REEF WATER QUALITY

Reef Water Quality Science Program

2009-2015

Our research investment

Queensland Government

Minister’s foreword

Much is being done to restore the Great Barrier Reef’s resilience to natural impacts. We need to continue reversing the effects of pollution and reduce pressures caused by fishing, transport and tourism. But to meet the water quality improvement targets we have set ourselves, we must do more. And we need a solid evidence base upon which to anchor our priorities, investments and common purpose.

In 2009, as part of the Queensland Government’s investment under the joint Australian and Queensland Governments’ Reef Water Quality Protection Plan (Reef Plan), a five year program of research, regulation, education and extension was developed. Core questions in the Reef Water Quality Science Program’s design challenged government, and the cane and grazing industries to better meet the needs of commercial operations to be productive whilst delivering environmental outcomes.

This information proved equally important for industry development and best management systems in the cane and grazing industries, and associated standards for nutrients, sediment and pesticide management.

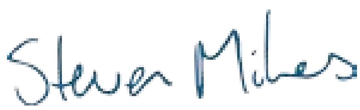
Extraordinary demands are placed on our primary producers to continually juggle competing financial, operational and environmental pressures. I am in no doubt that we must continue providing the best support to our primary producers, and delivering information and tools needed to build resilience into their enterprises while improving the reef’s resilience.

Project results from the Reef Water Quality Science Program will help guide considerations for achieving Queensland Government and Reef Plan targets for pollution load reduction. Our sincere thanks is extended to all project proponents and partners who have worked tirelessly to deliver projects described in this report and beyond.

The science described in this report has already started flowing into industry bodies, extension networks, natural resource management bodies and primary producer groups to enhance existing education and extension services, and strengthen best management practice systems.

We have worked hard to ensure this science program complements and builds on the research of our partners and other Reef Plan research programs, as well as the collaborative efforts of all those taking action for change.

But we’re not done yet. Going forward, we need to maintain our effort and investment to fill gaps in our knowledge, continue the work that requires consideration of seasons and production, and to keep our eyes fixed on the goal of a strong agricultural sector alongside a healthy, resilient reef.



Dr Steven Miles MP

Minister for Environment and Heritage Protection

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INTRODUCTION

Reef Water Quality Science Program 2009–2015

The Reef Water Quality Science Program has produced a suite of science products that delivered valuable, knowledge-based and practical tools and information for landholders, advisors and government decision-makers. This investment of $11 million since 2009 for various trials, products, landscape analysis and catchment prioritisation has shown where scientific and policy efforts should be focused. Ongoing water quality research drives a continuous review of strategic approaches and priorities to better shape policy responses and achieve measurable outcomes.

This report provides an outline of completed research projects funded or co-funded by the Reef Water Quality (RWQ) Science Program between 2009 and 2015. This research has helped us understand more about where and how to manage impacts upon the quality of water entering the reef.

It gives landholders, regional natural resource management organisations, industry bodies, conservation groups and government, evidence and resources needed to help to meet the Reef 2050 Long-Term Sustainability Plan targets.

Sharing these research outcomes and utilising these tools will help drive practice changes on properties throughout Great Barrier Reef catchments, as well as inform innovative solutions.

Where can I find further information?

You can find further information online:

1. Research reports: www.qld.gov.au/environment/agriculture/sustainable-farming/reef-projects-completed/
2. Reef Water Quality Research, Development and Innovation Strategy for 2014-19: www.ehp.qld.gov.au/assets/documents/reef/reef-water-quality-strategy.pdf.

This report is provided in good faith on the understanding that the information is not used out of the context explained within the publication, recognising that science and responding policy evolve over time.

Citation

Reef Water Quality Science Program, 2009-2015, Our research investment. State of Queensland.

REEF WATER QUALITY SCIENCE PROGRAM 2009–2015

101 QUESTIONS
INFORMED THE RESEARCH THEMES

PRIORITISATION AND RESPONSE

- Risks and impact of changes
- Prioritising management responses
- Synthesising knowledge of emerging science

CANE MANAGEMENT SYSTEMS

- SYSTEMS AND LOADS
- LANDSCAPES AND SEDIMENT SOURCES
- POLLUTANT TRANSPORT AND FATE
- NUTRIENT MANAGEMENT
- WEEDS AND PESTICIDES
- DECISION SUPPORT TOOLS
- SOCIO-ECONOMIC

GRAZING AND SEDIMENT MANAGEMENT

- DECISION SUPPORT TOOLS
- LAND MANAGEMENT
- LANDSCAPES AND SEDIMENT SOURCES

420 PROJECTS ACROSS **GBR** CATCHMENTS

$11 MILLION INVESTMENT

THE JOURNEY THUS FAR...

The science program was designed to support the joint Australian and Queensland Governments' commitment under the Reef Water Quality Protection Plan (Reef Plan) 2013 to:

> *'...ensure that by 2020 the quality of water entering the reef from broadscale land use has no detrimental impact on the health and resilience of the Great Barrier Reef.'*

The markers that are motivating research are compelling. The Australian Institute of Marine Science's (AIMS) long-term marine monitoring program shows that the reef's hard coral cover had declined by 50% over the previous 27 years. The study identified that, of this 50%, tropical cyclones account for 48%, coral predation by crown-of-thorns starfish (COTS) 42% and coral bleaching 10%.

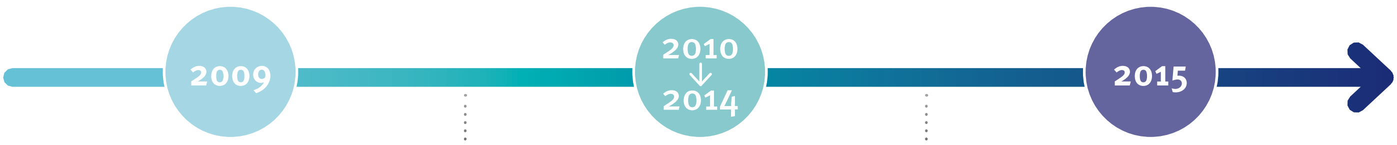
Unnaturally large COTS populations are linked to increased loads of nutrients in reef waters. Understanding how to reduce nutrients reaching the reef lagoon remains a vital land management priority in the reef's catchments. Similarly, as water-borne sediments from land erosion impair photosynthesis in reef organisms and smother coral growth, requiring a heightened commitment from land managers to retain groundcover and reduce erosion.

The science program provided evidence for the following:

- improved on-ground management and extension
- regulatory interventions in priority areas
- grazing and cane industry Best Management Practice program standards and priorities
- Reef Plan 2013 and Scientific Consensus Statement 2013.

The Research, Development and Innovation Strategy 2014/15-2018/19 outlines the focus over the next five years, and will continue to be reviewed to take into account changing Queensland and Australian Government investment priorities.

The diagram below describes the journey, what influenced our work and what we still need to undertake.



What we set out to do in 2009

Where:

Primary catchments Wet Tropics, Burdekin, Mackay-Whitsundays, with ability to transfer learning across Queensland.

Focus to:

1. Understand sources, transport and fate of reef pollutants
2. Understand cane and grazing management, and contribution to reef pollution
3. Develop reasonable and practical solutions that growers and graziers can adopt to improve water quality outputs at least cost
4. Improve uptake of solutions through better understanding of cane community
5. Track management changes and impacts on the reef.

Science projects we undertook (2009-15):

- invested $11 million
- fifty collaborative reef water quality research projects, including:

- **nutrient, pesticide and sediment management on sugarcane-growing lands**
  - nutrients, weeds and pesticide management
  - socio-economics and cost-effectiveness
  - cane decision-support tools
  - systems and loads
  - landscapes and sediment pollutant sources and fate
  - prioritisation and future direction
- **sediment management on grazing lands**
  - grazing land management
  - landscapes and sediment sources
  - land management decision-support tools
- **synthesis of knowledge across reef catchments**
  - risks and impact of changes to the reef across all commodities
  - pollutant contribution through groundwater pathways.

What happens next, up to 2019

Extending the program from Wet Tropics, Burdekin, Mackay-Whitsundays to include projects in other reef catchments (Fitzroy, Burnett-Mary and Cape York).

Focus on:

- **sugarcane**
  - nutrient use efficiency
  - weed management systems and pesticides in key catchments
- **cattle grazing**
  - sediment management and land condition
- **bananas**
  - nutrient use efficiency, weed management system and pesticides
- **across agriculture**
  - program prioritisation, monitoring and evaluation
  - changes to agricultural landscapes and commodities
  - implementing Great Barrier Reef Water Science Taskforce recommendations, response to Reef Plan 2013 and the Scientific Consensus Statement 2013.

Our collaborators and reviewers

The RWQ Science Program has been strengthened by the expert advice and research services delivered by, among others:

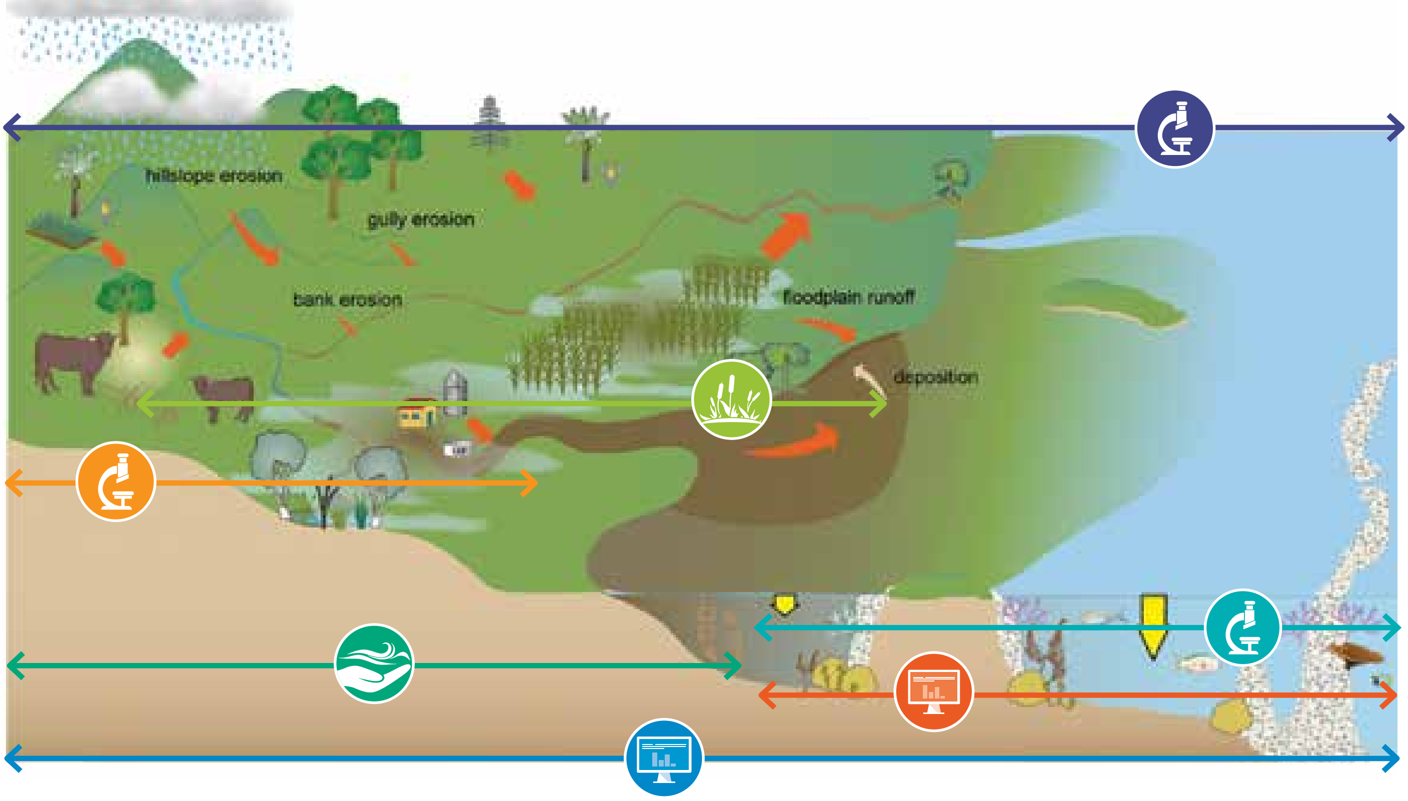
- Department of Science, Information Technology and Innovation (DSITI)
- Department of Agriculture and Fisheries (DAF)
- Department of Natural Resources and Mines (DNRM)
- CSIRO
- Australian Institute of Marine Science (AIMS)
- Sugar Research Australia (SRA, formerly BSES Limited)
- National Centre for Engineering in Agriculture (NCEA)
- CANEGROWERS
- Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC)
- Tully Cane Productivity Services Limited
- reef catchment-based natural resource management (NRM) groups, NQ Dry Tropics, Terrain and Reef Catchments.
- Great Barrier Reef Foundation
- Centre for Tropical Water and Aquatic Ecosystem Research/James Cook University
- Griffith University
- Central Queensland University
- University of Southern Queensland
- individual research specialists including Dr Heather Hunter, Mr Colin Creighton and Dr John McIvor, among others.

Continuing engagement with scientific, strategic and practical expertise shaped the design of the science program and information delivery to the cane and grazing industries. In 2011, the program was reviewed formally through workshops with industry, scientists, policy-makers, end-users and other research programs to confirm proposed themes.

Once projects started, their products and outcomes were reviewed through established processes:

- annually with cane and grazing stakeholders to review the direction and usability of products specific to their industries
- at key research forums by other research providers such as Australian Government's Reef Rescue and Sugar Research Australia (SRA)
- peer review of reports, and where relevant, trialling of results in industry-based cane and grazing science forums
- via the Reef Plan's Independent Science Panel.

COMPLEMENTARY PROGRAMS 2009-2013



RESEARCH AND DEVELOPMENT CORPORATIONS

- Management practices – productivity and profitability

eREEFS

- Phase 1 - Receiving water model

REEF PROTECTION PROGRAM
REEF WATER QUALITY PROGRAM

- Informing/influencing land management
- Management practice effectiveness
- Pollutant generation processes

NATIONAL ENVIRONMENTAL SCIENCE PROGRAM

- GBR status – biological and socio economic
- Ecosystem function and links
- GBR management strategies

QUEENSLAND WETLANDS PROGRAM

- *WetlandsInfo* (Mapping, assessments, policy, guidelines, information, etc.)

REEF RESCUE R&D (2009-2013)

- Management practice effectiveness
- Pesticide source, transport and fate
- Socio economic drivers
- Load assessing
- WQ reporting tools

REEF PLAN PADDOCK TO REEF PROGRAM

- Management practice effectiveness
- Management practice adoption
- Catchment indicators (riparian, wetlands and groundcover)
- End of catchment loads (sediments, nutrients and pesticides)
- Marine status – water quality and ecosystem health
- Reporting against targets

Research area: Prioritisation and future direction

These projects sought to direct future action across the GBR catchments:

- Where, and in which catchments?
- Which pollutants?
- Which land uses?
- Which pollutant-generating processes?
- Where, and what, is least-cost abatement?

In carrying out assessments to prioritise management action for improved water quality in Reef Plan 2003, the best available methodologies at the time were used. However, they were limited by the underpinning datasets and knowledge regarding the relative risk of nutrients, sediments and pesticides to the reef from key land uses such as grazing and sugarcane, which impacted the ability of investors to set priorities for management responses.

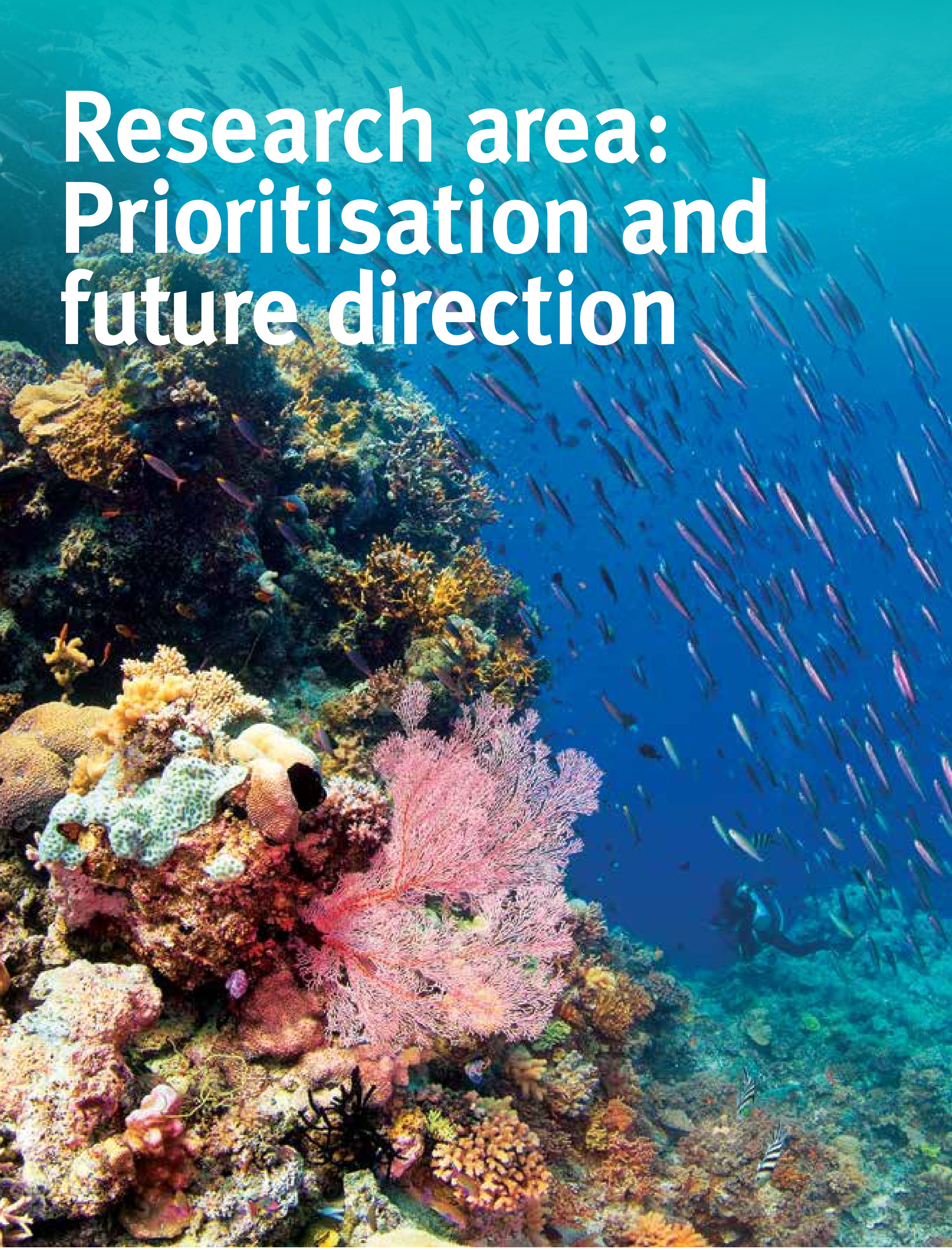
It also affected the ability to model outcomes through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) as well as report on outcomes of management actions and investments.

At the time, having comprehensive datasets that would underpin scientific reasoning and decision-making was seen as another missing piece.

Prioritisation and future direction projects:

- **Relative risk assessment update (RP72P)**
- **Historical land use change and pollutant loads (RP71P)**
- **Land use change and updated land use mapping for Great Barrier Reef catchments (RP01)**

Research area: Prioritisation and future direction



RELATIVE RISK ASSESSMENT UPDATE *(RP72P)*

Project partners: TropWATER, James Cook University, CSIRO, AIMS, Australian Government and the Queensland Department of Premier and Cabinet

Several assessments had been carried out to prioritise management action for improved water quality in Reef Plan 2003, Reef Rescue and the Reef Water Quality program. The methodologies used in each of these analyses, though best available at the time, were limited by the available datasets.

> The relative risk assessment report and its supporting studies, compiled by a panel of 30 scientists, underpinned the Scientific Consensus Statement 2013.

What issue was this project trying to resolve?

While there is ample evidence that nutrients, PSII pesticides and sediments are having an adverse effect on the Great Barrier Reef, a comprehensive assessment was needed to see how reef pollutants have changed through time in response to land use and related management changes. This project aimed to provide robust, targeted scientific evidence of where in the catchment and sub-catchments these changes have occurred, and from which industries.

How did we go about it?

A flexible, ecological risk assessment methodology was employed, based on well-recognised international approaches, to assess the relative risk of contaminants and associated land uses to the reef's health. The approach considered land uses, catchment characteristics and contaminants.

The methodology employed a combination of quantitative assessments of the relative risk to water quality from major agricultural land uses based on the data available. It looked at the relative risk posed by different reef contaminants, including sediments, nitrogen, phosphorus and pesticides to different ecosystems, such as wetlands, seagrasses and coral reefs.

What was the outcome?

The main findings of the risk assessment were that increased loads of suspended sediments, nutrients (nitrogen and phosphorus) and pesticides all pose a high risk to some parts of the reef. However, the risk differs between individual pollutants, source catchments and distance from the coast.

Overall, increased concentrations of nitrogen from catchments between the Daintree and Burdekin Rivers pose the greatest risk to coral reefs. Run-off from these rivers during extreme and early wet seasons is associated with outbreak cycles of the coral eating crown-of-thorns starfish on the northern reef shelf that subsequently generate secondary outbreaks throughout the central and southern reef. It was estimated that crown-of-thorns starfish have affected more than 1,000 of the approximately 3,000 reefs within the reef over the last 60 years.

Also found, and of equal importance, was the risk to seagrass meadows from suspended sediments discharged from rivers in excess of natural erosion rates, especially fine particles (clays). Whether carried in flood plumes or re-suspended by wave action, suspended particulate matter creates a turbid water column that reduces the light required by seagrass and corals. High turbidity has been estimated to affect about 200 inshore reefs and most seagrass areas. The Burdekin and Fitzroy regions present the greatest risk to the reef from increased suspended sediment loads.

The report found that loss of seagrass habitat as a result of cyclones, floods and degraded water quality appeared to be associated with higher mortality of dugong and turtles. The risk to coastal seagrass beds, and freshwater and estuarine wetlands from the six commonly used PSII herbicides was assessed as highest in the Mackay-Whitsunday and Burdekin regions, followed by the Wet Tropics, Fitzroy and Burnett Mary regions. Concentrations of a range of pesticides, which exceeded water quality guideline thresholds, were found in many fresh and estuarine water bodies downstream of cropping lands.

Information from the risk assessment report has helped determine future priorities for managing priority reef contaminants by specifying where in the catchment/sub-catchments and from which industries key reef contaminants are generated. These priorities are reflected in Reef Plan 2013's management strategies, a project co-funded by the Australian and Queensland Governments.

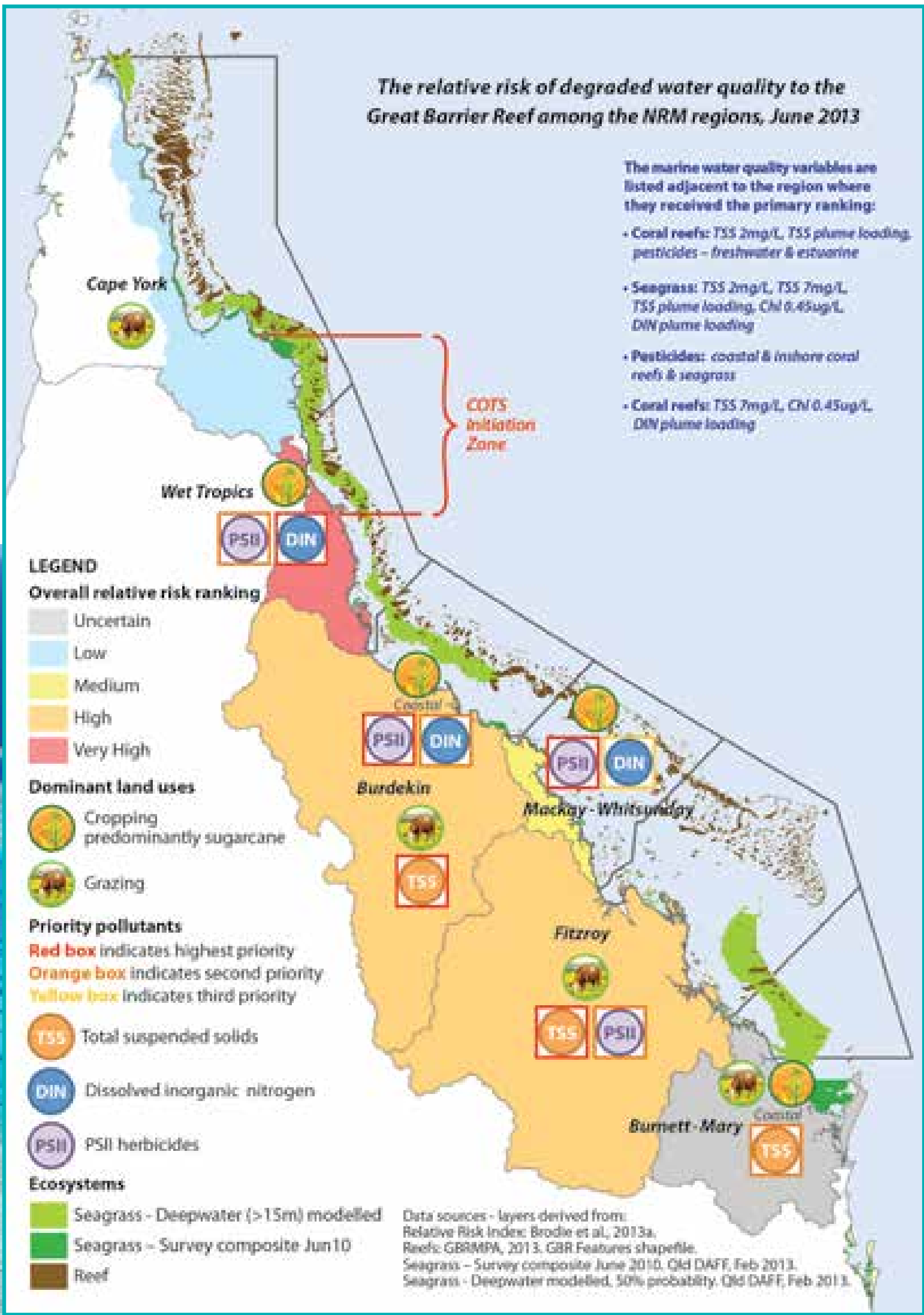
This project used greatly improved methodology and comprehensive datasets to refine understanding of the risks, and provide robust, targeted scientific evidence. It helped distinguish between baseline loads (including those associated with extreme climatic events) and agricultural activity.

