2022 Scientific Consensus Statement

Question 7.1 What is the mix of programs and instruments (collectively and individually) used in Great Barrier Reef catchments to drive land management practices for Great Barrier Reef water quality benefits and how effective are they?

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Explanatory Notes for readers of the 2022 SCS Syntheses of Evidence

These explanatory notes were produced by the SCS Coordination Team and apply to all evidence syntheses in the 2022 SCS.

What is the Scientific Consensus Statement?

The Scientific Consensus Statement (SCS) on land use impacts on Great Barrier Reef (GBR) water quality and ecosystem condition brings together scientific evidence to understand how land-based activities can influence water quality in the GBR, and how these influences can be managed. The SCS is used as a key evidence-based document by policymakers when they are making decisions about managing GBR water quality. In particular, the SCS provides supporting information for the design, delivery and implementation of the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) which is a joint commitment of the Australian and Queensland governments. The Reef 2050 WQIP describes actions for improving the quality of the water that enters the GBR from the adjacent catchments. The SCS is updated periodically with the latest peer reviewed science.

C_2O Consulting was contracted by the Australian and Queensland governments to coordinate and deliver the 2022 SCS. The team at C_2O Consulting has many years of experience working on the water quality of the GBR and its catchment area and has been involved in the coordination and production of multiple iterations of the SCS since 2008.

The 2022 SCS addresses 30 priority questions that examine the influence of land-based runoff on the water quality of the GBR. The questions were developed in consultation with scientific experts, policy and management teams and other key stakeholders (e.g., representatives from agricultural, tourism, conservation, research and Traditional Owner groups). Authors were then appointed to each question via a formal Expression of Interest and a rigorous selection process. The 30 questions are organised into eight themes: values and threats, sediments and particulate nutrients, dissolved nutrients, pesticides, other pollutants, human dimensions, and future directions, that cover topics ranging from ecological processes, delivery and source, through to management options. Some questions are closely related, and as such readers are directed to Section 1.3 (Links to other questions) in this synthesis of evidence which identifies other 2022 SCS questions that might be of interest.

The geographic scope of interest is the GBR and its adjacent catchment area which contains 35 major river basins and six Natural Resource Management regions. The GBR ecosystems included in the scope of the reviews include coral reefs, seagrass meadows, pelagic, benthic and plankton communities, estuaries, mangroves, saltmarshes, freshwater wetlands and floodplain wetlands. In terms of marine extent, while the greatest areas of influence of land-based runoff are largely in the inshore and to a lesser extent, the midshelf areas of the GBR, the reviews have not been spatially constrained and scientific evidence from anywhere in the GBR is included where relevant for answering the question.

Method used to address the 2022 SCS Questions

Formal evidence review and synthesis methodologies are increasingly being used where science is needed to inform decision making, and have become a recognised international standard for accessing, appraising and synthesising scientific information. More specifically, 'evidence synthesis' is the process of identifying, compiling and combining relevant knowledge from multiple sources so it is readily available for decision makers[1]. The world's highest standard of evidence synthesis is a Systematic Review, which uses a highly prescriptive methodology to define the question and evidence needs, search for and appraise the quality of the evidence, and draw conclusions from the synthesis of this evidence.

In recent years there has been an emergence of evidence synthesis methods that involve some modifications of Systematic Reviews so that they can be conducted in a more timely and cost-effective

[1] Pullin A, Frampton G, Jongman R, Kohl C, Livoreil B, Lux A, ... & Wittmer, H. (2016) Selecting appropriate methods of knowledge synthesis to inform biodiversity policy. *Biodiversity and Conservation*, 25: 1285-1300. https://doi.org/10.1007/s10531-016-1131-9

manner. This suite of evidence synthesis products are referred to as **'Rapid Reviews'**[2]. These methods typically involve a reduced number of steps such as constraining the search effort, adjusting the extent of the quality assessment, and/or modifying the detail for data extraction, while still applying methods to minimise author bias in the searches, evidence appraisal and synthesis methods.

To accommodate the needs of GBR water quality policy and management, tailormade methods based on Rapid Review approaches were developed for the 2022 SCS by an independent expert in evidence-based syntheses for decision-making. The methods were initially reviewed by a small expert group with experience in GBR water quality science, then externally peer reviewed by three independent evidence synthesis experts.

Two methods were developed for the 2022 SCS:

- The **SCS Evidence Review** was used for questions that policy and management indicated were high priority and needed the highest confidence in the conclusions drawn from the evidence. The method includes an assessment of the reliability of all individual evidence items as an additional quality assurance step.
- The **SCS Evidence Summary** was used for all other questions, and while still providing a high level of confidence in the conclusions drawn, the method involves a less comprehensive quality assessment of individual evidence items.

