporting facets of managements
   - increase the use of maps by producers
   - improve the successful access to educational and funding opportunities
   - for maps to introduce new information about the resources they manage
   - present technical/spatial information in a visual way.

   Outputs:
   - development of an instrument that measures the effectiveness of maps
   - documented mapping procedure.

5. **Focus:** To achieve an improvement in the productivity of land (improved soil health & better pastures) by 40-50% by implementing two methods of regrowth

control (Graslan & blade ploughing) on two soil types (popular box & brigalow) until July 2005.

Outcomes:
- better pastures (increase in types of grass, water infiltration and number of grasses)
- improve stock management
- increased stocking rate; kg/ha
- improve water quality.

6. **Focus:** To achieve a better quality of grass and grass coverage (more grass types, increased number of clumps and more germination) to hold soil and stop erosion by using fire in Creek paddock by July 2005.

   Outcomes:
   - better quality of grass, thicker coverage
   - better understanding of how grasses respond to fire
   - be able to identify more native grasses
   - develop better burning strategies
   - better understanding of the interaction between erosion and burning
   - control suckers and weeds.

7. **Focus:** To achieve a reduction in erosion in cultivated paddocks by sorting out government regulations associated with water usage and develop a design for contouring by July 2005.

   Outcomes:
   - reduce soil loss
   - improve sustainability of country
   - provide an outcome and direction for country above the dam
   - sort out a passage through regulations for future benefit
   - achieve cooperation and commitment of a government officer to develop an agreement on future action
   - someone to provide a service to ensure farmers work within regulations.

8. **Focus:** To achieve a motivating and supportive environment every 30 days for the Fish Creek group to improve the implementation of projects until July 2005.

   Outcomes:
   - participants sharing projects in a way that elicits high quality support
   - projects that are continually progressing towards the focus with building confidence, knowledge and skills
   - know what support people found helpful, not helpful
   - measure of participant's response to support by monitoring their confidence, participation and enthusiasm
   - participants supported in designing and implementing projects
   - people who have had a positive experience and wish to continue participating
   - a supportive culture among participants to practice continuous improvement and innovation.

9. **Focus:** To achieve reduced erosion in Front and Old Wheat paddock (1300 acres) by adding contour banks and straightening out waterways by July 2005.

   Outcomes:
   - better production, better pasture and animals
   - less soil erosion
   - better profit
   - improve value and look of property.

10. **Focus:** To achieve an improvement in kg/ha of animal production and in country (better grass quality nitrogen and protein content, better grass response,

increased number of plants/area, ability of grass to hold on & success of legume establishment) and reduce soil runoff by using ripping on House paddock until July 2005.

Outcomes:

- more kg/ha animal production
- better soil health & water quality
- satisfaction that I've fully explored ripping
- good ideas on monitoring from outside support
- get an idea of how long soil will last before needing to be ripped again.

Steering Group

Group Focus: To achieve continuous improvement and innovation with beef producers and other relevant partners to improve water quality in the Southern Mimosa Catchment in the next 10 months.

Individual projects:

11. **Focus:** To achieve a management practice (stocking rates, burning, spraying etc.)
that will encourage more palatable grasses in purple pigeon grass dominated pasture by establishing current pasture composition and monitor effects of remedial practices in Little Horse paddock, Poddy paddock and a section of North Chisom into the future.

Outcomes:

- carry more cattle
- encouraging cattle not to concentrate on a small area
- less pressure on existing palatable species
- improve productivity
- find out how wide spread the problem is
- maintain ground cover.

Outputs:

- photographic records
- Grass check records
- recommended management practice.

12. Focus: To achieve an improvement of the understanding of natural processes (water cycle, nutrient cycle, energy, succession) for better management by developing a different take on two way communication between research findings and producers, in the development of information and its communication; incorporating producer knowledge with ecological functioning until July 2005.

Outcomes:

- a process whereby research information is better received by producers
- develop an opportunity for people to identify knowledge gaps
- use learnings in another context
- identifying how concepts are adopted.