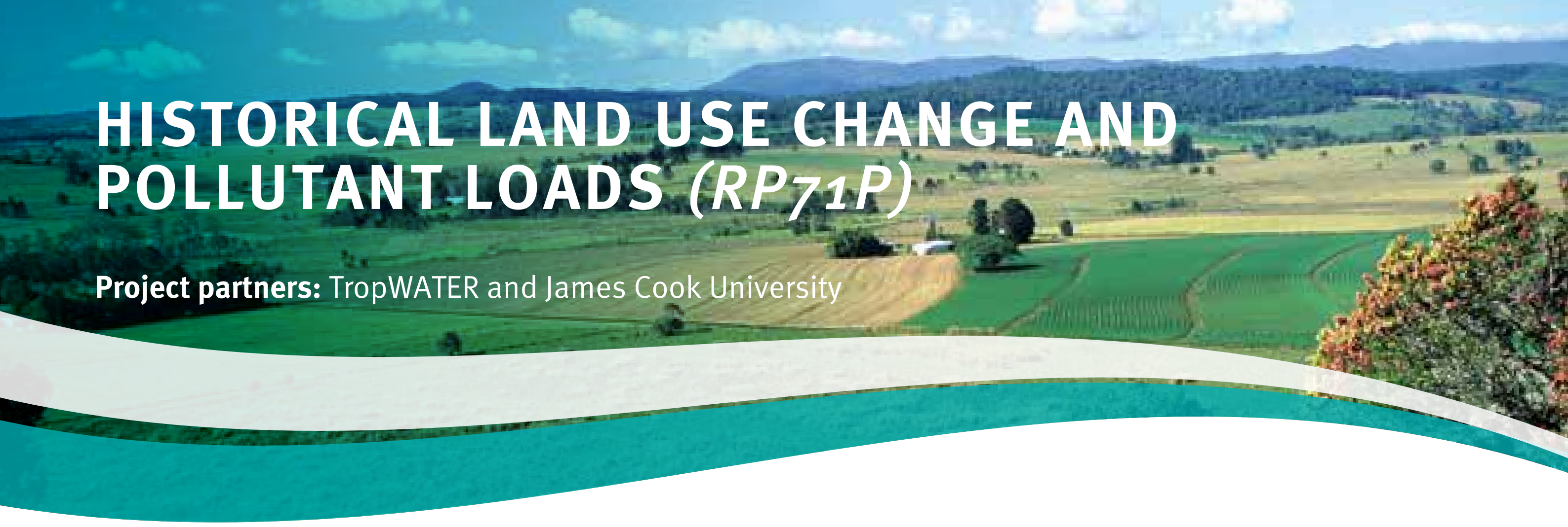
Jon Brodie, Project Leader, James Cook University

Note: This map is a sample of an outcome from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

This map illustrates relative risk of degraded water quality to the Great Barrier Reef based on dominant land uses and priority pollutants.

Figure sourced from Brodie, J., Waterhouse, J., Maynard, J., Bennett, J., Fumas, M., Devlin, M., Lewis, S., Collier, C., Schaffelke, B., Fabricius, K., Petus, C., da Silva, E., Zeh, D., Randall, L., Brando, V., McKenzie, L., O'Brien, D., Smith, R., Warne, M., Brinkman, St. J., Tonin, R., Bainbridge, Z., Bartley, R., Negri, A., Turner, R.D.R., Davis, A., Bentley, C., Mueller, J., Alvarez-Romero, J.G., Henry, N., Waters, D., Yorkston, H. and Tracey, D. (2013). Assessment of the relative risk of water quality to ecosystems of the Great Barrier Reef. A report to the Department of the Environment and Heritage Protection, Queensland Government, Brisbane, TropWATER, Report 13/28, Townsville, Australia, page 10.





HISTORICAL LAND USE CHANGE AND POLLUTANT LOADS *(RP71P)*

Project partners: TropWATER and James Cook University

Over time, pollutant loads have changed in response to land use change, including changes in cattle stocking rates, agricultural expansion and improved management practices.

What issue was this project trying to resolve?

Improving our knowledge about land use changes helps to modify farming systems and deliver improved water quality. This project aimed to quantify changing loads over time, creating baseline pre-European loads, so that more precise pollutant targets can be set.

How did we go about it?

The project compiled a wealth of statistical data that included land use change, hydrological data, measured contaminant loads, and fertiliser and herbicide application data. The work linked historical records with environmental signals laid down in the corals of the Great Barrier Reef. This project synthesised historical land use change, fertiliser and pesticide usage, and pollutant load data in the reef catchments to quantify baseline and changing pollutant loads exported to the reef.

> The data outputs provide a validation for modelling exercises, and another line of evidence for the links between what happens on land and the water quality in the Great Barrier Reef lagoon.

What was the outcome?

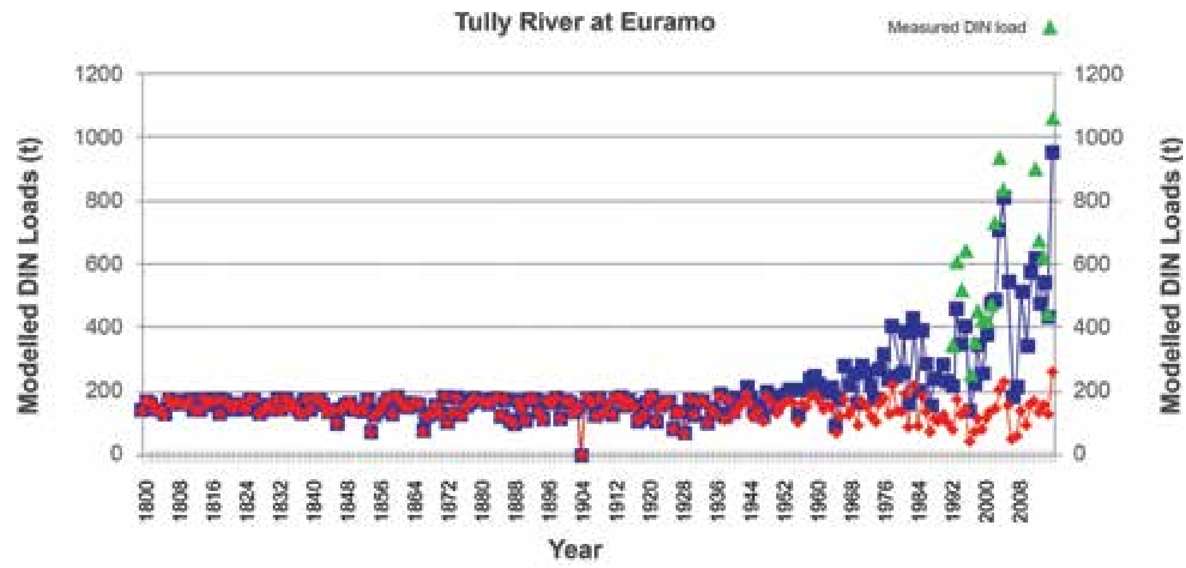
The report describes annual loads of sediments, nutrients and pesticides since European settlement. It helps examine and connect shifts in industry practice over time, for example, introducing drought resistant cattle, and improves understanding of the key drivers for these shifts. The project provided an estimate of how loads of dissolved inorganic nitrogen and dissolved inorganic phosphorus have changed over time due to fertiliser loadings in the Wet Tropics, Burdekin and Mackay-Whitsunday regions, including their baseline values.

The ability to identify pollutant loads with reasonable reliability was the most important outcome of this study, as it allowed for the basin prioritisation used under the Water Quality Improvement Plans, leading to improved decision-making. The data outputs from this project have also been used to examine linkages with COTS outbreaks.

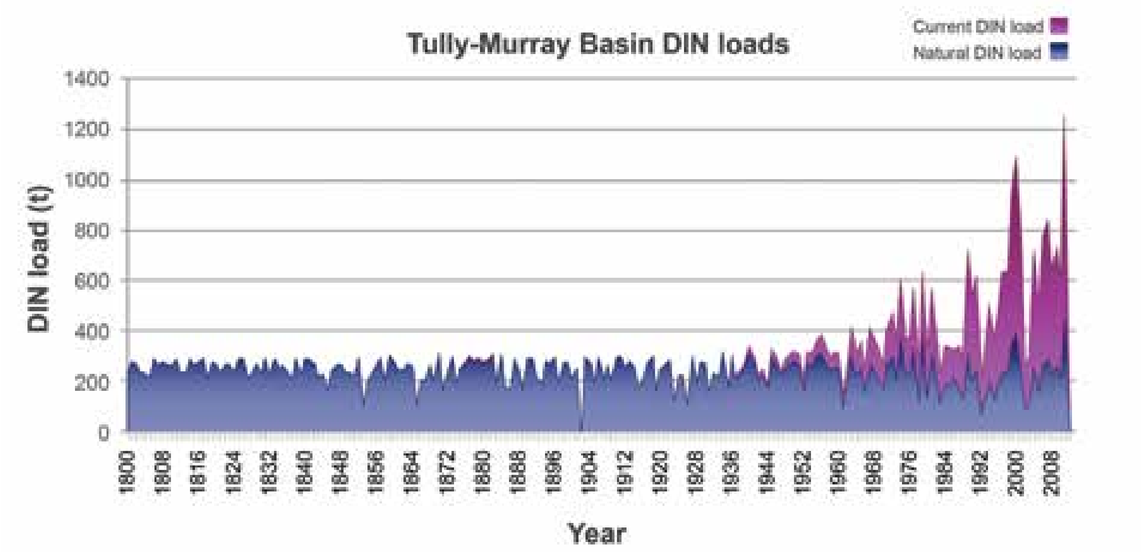
This project compiled, for the first time, a wealth of statistical data from across the Wet Tropics, Burdekin and Mackay-Whitsunday Natural Resource Management regions that included land use change, hydrological, measured load and fertiliser and herbicide application data. We show that where this data is available, loads can be predicted with medium to high confidence. In that regard, the loads of dissolved inorganic nitrogen can be charted back through time for most of these basins, which is critical given its influence on COTS outbreaks.

Stephen Lewis, Project Leader, TropWATER

Note: These graphs are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.



The above graph is an example of how loads of NOx have changed at the Tully River (Euramo site) since 1800. Note the comparison between the measured (green triangles) and the modelled loads (blue squares).



The above graph shows modelled loads of dissolved inorganic nitrogen (DIN) in the Tully-Murray basin since 1800.

Figures sourced from Lewis, S., Brodie, J., Endo, G., Lough, J., Furnas, M., and Bainbridge, Z., (2014). 'Synthesising historical land use change, fertiliser and pesticide usage and pollutant load data in the regulated catchments to quantify baseline and changing loads exported to the Great Barrier Reef.' Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) Technical Report 14/20, James Cook University, Townsville, 105 pp, page 14.

LAND USE CHANGE AND UPDATED LAND USE MAPPING FOR GREAT BARRIER REEF CATCHMENTS *(RP01)*

Project partner: DSITI

Land use mapping information is a fundamental requirement for understanding the relationship between what happens on land and the quality of water being delivered to the Great Barrier Reef lagoon.

What issue was this project trying to resolve?

This project aimed to map land uses across all reef catchments and describe land use change over time, thereby improving our knowledge of land practices and their impact on the reef.

In 2009, the coverage and benchmarking of agricultural land use across reef catchments was of varying scales and accuracy. The lack of consistent spatial coverage of land use information impacted on the ability of reef programs to model and report on management practice and land use change. Identifying risks and target interventions and responses through the Scientific Consensus Statement 2009, and catchment-based Water Quality Improvement plans 2003-09 was also challenging due to the lack of consolidated mapping.

How did we go about it?

The project used existing databases of land use information, Queensland Land Use Mapping Program (QLUMP) data, as well as satellite imagery and aerial photography to update the land use mapping for the reef catchments to 2009. Local knowledge was also an important component of the mapping. Mapping land use was undertaken in accordance with a nationally accepted classification scheme, and the remote sensing scientists undertook some field work to ground truth the data.

> The project provided a giant 'snapshot' of the Great Barrier Reef catchments, and how every part of land in the area was being used, and how it has changed over time.

What was the outcome?

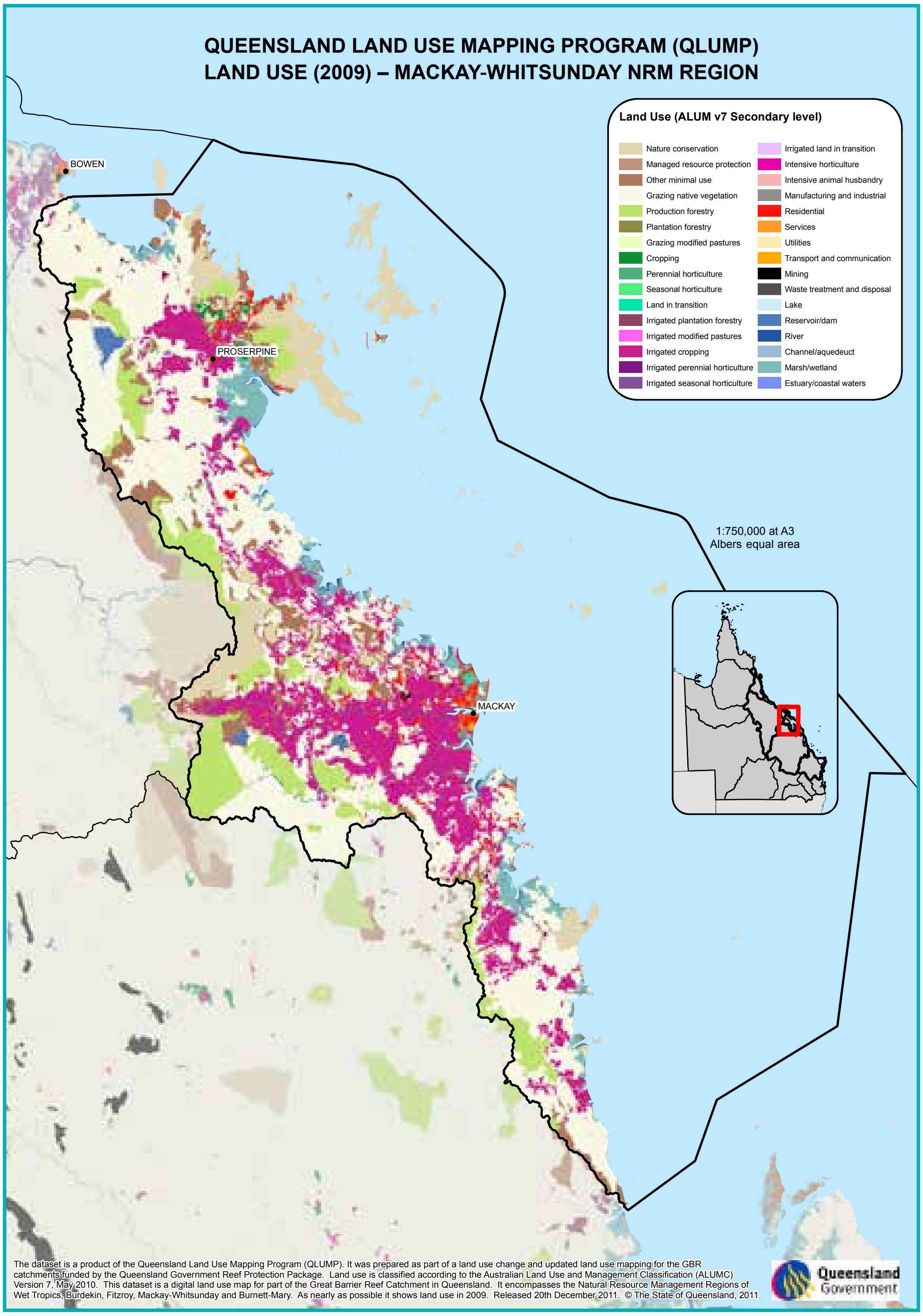
The mapping developed through the project, captured land use in the Wet Tropics, Burdekin, Mackay–Whitsunday, Fitzroy and Burnett–Mary Natural Resource Management (NRM) regions for 2009. Summary reports showed that relatively natural environments accounted for 82% of the catchments, conservation and natural environments contributed 10% and other land uses included dryland, irrigated agriculture, and intensive classes of mining and residential development.

The project also reported on the changes in land use from 1999 to 2009, providing a base for identifying any further land use changes in the catchments that may contribute to sediment and nutrients entering the Great Barrier Reef.

Critically, the data is applied in the Paddock to Reef Program coupled with land management change data to determine water quality improvements that have resulted from targeted intervention and investment. The mapping has also been used to support biosecurity response and targeted natural disaster response, particularly after cyclones.

The project provided consistent and reliable spatial information about land use in reef catchments. Land use data is critical for sustainable natural resource management by government, non-government and research organisations. As a fundamental dataset, it has been used to inform a variety of programs in reef catchments and provided a reliable basis for management decision-making.

Note: This map is a sample of an outcome from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.



Research area: Sugarcane management systems

In 2011, critical gaps with respect to managing sugarcane systems were identified as:

- understanding what constituted best management across cane-growing regions
- understanding where and how to respond to different cane landscapes and soil properties
- applying fertiliser and managing nutrients
- managing weeds and herbicides
- the potential to treat farm run-off by using interventions, such as vegetated treatment strips
- sharing information through decision support tools
- understanding the costs and benefits of management responses on properties.

Sediment management was a lower priority, with peer reviews identifying that sufficient knowledge already existed about management options to reduce risks of sediment loss from cane properties. Four projects were undertaken to fill these gaps.

Sugarcane management systems projects:

- **Mapping environmental characteristics important for reef water quality (RP07)**
- **Compendium of Smart Sugar Practices (RP79C)**
- **Sub-catchment monitoring and adaptive management in cane farming (RP85C)**
- **Improving nutrient and chemical management (RP83C)**

Research area: Sugarcane management systems

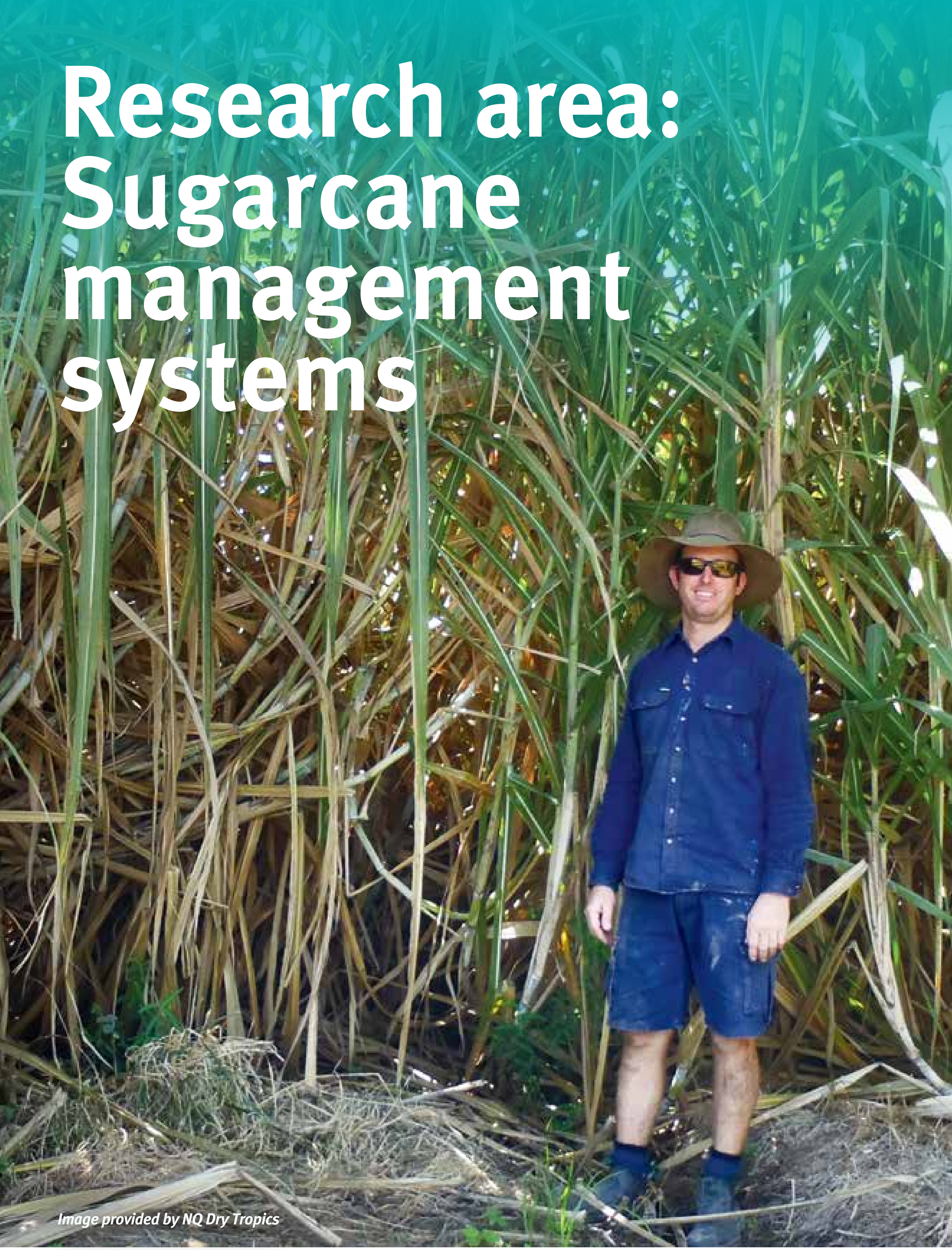


Image provided by NQ Dry Tropics

MAPPING ENVIRONMENTAL CHARACTERISTICS IMPORTANT FOR REEF WATER QUALITY *(RP07)*

Project partners: TropWATER, James Cook University, CSIRO and AIMS

Image provided by DSITI

Environmental characteristics information can help landholders take a risk-based approach to managing land.

What issue was this project trying to resolve?

The project set out to provide landholders and advisors in the Wet Tropics, Burdekin and Mackay-Whitsunday catchments with local environmental maps and guidance to determine practices to reduce soil and water movement from cane lands.

How did we go about it?

Four characteristics were mapped: erosion potential, flooding frequency, dominant water pathway and soil transport potential.

The method was reviewed by experts who had knowledge of local soils, cane-growing requirements, and water and pollutant pathways. Growers, agronomic extension officers, milling companies and policy end-users such as regulators were also consulted to determine how best to describe and explain the four characteristics, and how they could be managed on farms.

This method of data collation, assessment, review and reporting for the Wet Tropics was then rolled out to cane lands within the Burdekin and Mackay-Whitsunday catchments.

> This project mapped environmental characteristics of cane lands in the Wet Tropics, Burdekin and Mackay-Whitsunday catchments.

What was the outcome?

Environmental characteristic maps were produced for cane lands of the Wet Tropics, Burdekin and Mackay-Whitsunday catchments. The project also produced technical reports explaining how the maps were made, and user guides to help landholders and advisors understand and interpret them to ensure they are not used out of context. The user guides include a description of the datasets, advice on how the characteristics may affect water quality, information to support on-property interpretation and general implications for management.