Authors were asked to follow the methods, complete a standard template (this 'Synthesis of Evidence'), and extract data from literature in a standardised way to maximise transparency and ensure that a consistent approach was applied to all questions. Authors were provided with a Methods document, *'2022 Scientific Consensus Statement: Methods for the synthesis of evidence'*[3], containing detailed guidance and requirements for every step of the synthesis process. This was complemented by support from the SCS Coordination Team (led by C_2O Consulting) and the evidence synthesis expert to provide guidance throughout the drafting process including provision of step-by-step online training sessions for Authors, regular meetings to coordinate Authors within the Themes, and fortnightly or monthly question and answer sessions to clarify methods, discuss and address common issues.

The major steps of the Method are described below to assist readers in understanding the process used, structure and outputs of the synthesis of evidence:

1. **Describe the final interpretation of the question.** A description of the interpretation of the scope and intent of the question, including consultation with policy and management representatives where necessary, to ensure alignment with policy intentions. The description is supported by a conceptual diagram representing the major relationships relevant to the question, and definitions.
2. **Develop a search strategy**. The Method recommended that Authors used a S/PICO framework (Subject/Population, Exposure/Intervention, Comparator, Outcome), which could be used to break down the different elements of the question and helps to define and refine the search process. The S/PICO structure is the most commonly used structure in formal evidence synthesis methods[4].
3. **Define the criteria for the eligibility of evidence for the synthesis and conduct searches.** Authors were asked to establish **inclusion and exclusion criteria to define the eligibility of evidence** prior to starting the literature search. The Method recommended conducting a **systematic literature search** in at least **two online academic databases**. Searches were typically restricted to 1990 onwards (unless specified otherwise) following a review of the evidence for the previous (2017) SCS which indicated that this would encompass the majority of the evidence

[2] Collins A, Coughlin D, Miller J, & Kirk S (2015) The production of quick scoping reviews and rapid evidence assessments: A how to guide. UK Government. https://www.gov.uk/government/publications/the-production-of-quick-scoping-reviews-and-rapid-evidence-assessments

[3] Richards R, Pineda MC, Sambrook K, Waterhouse J (2023) 2022 Scientific Consensus Statement: Methods for the synthesis of evidence. C_2O Consulting, Townsville, pp. 59.

[4] https://libguides.jcu.edu.au/systematic-review/define

base, and due to available resources. In addition, the geographic **scope of the search for evidence** depended on the nature of the question. For some questions, it was more appropriate only to focus on studies derived from the GBR region (e.g., the GBR context was essential to answer the question); for other questions, it was important to search for studies outside of the GBR (e.g., the question related to a research theme where there was little information available from the GBR). Authors were asked to provide a rationale for that decision in the synthesis. Results from the literature searches were screened against **inclusion and exclusion** criteria at the title and abstract review stage (**initial screening**). Literature that passed this initial screening was then read in full to determine the eligibility for use in the synthesis of evidence (**second screening**). Importantly, all literature had to be **peer reviewed and publicly available.** As well as journal articles, this meant that grey literature (e.g., technical reports) that had been externally peer reviewed (e.g., outside of organisation) and was publicly available, could be assessed as part of the synthesis of evidence.

4. **Extract data and information from the literature**. To compile the data and information that were used to address the question, **Authors were asked to complete a standard data extraction and appraisal spreadsheet**. Authors were assisted in tailoring this spreadsheet to meet the needs of their specific question.
5. **Undertake systematic appraisal of the evidence base**. Appraisal of the evidence is an important aspect of the synthesis of evidence as it provides the reader and/or decision-makers with valuable insights about the underlying evidence base. Each evidence item was assessed for its spatial, temporal and overall relevance to the question being addressed, and allocated a relative score. The body of evidence was then evaluated for overall relevance, the size of the evidence base (i.e., is it a well-researched topic or not), the diversity of studies (e.g., does it contain a mix of experimental, observational, reviews and modelling studies), and consistency of the findings (e.g., is there agreement or debate within the scientific literature). Collectively, these assessments were used to obtain an overall measure of the level of confidence of the evidence base, specifically using the overall relevance and consistency ratings. For example, a high confidence rating was allocated where there was high overall relevance and high consistency in the findings across a range of study types (e.g., modelling, observational and experimental). Questions using the **SCS Evidence Review Method** had an **additional quality assurance step**, through the assessment of reliability of all individual studies. This allowed Authors to identify where potential biases in the study design or the process used to draw conclusions might exist and offer insight into how reliable the scientific findings are for answering the priority SCS questions. This assessment considered the reliability of the study itself and enabled authors to place more or less emphasis on selected studies.
6. **Undertake a synthesis of the evidence and complete the evidence synthesis template** to address the question. Based on the previous steps, a narrative synthesis approach was used by authors to derive and summarise findings from the evidence.