Outputs:

- communication process documented
- reference list on relevant topics
- written material on the natural processes.

13. **Focus:** To achieve producer involvement (two neighbourhood catchment groups + steering group) in natural resource management projects (water quality) that

results in regular improvement and innovation (the creation & implementation of best practice) in the Southern Mimosa Catchment now and until July 2005.

Outcomes:

- two NC groups + one steering group
- knowledge of what strategies did and did not work
- practical projects and guidelines that improve water quality
- a better description of who producers are in our catchment
- process that increases the capacity of land managers to improve the health of the country this year and into the future.

Outputs:

- project Action Designs and Focus Tools

14. **Focus:** To achieve a competency (self sufficient user) in mapping (construction, use it, make changes, work with electronic copies) until July 2005.

Outcomes:

- tool in management decisions
- help with conservation
- extension of learning to wider community
- establish support network.

Outputs:

- two properties mapped out on computer with relevant information in regard to management of property
- a record of progress.

15. **Focus:** To achieve an improvement in the management of Thalmera as a sustainable system (management practices working with the environment) by writing and implementing an Environmental Management System which will initially support sound thinking and an innovative approach to reducing erosion (diverting water, tree planting, watering system, soil & pasture health and monitoring) until July 2005.

Outcomes:

- proactive stance to pending environmental standards; one step ahead
- getting trees re-established
- prove that we are doing the right thing
- improving pasture quality through cattle management and monitoring.

Outputs:

- EMS manual
- data organised in a useful way.

16. Focus: To achieve a better understanding of the grazing industry amongst the urban community (general public) by promoting positive stories about activities being undertaken and foster a greater interest amongst producers in becoming involved in projects about improving and understanding sustainable management practices with the use of media (written, visual and spoken) until July 2005.

Outcomes:

- better understanding or rural production amongst urban people
- A growing interest from rural people to become involved
- improved media skills of producers
- establish positive working relationships within media
- strengthen rural communities
- build partnerships with research organisations to promote innovative management.

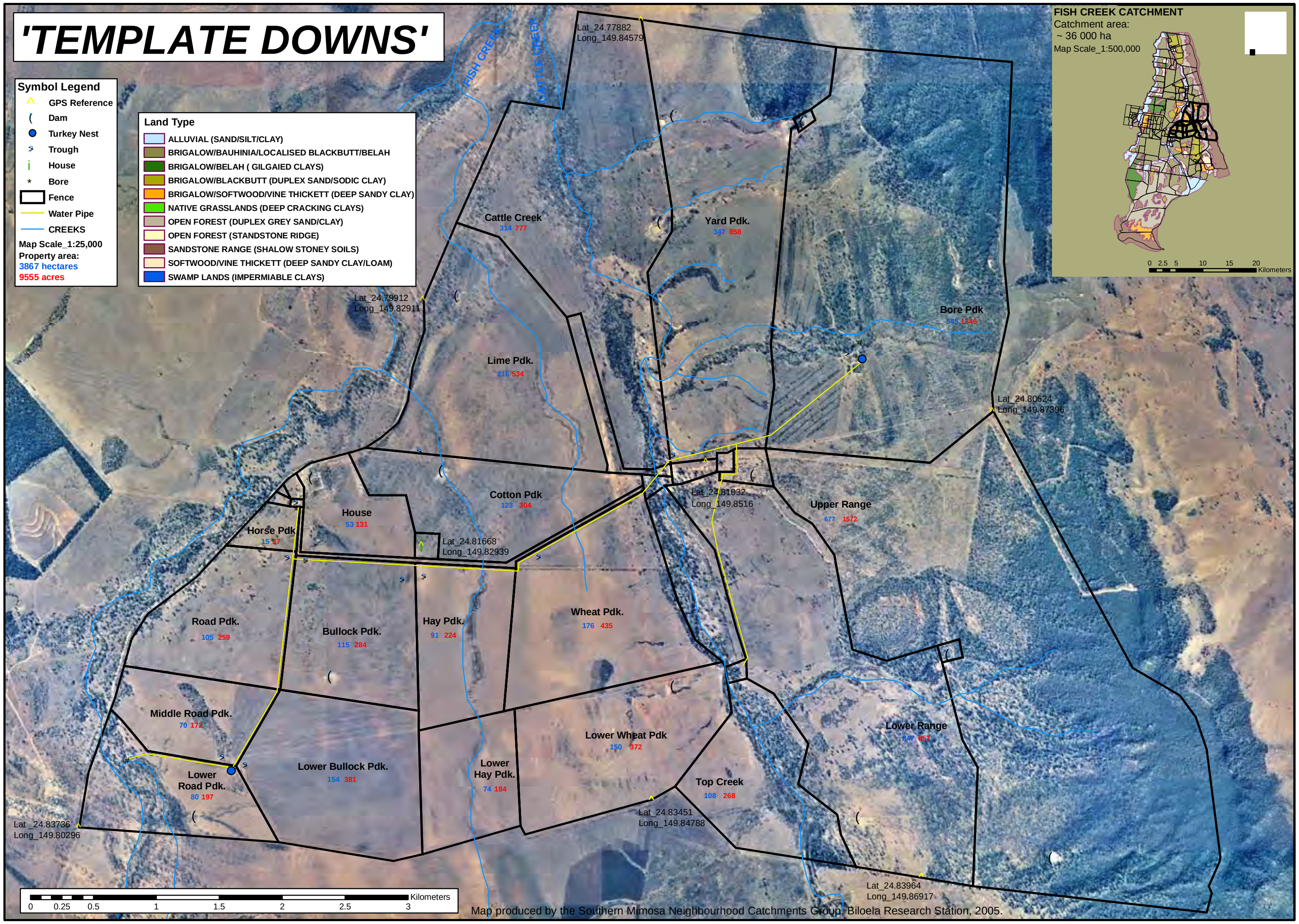
Outputs:

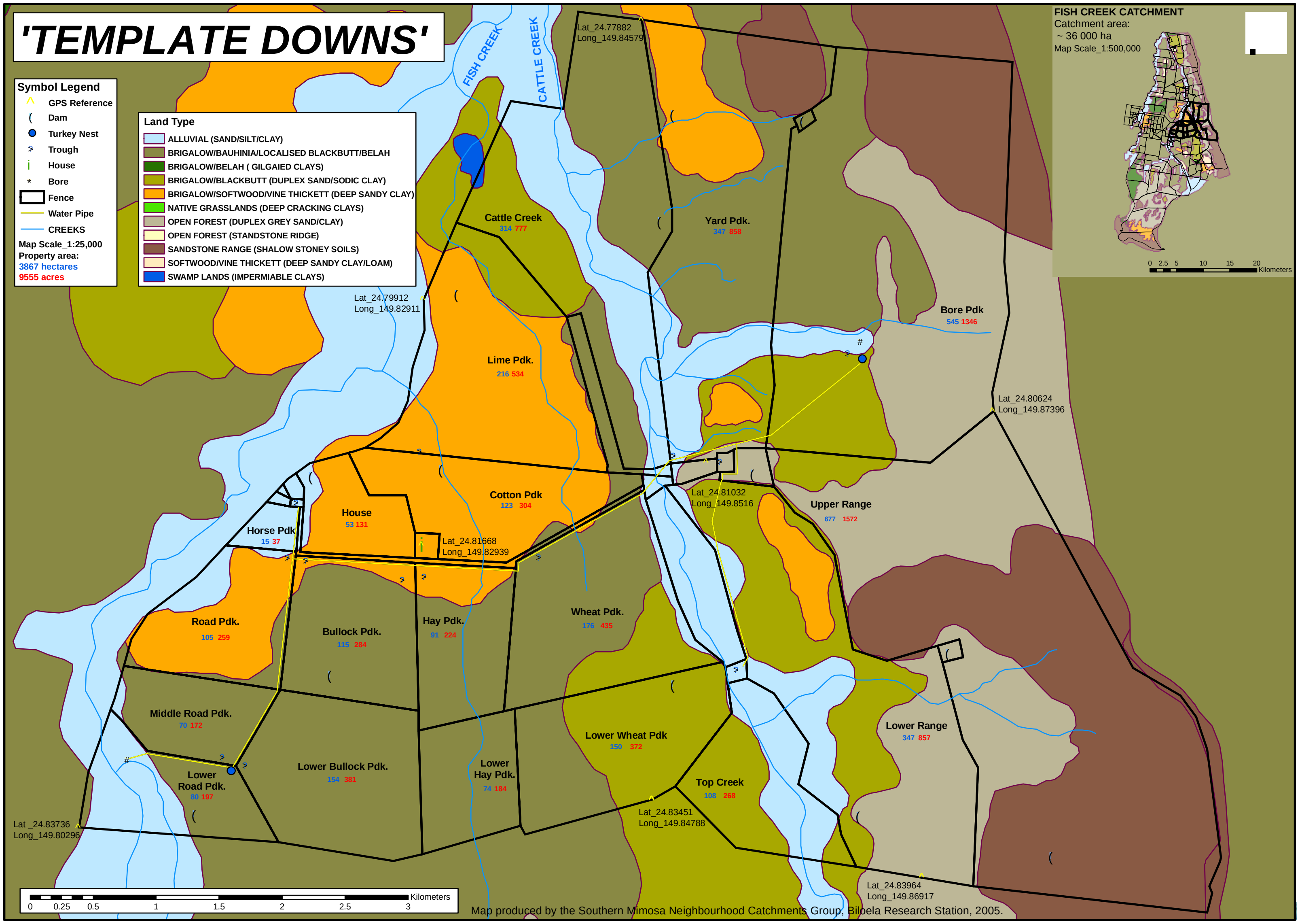
- press releases
- newsletter
- list of current sustainable management projects.