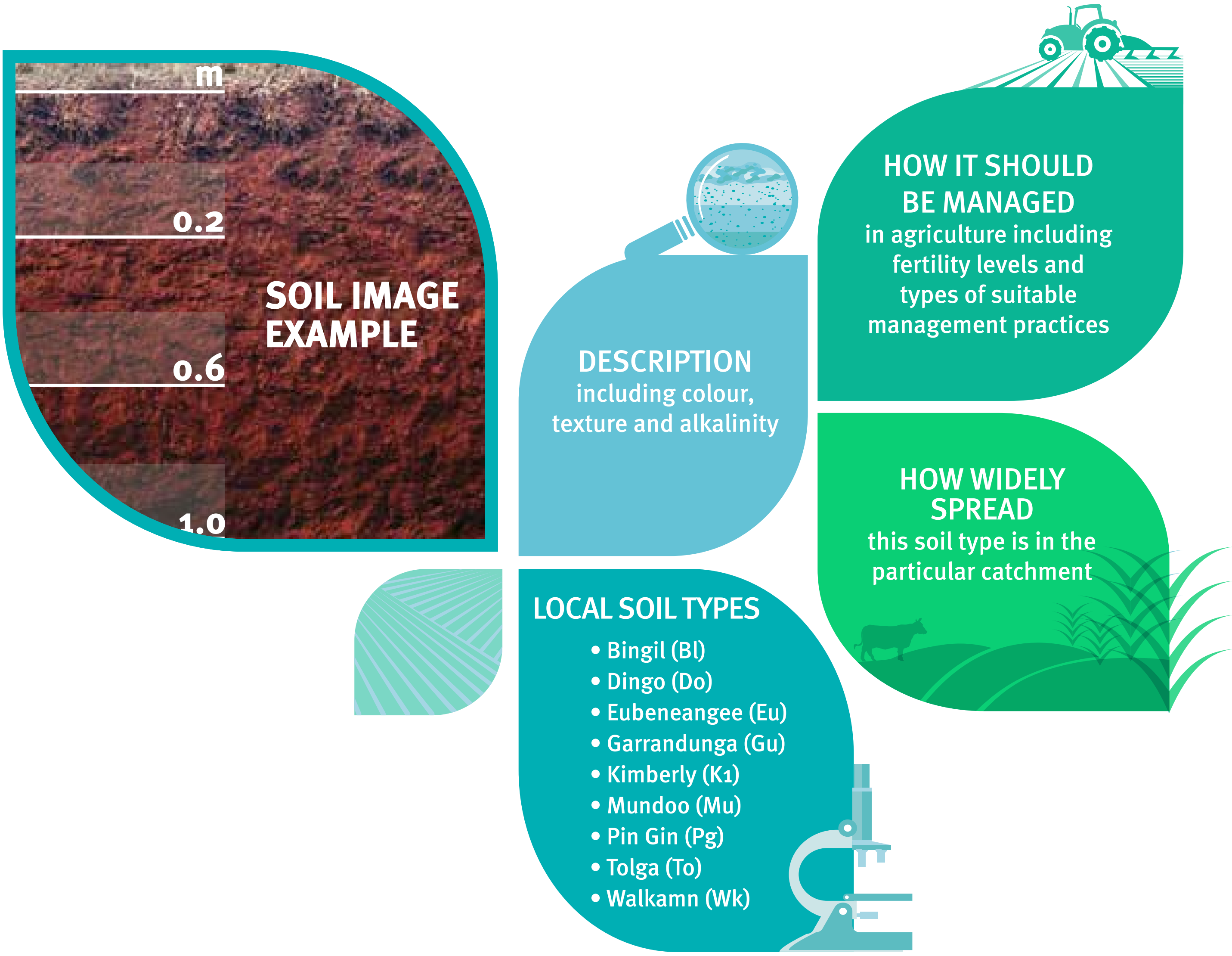
At the time of their release, the maps, technical reports and user guides for each catchment were distributed to government regulators, industry advisors and extension staff. They are available for download on the Queensland Spatial Catalogue.

This project (amongst others) also helped to improve underlying soil datasets. These improved soil datasets were integrated into the Paddock to Reef Program and included in the departmental soils database, which underpins Queensland soil survey sites.

One of the land conditions mapped in the guide; steambank erosion - the direct removal of soil from banks by flowing water is exacerbated during periods of high streamflow or lack of vegetation cover.

The environmental characteristic maps are intended to help identify the potential for cane lands to contribute to surface water quality decline. When this data is combined with land management factors, it can help to target investment and education, and extension activities to address the drivers of surface water quality decline.
For instance, the data can be used by regional natural resource management groups to support prioritisation and planning activities.

This guide mapped soils across priority catchments, providing soil overview and agricultural management recommendations. Illustration below depicts mapping outlined in the guide.



COMPENDIUM OF SMART SUGAR PRACTICES (RP79C)

Project partner: Dr Colin Creighton

Image provided by SRA

Good data is vital to assess the impact of management practice change on water quality improvement or identify where management improvement is most needed.

What issue was the project trying to resolve?

The project set to synthesise available information and identify management options that can be easily and cost-effectively adopted by the majority of growers for improving the quality of water in run-off from cane farms in priority catchments.

How did we go about it?

The project team drew information from and consulted with the full range of extension programs and R&D projects, assessing environmental impacts and economics of cane-growing practices. In particular, it incorporated work by the then Department of Agriculture, Fisheries and Forestry under Reef Plan Action 4 to identify improved land management practices to maximise reef quality improvements, and drew on research being funded or undertaken by the National Environmental Research Program (NERP), Reef Rescue R&D, CSIRO, BSES, and the Sugar Research and Development Corporation. The team also consulted with CANEGROWERS, the Australian Cane Farmers Association, the Australian Marine Conservation Society, and the Terrain, North Queensland Dry Tropics and Reef Catchments NRM groups.

> This guide examined contemporary best management solutions that were delivering good results in the Wet Tropics, Burdekin and Mackay-Whitsunday regions, taking account of the differing regional agricultural systems as of 2013.

What was the outcome?

Colin Creighton and an expert regional team prepared a compendium documenting evidence of profitable cane farming practices suitable to each Great Barrier Reef growing region to improve water quality. These practices have the potential to enhance grower choices and opportunities for enterprise improvement Australia wide.

The project examined existing cane management systems, and acknowledged that research and development needed to be continuous to improve practices.

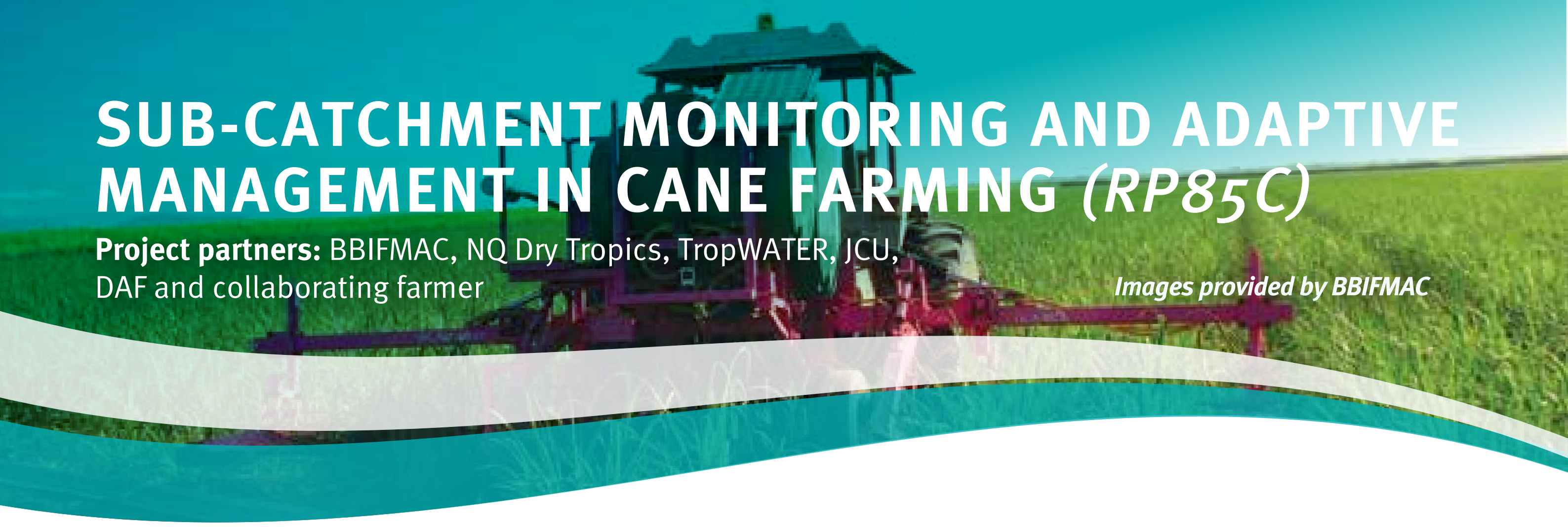
Zonal application of mill mud practice options in all four regions including the Herbert

Boosting sugar production by using the most up-to-date methods is the smartest way to achieve sustainable and profitable production. The project team, representing the different cane growing regions, developed a relevant compendium which complemented the development of the Cane Best Management Practice (BMP) modules for nutrient, chemical and sediment management, and property planning.

These images are examples of practices identified in the guide. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

Raised bed guidance to reduce impaction - Mackay

Green cane trash blanketing is a viable option in most cane in most cane growing regions of Queensland



SUB-CATCHMENT MONITORING AND ADAPTIVE MANAGEMENT IN CANE FARMING *(RP85C)*

Project partners: BBIFMAC, NQ Dry Tropics, TropWATER, JCU, DAF and collaborating farmer

Images provided by BBIFMAC

Sugar cane production is a major land use in the Burdekin River Irrigation Area (BRIA), and it has been identified as an important source of diffuse pollution. In the BRIA, water containing sediment, nutrients and pesticides leaves farm lands and runs into a system of purpose-built drains or directly into natural creeks. This water then travels to the Burdekin River or into coastal wetlands, including those that are Ramsar listed or of national significance, and inevitably enters the marine environment, including the Great Barrier Reef lagoon. Changes to on-farm management practices in the BRIA are required to reduce the amount of sediment, nutrients and pesticides in farm run-off.

What issue was this project trying to resolve?

Despite previous water quality monitoring initiatives, growers were demanding evidence to show how well the in-stream results reflected what was actually happening on their individual farms.

How did we go about it?

BBIFMAC explored the direct connection (paddock to stream) by intensively monitoring in real-time the run-off at the downstream end of the sub-catchment stream or drain, and undertaking grower group discussions to track spikes in nutrients and sediments back to the farm and paddocks.

> This project concluded that rainfall rather than irrigation is responsible for the largest losses of nitrogen. It also demonstrated the value of real-time monitoring for farm management.

Inappropriate management practices could then be quickly identified and modified, and alternative practices considered for discussion among the sub-catchment group.

What was the outcome?

From a full year of monitoring the catchment, more than three-quarters of the nitrogen lost to run-off was from rainfall events, suggesting rainfall rather than irrigation was responsible for the largest losses of nitrogen. This information was provided to the collaborating farms through the project, and was positively accepted. It raised awareness of the potential for losses from the farming system. This information and process of engagement stimulated farmers' thoughts about the relationship between their farm practices and water quality leaving their farm. Many have already changed, or are contemplating changing their practices to reduce nutrient losses from their farms as a result of the project.

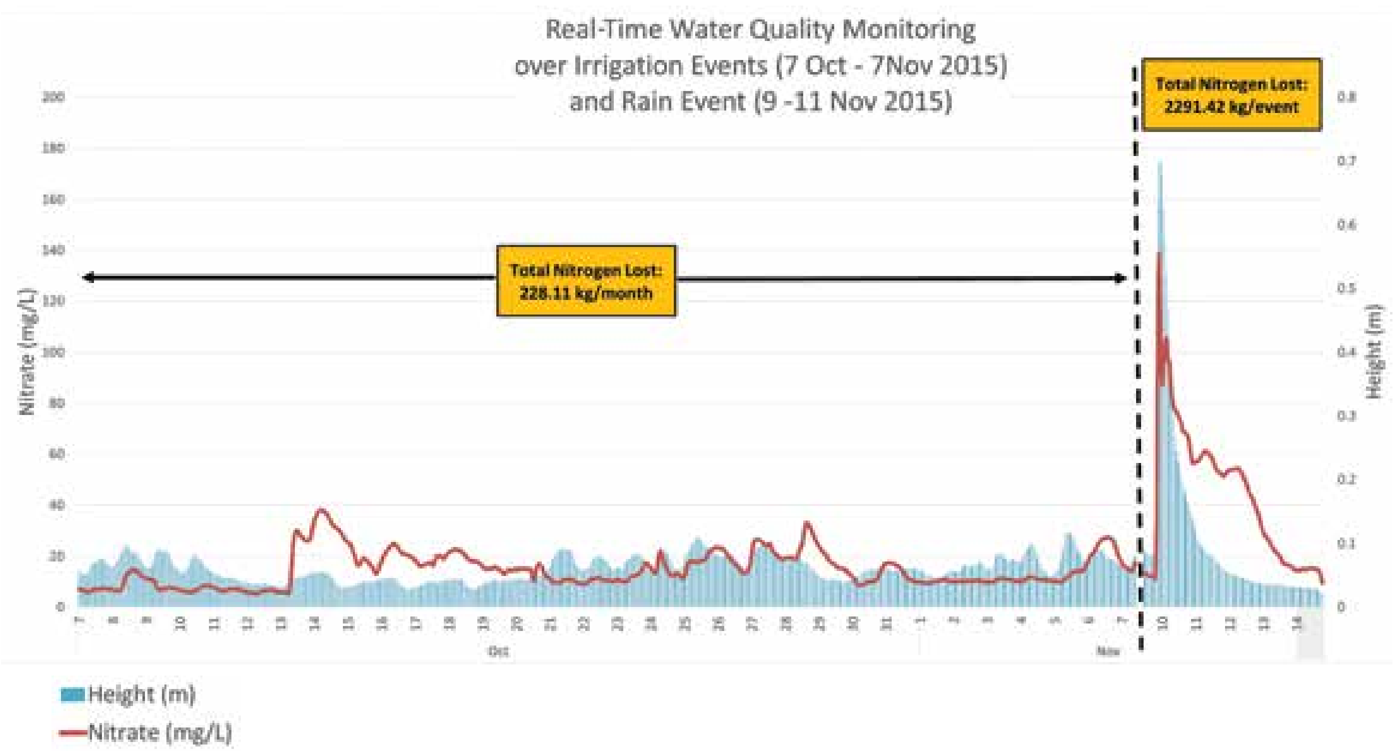
Information from this project is being used by productivity services to improve on-farm practices and reduce nitrogen losses.

Heavy rainfall was clearly associated with elevated nitrates in the water quality monitoring data

The real-time water quality monitoring systems assist sub-catchment farmers to clearly identify the farm management practices that yield poor water quality outcomes. Throughout the project, it was generally evident that mineral nitrogen from farms was lost through both irrigation and rainfall events. The rate of nitrogen flux from farms varied greatly throughout the season, and was strongly influenced by farm management practices, weather conditions and stage of crop growth. The real-time water quality monitoring has gone a long way to clarify the connection between the water quality leaving farms and how it may impact on downstream ecosystems. In order to gain the confidence of land managers on a broader scale, further monitoring should be undertaken in areas with different farm practices, inputs and soil types. The results of this monitoring should be promoted and made available to the wider industry to increase their understanding of the practices and processes that lead to losses of fertiliser originated nitrogen from farms.

Tom McShane, Project Leader, BBIFMAC

Real-time water quality monitoring over irrigation and rain events.



Case study, Adaptive Management, NQ Dry Tropics – Figure 1: Nitrate levels and height of water above constructed weir recorded at sampling site.

IMPROVING NUTRIENT AND CHEMICAL MANAGEMENT *(RP83C)*

Project partners: Reef Catchments, DNRM, Mackay Area Productivity Services and CANEGROWERS

Images provided by Reef Catchments

Results of catchment and marine monitoring show that cane-growing in sub-catchments in the Mackay-Whitsunday region can generate significant loads of reef pollutants, particularly nitrogen and photosystem II-inhibiting (PSII) pesticides.

What issue was this project trying to resolve?

This project aimed to validate and extend the economic and environmental benefits of adopting improved nutrient and chemical management on farms in the Mackay-Whitsunday region.

How did we go about it?

Two additional treatments using precision application of PSII herbicides and nitrogen were compared with more common management practices on Paddock to Reef Program monitoring trial sites in the Mackay-Whitsundays region.

Conventional broadcast of PSII chemicals was compared with an improved banded-plus-knockdown application, and conventional nutrient rates were compared with Six Easy Steps with improved nitrogen replacement.

> The project has validated that industry-promoted best practices can improve growers' profitability and provide water quality benefits.

What was the outcome?

The trial has shown that banded residual herbicides maintained productivity while having a lesser impact on water quality when compared to broadcast residuals.

The study, using rainfall simulators, also identified that the timing and amount of rainfall and irrigation after application was a critical factor influencing seasonal herbicide run-off losses.

With respect to nutrients, the simulators revealed that initial nitrogen concentrations in run-off are dependent on the amount applied and period of time between application and the first run-off event. The greater the time between application and the first run-off event, the fewer nutrients were lost in run-off.

Information from this project is being used in extension work by NRM groups working with farmers on practice changes.

Extending the project outcomes at field days

Advice for farmers - ***Farmers can reduce potential residual herbicide losses by using overhead irrigation after spraying. However, they should also follow recommendations on the product label and any associated regulations which may include waiting at least two days after herbicide application on bare soil before watering in, not applying herbicides to water logged soil and delaying application if run-off-causing rainfall is predicted within 48 hours of the planned application.***

A Paddock to Reef Water Quality monitoring site with instrumentation to capture run-off

Run-off samples

Measuring a run-off event through a flume set up at one of the Paddock to Reef Water Quality monitoring sites

Research area: Sugarcane systems - nutrient management

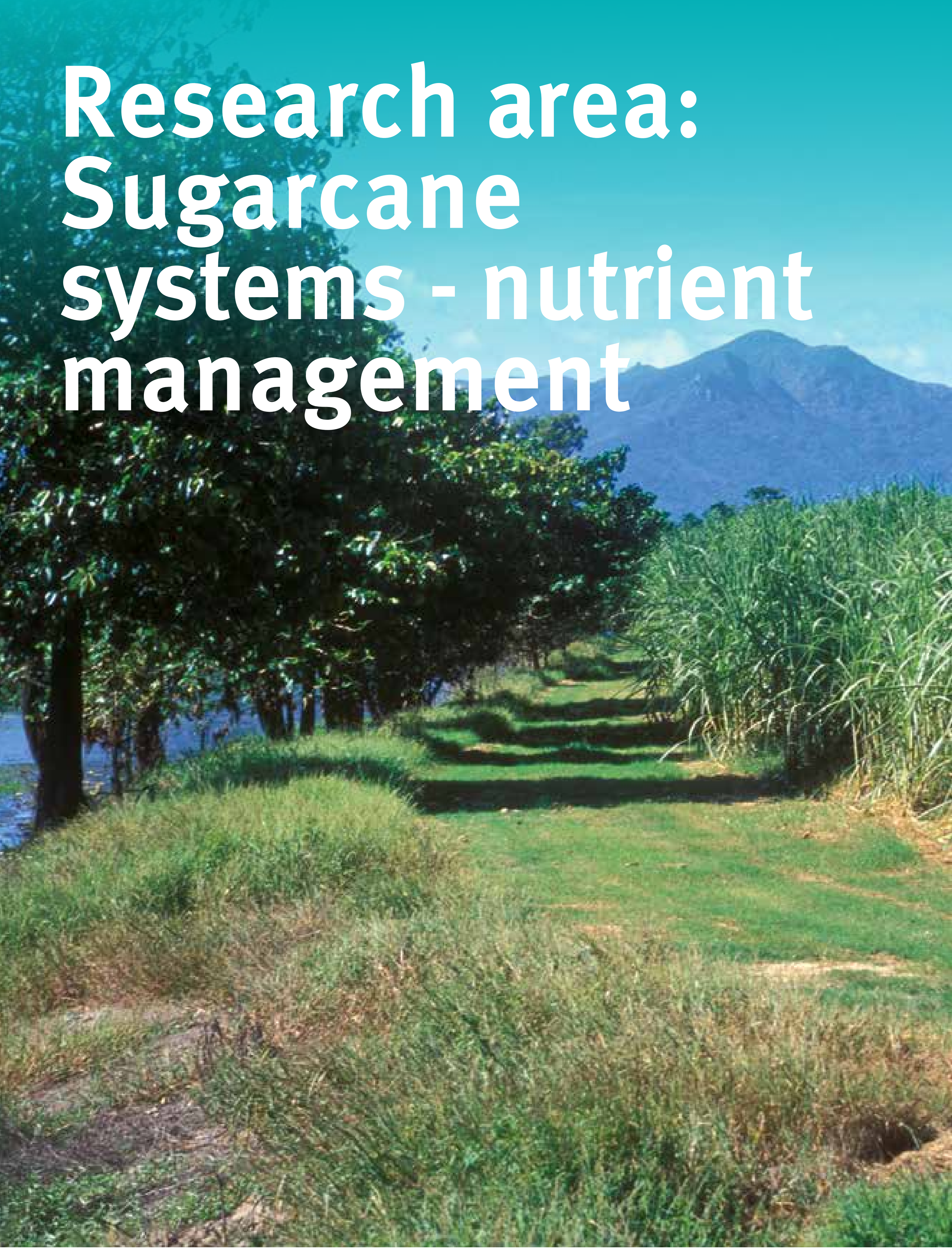
Reducing nutrient losses to catchment waters is critical for the Great Barrier Reef's long-term health and resilience. If cane farmers are to take up improved approaches to existing industry methods, particularly Six Easy Steps, a clearer picture of the consequences of nitrogen losses, effects of any changes upon productivity, and an understanding of the different sources of nitrogen available to growers is required.

Eight projects looked at different sources of nutrients, application rates and pathways along which nitrogen is lost from the paddock. These Department of Science, Information Technology and Innovation (DSITI)-led projects intended to update the 2010 regulated method based on improved evidence, and also inform the sugarcane industry review of their nutrient management standards and practices. The outcomes of this work will inform updates of extension, industry best management practice systems, regulatory policy and other management interventions. Four projects were undertaken to fill these gaps.

Sugarcane management systems - nutrient projects:

- **Initial recognition and monitoring (RP22C) and Nitrates in nutrient budgeting (RP84C)**
- **Mill mud and mill mud products efficacy (RP12C)**
- **Understanding the nitrogen cycle (RP58C, RP59C, RP60C)**
- **SafeGauge for Nutrients (RP10C)**

Research area: Sugarcane systems - nutrient management



INITIAL RECOGNITION AND MONITORING *(RP22C)* AND NITRATES IN NUTRIENT BUDGETING *(RP84C)*

Images provided by BBIFMAC

Project partners: BBIFMAC, Burdekin Productivity Services, AgriTech Solutions and Burdekin Water Boards

Much is known about the long-term impacts of current and improved nitrogen management strategies on the downstream ecosystem, aquifers and fresh water and marine environments. Industry and government were considering how to account for the nitrogen applied to sugarcane crops from sources such as irrigation water and mill mud into nutrient management strategies.

What issues were these projects trying to resolve?

Although there is some local industry knowledge about the presence of nitrates in groundwater in the Burdekin Delta area, many producers currently lack the understanding and confidence to accept that these groundwater nitrates can contribute signifcantly to their crop nitrogen requirements.

How did we go about it?

The project, and an earlier scoping project in the same area, supported a selected number of farmers in the Lower Burdekin to take account of the nitrate applied through irrigation water.

Stage 1 provided a free service to voluntarily participating farmers to regularly sample and analyse irrigation water from their groundwater bores.

All participating growers received a simple water quality monitoring kit for fast and easy analysis of on-farm water quality. This was backed up with laboratory analysis of farm samples for nitrate and phosphate. All growers were provided with on-farm training in correct use of the kits and water quality monitoring procedures through one-on-one, hands-on demonstrations.

Stage 2 encouraged the collaborating farmers to conduct small area strip trials on their farms. They were given support to develop a modified nutrient management strategy that took into account the nitrogen applied through their irrigation water. Nitrate concentrations in groundwater, crop agronomy and final yield were continually monitored. A closed economic study was also conducted to highlight the economic benefits of this modified nutrient strategy.

> Growers in the Burdekin that have opted to build groundwater nitrate into their nutrient management plan have managed to maintain production with reduced inputs of fertiliser.

What was the outcome?

By conducting strip trials that deliver water quality and soil analysis information in which the groundwater nitrate is accounted for in the nitrogen budget, adjustments may be made to the overall nutrient budget. This information helps growers review their nitrogen application, monitor crop growth and assess final yields.

A few growers in the Burdekin have opted to build groundwater nitrate into their nutrient management plan, and have maintained production with reduced inputs of fertiliser.

This research is the initial step towards a better understanding of how the nitrate in irrigation water can be utilised in the Burdekin catchment. Following this, a more robust trial design would be needed over a larger scale with control over inputs. This would help define appropriate methodologies for farmers to utilise this resource without risking a yield penalty.

"Farmers in the Burdekin Delta area access water from the extensive underground aquifer to irrigate their sugarcane crop. These aquifers invariably contain dissolved nitrates, however, the concentration varies considerably. These projects alerted the farmers to the concentration of nitrate in their particular aquifer, and provided them with the option of making adjustments in their nitrogen budget to account for these nitrates. Trials on selected farms in the Delta demonstrated that the aquifer nitrates could in fact replace applied nitrogen in the nitrogen budget."

Tom McShane, BBIFMAC

Groundwater irrigation supplies nitrates to the cane crop

BBIFMAC staff member showing how to use a water quality monitoring kit to test for nitrates

Irrigating the strip trials with groundwater

MILL MUD AND MILL MUD PRODUCTS EFFICACY *(RP12C)*

Project partners: DSITI and SRA

Approximately 1.5 million wet tonnes of mill mud and 200,000 wet tonnes of mill ash are produced annually in Queensland. Together, these mill by-products contain approximately 5,600 tonnes of total nitrogen and 3,400 tonnes of total phosphorus. The total nitrogen to phosphorus ratio in mill mud of approximately 1:6 is significantly out of balance with crop nutrition requirements.

What issue was this project trying to resolve?

The yield benefits of using mill mud and mud ash as nutrient sources are well-recognised. Calculations are available to deduct fertiliser and include its nutritional value in current best practice recommendations. However, it has been identified that there is very limited information available on the rates of release of bioavailable nitrogen, phosphorus and potassium from mill mud and mill ash when applied to soil, and on the beneficial effects to soil properties of the organic carbon in these products. This project set out to develop guidelines for the application of mill mud and mill mud products to maximise productivity benefits and minimise the risk of off-site nutrient movement.

How did we go about it?

The project used pot experiments to estimate the plant availability of nutrients contained in mill mud/ash, its efficacy for improving soil health and to assess the environmental risks of differing application methods.

> The project assessed the effectiveness of mill mud in providing nutrients for growing cane crops.