Guidance for using the synthesis of evidence

Each synthesis of evidence contains three different levels of detail to present the process used and the findings of the evidence:

1. **Executive Summary**: This section brings together the evidence and findings reported in the main body of the document to provide a high-level overview of the question.
2. **Synthesis of Evidence:** This section contains the detailed identification, extraction and examination of evidence used to address the question.
    - ***Background***: Provides the context about why this question is important and explains how the Lead Author interpreted the question.
    - ***Method:*** Outlines the search terms used by Authors to find relevant literature (evidence items), which databases were used, and the inclusion and exclusion criteria.
    - ***Search Results:*** Contains details about the number of evidence items identified, sources, screening and the final number of evidence items used in the synthesis of evidence.

- ***Key Findings:*** The **main body of the synthesis**. It includes a summary of the study characteristics (e.g., how many, when, where, how), a deep dive into the body of evidence covering key findings, trends or patterns, consistency of findings among studies, uncertainties and limitations of the evidence, significance of the findings to policy, practice and research, knowledge gaps, Indigenous engagement, conclusions and the evidence appraisal.

3. **Evidence Statement:** Provides a succinct, high-level overview of the main findings for the question with supporting points. The Evidence Statement for each Question was provided as input to the 2022 Scientific Consensus Statement Summary and Conclusions.

While the Executive Summary and Evidence Statement provide a high-level overview of the question, it is **critical that any policy or management decisions are based on consideration of the full synthesis of evidence.** The GBR and its catchment area is large, with many different land uses, climates and habitats which result in considerable heterogeneity across its extent. Regional differences can be significant, and from a management perspective will therefore often need to be treated as separate entities to make the most effective decisions to support and protect GBR ecosystems. Evidence from this spatial variability is captured in the reviews as much as possible to enable this level of management decision to occur. Areas where there is high agreement or disagreement of findings in the body of evidence are also highlighted by authors in describing the consistency of the evidence. In many cases authors also offer an explanation for this consistency.

Peer Review and Quality Assurance

Each synthesis of evidence was peer reviewed, following a similar process to indexed scientific journals. An Editorial Board, endorsed by the Australian Chief Scientist, managed the process. The Australian Chief Scientist also provided oversight and assurance about the design of the peer review process. The Editorial Board consisted of an Editor-in-Chief and six Editors with editorial expertise in indexed scientific journals. Each question had a Lead and Second Editor. Reviewers were approached based on skills and knowledge relevant to each question and appointed following a strict conflict of interest process. Each question had a minimum of two reviewers, one with GBR-relevant expertise, and a second 'external' reviewer (i.e., international or from elsewhere in Australia). Reviewers completed a peer review template which included a series of standard questions about the quality, rigour and content of the synthesis, and provided a recommendation (i.e., accept, minor revisions, major revisions). Authors were required to respond to all comments made by reviewers and Editors, revise the synthesis and provide evidence of changes. The Lead and Second Editors had the authority to endorse the synthesis following peer review or request further review/iterations.

Contents

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Executive Summary

Question

Question 7.1 What is the mix of programs and instruments (collectively and individually) used in the Great Barrier Reef catchments to drive improved land management actions for Great Barrier Reef water quality benefits and how effective are they?

Background

In response to the ongoing decline in runoff water quality and the impact that this is having on the Great Barrier Reef (GBR), there has been an established history of programs and instruments[5] since 2003 aimed at improving GBR water quality through improved land management practices from agricultural and non-agricultural lands. In the last 20 years, this investment has totalled approximately AUD$1.1 billion with approximately $390 million invested in 'on-ground' programs in the 2017-2022 period. This investment has originated from either the Australian or Queensland Government (or both), with implementation occurring through government entities and the private sector.