17. **Focus:** To achieve a better utilisation of available feed and improve the quality of grass (maintain grasses in phase two),1.2 kg per head per day wt gain through all seasons, throughout the property by using rest of paddocks and rotation from July 2005 onwards.
    Outcomes:
    - improved take home dollars
    - better ground cover
    - higher moisture infiltration
    - increased cattle numbers
    - less labour.

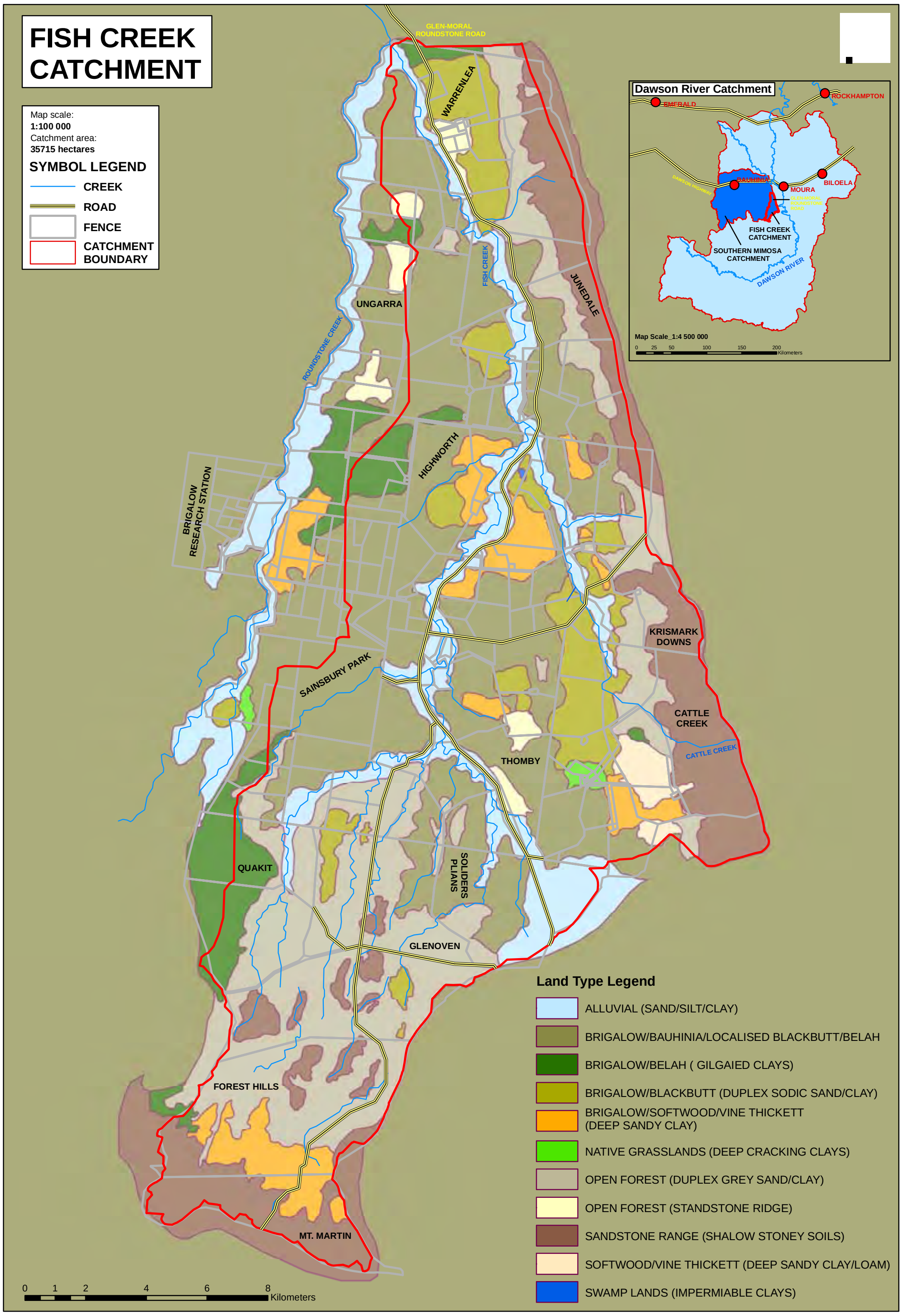
18. **Focus:** To achieve a better soil health (humus, root system, N levels, soil organisms, ground cover) by introducing legumes (butterfly pea, leuceana, seca stylo, etc.) into current pastures (mainly buffel) to reduce soil movement.

9.5 Appendix 5 – Property and land type map for producers




'TEMPLATE DOWNS'
Symbol Legend
GPS Reference
Dam
Turkey Nest
Trough
House
Bore
Fence
Water Pipe
CREEKS
Map Scale_1:25,000
Property area:
3867 hectares
9555 acres
Land Type
ALLUVIAL (SAND/SILT/CLAY)
BRIGALOW/BAUHINIA/LOCALISED BLACKBUTT/BELAH
BRIGALOW/BELAH (GILGAIED CLAYS)
BRIGALOW/BLACKBUTT (DUPLEX SAND/SODIC CLAY)