During this process, the team collated and reviewed readily available data on composition variability and nutrient bioavailability of mill mud and mill mud products. To identify knowledge gaps, glasshouse plant growth experiments and lab incubation experiments were conducted that determined nitrogen and phosphorus bioavailability over time from mill mud and its products.

What was the outcome?

While 35% of the total nitrogen in mill mud and mud ash is available for uptake by the first crop following application, availability of residual nitrogen to subsequent crops is unpredictable.

Results indicate there is a risk of excessive phosphorus losses from applications greater than 100 wet tonnes per hectare. These findings are now feeding into new projects that will increase our understanding of crop nutrient uptake and nutrient losses from the farm following mill mud application.

Banded mill mud applied on a cane farm

Project results suggest 35% of the nitrogen contained in mill mud and mud ash is available for uptake by the first crop following application.

Banded mill mud tractor application

UNDERSTANDING THE NITROGEN CYCLE *(RP58C, RP59C, RP60C)*

Project partners: DSITI, SRA and DAF

Managing the nitrogen cycle in sugarcane production involves understanding the contributors of nitrogen movement off-site, including through gaseous losses, drainage through the soil and run-off.

What issue were these projects trying to resolve?

Nitrate is a form of nitrogen that is extremely mobile in the environment. It moves with water as run-off or drainage as most soils have no capacity for the soil particles to hold the nitrate. Nitrate can also be lost by denitrification (a process whereby the nitrogen is lost as a greenhouse gas). The primary objective of the 'Managing the Nitrogen Cycle' theme was to minimise the quantity of applied N required to produce a tonne of cane sugar with no loss in productivity.

How did we go about it?

In order to better understand the nitrogen dynamics in the cane crop, nitrogen budgets were calculated by measuring the amounts of nitrogen applied, and the amounts taken up by the crop and lost to the environment. As well as field observations and trials, this project conducted pot trials under glasshouse conditions to characterise the bioavailability of nitrogen from legume tops and roots under conditions conducive to N loss by leaching or denitrification.

What was the outcome?

Water-filled pore space (WFPS) was identified as the main driver of denitrification across soils, sites and seasons. Denitrification increases as the soil water content increases from field capacity (about 60% WFPS) to saturation (100% WFPS). The data indicated an average daily relative denitrification rate of 2% of available nitrate-N in saturated soil conditions. The first few rainfall events after fertiliser application consistently triggered a major flush of nitrous oxide gas emissions.

> Managing the nitrogen cycle aims to maximise crop nitrogen uptake. This project discusses a number of key strategies for achieving this.

In the case of urea and urea plus nitrification inhibitor, later rainfall events did not generally cause further gas flushes. However, polymer-coated urea did sometimes demonstrate another emission flush with later rainfall events.

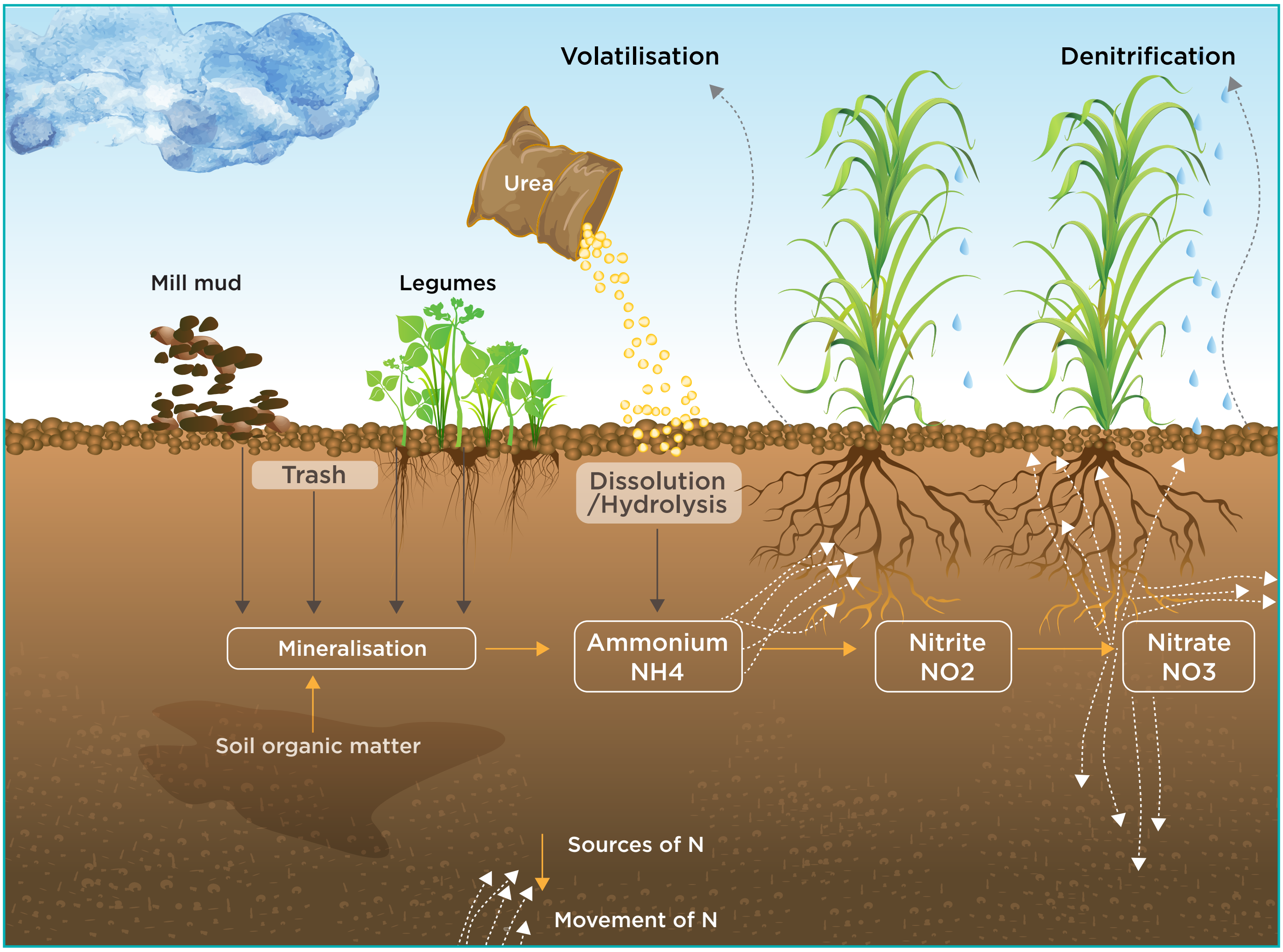
In order to minimise losses by denitrification, farmers should maintain an aerobic (i.e. WFPS<60%) root and fertiliser zone, and keep the applied nitrogen in the ammonium form for as long as possible. In the case of irrigated systems, irrigation method, irrigation scheduling, furrow run length and rate of water application will all impact on the risk of denitrification. These management factors also impact on water use efficiency (WUE), and maximising WUE will minimise denitrification risk.

This project provided valuable information for a number of projects that followed. The methodology ensured that the nitrogen mineralisation and denitrification components of the research were also applicable to results from other Reef Water Quality projects, including the nitrogen trials in the BRIA and Burdekin Delta (RP20), and bioavailability of nutrients in mill mud (RP12), allowing a holistic approach to maximising nitrogen use efficiency based on the nitrogen budget approach. This approach assisted in data improvement for Paddock to Reef modelling of nitrogen behaviour at paddock to catchment scale, and provided validation data for the SafeGauge for Nutrients web tool.

We discovered that crop N uptake at about 120 days ranged from 7.5-18% of total N applied as legume residues compared with about 50% from urea-N under conditions where N loss was minimal. The residues are therefore behaving like a slow release N source. However, the continuing rate of N release from legume residues is unknown and will require further research.

Phil Moody, Project Leader, DSITI

Sources and movement of nitrogen in the cane production system



Legumes fallow planted into cultivated beds

Image provided by SRA

SAFEGAUGE FOR NUTRIENTS *(RP10C)*

Project partners: TropWATER, James Cook University, CSIRO and AIMS

Sustainable nutrient management aims to maximise nutrient use efficiency by the crop and minimise nutrient losses to the environment.

What issue was this project trying to resolve?

The project aimed to assess, at a farm paddock scale, the risk of nutrients (specifically nitrogen and phosphorus) moving from a cane block, taking into account its position in the landscape, long-term rainfall data, soil characteristics and management practices.

How did we go about it?

This innovative project grew out of an earlier CD-based tool, turning it into an online tool using a Google Maps interface that linked with online nutrient management tools like NutriCalc.

SafeGauge was built using Visual Studio .NET20015 software, combining embedded scientific information on soil characteristics and nutrient properties with on-farm management choices, and used in the Google map interface to identify farm blocks.

What was the outcome?

SafeGauge helps growers develop nutrient management strategies that meet crop requirements and consider the risk of nutrient loss. In order to assess the risk of nutrient losses,

> SafeGauge for Nutrients is an on-farm tool that helps farmers determine the likelihood of nutrients, nitrogen and phosphorus leaving their farms.

SafeGauge integrates information on site-specific long-term average daily rainfall, soil data (drainage, permeability and erodibility characteristics), time and rate of nutrient application, placement method and crop nutrient uptake.

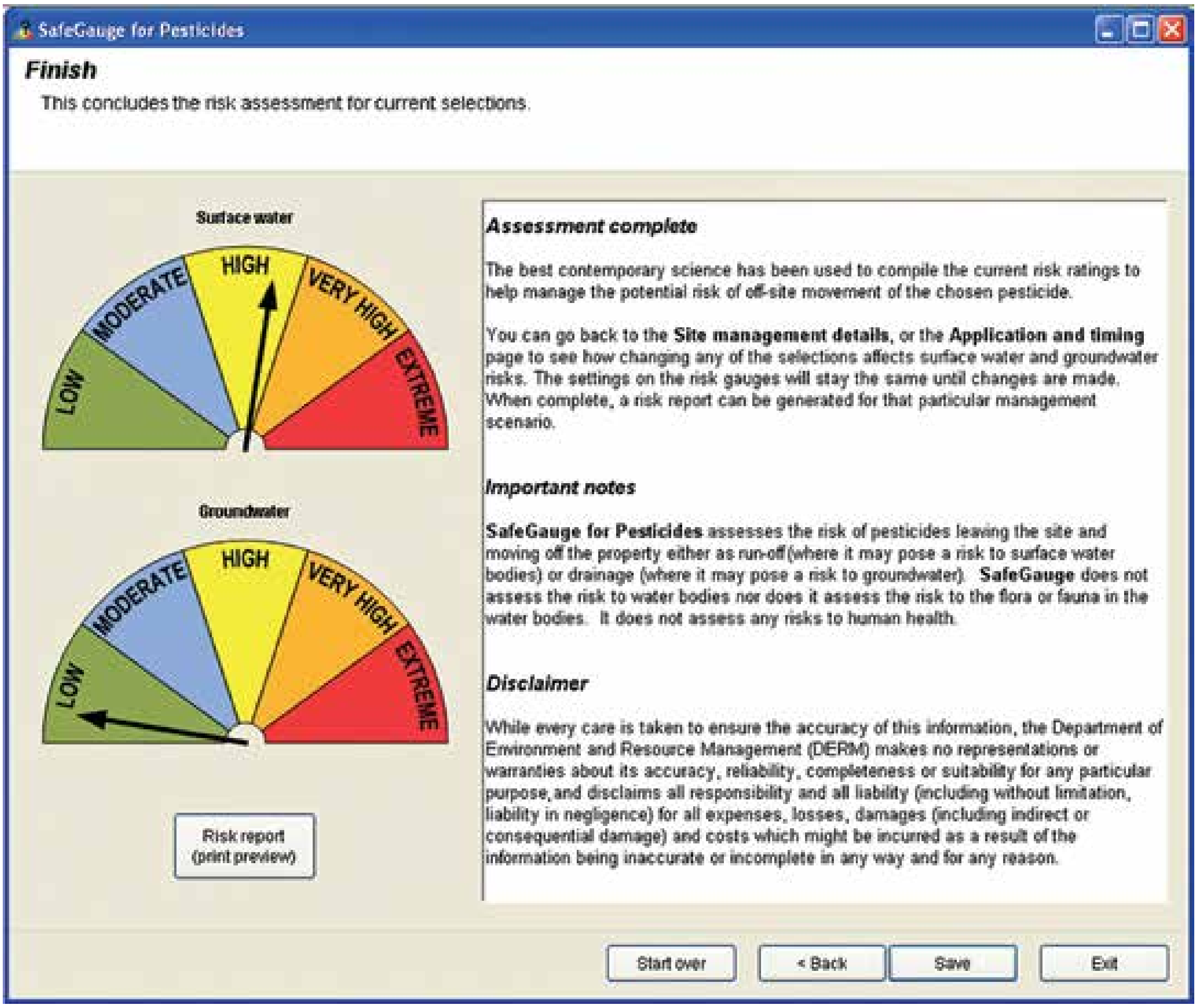
Growers can keep records of nutrient use in SafeGauge, and test different scenarios when applying nutrients, such as fertiliser form, timing, rate, placement and irrigation to assess the risk of nutrient losses from their different blocks. An on-screen dial shows the potential risk of denitrification, and nitrogen and phosphorus movement to surface and ground waters. An application history can be saved for each farm block.

SafeGauge could be used in training courses for accredited fertiliser resellers, and SRA has used it to support NutriCalc. SafeGauge will be updated as more information becomes available on how to best manage soil and nutrient properties with on-farm management choices.

Using this tool, a bit of time at the computer can help farmers track and respond to the risk of nutrients being lost. This is a big deal for farm management and for Great Barrier Reef catchment waterways because the whole aim of effective nutrient management is to maximise the amount of applied nutrient that is captured by the crop. Once farmers work out their crop's nutrient requirements, they can run SafeGauge to see what potential risk there is of nitrogen and phosphorus loss (and the hard-earned cash that paid for it) moving off the block the next time it rains. By running SafeGauge with NutriCalc, farmers can now make decisions based on sound agronomy and the latest water quality science, with the potential to save money. Putting SafeGauge to work is good for farmers and good for the reef.

Phil Moody, Project Leader, DSITI

This is an example of SafeGauge results as tested on the SafeGauge website www.nutrientbudgettool.nceaprd.usq.edu.au/SGlogin.aspx.



Research area: Sugarcane management systems - pollutant transport

Applying nutrients and pesticides to cane paddocks inevitably means consequent losses of nitrogen, phosphorus and pesticide chemicals to reef catchment waterways. But, how it is lost, in what quantities, where does it go and how does this impact on the health of the reef?

To achieve the Reef Plan objectives, it is important to know the best options for minimising nutrient and pesticide losses from cane farms. Only limited research has been done to explore the efficiency of systems such as riparian vegetation and wetlands to trap pollutants in Great Barrier Reef catchments. Knowledge gaps were filled through five projects undertaken in this research theme.

Sugarcane management systems - pollutant transport projects:

- **Comparative effectiveness of community drainage schemes, and effective vegetated areas (RP23C), and treatment of pollutants in run-off from cane farms (RP52C)**
- **Nutrient and herbicide in groundwater flows study (RP51C)**
- **Groundwater pollutant prevalence and transport (RP53C)**
- **Baseline groundwater pesticide data (RP54C)**
- **Herbert Catchment water quality monitoring (RP27C)**

Research area: Sugarcane management systems - pollutant transport

COMPARATIVE EFFECTIVENESS OF COMMUNITY DRAINAGE SCHEMES AND EFFECTIVE VEGETATED TREATMENT AREAS *(RP23C)*, AND TREATMENT OF POLLUTANTS IN RUN-OFF FROM CANE FARMS *(RP52C)*

Project partners: James Cook University, TropWATER, CSIRO and DNRM ***Images provided by James Cook University***

Pollutants may be prevented from reaching the reef or other ecologically sensitive areas by filtering through vegetated systems, sediment traps, or by being distributed, settled or re-mobilised through overbank flow across floodplains.

What issue were these projects trying to resolve?

This project aimed to improve our knowledge about the effectiveness and efficiency of end-of-paddock and end-of-farm options to reduce nutrient, pesticide and sediment loss in run-off. It also assessed the relative capacity of on-paddock, end-of-paddock and off-farm options to mitigate cane farm pollution.

How did we go about it?

A literature review and field studies investigated the role of vegetated and non-vegetated systems in trapping nutrients, pesticides and sediments from cane lands within different parts (freshwater and estuarine) of the reef catchments. This work compared the effectiveness of on-paddock management practices with downstream, end-of-paddock management options, such as effective vegetated treatment areas (EVTAs), sediment traps and off-farm vegetated areas in reducing nutrient, pesticide and sediment losses to catchment waterways.

> Research clarified that constructed wetlands, sumps or vegetated areas are capable of trapping significant levels of all pollutants, however, long residence times are essential for their effectiveness.

What was the outcome?

Research clarified that constructed wetlands, sumps or vegetated areas with long residence times are capable of trapping significant levels of all pollutants. This is more likely to be effective in dryer tropical systems, such as in the Burdekin than in high rainfall systems such as the Wet Tropics.

Further research is needed to better quantify the potential degree of trapping across the reef catchment, and the role of constructed or natural wetlands systems on river floodplains in slowing down flow in overbank flood events.

Constructed wetland in Innisfail—South Johnstone region

"While it is clear that constructed wetlands, sumps and vegetated areas with long residence times are capable of trapping significant levels of all pollutants, further research is needed to more accurately quantify the potential degree of trapping in the varying circumstances across the Great Barrier Reef catchment. Field studies in the current project only focused in the Wet Tropics and Burdekin dry tropics areas. Some of the lessons learnt here and from the literature review may be applicable in other parts of the Great Barrier Reef catchment, however, the conclusions would need to be validated in the actual region e.g. the Fitzroy catchment."

Jon Brodie, Project Leader, James Cook University

These images are examples of practices identified in the project report. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

Sampling sites within the South Johnstone constructed wetland: a) Inlet/bypass drain, b) Inlet, c) Mid-point, d) Outlet

NUTRIENTS AND HERBICIDES IN GROUNDWATER FLOWS STUDY *(RP51C)*

Project partner: Dr Heather Hunter

Much is known about the contaminant loads entering reef waters through streams and overland flow networks, but we know relatively little about subsurface pathways and processes, and how much they contribute to total contaminant loads.

What issue was this project trying to resolve?

This study aimed to review and synthesise current knowledge of how groundwater accesses and transforms nitrogen (N), phosphorus (P) and herbicides, and transports them to reef waters. Herbicides targeted were specifically those that act by impairing photosynthesis, the 'PSII herbicides'. The review focused on coastal sugarcane production areas in the Wet Tropics, lower Burdekin and Mackay-Whitsunday region.

How did we go about it?

This project was essentially a literature review guided by the following three priority needs: inform policy development, identify options for on-farm mitigation, and ensure Paddock to Reef scale monitoring, modelling and reporting programs account for groundwater discharges of these contaminants. The review and report were structured around four inter-related themes:

- aquifers and groundwater processes in the study areas
- the occurrence of N, P and PSII herbicides in groundwater in these areas
- processes affecting the fate of these contaminants in subsurface environments, and the links to their on-farm management
- groundwater fluxes of N, P and PSII herbicides to the reef.

> Evidence suggests that nitrogen, phosphorus and PSII herbicides may be discharged through groundwater into the reef lagoon, with significant impact on environmentally sensitive and highly diverse ecosystems.

What was the outcome?

The study collated the datasets and identified that there are many gaps in quantitative data across the study area that could be used to shape modelling parameters and management responses.

Indications suggest that, in most cases, groundwater fluxes of contaminants to reef waters may be relatively small compared with those discharged by rivers. However, they could have a disproportionate impact on environmentally sensitive and highly diverse ecosystems in receiving environments along the coastal margins and in riverine environments.

It is not yet possible to assess with confidence the importance of groundwater flows of nitrogen, phosphorus and PSII herbicides to the reef lagoon relative to surface water flows, but the evidence suggests that significant groundwater fluxes of these contaminants may occur.

Critically, the study identified the need for better understanding and improved communication of groundwater pathways. Therefore, with the assistance of experts, improved communication tools and diagrams were created. For instance, the conceptual diagram on the right (Figure 1) shows the many subsurface pathways and processes affecting the fate of nitrogen, phosphorus and PSII herbicides from paddock to reef. Fourteen conceptual diagrams were produced as an outcome of this project. These diagrams are available as extension resources.

"This study was the first to synthesise current knowledge of the groundwater transport of nitrogen, phosphorus and PSII herbicides from the farm paddock to the reef. A highlight was the set of fourteen conceptual diagrams developed to encapsulate in pictures the key subsurface pathways and processes involved. These have been very successful in communicating the study findings to stakeholders."

Heather Hunter, Project Leader

Note: This graphic is a sample of the outcomes from this project. The project resulted in a number of conceptual diagrams as indicated in the graphics below. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

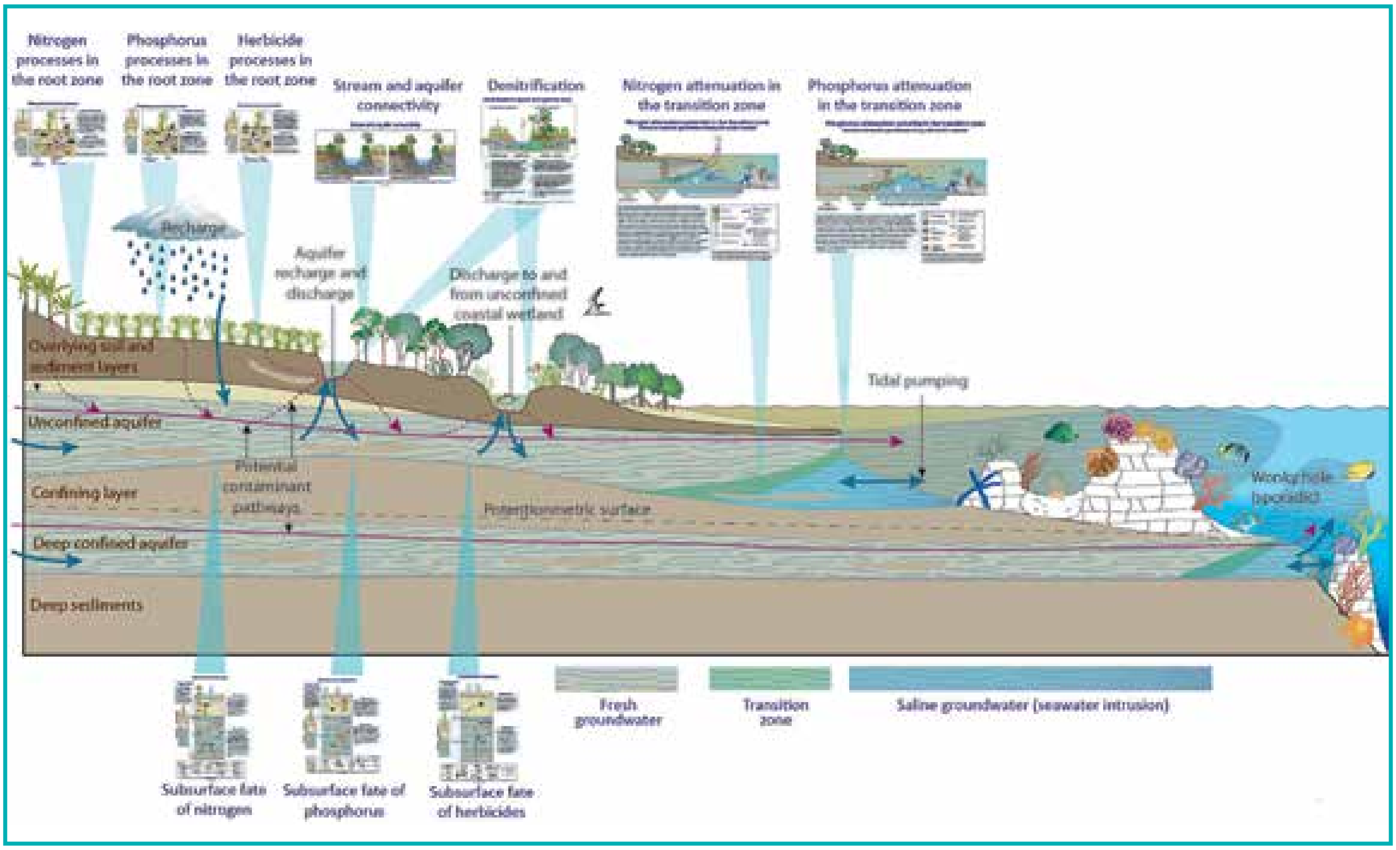


Figure sourced from Hunter, H.M. (2012). Nutrients and herbicides in groundwater flows to the Great Barrier Reef lagoon: Processes, fluxes and links to on-farm management, September 2012, pages 29, 33, 34 and 43.

GROUNDWATER POLLUTANT PREVALENCE AND TRANSPORT *(RP53C)*

Project partner: DSITI

Increasing our understanding of the groundwater transport of pollutants off-farm through on-ground monitoring can help identify a better management response.

What issue was this project trying to resolve?

The project looked at the role of groundwater in transporting PSII pesticides and dissolved nutrients to rivers from cane cropping in the lower Burdekin, particularly focusing on Barratta Creek.

How did we go about it?

Four sites (Haughton River, Burdekin River and two in Barratta Creek) were monitored to better understand groundwater systems. Samples were collected and analysed monthly for 18 months for PSII and other pesticides, and dissolved nutrients. Where possible, data was gathered during spraying times, as this can strongly influence the risk of loss to groundwater.