Methods

- A formal Rapid Review approach was used for the 2022 Scientific Consensus Statement (SCS) synthesis of evidence. Rapid reviews are a systematic review with a simplification or omission of some steps to accommodate the time and resources available[6]. For the SCS, this applies to the search effort, quality appraisal of evidence and the amount of data extracted. The process has well-defined steps enabling fit-for-purpose evidence to be searched, retrieved, assessed and synthesised into final products to inform policy. For this question, an Evidence Summary method was used.
- Web of Science was the primary literature database searched with Scopus also explored but only returning a small number of additional references to the primary search. Literature retrieved was cross-referenced with known databases of land management improvement initiatives. Search terms were also employed to interrogate relevant special issues such as the Rural Extension and Innovation Systems Journal.
- Main sources of evidence focused on studies conducted in the GBR catchment area focusing on evidence reported since 2015.
- 210 evidence items (from all searches) were originally included as relevant for initial screening Following second screening, a total of 86 evidence items were included in the Evidence Summary.

Method limitations and caveats to using this Evidence Summary

For this Evidence Summary, the following caveats or limitations should be noted when applying the findings for policy or management purposes:

- Only studies written in English were included.
- Only two academic databases were searched. However, extensive additional literature was discovered in searches in specific special issue journals, the Queensland Government's Queensland Reef Water Quality Program Collection of Reef and Land (CORAL) database and reports housed on the National Environmental Science Programme (NESP) Tropical Water

[5] **Programs** are the larger common governance and funding provider of usually a number of projects. **Projects** are usually one stream of application to achieve the program goals. One project may seek to achieve objectives through a number of **instruments**. For example, the Reef 2050 Water Quality Improvement Plan is the program, Grazing And Sustainable Solutions (GRASS) is the project under which landholders are encouraged to adopt land management practices for GBR water quality benefit through the instruments of extension and financial incentives.

[6] Cook CN, Nichols SJ, Webb JA, Fuller RA, Richards RM (2017) Simplifying the selection of evidence synthesis methods to inform environmental decisions: A guide for decision makers and scientists. *Biological Conservation* 213: 135-145 https://doi.org/10.1016/j.biocon.2017.07.004

Quality Hub website. Evidence to answer the 'what' component of the question was also retrieved from website searches (e.g., Great Barrier Reef Foundation (GBRF) website).

- A large amount of web-based information could not be included to answer the 'how effective' component of the question because it did not fulfill the criteria of being independently peer reviewed.
- Only studies published between January 2015 and 31 March 2023 were included.
- Evaluations of procedural governance (as a type of program) were not included in the evaluation. Without knowledge of the effectiveness of overarching institutions and governance, a complete understanding of effectiveness cannot be achieved. Understanding broader institutional processes is important to gain a complete understanding of new approaches to packaging investment such as that applied by the Major Integrated Projects (MIPs).

Key Findings

Summary of evidence to 2022

Part 1: What is the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?

Improved land management actions for GBR water quality benefits from agriculture has primarily been generated through facilitative instruments (extension), incentive-based instruments (primarily financial incentives) and regulation/coercion. For urban land, actions have been motivated primarily through facilitative instruments and regulation. Programs and instruments are implemented by the Australian and Queensland Governments (and sometimes through a combination of these).

Australian Government

Since 2015, the two key pathways for Australian Government investment into agricultural land management for GBR water quality improvement has been through the **Reef Trust Program** and the **Reef Trust Partnership Program**.

Reef Trust Program

The Australian Government committed over $3.2 billion to the Reef Trust and some of this investment is focused on water quality improvement. Of the 86 peer reviewed evidence items retrieved in the literature search, 7 of these reported on the mix or a component of the Reef Trust investment. Reef Trust investment has been predominantly focused on providing financial incentives to support land management change focusing on the grazing and sugarcane sectors.

Reef Trust Partnership Program

The **Reef Trust Partnership Program** (the Partnership) is an AUD$443 million six-year grant program focusing on:

1) Water quality early investments (primarily extension).
2) Water quality regional programs – Herbert, Lower Herbert, Upper and East Burdekin, Lower Burdekin, Bowen Broken Bogie, Mackay Whitsunday, Fitzroy, Mulgrave-Russell, Tully Johnstone (support for extension and some trialling of financial instruments such as Reef Credits).
3) Innovation and system change (technology trialling).

Queensland Government

The key pathways for Queensland Government investment into GBR water quality improvement has been through the Reef Water Quality Program. Of the 86 peer reviewed evidence items returned from the extensive literature search, 15 related to applications of the Queensland Water Quality Protection Program.

Part 2 - How effective are the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?

Effectiveness of programs and instruments was assessed using a scale starting with an assessment of if the objectives of the program and instrument were met and graded based on indicators of effectiveness (Bronze, Silver, Gold, Platinum and Taupo[7]). Additional information such as cost effectiveness, insights from modelled studies and literature that critiques effectiveness methodologies was also included in the analysis.