BRIGALOW/SOFTWOOD/VINE THICKETT (DEEP SANDY CLAY)
NATIVE GRASSLANDS (DEEP CRACKING CLAYS)
OPEN FOREST (DUPLEX GREY SAND/CLAY)
OPEN FOREST (STANDSTONE RIDGE)
SANDSTONE RANGE (SHALOW STONEY SOILS)
SOFTWOOD/VINE THICKETT (DEEP SANDY CLAY/LOAM)
SWAMP LANDS (IMPERMIABLE CLAYS)
FISH CREEK CATCHMENT
Catchment area:
~ 36 000 ha
Map Scale_1:500,000
FISH CREEK
CATTLE CREEK
Lat_24.77882
Long_149.84579
Cattle Creek
314 777
Yard Pdk.
347 858
Bore Pdk
545 1346
Lat_24.79912
Long_149.82911
Lime Pdk.
216 534
Lat_24.80624
Long_149.87396
Cotton Pdk
123 304
Lat_24.81032
Long_149.8516
Upper Range
677 1572
House
53 131
Horse Pdk
15 37
Lat_24.81668
Long_149.82939
Wheat Pdk.
176 435
Road Pdk.
105 259
Bullock Pdk.
115 284
Hay Pdk.
91 224
Middle Road Pdk.
70 172
Lower Wheat Pdk
150 372
Lower Range
347 857
Lower Road Pdk.
80 197
Lower Bullock Pdk.
154 381
Lower Hay Pdk.
74 184
Top Creek
108 268
Lat_24.83736
Long_149.80296
Lat_24.83451
Long_149.84788
Lat_24.83964
Long_149.86917
0 0.25 0.5 1 1.5 2 2.5 3 Kilometers
0 2.5 5 10 15 20 Kilometers
Map produced by the Southern Mimosa Neighbourhood Catchments Group, Biloela Research Station, 2005.