Samples were collected using methods outlined in Australian Standard AS/NZS 5667.11:1998, and are consistent with methods used in the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP). Data was interpreted based on the outcomes of the review of groundwater in the Burdekin (RWQ Project RP51C) and based on the detected patterns of prevalence.

What was the outcome?

Concentrations of nitrate and phosphorus decreased through the riparian zone at Barratta Creek at Northcote and the Burdekin River at Clare. It is not fully understood why there was no observed change at the Haughton River at Powerline, however, hydraulic connectivity with the Haughton River in this area was not apparent. The concentration of ammonium did increase towards the river, particularly at Barratta Creek at Northcote, and is possibly due to the decomposition of organic material within the riparian zone.

> In the lower Burdekin sites, groundwater flow has relatively low importance for directly transporting pollutants to the reef compared with surface water. However, this did not appear to be the case for ammonia and some pesticides in Barratta Creek.

Concentrations of pesticides were present, but were generally low in the groundwater at all sites, apart from the transect area of Barratta Creek at Northcote. However, there is some uncertainty over the results at this site, which indicated large variations in pesticide concentration over time, and the likelihood of lateral exchange occurring with the creek's surface water.

Findings suggest that the relative importance of groundwater flow for transporting pollutants to the reef was low compared with surface water in the three sites under study. However, this was not the case for ammonium, with estimations indicating that groundwater contributes significantly to the overall ammonium loads.

Stream and groundwater interactions were found to be complex, and more research over a longer period is suggested. This study established a monitoring method that has been used in other pesticide monitoring projects.

Overall, the contribution of groundwater to the total load of nutrients and pesticides in monitored waterways in the Lower Burdekin was low compared to that of surface water, apart for ammonia. In Barratta Creek only, groundwater contributed significantly to loads of some pesticides. It is most likely that these atypical pesticide results are due to the uncertainty in estimates of groundwater flow, combined with the uncertainty in measuring low pesticide concentrations. Further research is needed to confirm this – such as monitoring over a longer period of time.

Suzanne Vardy, Project Leader, DSITI

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

Mean concentrations of ammonium-N, nitrate-N and phosphate-P measure in bores found during the monitoring period

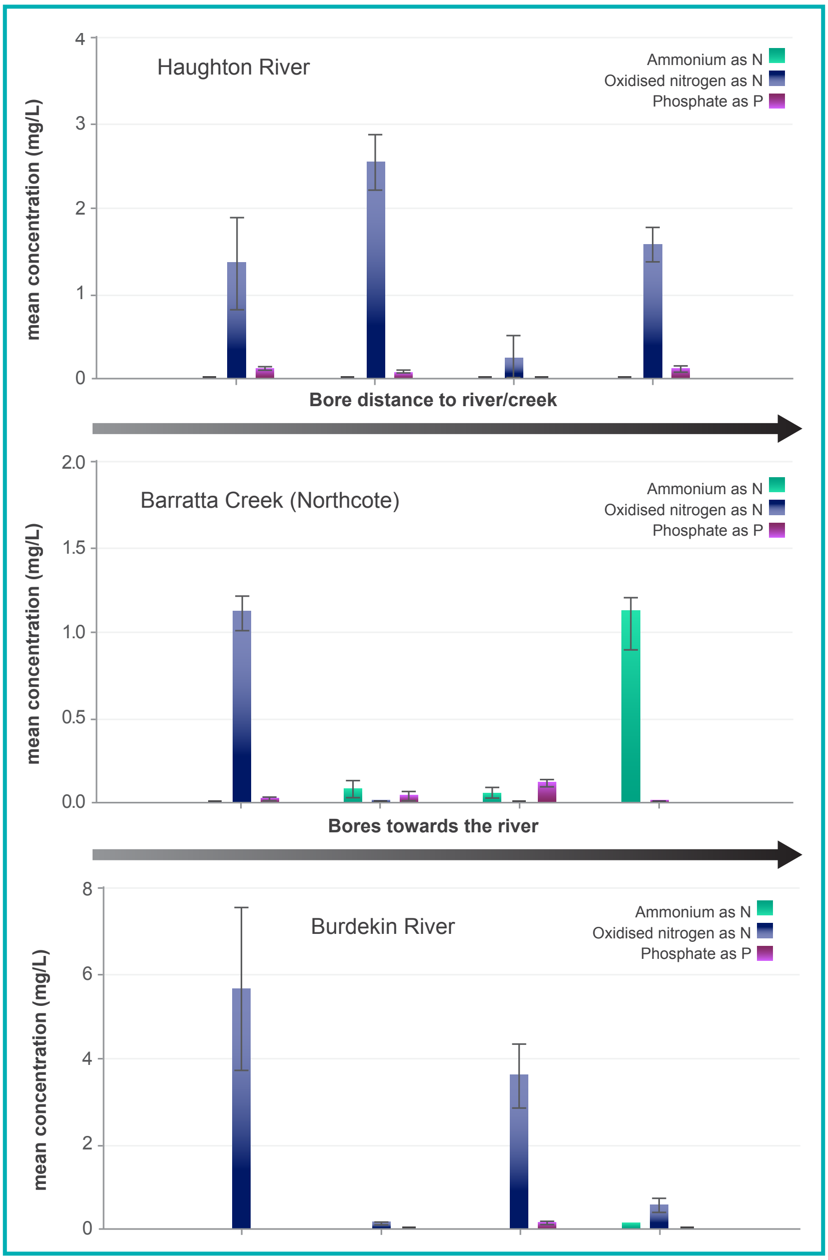


Figure adapted from Vardy, S., Turner, R.D.R., Lindemann, S., Orr, D., Smith, R.A., Huggins, R., Gardiner, R., and Warne, M.St.J., (2015). Pesticides and nutrients in groundwater, and their transport to rivers from sugarcane cropping in the Lower Burdekin. Department of Science, Information Technology, Innovation and the Arts, Brisbane, page 35.

BASELINE GROUNDWATER PESTICIDE DATA (RP54C)

Project partners: DNRM

Image provided by James Cook University

Whilst there has been considerable effort invested in understanding surface (stream and overland) transport of pesticides to the reef, much less is known about the transport of pesticides through the groundwater system.

What issue was this project trying to resolve?

The relative contributions of surface run-off and groundwater loads, and consideration of the role of groundwater-transported contaminants from paddock to coastal waters were priority knowledge gaps affecting the ability to manage reef pollution. There is limited quantitative data with respect to pesticides. This project aimed to increase understanding of pesticide movement across a broader area of the Burdekin and Wet Tropics.

How did we go about it?

This project utilised more monitoring points than previous projects, collecting groundwater samples from 55 bores in the Burdekin and Wet Tropics. By combining data with known rates of water movement from groundwater to streams and the ocean (such as in the Lower Burdekin), estimates were made of the possible flux of pesticide losses from cane farms compared with losses from surface flows.

> It is likely that a major loss pathway for groundwater in sugarcane is through constructed drains. This is an area that is currently poorly understood.

What was the outcome?

This project identified that it is likely that a major loss pathway for groundwater in sugarcane is through constructed drains. The pesticides which persist in the leachate may be transported into these constructed drains, which flow to waterways and eventually into the reef, or may be transported deeper into groundwater.

The project provided a strong pilot method that could be applied to determine the relative contributions of groundwater to pollutant loads delivered to the reef from major agricultural land uses. Results from this project were used in monitoring for the Paddock to Reef Program. Further work would be required to understand how land management practices could influence pollutant loads transported through groundwater.

Freshwater creek

This study was designed as a pilot to determine whether pesticides were able to be detected in groundwater in nearby Queensland agricultural areas to further understanding of the potential for transport to the reef via this pathway. The study has provided fundamental data on the presence and concentrations of pesticides in areas where limited information previously existed. The results showed that there are pesticides present in both leachate and in groundwater, although the concentrations do not exceed drinking water guidelines and rarely exceed freshwater environmental guidelines.

Mark Silburn, Project Leader, DNRM

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au

PESTICIDES IN GROUNDWATER FLOWS TO THE REEF
Over view of transport, transformation and attenuation processes

Figure amended and originally sourced from Hunter, H.M. (2012). Nutrients and herbicides in groundwater flows to the Great Barrier Reef lagoon: Processes, fluxes and links to on-farm management, September 2012.

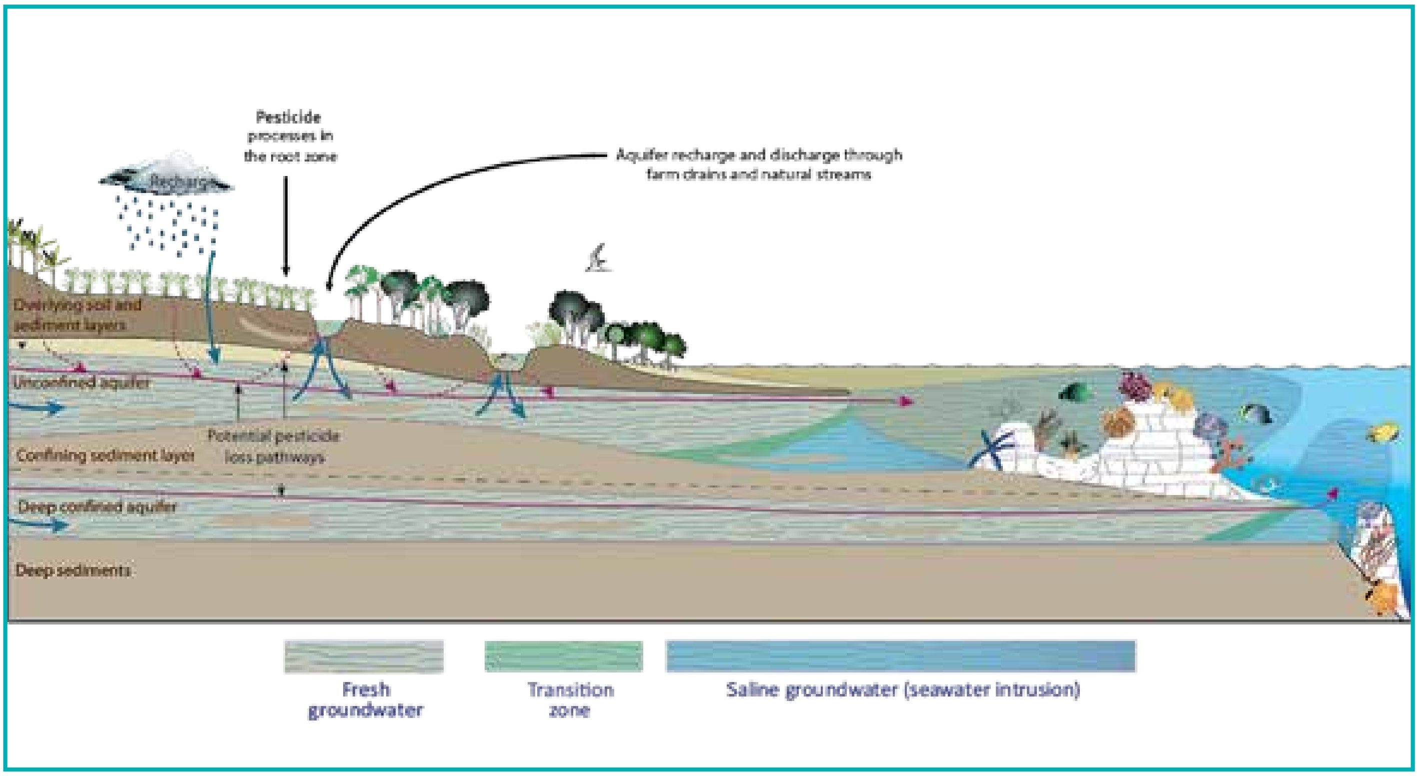


Figure 1 Pathways for transport of pesticides to the Reef lagoon through groundwater. Blue arrows show the movement of water, while red arrows show the potential pesticide loss pathways. (Figure by Lana Baskerville, apdapted from Hunter et al, 2012)

HERBERT CATCHMENT WATER QUALITY MONITORING *(RP27C)*

Image provided by Terrain NRM

Project partners: Terrain NRM, HCPSL, CANEGROWERS-HR, TropWATER, James Cook University, SRDC, DAF, Herbert River Catchment Group, Hinchinbrook Shire Council, Tablelands Regional Council and Forestry Plantations Queensland

Unlike many other coastal streams in the Wet Tropics, the Herbert River, which occupies approximately 10,000km^2, has a significant inland component dominated by areas of relatively low rainfall (<1,000mm per annum).

What issue was this project trying to resolve?

The project was initiated by stakeholders in the Herbert River Catchment who sought to fill a gap in local data available to validate the Paddock to Reef (P2R) Monitoring and Modelling Program as part of Reef Plan 2009. The studies aimed to provide scientifically robust water quality data to estimate loads and better understand the relative contributions of reef pollutants on land use, sub-catchment and paddock scales. This understanding would help extension staff and catchment managers prioritise and target sustainable land management practices to the point where the greatest gains in water quality could be achieved.

How did we go about it?

Concentrations of pollutants were measured between 2011 and 2013 by manual sampling at all sites frequently (five to 10 times) from first flush, and major rainfall events during the wet season. Ambient concentrations were also collected bi-monthly to provide measures of concentration and assess potential downstream impacts.

Water samples were collected at each site by Terrain NRM staff and landholder volunteers who had been trained in the correct handling and storage of water samples for the quantification of nutrients, sediment and pesticide concentrations.

What was the outcome?

Results demonstrate that there are clear links between how the land is used and the quality of local water within the upper and lower catchments of the Herbert River.

Dissolved nitrogen and pesticide concentrations were highest in waters draining from sugarcane sites, though the range and average concentrations measured in this study are comparable with those reported in waters sampled in other Australian sugarcane-growing regions.

> There are distinct differences in the impacts of land use on local water quality within the Herbert Catchment. Sugarcane production in the lower catchment is a major contributor to nutrient and pesticide loads, while the timing and intensity of rain is an important driver of pollutant losses on all land uses.

However, both nitrogen and pesticide losses in the Herbert are not uniform across sugarcane paddocks, and industry has used this data to tailor agronomic solutions to reduce diffuse agricultural pollution in specific high risk sub-catchments. While sugarcane land supplies the majority of dissolved nitrogen and significant chemical contributions, water quality testing from urban run-off has also shown some chemical constituents and significant phosphorus, particularly dissolved inorganic phosphorus contributions.

Overall, the upper catchment does not contribute significantly to contaminant levels in the water quality observed within the lower catchment.

Sediment concentrations were relatively low compared with those reported in neighbouring catchments (Burdekin and Tully), despite being above water quality guidelines for lowland freshwater river systems at times. Pre-wet season rainfall and subsequent groundcover in the upper catchment plays an important role in erosion processes in the catchment.

Continuing until 2016, monitoring of water quality is supported by engagement with local communities to support improved practice adoption and response.

This project has provided participating industries with independent, scientifically robust data at a scale appropriate to land managers. It provided the opportunity for industry leaders and producers to identify specific issues, and take a proactive approach to reducing the impacts of diffuse agricultural pollutants to the Great Barrier Reef. This project has been the catalyst for significant ongoing extension and engagement activities in the Herbert, and is now being replicated in other regions to engage land managers in other priority water quality hotspots.

Michael Nash, Project Leader, Terrain NRM

Terrain Project Leader demonstrates WQ sampling processes to nearby farmer interested in the results

Research area: Sugarcane management systems—weeds and pesticides

For long-term control of weeds, a property needs an effective management system to monitor, identify and respond to the influx of weeds, and then appropriately apply pesticides. To be most effective, the overall management strategy needs to take account of the type of pesticide, the optimal amount and the timing and placement.

Growers will not readily adopt alternative or new practices that they consider will pose a risk to profit. Managing for improved water quality is more likely to be adopted if it also improves enterprise profitability.

The Scientific Consensus Statement 2013 recognises that sugarcane-growing areas contribute 94% of the pesticide load to the reef, particularly from the Wet Tropics, Burdekin and Mackay-Whitsunday regions.

Under the Reef Plan, reef regulations and other investments focused on the use of five regulated pesticides which specifically act by impairing photosynthesis, the ‘PSII herbicides’. With new agricultural chemical products coming on to the market, clarity was also needed on the effects of these as replacements to existing chemicals. Five projects were undertaken to fill these gaps.

Sugarcane management systems—weeds and pesticides projects:

- **Trends in pesticide use by cane farmers (RP56C)**
- **Monitoring alternative pesticide use (RP57C)**
- **Monitoring the use of non-regulated pesticides (RP86C)**
- **Economics of pesticide management on cane farms (RP62C)**
- **SafeGauge for Pesticides 2.0 (RP09C)**

Research area: Sugarcane management systems—weeds and pesticides

TRENDS IN PESTICIDE USE BY CANE FARMERS *(RP56C)*

Project partners: James Cook University and DNRM

Images provided by James Cook University

In order to fully comprehend their potential impacts on the reef, it is important to understand the shifting trends in the use of regulated and non-regulated PSII chemicals, as well the comparative environmental and physio-chemical characteristics of all relevant pesticides.

What issue was this project trying to resolve?

This project aimed to increase understanding of the potential impacts of alternative chemicals and whether there were any broadscale shifts in pesticide usage. Better understanding was needed to improve extension and boost grower knowledge of PSII chemical use.

How did we go about it?

The project reviewed existing literature and data, and used cane industry expertise to initially collate information on the use of regulated and non-regulated PSII chemicals. It then identified available information about environmentally relevant characteristics of non-regulated, of-concern pesticides (i.e. alternative pesticides), and when, where and why these pesticides are being used.

It also considered the constraints and opportunities for using alternative, non-PSII pesticides in the cane industry. Interactions between non-PSII pesticides and key on-farm management practices were investigated to obtain critical knowledge about how pesticide use is changing.

> More research is required on the long-term effects of alternative chemicals on the environment, enterprise productivity and profitability.

What was the outcome?

The results show a shift in use from the commonly used priority regulated pesticides towards the suite of alternative pesticides (also described in project RP57C). It also identified the comparative environmental and physio-chemical characteristics of all relevant pesticides, recognising that some of the alternative pesticides potentially pose a similar or worse risk to reef health. Further research is required into understanding long-term effects of alternative chemicals on our environment.

In addition, further guidance is required for growers on the potential impacts, enterprise productivity and profitability of alternative pesticide use.

The results of this study informed the Scientific Consensus Statement 2013, and put greater emphasis on preparing guidelines on the associated eco-toxicological effects. The results have also been utilised through extension work.

“Project results have greatly informed our understanding of the pros and cons of alternative herbicides, and were used in projects like the Herbert River Project, where growers and Productivity Services discussed the use of alternatives.”

Aaron Davis, Project Leader, James Cook University

Close up of sprayer

Shielded sprayer used to apply the herbicides in the banded treatment

MONITORING ALTERNATIVE PESTICIDES IN WATERWAYS *(RP57C)*

Project partner: DSITI

A move away from PSII pesticides to reduce adverse ecological effects is a desirable long-term goal, but only if the pesticides used in their place have a lesser environmental impact, and do not lead to an unwarranted loss of productive capacity.

What issue was this project trying to resolve?

As a companion project to RP56C, this project set out to understand what pesticides are turning up in waterways in damaging concentrations.

How did we go about it?

Six sites that are part of the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP) were sampled in the wet and dry seasons over 2012-13 to determine if PSII type pesticides are reaching the end of catchment, and what amounts are being discharged to the reef. Sites included the Wet Tropics (Herbert, North Johnstone and Tully Rivers), Burdekin (Barratta Creek) and Mackay-Whitsunday (Sandy Creek and Pioneer River) regions.

Data analysis was performed to provide trends in the presence of the non-regulated pesticides compared with regulated pesticides on a spatial scale. For a limited number of non-regulated pesticides, i.e. those in which analytical methods are currently available (metolachlor, metribuzin, trifluralin and pendimethalin), temporal trends were compared and analysed against regulated pesticides.

> Research verified some expectations, including that alternate pesticides are being used, and that these compounds are being transported to waterways.

What was the outcome?

The project delivered a report on the concentrations and loads of acifluorfen, imazapic, imazethapyr, isoxaflutole, metribuzin and trifloxysulfuron-Na, metolachlor, trifluralin and pendimethalin at six end-of-catchment locations, and analyses of policy implications. It provided the first evidence for evaluating trends in pesticide usage as farmers switch from the traditional PSII to alternative pesticides.

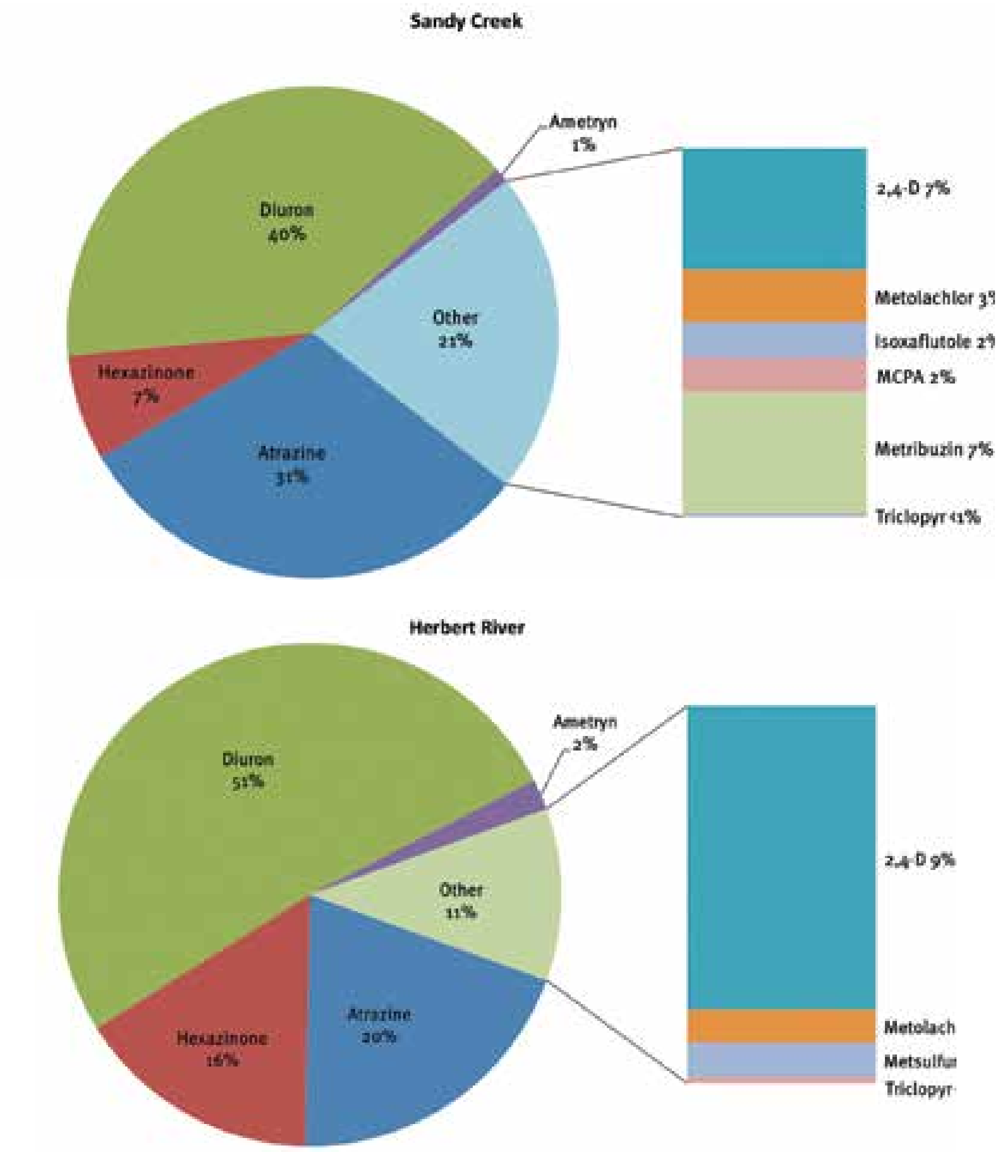
The results from this project also verified that alternate pesticides are being used, and that these compounds are being transported to waterways. However, further research would be needed to examine these trends fully, taking into account the temporal changes in usage over the whole catchment, as well as climatic variability over multiple years.

Anecdotal information from farmers and extension officers also indicates that there has been a dramatic increase in amounts of knockdown herbicides. This project has been extended to include an additional year of data, as well as sampling and analysis for glyphosate, one of the most widely used pesticides in Great Barrier Reef catchments, which has not previously been monitored or shown to pose an acceptable risk. Findings have also fed into Paddock to Reef Program monitoring.

This project has demonstrated that a number of pesticides apart from the routinely monitored PSII herbicides are present in catchments that should be accounted for when calculating the pesticide load transported to the Great Barrier Reef. This information has been presented to the Reef Plan Independent Science Panel and has been noted in the P2R redesign. By including alternative pesticides in the loads calculation, we will have a more representative measure of the total pesticide loads and therefore, a more realistic indication of potential pesticide impacts on the reef.

Dr Rachael Smith, Project leader, DSITI

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.



The contribution of priority photosystem II inhibiting herbicides (Diuron, Hexazinone, Atrazine, Ametryn segments) and the alternate pesticides (other pie segments) to the total pesticide load in the various catchments. Figure amended from *An evaluation of the prevalence of alternate pesticides of environmental concern in Great Barrier Reef catchments (RP57C).*

TRIALLING THE USE OF NON-REGULATED PESTICIDES *(RP86C)*

Project partner: Tully Productivity Services Limited

Images provided by SRA

Anecdotal information and monitoring results from RP57 suggest that farmers have begun replacing the regulated PSII herbicides with non-regulated herbicides, the impacts of which are uncertain.

Changes to pesticide use may be accelerated by increased restrictions on the use of diuron by the Australian Pesticides and Veterinary Medicines Authority (APVMA).