Grazing

Evidence about effectiveness of programs and instruments for grazing

The most peer reviewed evidence about effectiveness exists for extension. The most common way of understanding effectiveness was in terms of achieving a change in knowledge, aspirations, skills and attitudes (KASA). A few studies (n=6) provided insight into the extent of land management practice change that occurred as a result of the extension intervention. Five pieces of evidence linked extension to some change in water quality improvement (ranked by the authors as Taupo standard). It is important to note here that this is an under-representation of the number of studies exploring effectiveness, as one single study analysed 25 applications of extension (some with financial support attached) for grazing, all of which report on a modelled change in water quality (ranked by the authors as Taupo standard).

How effective have these programs and instruments been?

There was extensive variation in what has been measured to gauge effectiveness as well as variations in the method to measure effectiveness. Therefore, it was not possible to comment on what approach was most effective to bring about an improvement in land management for a water quality outcome. However, some observations include:

- Many programs implemented extension/facilitation interventions and achieved engagement and/or skill improvement objectives but achieved outcomes below targeted accredited[8] change, at least initially. For example, Queensland Audit Office (2015) reports an objective of 30 businesses accredited as a part of Grazing Best Management Practice (BMP) with only 10 achieving accreditations.
- The best understanding about cost effectiveness of programs has been conducted for Reef Trust investments. For these, effectiveness has been assessed using a cost effectiveness methodology. Cost effectiveness was reported to range from $16/tonne through to $17,000/tonne of sediment removed. However, analysis of cost effectiveness only assessed sediment reduction and not broader social change associated with the intervention.

Sugarcane

Evidence about effectiveness of programs and instruments for sugarcane

Out of the 86 peer reviewed studies, 12[9] directly assessed the implementation of a program or instrument to generate land management change for a GBR water quality outcome from sugarcane and provided any evidence of effectiveness.

How effective have these programs and instruments been?

Once again, there was extensive variation in what has been measured to gauge effectiveness as well as variations in the method to measure effectiveness. Therefore, it was not possible to comment on what approach was the most effective. However, some observations include:

[7] Taupo is an indicator coined by the authors to be the very best and refers to when the environmental benefits of the intervention are known or can be reliably modelled. The word 'Taupo' is used to refer to the effective nitrogen trading scheme applied to improve water quality in Lake Taupo, New Zealand.

[8] For grazing, the accreditation process is a 6-step process involving registration that all self-assessment modules are complete, collection of evidence, facilitator assessment and audit through to accreditation at or above industry standard.

[9] Although the Alluvium (2023) study provided analysis of 15 Reef Trust funded applications.

- Similar to grazing, many programs implemented for sugarcane applied extension/facilitation style instruments with engagement and/or skill improvement objectives. Most achieved their implementation objectives. The exception to this was the assessment of SmartCane BMP where accreditation was well below the objective.
- Similar to grazing, the most complete understanding of effectiveness applied a cost effectiveness methodology to sugarcane focused programs conducted for Reef Trust investments. For these, cost effectiveness ranged from $49/kg through to $554/kg of DIN removed. Once again, analysis of cost effectiveness only assessed sediment reduction and not broader social change associated with the intervention.

Other agriculture

Consistent with the studies focused on grazing or sugarcane, the effectiveness of interventions in other agricultural industries was well understood for objectives such as increased engagement and improvement in skills. It was less common for studies to report on a water quality impact. Where it was noted, it was only quantified in the study that focused on Reef Trust investments conducted by Alluvium (2023).

Urban

Partnership reports provided information on 36 initiatives underway across the partnerships with objectives of improving water quality from urban areas to the GBR. Despite the 36 initiatives, only a few reported the impact to GBR water quality. The Urban Water Stewardship Framework assessments provide the most complete performance assessment of urban initiatives to water quality outcomes. A "C" ranking was achieved overall, indicating that the regions, as a whole, meet the current minimum industry standards.

Regulation

A new regulatory package, aimed at providing measures to improve water quality entering the GBR, came into effect in September 2019. The effectiveness of this regulation has not yet been assessed.

Recent findings 2016-2022

All findings are from 2015 so no additional information is provided here.

Significance for policy, practice, and research

Quantity and quality of peer reviewed evidence

There is significant evidence available about the performance of projects implementing a range of instruments, but the majority of this evidence is not peer reviewed. Only 86 pieces of peer reviewed evidence could be found to assess effectiveness. The quality of peer reviewed evidence was also variable, ranging from peer reviewed journal papers to peer reviewed reports.