9.6 Appendix 6 – Example of neighbourhood catchment land type map



9.7 Appendix 7 – Catchment water quality for TSS concentrations (mg/l)

Catchment	Catchment ID	Feb03	Dec03	Jan04	Feb04	Nov04	Dec04	Feb05	Mar05	Apr05	May05	Jun05	Aver
Roundstone	14	750	4620	1880	1868	2636	1250	3948	1856		1488	2433	2273
Muddy	9	954		1213	3150	1983	1300			1900	1500	1213	1652
Palmgrove	10			710	900	2250	2200						1515
Little Roundstone	7			1175	2050	2485					930	320	1392
Rocky	13			1170	660	1500	1800			640	2000		1295
Kangaroo	6			880	650	2128	1400						1265
Mimosa	8			775	715	2125	1514				360	1293	1130
Conciliation	3			700	340		2200						1080
Prospect	11			1300	190		2466			1000	950	160	1011
Fish	5					1500	1030					260	930
Fish	4			550	1480	703	900					500	827
Spottswood	15	498	415	510	435	1584	885			470	950	702	717
Zamia	17			400	280	640	1010						583
Zamia	18		660	936	548	590	584				367	267	565
Repulse	12			970	50							220	413
Spottswood	16	318	295	446	80	387	190					583	328
Paddock													
BRS Forest		282		1009									646
BRS Cropping		150		418		737	657				758		544
BRS Grazing		293											293
CP Trial		397		440	1250	2630	1390			710	1600		1202
PP Trial				918	580	1340	1305			520	190		809
Aver (Catchments)		630	1498	908	893	1578	1338	3948	1856	1003	1068	723	1404
Aver (Paddock)		281		696	915	1569	1117			615	849		863
Aver (BRS)		242		714		737	657				758		621
Aver (CP/PP)		397		679	915	1985	1348			615	895		976

9.8 Appendix 8 – Catchment water quality for TKN concentrations (mg/l)

Catchment	Catchment ID	Feb03	Dec03	Jan04	Feb04	Nov04	Dec04	Feb05	Mar05	Apr05	May05	Jun05	Aver
Palmgrove	10		5.0	1.5	2.3	4.0	6.6						3.9
Little Roundstone	7	1.6	9.6	1.3	3.9	4.3					2.1	1.1	3.4
Rocky	13			1.5		3.9	3.6			1.7	3.7		2.9
Roundstone	14	1.2	3.3	1.7	3.5	5.2	3.1		2.6		2.5	1.6	2.7
Conciliation	3			0.3	1.4		5.9						2.6
Fish	4			1.8	2.5	3.0	2.7					1.7	2.3
Muddy	9	1.1		1.4		4.0	2.6			2.7	2.5	1.5	2.3
Fish	5					2.7	2.6					1.3	2.2
Mimosa	8		2.2	1.1	1.5	3.2	3.6				1.2	1.8	2.1
Kangaroo	6			1.3	1.9	2.7	2.3						2.1
Zamia	17			1.2	1.6	2.4	2.8						2.0
Spottswood	15	1.0	1.9	1.4	1.6	3.1	1.9			1.7	1.6	1.5	1.7
Prospect	11			1.3	1.2		3.0			1.5	1.2	1.2	1.6
Spottswood	16	2.1	1.5	1.2	1.3	1.9	1.3					1.4	1.5
Zamia	18		1.1	1.7	1.5	2.1	1.5				1.1	1.1	1.4
Repulse	12			1.0	1.1								1.0
Paddock													
BRS Forest				9.5									9.5
BRS Cropping				6.1	7.9	4.3	5.3				3.5		5.4
BRS Grazing													
CP Trial		2.5		0.8		9.6	3.8			2.2	3.3		3.7
PP Trial		0.7		1.5	4.9	4.9	3.7			3.9	1.7		3.3
Aver (catchments)		1.4	3.5	1.3	1.9	3.3	3.1		2.6	1.9	2.0	1.4	2.2
Aver (paddocks)		1.6		4.5	6.4	6.3	4.2			3.1	2.8		4.2
Aver (BRS)				7.8		4.3	5.3				3.5		5.2
Aver (CP/PP)		1.6		1.2	4.9	7.3	3.7			3.1	2.5		3.6