What issue was this project trying to resolve?

Located in the Wet Tropics, this project set to identify and trial alternative (non-regulated) chemical options, with the aim of reducing the use of high priority (regulated) PSII chemicals.

How did we go about it?

The trials, conducted in the Tully district, incorporated a range of a soil types, and climate and management regimes. All the trials followed a similar procedure, and information on rates and chemical usage were presented, along with productivity and expenses to determine the economic value.

> The timing of pesticide application drives the best results and improved water quality outcomes.

What was the outcome?

The project concluded that to be effective, pesticides must be applied as part of a holistic weed management strategy. It also identified alternative chemicals can have the same weed control outcome, and developed a new approach to application timing, rates and chemicals used. The timing of the application drives the best results, leading to improved water quality outcomes.

The study also noted that the alternative chemicals are currently expensive, and their use over a large area would increase costs significantly.

Pre-emergence application - by using residual chemicals early, growers can gain more advantage to control their weed problem

Environmental conditions, where to apply, and what types of weeds you need to control are vital considerations in weed management. By using residual chemicals early, growers can gain more advantage in controlling weeds. By the time the wet season starts, they can then apply a low rate of residual chemical or just a knockdown chemical.

Jordan Villarus, Project Leader, Tully Cane Productivity Services Limited

Spray boom calibration is essential as part of pesticide best management practices

ECONOMICS OF PESTICIDE MANAGEMENT ON CANE FARMS *(RP62C)*

Project partner: DAF

Adopting progressive pesticide management practices as part of an integrated weed management program is an important step towards improving cane farm profitability and water quality. While considerable literature exists about practice changes to minimise pesticide loss from farms, the advice can be conflicting and lack economic assessment.

What issue was this project trying to resolve?

The project set out to give cane producers greater confidence about the likely water quality and profitability benefits, and risks of various management options. Better understanding was required about paddock-scale economic implications of altering cane production systems for enhanced reef water quality outcomes.

How did we go about it?

The project analysed available information about the economics of management practice improvement, and extended knowledge about improved pesticide management through targeted research.

The project also included a survey of more than 60 North Queensland cane farmers from Ayr, Ingham and Tully. The aim of the survey was to develop a profile of grower perceptions towards the characteristics and economic impacts of various management practices.

What was the outcome?

The project identified key sugarcane management practice options that have the potential to improve water quality (or facilitate improvement) and grower profitability. Economic and water quality results were found to be critically dependent upon regionally specific variables, including biophysical characteristics and enterprise structure, such as farm size and location. For example, analysis showed that progressing from conventional to best herbicide management practices is generally profitable, and the magnitude of the return on investment rises with increasing farm size.

> Analysis showed that progressing from conventional to best herbicide management practices is generally expected to be profitable and provides the highest return on investment across the farm sizes and cane districts evaluated.

The results of the study have fed into Action 4 of Reef Plan – which aims to improve the understanding of cost-effectiveness of management practices that are adopted on farms.

Connected to this, complementary research through the Reef Rescue Research and the Paddock to Reef Monitoring and Modelling Programs has analysed the economics associated with managing nutrients, and assessed the water quality benefits of preferred management practices (Van Grieken et al., 2014).

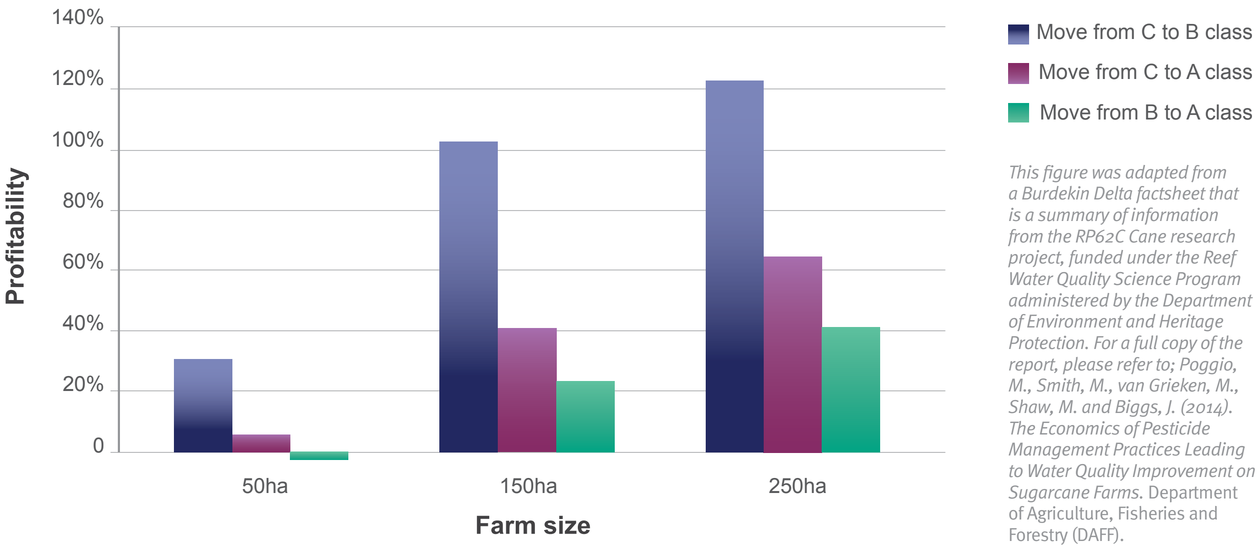
This economic analysis showed that there are expected benefits to growers through transitioning to improved cane management.

(Van Grieken, M., Poggio, M., Smith, M., Taylor, B., Thorburn, P., Biggs, J., Whitten, S., Faure, C., and Boullier, A. (2014). Cost-effectiveness of management activities for water quality improvement in sugarcane farming. Report to the Reef Rescue Water Quality Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (85pp.).

> *The project has identified profitable management and priority areas for the reduction of PSII herbicides within a specific set of systems and practices. For example, improved herbicide management (rate, application method and strategy) was identified as having a greater impact on PSII losses compared to tillage and fallow management. The adoption of best herbicide management practices can lead to a reduction of PSII Herbicide Equivalent (PSII-Heq) levels of between 32% and 59% compared to conventional practices. The adoption of banded spraying e.g. shields as part of the improved herbicide management practices can reduce PSII-Heq levels by at least 69%.*
>
> *Mark Poggio, Project Leader, DAF*

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au

Return on investment with practice improvement - Burdekin Delta



This figure was adapted from a Burdekin Delta factsheet that is a summary of information from the RP62C Cane research project, funded under the Reef Water Quality Science Program administered by the Department of Environment and Heritage Protection. For a full copy of the report, please refer to; Poggio, M., Smith, M., van Grieken, M., Shaw, M. and Biggs, J. (2014). The Economics of Pesticide Management Practices Leading to Water Quality Improvement on Sugarcane Farms. Department of Agriculture, Fisheries and Forestry (DAFF).

What is the rate of return on the investment?

The rate of return on the investment represents the amount of money returned to the grower each year as a percentage of the initial money invested (i.e. cost of equipment). Individuals will require different rates of return depending on their perceptions about the risk of adopting each practice, and how it will likely affect their farming business. The results presented in Table 6 show that moving from C to B Class has the highest annual rate of return, whilst moving from C to A Class and B to A Class also had a positive return for 150ha to 250ha growers. A 50ha grower moving from B to A Class will lose 3% of the initial investment per year. Risk analysis illustrated the importance of ensuring production is maintained when progressing to A Class herbicide management, which is based on practices under research and not thoroughly tested on a commercial scale.

SAFEGAUGE FOR PESTICIDES 2.0 *(RP09C)*

Project partners: DSITI, DAF and Bruce Simpson - consultant

A method to assess the risk of pesticides moving off a property, either as run-off or drainage and the potential risk to surface and groundwater, will aid better management decisions.

What issue was this project trying to resolve?

This project set out to provide easy to understand and traceable information for cane farmers and their advisors to analyse the effects of changing their farm management practices, especially the timing of pesticide applications, on the potential risk of off-site pesticide movement.

How did we go about it?

In order to produce an updated CD version of SafeGauge for Pesticides, a database was created of all pesticides currently registered for use on sugarcane in Queensland, including the herbicides of interest: atrazine, ametryn, diuron and hexaninone.

The project also produced a user manual and system documentation to support the product and undertook literature research to collate the ecologically relevant properties of these pesticides.

User testing took place during workshops with the then BSES Limited (now SRA), CANEGROWERS, Department of Natural Resources and Mines, the then Department of Employment, Economic Development and Innovation (DEEDI) and Department of Environment and Heritage Protection to ensure the end product met user requirements. Final enhancements were then made including the coding for input of new pesticides and deletion of obsolete pesticides from the SafeGauge for Pesticides database.

> SafeGauge is an easy to understand process that enables the user to see the effects of changing farm management practices at the farm block level, especially the timing of pesticide applications, and the potential risk of off-site pesticide movement.

What was the outcome?

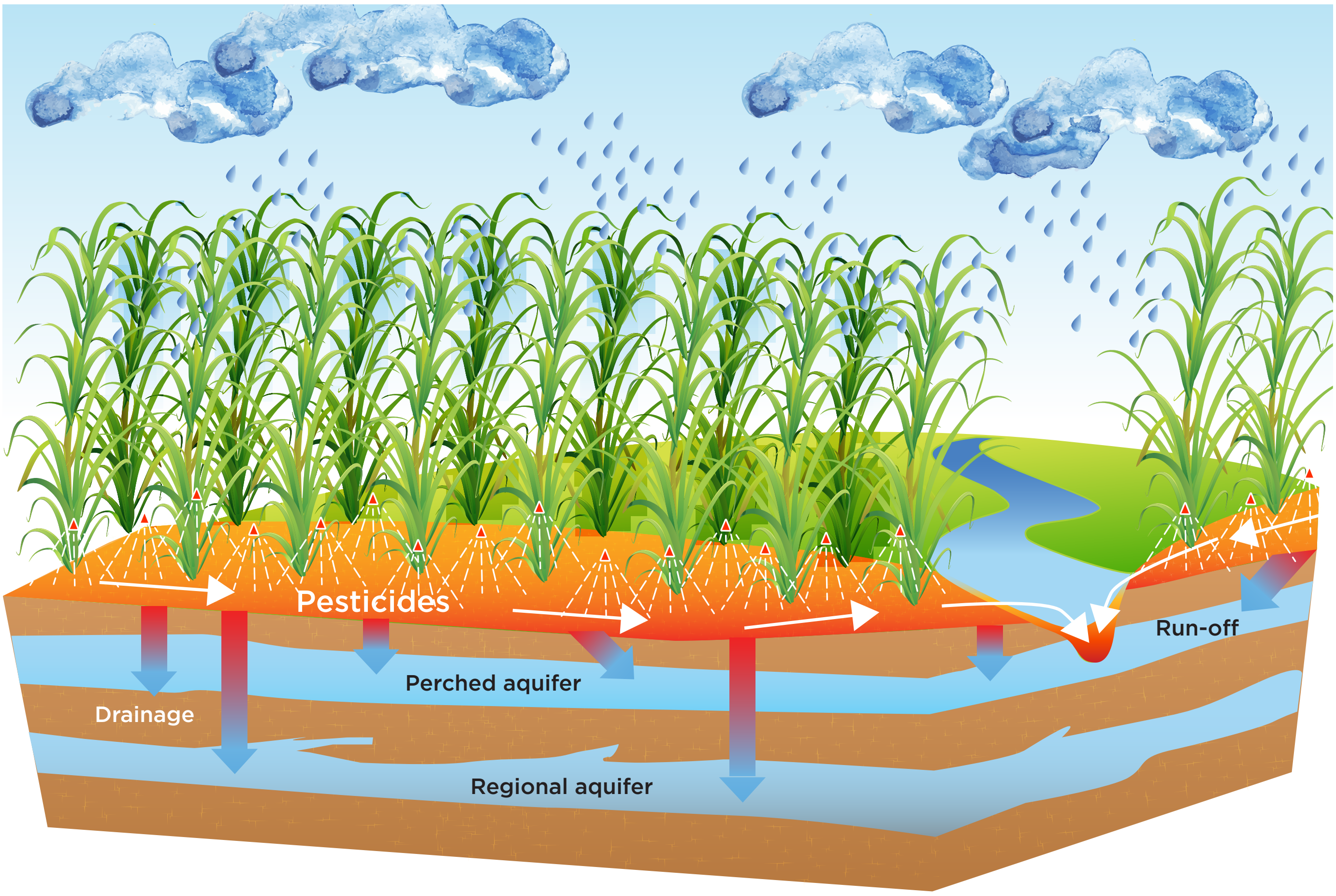
SafeGauge enables growers to develop pesticide management strategies that meet crop requirements and consider the risk of off-site pesticide movement. Allowing each of the major factors that affect environmental risk to be examined singularly, or considered in its interaction with other changeable factors, it incorporates site-specific, long-term rainfall data and soil data with time of application and pesticide degradation rates. As a result, it produces integrated potential risk ratings to both surface and groundwater resulting from pesticide application.

Growers can check the soil hydrology, site characteristics and historical climate records for a particular block or area, and nominate different scenarios of their farm management practices. They can then assess the potential risk of pesticide contamination of surface and subsurface water resulting from pesticide use and farm management practices.

This tool has been distributed to extension and regional government employees.

The work on SafeGauge for Pesticides and the learnings from this project were essential in building the next generation SafeGauge product for nutrients.

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au



Research area: Grazing management and advice systems

Profitably managing grazing lands remains a complex task affected by many external factors, including the weather, economics and soil erosion. Projects were devised to enhance knowledge in several key areas of grazing land management, focusing on the Burdekin Dry Tropics. Where possible, products such as FORAGE were developed and piloted in the Burdekin, and then made available across Queensland. Three projects were undertaken to fill these gaps.

Grazing management and advice projects:

- **Sustainable management systems of the Burdekin grazing lands (RP69G)**
- **Enhancing FORAGE for the Burdekin (RP68G)**
- **Grazing economics for the Burdekin Dry Tropics (RP70G)**

Research area: Grazing management and advice systems

SUSTAINABLE MANAGEMENT SYSTEMS OF THE BURDEKIN GRAZING LANDS *(RP69G)*

Project partner: Dr John McIvor

Reliable sustainable grazing information and materials assist growers to boost enterprise productivity, and protect water quality in the rangelands of the Burdekin Dry Tropics.

What issue was this project trying to resolve?

In 2011, the Reef Water Quality (RWQ) Science Program identified that while there were a range of grazing management publications, there was a need for an authoritative, up-to-date synthesis of information for advisors and graziers that also incorporated the implications of management practices on water quality for the Burdekin reef catchment.

How did we go about it?

Dr John McIvor, a widely respected grazing research scientist built on and updated an earlier unpublished set of principles and guidelines for management produced by the Northern Grazing Systems* (NGS) program that optimised animal production, profitability, land condition and water quality outcomes.

Information was sourced from a variety of reports from research in Northern Australia, outputs from computer models testing different management options, the combined knowledge and experience of beef producers and technical specialists and other information regarding impacts to grazing properties. The Department of Environment and Heritage Protection ensured the guide was extensively reviewed during development by a working group consisting of representatives from state government, NQ Dry Tropics NRM group and the grazing industry.

> This report has been used in the development and implementation of Grazing BMP programs, the grazing management practice risk framework underpinning the Reef Plan, and is an ongoing guide and induction document for extension staff and policy officers working with graziers.

What was the outcome?

This guide provides the evidence base and advice to help producers make grazing land management decisions, and was published on the FutureBeef website. The guide identifies reliable options for managing stocking rate, pasture spelling, developing infrastructure and prescribed burning to optimise animal production, profitability and land condition, and the minimising of soil loss and run-off.

The draft Burdekin Water Quality Improvement Plan (WQIP) 2016, cites this report's land management principles and guidelines as a pathway for improving water quality outcomes.

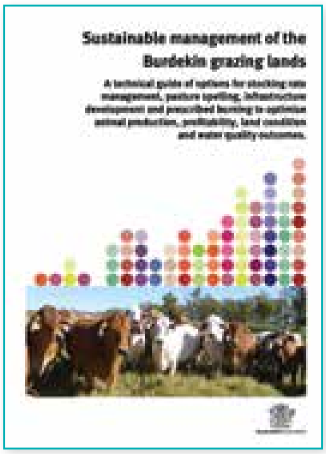
**The NGS program is run through a partnership with Meat and Livestock Australia (MLA), CSIRO, AgriScience Queensland, the former Department of Employment, Economic Development and Industry (DEEDI), the Northern Territory (NT) Department of Resources, and the Western Australian (WA) Department of Agriculture and Food, and is funded by MLA and the Australian Government's Caring for our Country Program. NGS underpins grazing extension across northern Australia, and is fully endorsed by the grazing extension providers for Reef Plan.*

This guide looks at various situations on a property, identifies the factors to consider and provides suitable management practice responses and options. It shows how good grazing practices also protect water quality and reduce the risk of soil loss to the Great Barrier Reef. Over time, this guide can be updated through advances in knowledge and as information and experiences are shared by producers, their advisors and researchers.

Information adapted from the guide to provide a brief overview.

Sustainable management of Burdekin lands guide was the outcome of this project

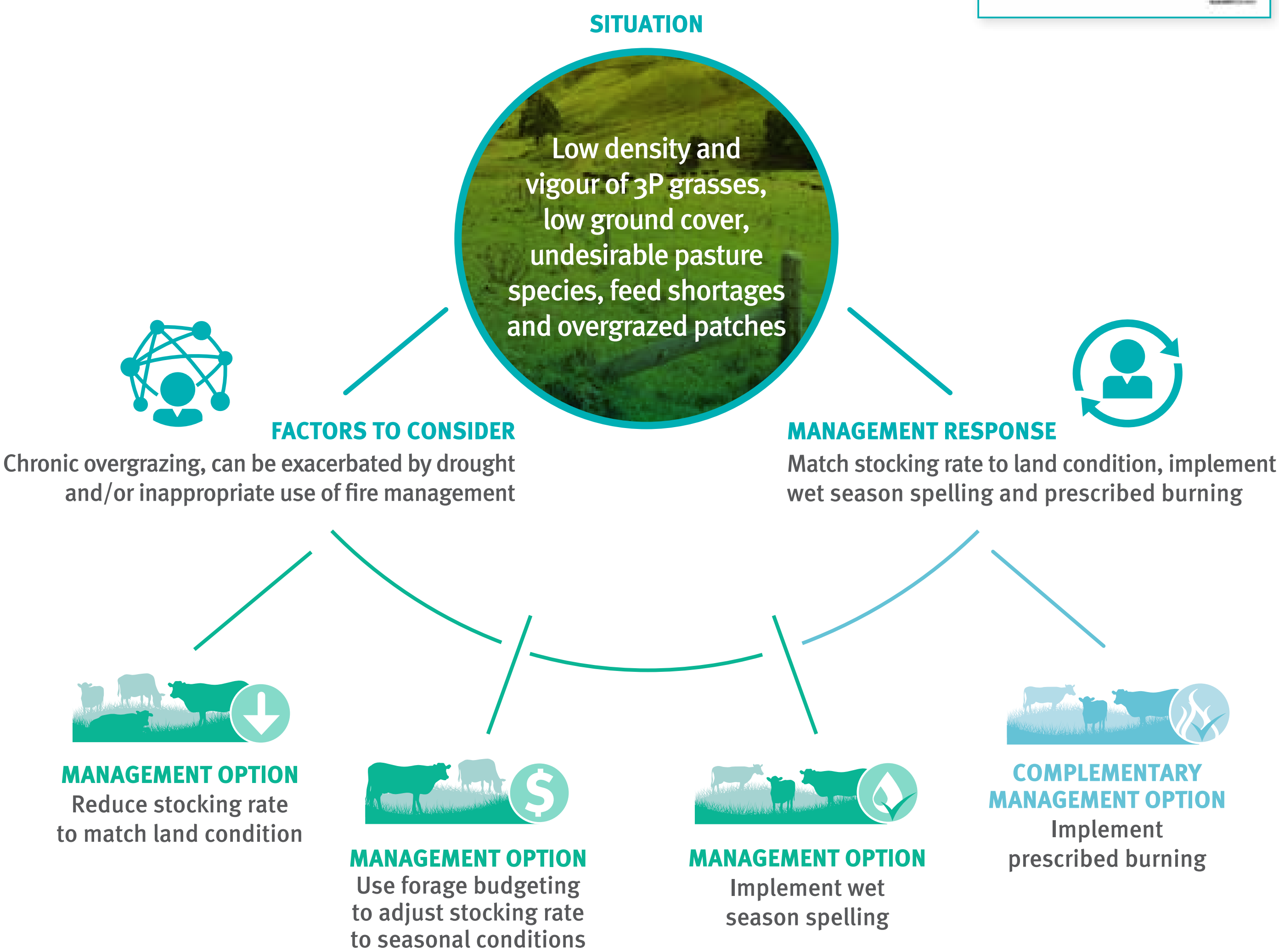
Throughout the *Sustainable management of the Burdekin grazing lands* guide, there are recommendations and various diagrams to guide land managers and extension officers to help manage the land more effectively.



McIvor, J., (2012). Sustainable management of the Burdekin grazing lands – A technical guide of options for stocking rate management, pasture spelling, infrastructure development and prescribed burning to optimise animal production, profitability, land condition and water quality outcomes. State of Queensland.

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

Example:
Improving land in poor (C) land condition situation



ENHANCING FORAGE *(RP68G)*

Project partner: DSITI

Providing online property-based information can help land managers in the catchments to better assess grazing land, and manage changes in groundcover and pasture growth.

What issue was this project trying to resolve?

The project set out to enhance the Department of Science, Information Technology and Innovation's existing user restricted FORAGE information system to produce easy-to-access property-based reports that graziers can either generate themselves or be used as part of grazing extension programs to improve management of grazing lands.

How did we go about it?

Synthesised data from a range of sources, including satellite imagery, modelled pasture growth and historical climate information were used to develop property-based reports. The project team ensured that FORAGE products were developed collaboratively with stakeholders, including the Department of Agriculture and Fisheries, industry groups and extension providers. Stakeholders were engaged to guide the design and development of reports to match industry needs.

What was the outcome?

Users have greater access to up-to-date information for their properties. Historical data in FORAGE reports allow users to track groundcover, pasture growth and climate for their property over time. For example, graziers can now access groundcover reports that compare groundcover for their dominant land types on their property with the same land types within a 50km radius of their property.

> FORAGE is an easy-to-use tool helping graziers to refine management of grazing lands and pastures.

This information can help identify and monitor impacts of management practices, such as the impact of stocking rates and events such as fire on groundcover and pastures for different land types. This tool provides a valuable resource for the grazing Best Management Practice Program and monitoring field trials. The suite of new and enhanced reports supported by the best available science includes:

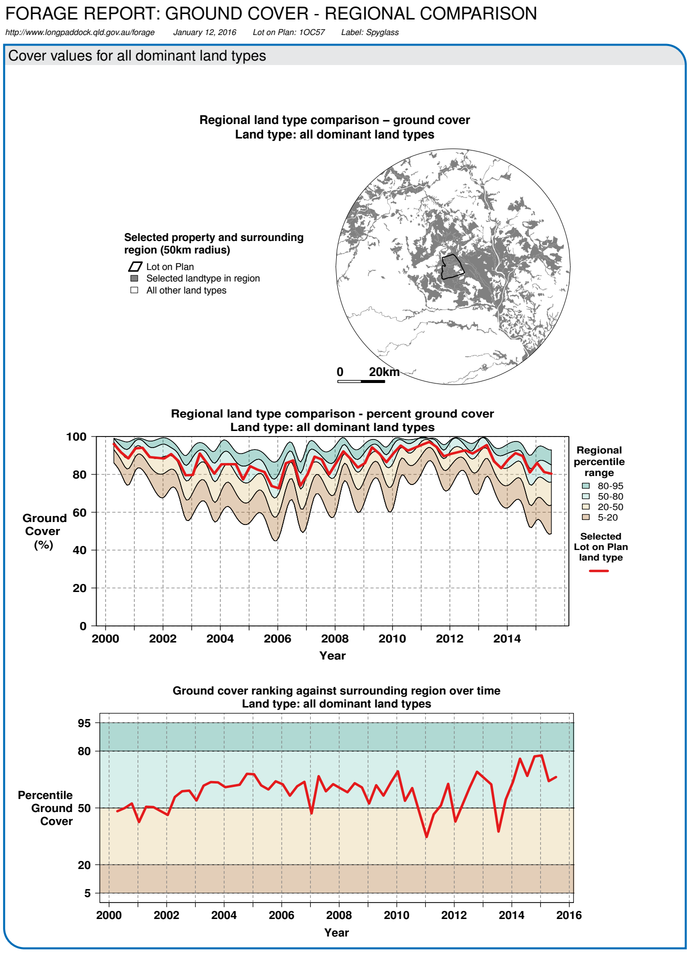
- Land type mapping
- Groundcover – compared with surrounding region
- Rainfall and pasture by land type
- Regional climate projections
- Foliage projective cover mapping
- Erodible soils mapping – Burdekin Dry Tropics
- Rainfall and pasture growth outlook.