Significance: additional support for obtaining high quality peer review of findings is required.

Variability in method to assess effectiveness resulting in an inability to provide an overall assessment

There are different ways to assess effectiveness. In many cases, the material that was reviewed for this synthesis may have been completely appropriate and fit for purpose for the intention of the original application but was not consistent with the methodology to assess effectiveness applied to this review. In this study, effectiveness was considered with reference to an improvement in water quality for the GBR. Therefore assessing effectiveness occurred on a scale starting from: 1) if the objectives of the intervention were met; 2) if it was known, if and how the intervention or initiative impacted on human capacity to change (Bronze); 3) if the impact on adoption of practice was known (Silver); 4) if the extent of change in practice was known (Gold); 5) if the legacy of the change was known (Platinum) and 6) if the impact on GBR water quality was known (or could be modelled through Paddock to Reef Integrated

Monitoring, Modelling and Reporting Program (P2R)[10]) (Taupo). Based on the review, the most comprehensive understanding of effectiveness (using the scale outlined) occurred for Reef Trust projects (26 grazing and 15 sugarcane focused interventions). Evaluating effectiveness is very nuanced and there are many other factors that could be included in an effectiveness evaluation. For example, an effectiveness evaluation could also include measures of natural, social and human capital as co-benefits that may arise as a result of engagement in a water quality improving activity. These co-benefits were not included in this review.

Significance: If an understanding of effectiveness across interventions is desired, a standard and coordinated approach to evaluating and reporting all aspects of effectiveness needs to be established, followed, reported on and peer reviewed.

Key uncertainties and/or limitations

- Despite the extent of investment in programs and instruments in the GBR catchment area to drive water quality improving land management practices, only 86 pieces of peer reviewed evidence, published since 2015, were eligible to assess effectiveness. Of these, 27 (41%) were from journals with a high-quality peer review process, 10 (15%) were from a journal with a less rigorous peer review process and 6 (9%) were conference proceedings. The remaining 50% (43) were peer reviewed reports.
- Within the evidence collected, methodologies to determine effectiveness vary. It is not possible to compare effectiveness of policies and programs when reporting methodologies differ.
- Evidence from before 2015 was not included.
- Peer reviewed literature evaluating effectiveness of regulation is very limited.
- This study did not include an assessment of the effectiveness of broader procedural governance.

Evidence appraisal

The synthesis of the evidence for **Question 7.1** was based on 86 studies conducted across the GBR catchment area and published between January 2015 and 31 March 2023. The synthesis includes a Moderate to High level of diversity of study types (with observational from primary and secondary data accounting for 80% of studies, and modelled studies accounting for the remaining 20%), and has a Limited to Moderate confidence rating (based on Low to Moderate consistency and Moderate (agriculture) and High (urban) overall relevance of studies).

Relevance

Agriculture (non-urban)

The relevance of the study approach and reporting of results for the overall body of literature was Moderate with a score of 1.6. The individual scores for relevance of the study approach/reporting of results that this score was calculated from included an adjustment (down) if the paper was a practice and not a research paper so as to reflect concern about the quality of the review process for some of the pieces used as evidence.

The spatial relevance was rated as Moderate (score 2.0) and the temporal relevance of the body of evidence was Moderate (score 2.3). The relevance of the overall body of evidence was on the high side of Moderate with a score of 5.9.

Urban

The relevance of the study approach and reporting of results for the overall body of literature for non-agricultural studies (urban) was Moderate with a score of 2 out of 3.

The spatial relevance was rated as High (score 3.0) and the temporal relevance of the body of evidence was High (score 3.0). The relevance of the overall body of evidence was High with a score of 8.

[10] P2R is the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program often referred to as Paddock to Reef or P2R. For more information see Paddock to Reef | Reef 2050 Water Quality Improvement Plan (reefplan.qld.gov.au)

Consistency, Quantity and Diversity

Since there was not one method used in the literature to assess effectiveness, it is not possible to make an accurate statement about the consistency of evidence but given this variability, the authors consider it to be Low to Moderate. In the authors experience and knowledge of the total potential available pool of evidence relating to the question, the quantity of evidence items eligible for inclusion was Low.

For the two main industries – sugarcane and grazing, the evidence presents a robust mix of direct observation, conceptual review, modelled analysis, and overarching review. For example, 27 of the 86 evidence items related to sugarcane. Of these, most of the evidence was focused on the implementation (n=8) or conceptual development of facilitative type instruments (n=7). Four were modelled studies and eight were secondary reviews. For grazing, most studies were based on primary information (n=11) followed by modelling (n=4), and observation from a role of technical support within a program (n= 2).