9.9 Appendix 9 - Catchment water quality for TP concentrations (mg/l)

Catchment	Catchment ID	Feb03	Dec03	Jan04	Feb04	Nov04	Dec04	Feb05	Mar05	Apr05	May05	Jun05	Aver
Palmgrove	10		2.0	0.4	0.7	2.0	2.5						1.5
Little Roundstone	7	0.8	2.4	0.8	1.5	2.2					1.8	1.1	1.5
Rocky	13			0.6		1.7	1.5			0.7	1.6		1.2
Conciliation	3			0.2	0.6		2.8						1.2
Roundstone	14	0.3	1.6	0.7	1.3	1.9	1.1		1.0		1.1	0.7	1.1
Zamia	17			0.5	0.6	1.3	1.5						1.0
Mimosa	8	1.1		0.4	0.6	1.5	1.5				0.5	0.9	0.9
Prospect	11			0.6	0.2		1.8			1.1	0.7	0.4	0.8
Kangaroo	6			0.4	0.5	1.5	0.9						0.8
Spottswood	16	0.7	0.7	0.7	0.4	0.9	0.8					0.7	0.7
Fish	4			0.5	0.9	0.8	0.8					0.5	0.7
Muddy	9	0.2		0.4		1.2	0.8			0.9	0.8	0.4	0.6
Fish	5					0.8	0.7					0.5	0.6
Zamia	18		0.5	0.6	0.5	0.8	0.6				0.5	0.3	0.6
Spottswood	15	0.2	0.5	0.4	0.4	1.3	0.6			0.6	0.5	0.5	0.5
Repulse	12			0.3	0.2								0.2
Paddock													
BRS Forest		0.3		0.5									0.4
BRS Cropping		0.6		0.6	1.3	1.0	1.0				1.0		0.9
BRS Grazing		0.4											0.4
CP Trial		0.4		0.3		2.0	1.0			0.5	1.0		0.9
PP Trial		0.1		0.4	1.3	1.2	0.9			0.9	0.4		0.7
Aver (catchments)		0.5	1.3	0.5	0.6	1.4	1.3		1.0	0.8	0.9	0.6	0.9
Aver (paddocks)		0.4		0.5	1.3	1.4	1.0			0.7	0.8		0.7
Aver (BRS)				0.6		1.0	1.0				1.0		0.9
Aver (CP/PP)		0.3		0.3	1.3	1.6	1.0			0.7	0.7		0.8

Note: Refer to Table 2, p. 20 for detailed description of catchment sites.

9.10 Appendix 10 - Glossary

Action
Action that is designed to achieve specific outputs and outcomes.

Action Design
Thinking through and describing (as an individual) the specific practices that will contribute to achieving a specific outcome.

Activity
Activity is defined as ‘doing’. In common usage activity does not necessarily imply purposefulness.

Adaptive management
A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs.

Catchment
An area of landscape encompassing numerous properties that drain into a single water flow (waterway, creek or tributary).

Change
A transformation from one state to another.