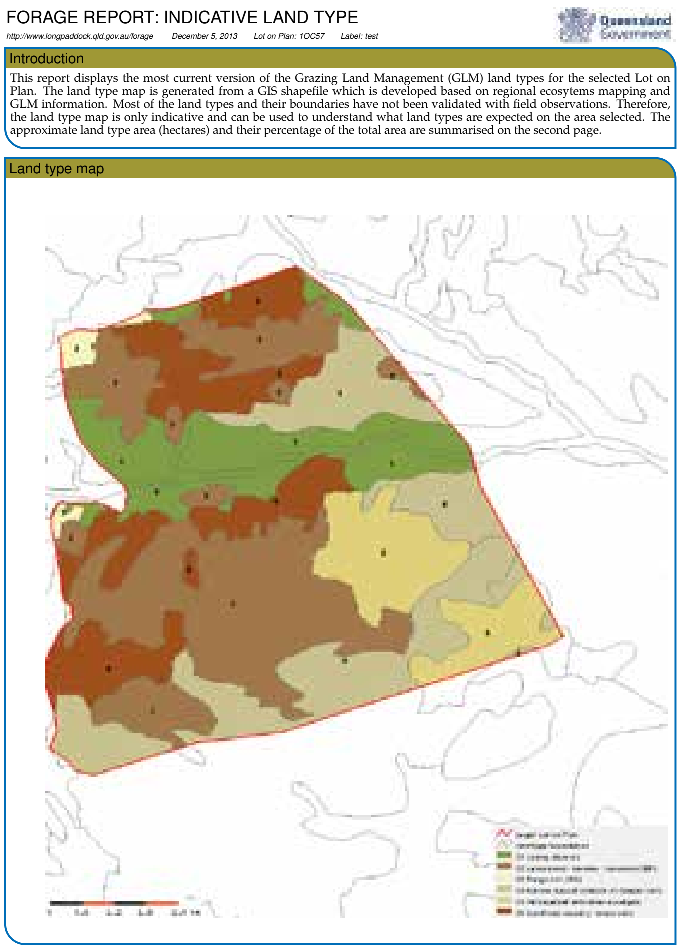
All reports except for the erodible soils report are now available for the whole of Queensland.

The Wambiana Field Day in August 2015 was one of the forums where FORAGE was presented to graziers. There was high grazier interest in the product, with over 100 graziers from more than 60 properties covering 1.4 million hectares attending the day. Over 50% of workshop participants evaluated FORAGE and rated it as useful for managing grazing. In the month following this field day, the website visits measuring FORAGE usage more than doubled, with almost 400 requests in September for the tool.

Information provided by DAF and DSITI following the Wambiana Field Day.

Note: These graphics are examples of reports a landholder is able to download from FORAGE online at www.longpaddock.qld.gov.au/FORAGE. For more information please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.





GRAZING ECONOMICS FOR THE BURDEKIN DRY TROPICS (RP70G)

Project partner: DAF

The significant decline in the health of the Great Barrier Reef due to increased pressures from poor water quality and climate change has prompted government programs and policies to halt in an attempt to reverse the decline.

Understanding the economic impact of mitigation and rehabilitation strategies is crucial to designing and assessing reef protection programs and policies.

What issue was this project trying to resolve?

This project set out to understand the private trade-offs of grazing pressure and wet season spelling for different levels of land condition. Although the benefits of increased groundcover are understood, knowing the economic implications of wet season spelling and improved land condition is essential to extension strategies, and to increasing acceptance and adoption of improved grazing management strategies.

How did we go about it?

The project explored three land types in the Burdekin region, using modelling to understand in more detail the economic implications of alternative methods of wet season spelling, stocking rates and improved land condition. After firstly reviewing the relevant literature to provide assumptions and underlying principles used in the analysis, an outline of the case studies and land types was detailed, followed by the parameters used in each case study comparing properties with high pasture cover to those that have gone through various extension programs, such as CQ BEEF.

> The project report offers insights into the trade-offs for stocking rate and wet season spelling, and the subsequent sediment reductions in the Burdekin region.

What was the outcome?

The project provides insight as to how best to focus policy and programs to encourage adoption of grazing management strategies that improve reef health, for example, improving land condition from C to B.

Results from this project provide information in a form that extension officers can use with graziers in the Burdekin to become aware of the management changes they need to make, including their likely costs and benefits in order to improve the quality of run-off from their properties.

Research from this project has highlighted that low capital cost management practices are more likely to be adopted due to the variability in grazing systems and low profit margins. Although there was not a significant amount of increased profits derived from wet season spelling, it did allow for further risk management in drier years. The results also highlighted the complexity of grazing systems and that further work needs to be completed to understand the links between cover, management practices and economic viability. The ability to make timely decisions was a key variable to achieving sustainable (economic and environment) outcomes.

Megan Star, Project Leader, DAF

Note: This graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

This figure highlights that at lower pasture utilisation rates, the risk of large profit losses is reduced. The pasture utilisation rate refers to the amount of biomass available as feed. If graziers utilise only up to 20% of that pasture length and move the cattle on when they reach that level, they can expect greater profitability gains, particularly if their land is already in A or B condition. For C condition land, the percentage didn't prove to be as remarkable, however, if pasture was utilised beyond 25%, graziers could expect to be losing money quicker.

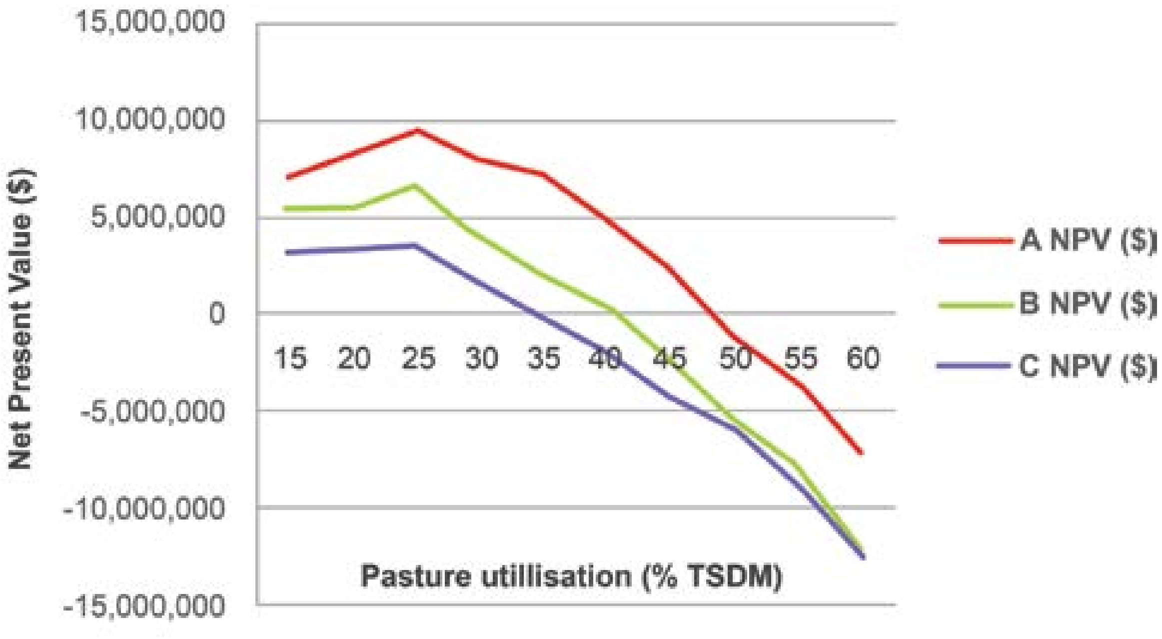


Figure sourced from Megan Star, John Rolfe, Giselle Whish, Understanding the trade-offs of grazing management practices, Department of Agriculture, Fisheries and Forestry, and CQ University, Rockhampton, page 26.

Research area: Grazing landscapes and sediment

Identifying sources of sediment loss from grazing lands and understanding the consequences is important for deciding where and how to invest in prevention or repair, and reduce the impacts of fine particulates on reef waters. Five projects were undertaken to clarify these knowledge gaps.

Grazing landscapes and sediment projects:

- **Burdekin grazing research (RP26G)**
- **Mapping erodible soils in grazing lands – Burdekin Dry Tropics (RP63G)**
- **Erosion sources and drivers in grazing lands (RP65G)**
- **Mapping gully locations, volumes and processes in the Burdekin (RP66G)**
- **Groundcover and fire management in grazing lands (RP64G)**

Research area: Grazing landscapes and sediment

BURDEKIN GRAZING RESEARCH *(RP26G)*

Project partner: CSIRO

The 2009 Scientific Consensus Statement identified that grazing lands in the dry tropics are a key contributor of sediment to the Great Barrier Reef. However, at the time of initiating this project, there was limited understanding of the key sources, processes and causes of sediment loss within grazing lands of the Burdekin catchment.

What issue was this project trying to resolve?

The project sought to address the limited understanding of erosion processes and sources within the Burdekin catchment, provide recommendations for management response and identify knowledge gaps for future research.

How did we go about it?

The project collated and synthesised research undertaken over the past 20 years on erosion and grazing management impacts in the Burdekin catchment.

What was the outcome?

The project provided a synthesis of knowledge (as at October 2011) of erosion processes and sources within the Burdekin catchment that contribute sediment to the Great Barrier Reef. The report findings contributed to the 2013 Science Consensus Statement, which supported the development of the Reef Plan 2013.

> The project, which utilised 20 years of research, informed the emerging issues identified in the 2013 Scientific Consensus Statement and formed the development of Reef Plan 2013.

Key findings related to the type of sediment that reaches marine waters and the dominant erosion processes, drivers and sources that contribute to this. Where formerly the focus was on managing hillslope erosion, emerging knowledge about the impact of fine sediment from subsurface erosion initiated a shift in priorities for research and extension activities. For instance, as a result of this project, the Reef Water Quality Program invested in mapping erodible soils and gullies, sediment tracing and ground cover science projects in the Burdekin (RP63G, RP66G, RP65G, RP64G and RP68G respectively). The recent outputs of these projects are being used to inform policy, extension and investment across the catchment (e.g. the Grazing Best Management Practice Program) and to inform the next round of knowledge gaps.

This project also contributed to the development of further scientific papers that discovered sediment impacts on coral reefs. Recently updated, the information from this project has been used to inform the Burdekin Water Quality Improvement Plans.

Gullies are highly susceptible to erosion and their management is complex and often costly

This project delivered an initial understanding of erosion processes and sources that contribute sediment to the central Great Barrier Reef. Importantly, it provided direction on key knowledge gaps to be addressed to validate this initial understanding. As a result of this project, investment was made into gully mapping, erodible soils mapping and sediment tracing projects for the Burdekin. All of these projects (along with other research) have provided multiple lines of evidence to validate our understanding of key erosion processes and sources in the Burdekin catchment.

The model below utilises the learnings from this project to describe the different forms of erosion occurring in grazing lands if overgrazed.

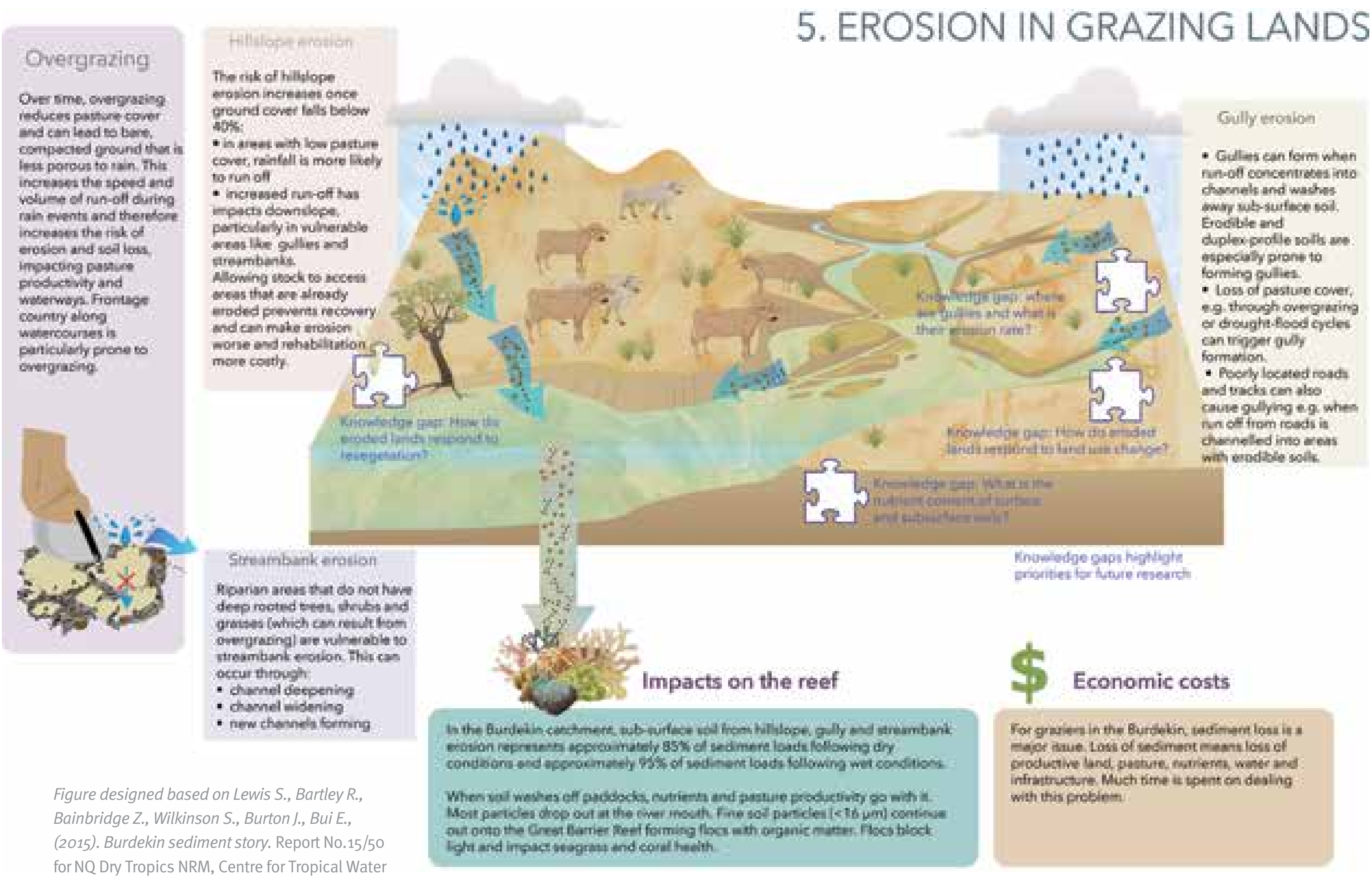


Figure designed based on Lewis S., Bartley R., Bainbridge Z., Wilkinson S., Burton J., Bui E., (2015). Burdekin sediment story. Report No.15/50 for NQ Dry Tropics NRM, Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) Publication, James Cook University, Townsville.

MAPPING ERODIBLE SOILS IN GRAZING LANDS – BURDEKIN DRY TROPICS (*RP63G*)

Project partner: DSITI

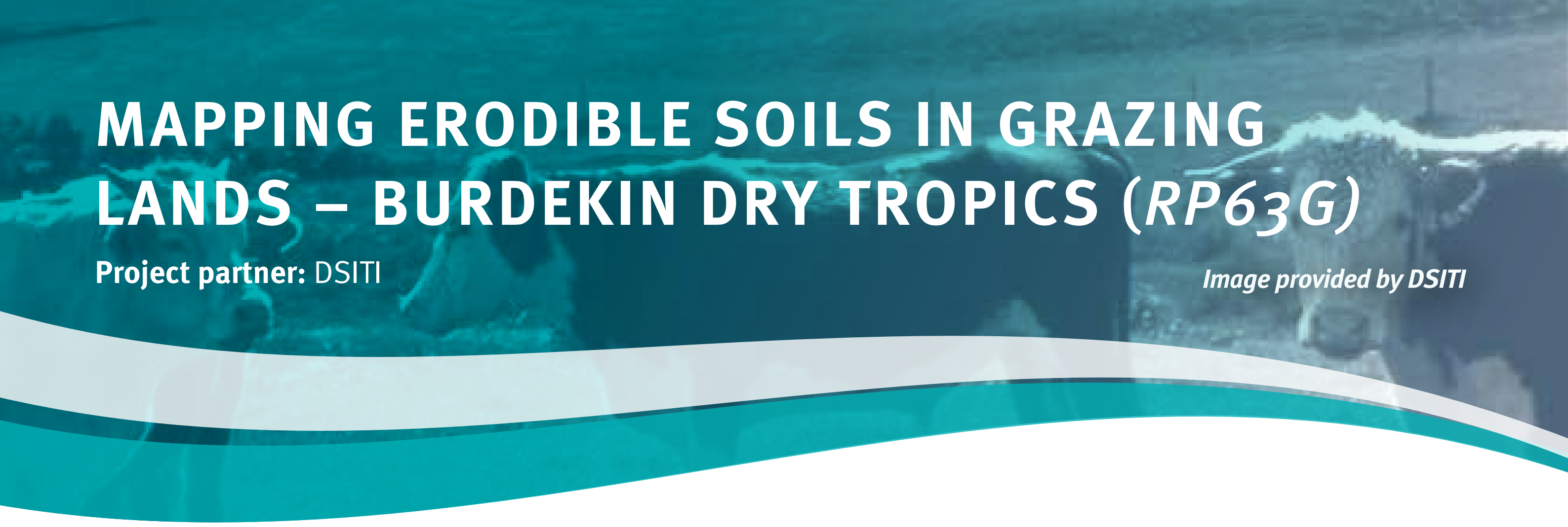


Image provided by DSITI

Improved understanding of potential sediment source locations is critical for targeting investment to reduce sediment loads reaching reef waters from grazing lands in the Burdekin Dry Tropics.

What issue was this project trying to resolve?

This project set out to provide a method of mapping erodible soils in the Burdekin catchment, and to improve soil data for landscape model development. Existing landscape and soils data were inadequate to pinpoint vulnerable areas at an appropriate scale for decision-makers to adequately prioritise investment.

How did we go about it?

Soil data used for these maps has come from more than 8,000 existing soil profile observations collected over the past 60 years. An additional 400 sites were observed and sampled in areas with few existing sites. Specific soil attributes, such as clay content and exchangeable sodium percentages, were selected to map the vulnerability of soils to erosion. This project used digital soil mapping techniques to produce a series of uniform soil attribute layers at a consistent resolution.

What was the outcome?

Three major datasets were produced providing information on the stability of the surface soil, dispersibility of the subsoil and overall vulnerability in the Burdekin catchment.

The project delivered a method of mapping soils in the Burdekin Dry Tropics, that refined the scale at which previous maps were provided, and improved the reliability of soils mapping by reinterpreting and verifying existing soils information.

Data from this project together with sediment tracing studies, ground cover and gully maps produced in other RWQ projects (RP65G, RP64G and RP66G respectively) and slopes are currently being used to:

> Project delivered a method for mapping soil erodibility across the Burdekin based on soil attributes that drive erosion, resulting in improved soil mapping reliability.

- guide Reef Water Quality policy and prioritise investment to reduce soil loss
- focus extension efforts and planning
- inform and improve Paddock to Reef models that are contributing to the state's Water Quality Improvement Plans (WQIPs) in the Burdekin
- support the Best Management Practice Program (BMP), in particular the Soil Health module
- provide online erodible soils reports for land managers and others at **www.longpaddock.qld.gov.au/forage/**.

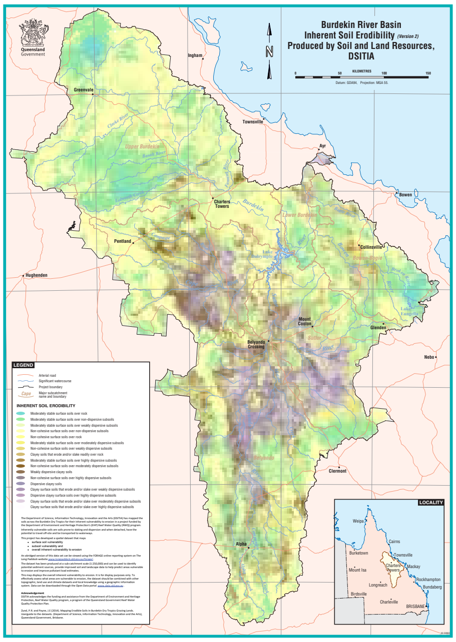
A similar project is underway for the Fitzroy Reef catchment under the RWQ Science Program.

This new soils mapping information will help to identify, spatially, areas in the landscape vulnerable to erosion and sediment run-off to the Reef. This data combined with other available information and knowledge, such as slope, ground cover, presence of gullies and climate help to fully assess this risk. The development of maps which indicate erodibility has been a key step in identifying potential erosion sources within the landscape.

Peter Zund, Soils Scientist, DSITI

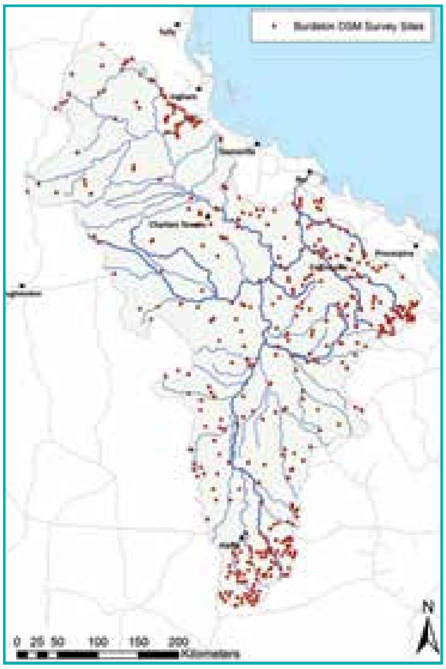
Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

Mapping erodibility of surface and subsurface soil



Erodible soils map in the Burdekin

Figure sourced from Open Data portal, www.data.qld.gov.au, Inherent soil erodibility map. Zund, P.R., and Payne, J.E., (2014). Mapping Erodible Soils in Burdekin Dry Tropics Grazing Lands. Userguide to the datasets. (Department of Science, Information Technology, Innovation and the Arts), Queensland Government, Brisbane.



Burdekin digital soil mapping sampling sites

EROSION SOURCES AND DRIVERS IN GRAZING LANDS *(RP65G)*

Project partners: DSITI, Griffith University, James Cook University and CSIRO

Fine sediment is one of the key water quality parameters of concern to the health of the Great Barrier Reef. In order to reduce the delivery of fine sediment, management practices which target the sources of this sediment must be put in place. To achieve this, we first needed an understanding of the erosion processes and spatial sources of fine sediment.

> This project identified potential erosion sources for fine sediment delivered to the Great Barrier Reef lagoon via the Burdekin River.

What issue was this project trying to resolve?

To improve the understanding of sediment sources and processes in the Burdekin catchment, this project set out to define dominant erosion processes, map spatial sources of sediment deposited in the Great Barrier Reef lagoon and understand temporal changes in the source of sediment deposited in the lagoon.

How did we go about it?

To define dominant erosion processes, the project team applied fallout radionuclide sediment source tracing methods to estimate the contribution of sediment from surface and subsurface erosion to fine river sediment. Applying geochemical tracing techniques at river merges determined the spatial distribution of sources within the Burdekin catchment delivering fine sediment to the Great Barrier Reef Lagoon in the water year 2011/12.

Sediment cores collected from key locations offshore from the Burdekin River were examined using optically stimulated luminescence and radiocarbon dating techniques to determine the fate and accumulation rates of sediments delivered to the Great Barrier Reef. The team also examined the geochemistry of two key sediment cores that lie in the current depositional area of the Burdekin River to determine if sources of sediment have changed over time.

What was the outcome?

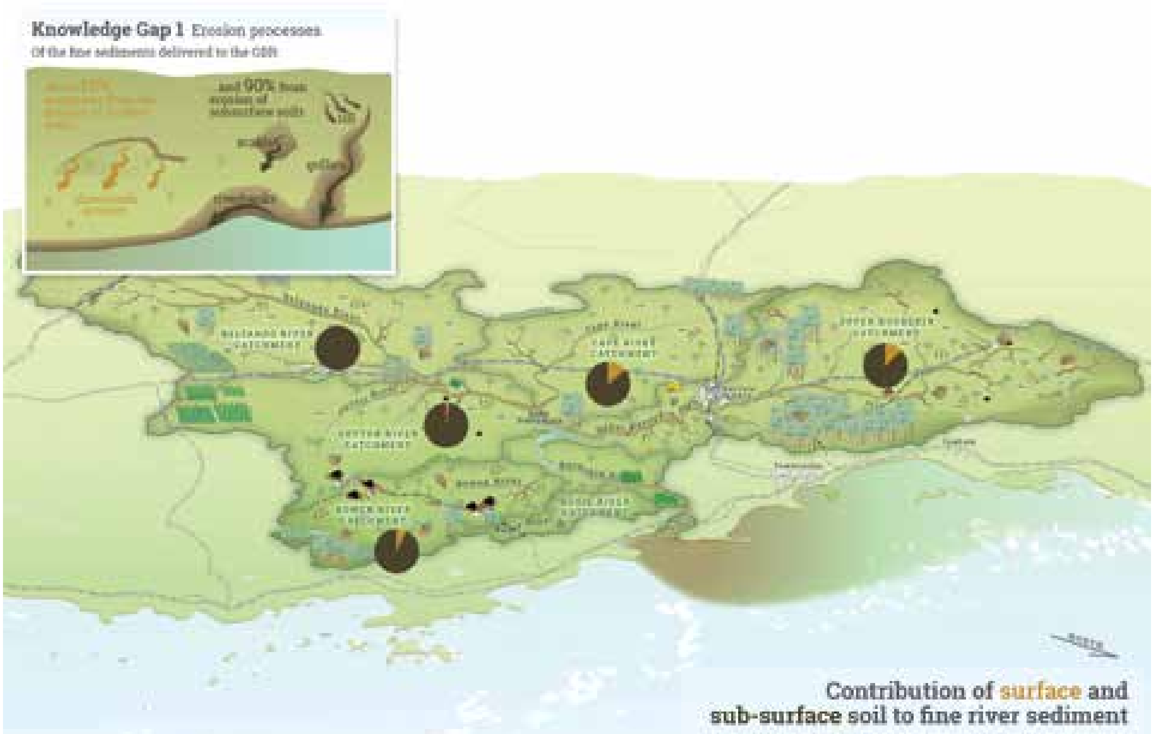
Data from this project was used to produce conceptual diagrams on the right and below. By assessing existing erosion sources and identifying whether or not erosion sources have remained consistent over time, extension officers and land managers can examine options to minimise erosion processes.