The 86 pieces of evidence used is not likely to be representative of all the evidence that is available about effectiveness. However, as noted throughout this report, the quantity of available peer reviewed evidence is low and there is extensive non-peer reviewed information available about the performance of programs and instruments.

Confidence

Based on the above assessment, the overall confidence in the body of evidence was Moderate to Limited. For agriculture, this resulted from Moderate relevance, and Low/Moderate consistency. For urban, this resulted from High relevance, and Low/Moderate consistency.

1. Background

The Great Barrier Reef (GBR) receives runoff from 35 basins draining 424,000 km^2 of coastal Queensland. These basins are aggregated into six Natural Resource Management regions – Cape York, Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy and Burnett Mary. Agriculture is the main land use across the catchment area with more than 90% of the total land area in some form of modified state (Waterhouse et al., 2016). Grazing is the predominant land use (73% of the land area), followed by nature conservation and natural environments (15%), forestry (4.6%), dryland and irrigated cropping (2.8%), sugarcane (1.2%), urban (0.7%), and horticulture (0.2%) (Australian & Queensland Government, 2021). Waterhouse et al. (2017a), reporting in Chapter 5 of the 2017 Scientific Consensus Statement (SCS), identified that the main land uses contributing to pollutant loads to the GBR were rangeland grazing for sediment and particulate nutrients, and sugarcane for dissolved inorganic nutrients and photosystem II inhibiting herbicides (PSII). Reporting on catchment modelling, Waterhouse et al. (2017b) demonstrates that ~9,900 kt yr^{-1} of fine sediment is delivered to the GBR with 7,930 kt yr^{-1} due to anthropogenic land uses. In addition to this, ~55 kt yr^{-1} of nitrogen (N) and 13.4 kt yr^{-1} of total phosphorus (P) is delivered to the GBR.

In response to the ongoing decline in runoff water quality and the impact that this is having on the GBR, beginning in 2003, there has been an established history of reviews[11], programs and instruments[12] aimed at improving GBR water quality through improved land management practices from agricultural and non-agricultural lands (see Figure 1). In the last 20 years, this investment has totalled approximately AUD$1.1 billion with approximately $390 million invested in 'on-ground' programs in the 2017-2022 period (Eberhard et al., 2021a) and come from the Australian or Queensland Government (or both), with implementation occurring through both government entities and the private sector.

Based on Whitten & Coggan (2013), interventions to improve land management for **agricultural land** can be classified as:

1) Facilitative: where measures are designed to improve the flow of information and corresponding signals and incentives without providing any direct incentive payments to landholders. Extension programs, designed to improve the capacity for landholders to conduct land management activities are a form of facilitative intervention.
2) Incentive based: where measures are designed to directly alter the structure of payoffs to land managers and are implemented with the intention to substitute for missing monetary signals that are generated within markets for other goods and services. Taxes on pollution, subsidies to produce environmental outcomes and payments for ecosystem services are all examples of incentive-based interventions. Market-based or market-like instruments fall within the incentive category of intervention. These forms of intervention encourage certain behaviours through market signals rather than explicit directives such as regulation (Stavins, 2003). Market based instruments can be price based (pay for a good either through a competitive (tender) or non-competitive process), quantity based, where regulation is used to set a baseline or target quantity of a product (such as water quality trading) or can operate through removing obstacles to the formation of a market (certification). Market based instruments often require support

[11] Reviews include the 2016 Queensland Governments Water Science Taskforce as well as previous Scientific Consensus Statements (SCS) - Waterhouse, J., Schaffelke, B., Bartley, R., Eberhard, R., Brodie, J., Star, M., Thorburn, P., Rolfe, J., Ronan, M., Taylor, B. & Kroon, F. 2017. 2017 Scientific Consensus Statement. Land Use Impacts on Great Barrier Reef Water Quality and Ecosystem Condition. Programs and instruments reported in this SCS question were developed as a result of these previous reviews.

[12] In this question, **Programs** are considered to be the larger common procedural and funding provider of usually a number of projects. **Projects** are usually one stream of application to achieve the program goals. One project may seek to achieve objectives through a number of i**nstruments**. For example, the Reef 2050 Water Quality Improvement Plan is the program, Grazing And Sustainable Solutions (GRASS) is the project under which landholders are encouraged to adopt land management practices for GBR water quality benefit through the instruments of extension and financial incentives.

through government processes. For example, a cap-and-trade instrument requires regulation on a cap and enforcement of this to generate the demand for a market transaction.