Continuous Improvement and Innovation
Individuals in teams, networks and partnerships regularly and frequently focusing their thinking and action to achieve improvement and innovation, now and in the future.

Extension
Processes that contribute to achieving positive outcomes for people. This usually involves contributing to changes in thinking, decisions and practices of people.

Facilitators
People with process knowledge and skills required to enable and support change and innovation.

Focus
A specific area and target outcomes on which to concentrate attention, thinking and action.

Gilgai
A natural depression (commonly referred as melon holes) of varying shapes and sizes found in brigalow clay soils.

Gully
Incised channels within the landscape created by the action of running water.

Improvement
Enhanced practices, processes, systems, products, services, outputs and outcomes.

Information
Something received or obtained through informing.

Innovation
A process of developing new practices, processes, systems, products and/or services for specific purposes and outcomes in the workplace and/or marketplace.

Key Performance Indicators (KPIs)
The specific, agreed measures that are of most value in measuring and assessing performance.

Knowledge
Knowing something well gained through experience. It can not be transferred.

Land type
An area of land with common characteristics of vegetation and associated soil properties (structure, depth and fertility) that supports varying capacities of cattle and crop practices.

Land system
An area of land within a landscape that features a recurring pattern of topography, soils and vegetation.

Landscape
An area of country characterised by different land types, land systems and catchments.

Learning
Process of acquisition and modification of existing knowledge, skills, habits or action.

Methods
Orderly way of achieving outcomes to fulfil needs: involving principles, systems/processes/practices, tools inputs and key performance indicators.

Methodology
An organised set of principles (methods or techniques) which guides action in trying to manage real world problem situations.

Model
Representation of the real thing, simplified for some purpose, they include those features that are essential for the purpose and they leave out those that are inessential.

Need
Necessity or requirement.

Neighbourhood catchment
Group of landholders and relevant partners working together in a drainage catchment (typically approximately 300 km^2). The term neighbourhood refers to the relationship between people, while the sub-catchment scale is sufficiently small to promote localised ownership in the catchment's land and water issues.

Network
A purposeful value-adding partnership based on reciprocal transactions between partners.

Outcome
The end result (impact) of activities, products and/or services, i.e. what is actually achieved in terms of measurable change as a result of activities.

Output
The interim results, the activities, products, and services designed to contribute to achieving outcomes.

Paradigm
A model, theory, perception, assumption, or frame of reference. It's the way we 'see' the world in terms of perceiving, understanding and interpreting.

Participation
To become actively involved in a process which includes decision-making and which is transparent and without hidden agendas.

Partnership
Interdependent (business-like) relationships between people for a specific purpose involving clear rights, roles and responsibilities.

Performance
The level of achievement as measured against a specific criterion or indicator.

Performance assessment
An assessment of the results of actions, according to the level of achievement of specific target outputs and outcomes, and other impacts both expected and unexpected.

Pollutants
Pollutant is defined as sediment or soil, nutrients or pesticides that are displaced from their point of origin through the action of runoff water.

Practice
A set and sequence of actions and tools to achieve specific outputs or outcomes.

Process
A set and sequence of interconnected steps, practices and tools to achieve specific outputs and outcomes.

Research
Moving through a series of steps searching through experiences that have already happened in order to gain a clearer understanding. This often leads to new knowledge.

Research & Development
A tightly coupled process of research and application of new knowledge by new practices, processes, systems, products and/or services to achieve a specific outcome in the work or market place.

Specialist
People with specialist (often technical) knowledge and skills to enable and support change and innovation.

System
A combination of parts forming a complex whole. The interactions and lessons from managing the interaction between the relevant combination of parts that make up the complex whole.

Theory
Principles underpinning methodology.

Technology
A specific item of equipment, a product or a process involving a specific set of practices and tools.

Tool
An instrument that makes achieving outcomes (through thinking and/or action) more effective and easier.

Training
Enabling people to acquire specific knowledge or skills.

Understanding
The ability to learn, apply and manage concepts and principles, judge and make decisions.

Well-being
A condition of health and contentment.