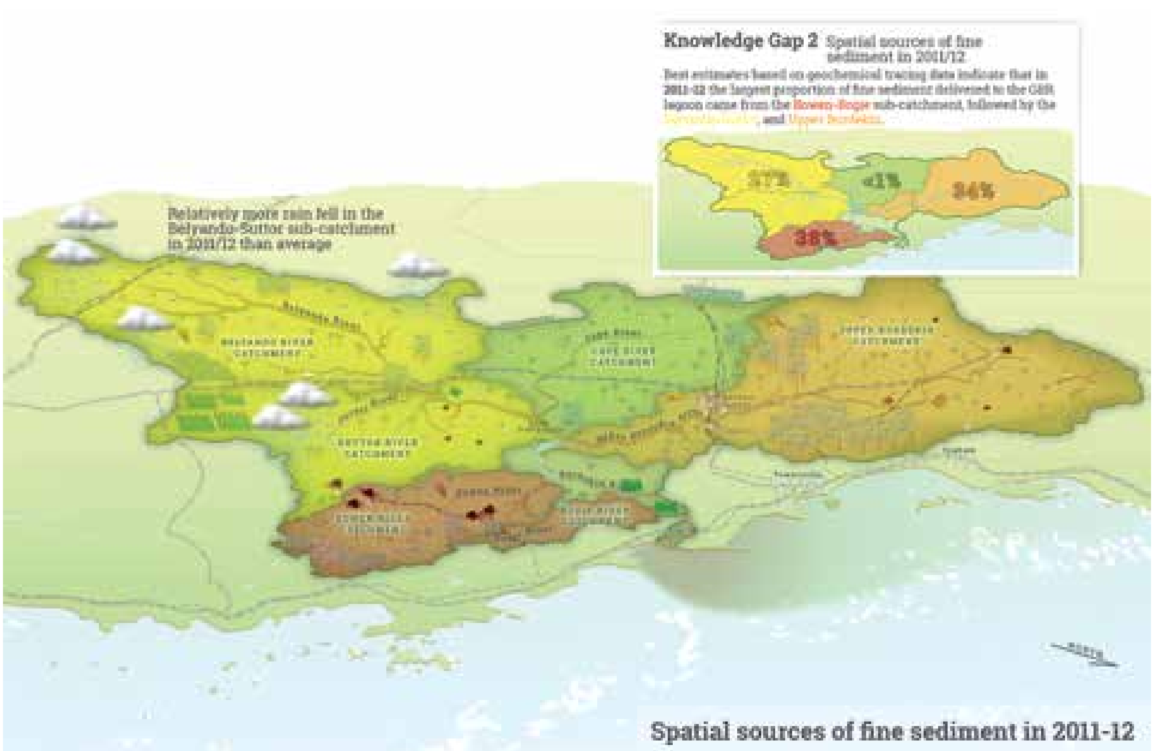
This project also informed the Burdekin Water Quality Improvement Plan. Extension officers have used results to help prioritise on-ground extension. In addition, the Paddock to Reef Program received updated information to improve modelling.

Understanding erosion processes and spatial sources of fine sediment is critical for establishing and implementing effective management strategies aimed at reducing erosion risk.

Jo Burton, Project Leader, DSITI

Note: These conceptual diagrams are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.





Figures sourced from Burton. J., Furuichi. T., Lewis. S, Olley. J., Wilkinson. S., Bainbridge. Z., Sharma. A., (2014). Identifying Erosion Processes and Sources in the Burdekin Dry Tropics Catchment - Synthesis Report. Department of Science, Information Technology and Innovation, Brisbane, December 2014.

MAPPING GULLY LOCATIONS, VOLUMES AND PROCESSES IN THE BURDEKIN *(RP66G)*

Project partner: DSITI

Image provided by DSITI

Studies of sediment sources in the Great Barrier Reef catchments have identified gully erosion as a dominant contributor of sediment reaching the reef lagoon. In addition, evidence suggested that fine sediment particles are of most concern to reef water quality, and significant amounts of these are derived from gullies.

What issue was this project trying to resolve?

Knowing where damaging sediment is coming from and having an understanding of the driving processes is essential to developing suitable management strategies. This project aimed to provide spatially-comprehensive mapping and monitoring of gully erosion in the Burdekin catchment to improve knowledge of where gullies occur, and to attempt to better understand the processes and drivers of gully erosion.

How did we go about it?

The project team used remote sensing and field surveys to map gully location at a range of scales, and to produce information on gully presence and risk of formation. Active and dormant gullies were mapped at targeted locations using aerial photography and satellite imagery to try to understand long-term rates of change in a range of soil types. A number of gullies were also mapped in three-dimension and changes to them quantified over time using highly detailed multi-date airborne Light Detection and Ranging (LiDAR). The LiDAR enabled the project team to accurately measure the volume of sediment which was being eroded and deposited in gullies, providing a detailed account of the rates of change in gullies due to different climate events.

> Data from this project, together with a number of other projects, has been used to support the prioritisation of investment, on-ground extension and Paddock to Reef models.

What was the outcome?

The project produced a number of maps that improved our knowledge and understanding of gullies. One of the maps was a broadscale (5km resolution) gully presence map for the Burdekin which was used to identify areas of high gully presence to inform mapping at a higher resolution (1km). The data is being used to improve water quality models for the Paddock to Reef Program, and will aid prioritisation activities for gully remediation and management.

Changes in gully extent and volume were mapped and quantified over multiple timescales and at different resolutions, improving knowledge on rates of changes and volumes of sediment loss when changes do occur. Importantly, the project also improved our understanding of the uncertainty in change estimates obtained from different technologies, especially airborne LiDAR. These uncertainties can be accounted for in any use of the information for water quality modelling, and to inform the capture specifications for future data acquisition.

This project also supported the development of guidelines and methods for gully mapping, which are now being applied to other reef regions, including the Burnett-Mary, Fitzroy and Wet Tropics. Data from this project, together with sediment tracing studies, groundcover and mapping erodible soils produced in other reef water quality projects (RP65G, RP64G and RP63G respectively) has been used to support the prioritisation of investment, on-ground extension and Paddock to Reef models.

Gully erosion presents a significant challenge to the grazing industry, impacting land condition and reducing productivity. This project has improved spatial and temporal information to help support remedial and preventative action.

Dan Tindall, Project Leader, DSITI

Scientists are developing approaches using this terrestrial laser scanner for highly detailed 3D monitoring of the changes in the gullies.

Example of an alluvial gully in the upper Burdekin region. These gullies form in alluvial areas which often have sodic soils which can erode easily as episodic rainfall events increase run-off and subsurface water flows. Being close to the major water courses, they can contribute large amounts of sediment to the overall sediment budget. They are also an important land degradation issue for graziers as they occur in high productive areas.

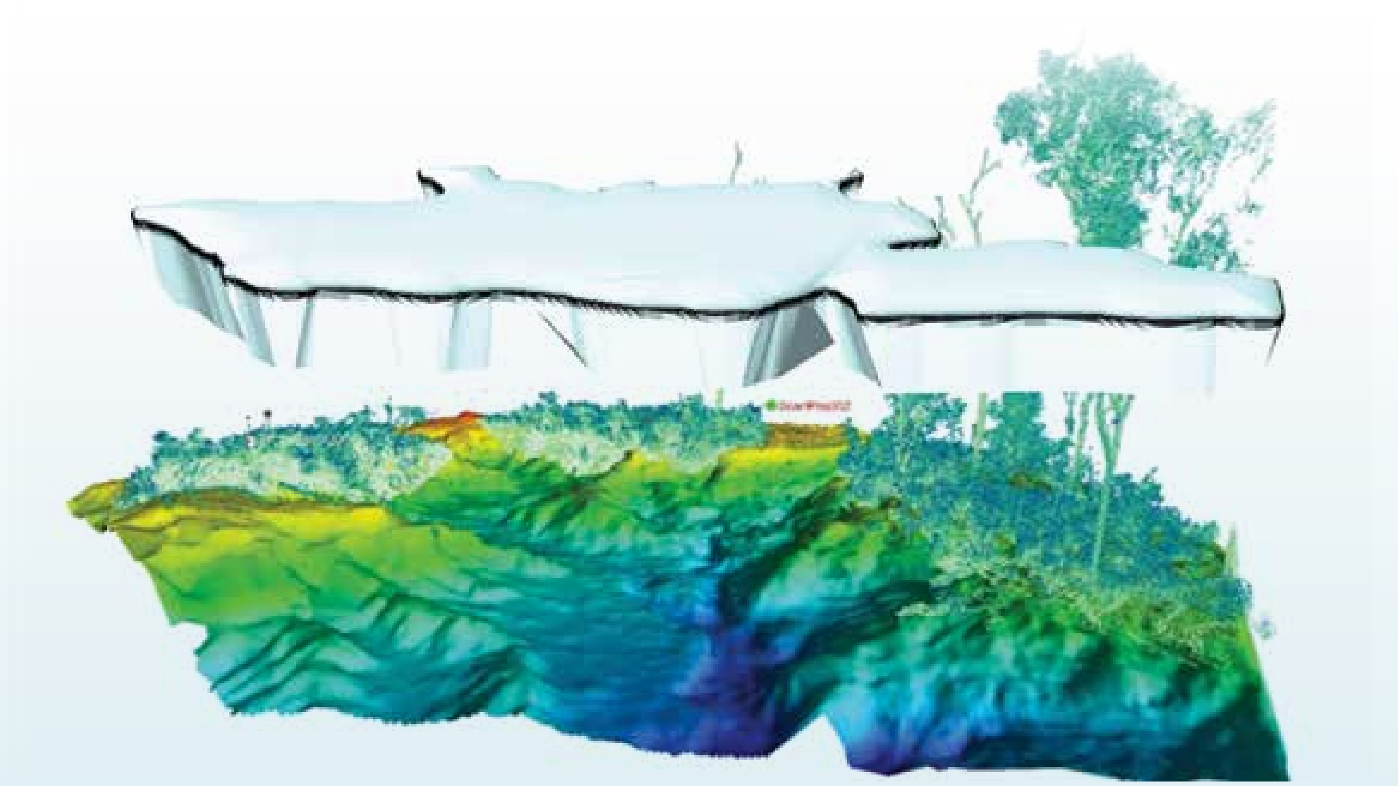


Image shows the volume and area of this gully as mapped using LiDAR technology.

GROUNDCOVER AND FIRE MANAGEMENT IN GRAZING LANDS *(RP64G)*

Project partner: DSITI

Image provided by DSITI

Grazing livestock in Great Barrier Reef catchments relies upon producing palatable and productive pasture. Unsustainable removal of groundcover degrades pasture composition and reduces the growing capacity of soil, leading to a decline in grazing land condition. Reduced levels of groundcover can also increase overland flow, exacerbating hillslope and gully erosion processes, and increasing sediment and nutrient delivery to waterways that drain to the reef lagoon.

What issue was this project trying to resolve?

This project set out to map groundcover on grazing lands due to its importance as an indicator of both productivity and erosion potential.

How did we go about it?

The Remote Sensing Centre (RSC) in the Department of Science, Information Technology and Innovation has produced annual, dry season groundcover data for some years. This data has been based on the Ground Cover Index applied to Landsat imagery.

The Ground Cover Index was only able to predict groundcover (and bare ground) for areas with low tree density (less than 15–20% foliage projective cover).

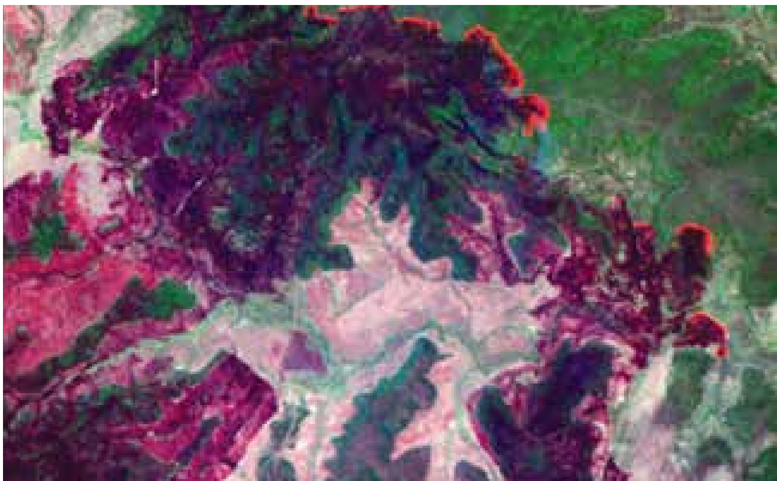
As part of this project, RSC used new field data and the Landsat satellite image archive to develop a new algorithm for measuring the green and non-green components of groundcover as well as bare ground. When combined with improved access to time-series Landsat imagery, data provides improved information about groundcover dynamics. The denser time series of Landsat imagery and additional information obtained from the different cover components also enabled the development of an approach for estimating groundcover in areas of higher tree coverage (up to about 60%) and production of a suite of seasonal products which help our understanding of groundcover in a variable climate.

The project team also developed an approach to identify and map burnt area as far back as 1986 based on the Landsat time-series. The approach identified and classified declines in reflectance of the land surface measured by the satellite which are caused by fires consuming fuel on the ground, leaving a blackened scar on the landscape.

> Landsat satellite imagery has been used to produce a long time-series of groundcover and fire data maps which provides information about the seasonal and management effects of rain, fire and groundcover levels.

What was the outcome?

For the first time, a time-series of groundcover and burnt area data is providing information about seasonal and management effects of rainfall, fire and grazing pressure on groundcover levels in reef catchment grazing lands. Land managers can use this to identify management triggers for groundcover response, and implement appropriate strategies for improved productivity and water quality outcomes. Whilst this project was initially tested and validated in the Burdekin, it has since been rolled out into other reef catchments and across Queensland. The data layers underpin the foundation of groundcover comparison reports available through FORAGE, and are facilitating the development of a range of other online grazing land management tools, including VegMachine and the NRM Spatial Hub.



Landsat satellite image from November 2009 has captured an active fire burning in Central Queensland

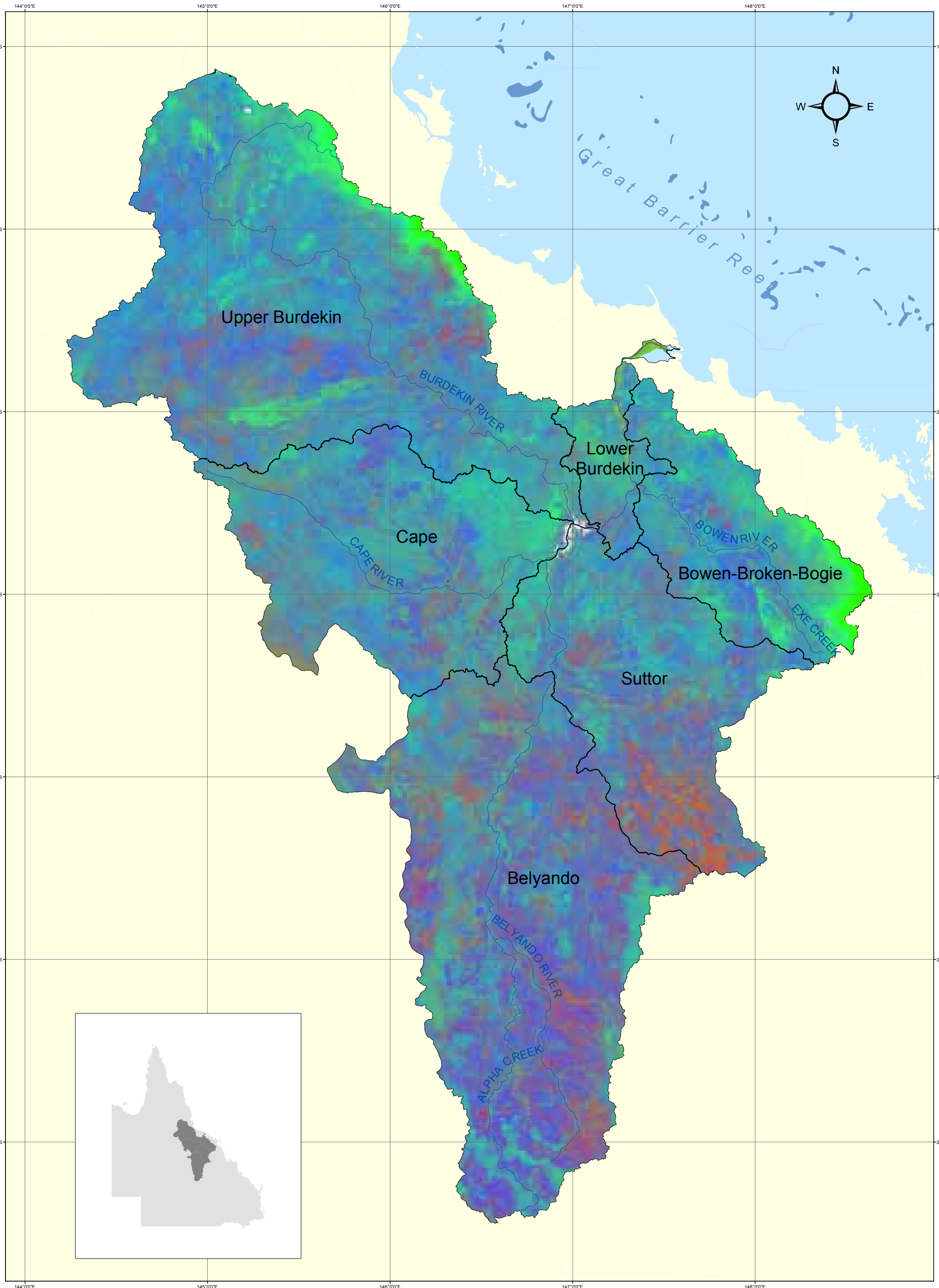
The recent availability of the entire archive of Landsat data free-of-charge has presented exciting opportunities for us to develop land cover monitoring tools which can inform a range of grazing land management requirements in reef catchments and across Queensland. This project enabled us to develop two new foundation data sets which pave the way for greatly improved understanding of our landscape dynamics and the development of a range of tools for graziers.

Dan Tindall, Project Leader, DSITI

Note: These graphics are samples of outcomes from this project. For more information, please contact Reef Water Quality at RWQinfo@ehp.qld.gov.au.

Landsat TM/ETM+ Seasonal Fractional Cover Burdekin Catchment Spring 2013

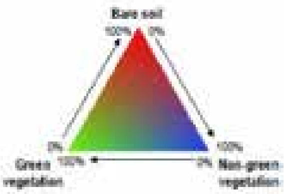
This project produced fractional vegetation cover mapping across Queensland. The map shows the photosynthetic ('green'), non-photosynthetic ('non-green') and bare ground fractions.



Legend

Rivers

Burdekin Subcatchments



Tindall, D., Trevithick, R., Scarth, P., Collett, L., Goodwin, N., Denham, R. and Flood, N., (2014). Ground cover and fire in the grazing lands: RP64G Synthesis Report. Department of Science, Information Technology, Innovation and the Arts. Brisbane.

UNDERSTANDING MOTIVATIONS AND BARRIERS TO COMPLIANCE WITH REEF PROTECTION LEGISLATION (RP14), AND UNDERSTANDING BEHAVIOURAL MOTIVATIONS AND CONSTRAINTS TO ACHIEVING BEST PRACTICE (RP19)

Project partner: DSITI

Introduction of the Reef Water Quality Program in 2009, via the Reef Protection legislation, brought with it a need to understand the circumstances, motivations and capabilities of affected communities to meet the requirements of the legislation.

What issue were these projects trying to resolve?

The project team wanted to better understand the communities it was working with to ensure clarity around messaging, and what communication channels would work best.

How did we go about it?

Over a two year period, the team undertook a literature review and then engaged with producers, industry, agricultural advisors and government through interviews, surveys and focus group discussions.

What was the outcome?

A picture was gained of how people might interact with information services, their familiarity with information systems, and their views and experiences of practice improvements on their properties.

These projects helped to increase our understanding of communities in reef catchments.

Information from these research projects provided a clearer understanding of the need to ensure effective, practical and open engagement with producers. This helped improve information processes, messaging and consultation, and enhanced engagement with and support from producers to achieve mutually beneficial outcomes.

Where to next?

To 2019, the Reef Water Quality Science Program will build upon the research highlighted in this document, and will continue to support the Queensland Government's policy response to improving the quality of water entering the Great Barrier Reef.

The next stage of the science program is a collaborative venture aiming to continue and extend partnerships, encourage co-investment, enhance scientific outcomes and distribute new knowledge to affect on-ground changes that will improve the reef's resilience. It is shaped by the Queensland Reef Water Quality Research, Development and Innovation Strategy 2014/15 – 2018/19 (RD&I) which is being updated to strengthen alignment with emerging reef-related science programs and activities such as the Australian Government Reef Trust and NESP programs.

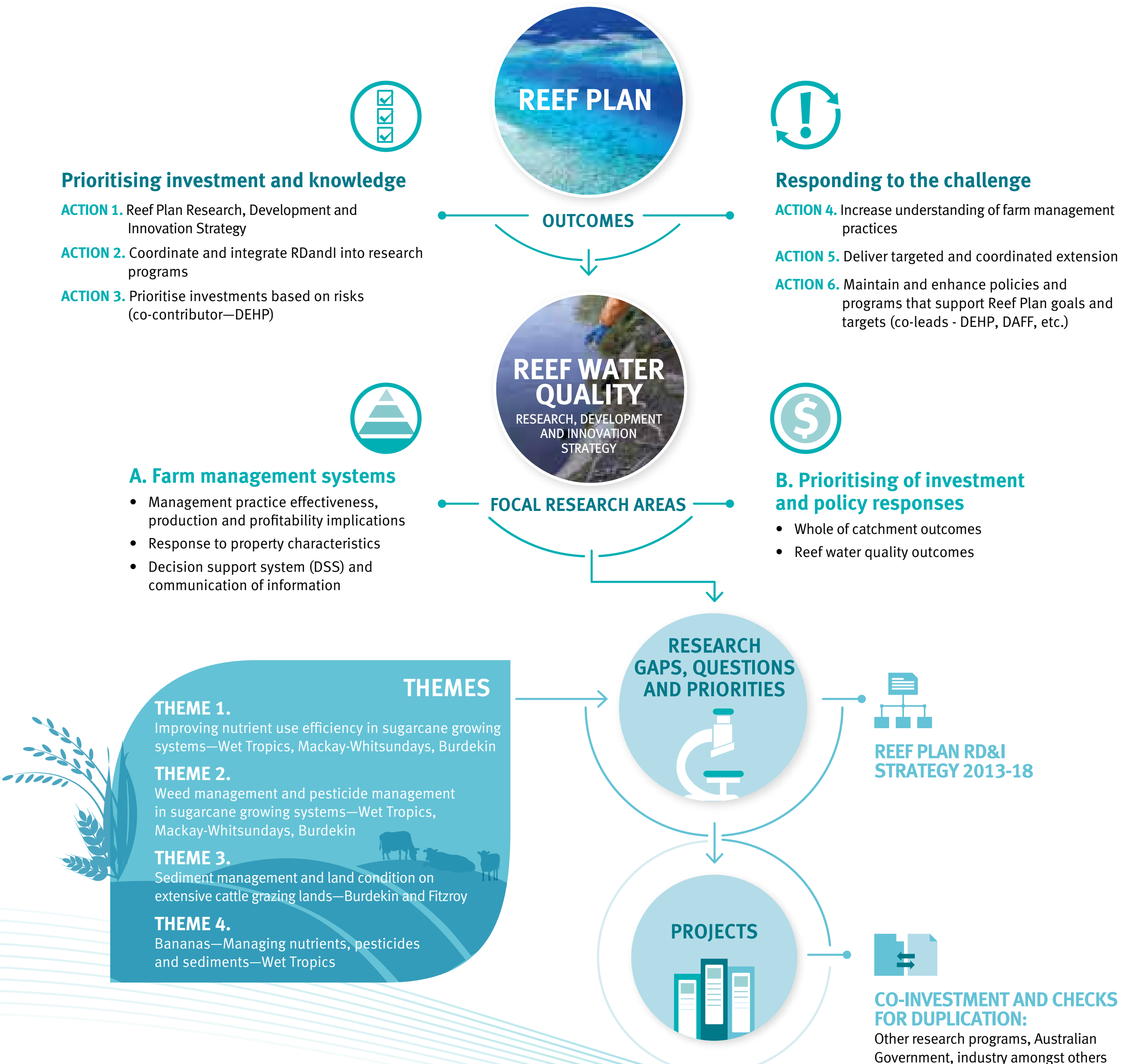
The strategy updates will focus on:

- communicating science results
- leveraging adaptive management solutions
- investigating alternative management responses such as off-farm ecosystem repair
- enhancing monitoring and evaluation of our science investment.

Outcomes of the Great Barrier Reef Water Science Taskforces report and future investment present an opportunity for the RWQ Program, through its RD&I investment, to complement and support this additional investment with targeted research.

The RD&I framework shown below will guide our program of work.

RD&I FRAMEWORK FOR RWQ SCIENCE PROGRAM



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