3) Coercive: where non-voluntary measures are designed to compel management change using the coercive powers of government. Regulation is an example of a coercive policy approach.

A fourth intervention type is also discussed in Eberhard et al. (2021a). This is referred to as procedural instruments or governance. This intervention influences the behaviour of the network of actors that interact around the policy issue. Procedural governance is not assessed as a part of this question. Of note is that intervention types are usually never implemented alone and almost always operate in layers with focus dependent on current and objective landholder performance. An example of intervention layers implemented according to current and objective land management performance for sugarcane (from the 2016 Water Science Taskforce) can be seen as Figure 2.

Eberhard et al. (2021a) demonstrated that the majority of the approximately A$390 million invested by the Queensland and Australian Governments (Australian & Queensland Government, 2018) in 2017-2022 for 'on-ground' projects focused on assisting landholders to adopt land management practices that should generate a water quality benefit has been focused on extension (51%), followed by financial instruments WITH extension (36%). A very small amount of the total funding for change has been applied to financial instruments in the absence of extension (3%), regulation and compliance (4%) and physical works such as on ground gully remediation (5%).

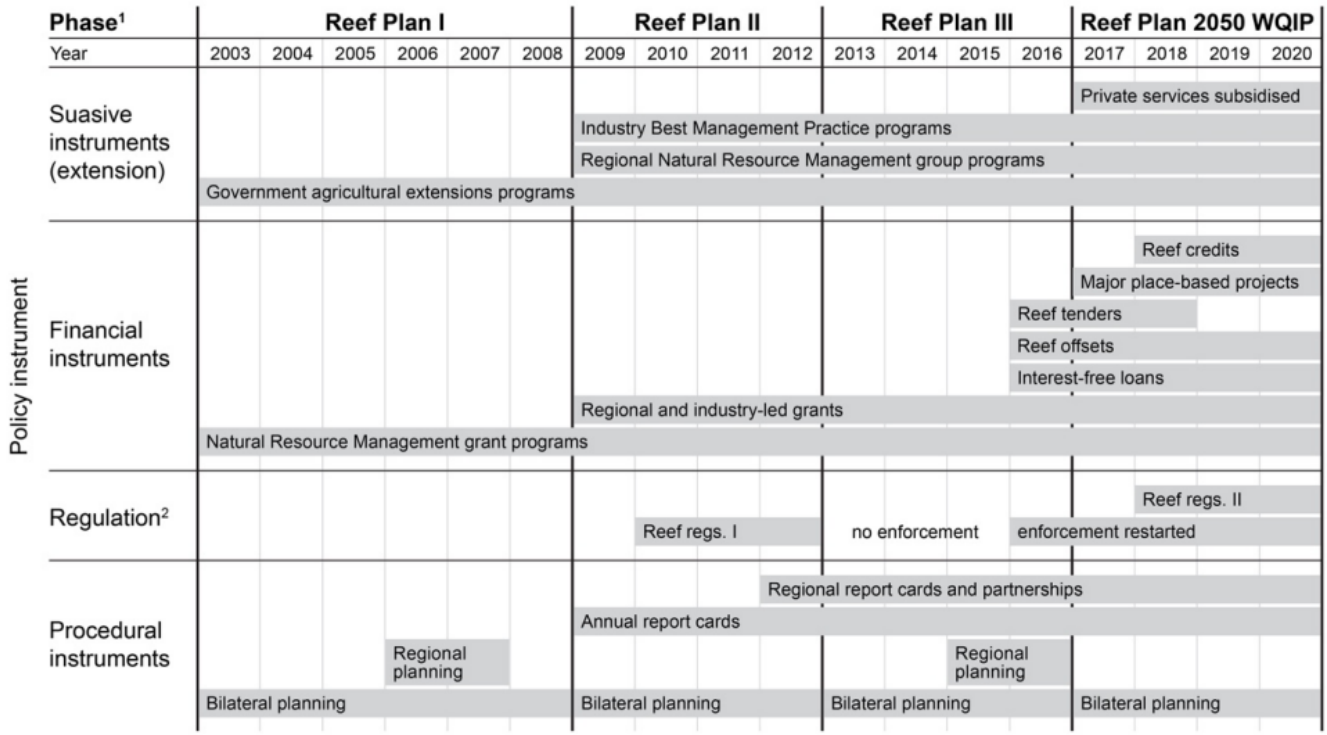


Figure 1. Timeline and spectrum of major policy programs and instruments for water quality improvement to the GBR from agricultural land. Source: Eberhard et al. (2021a).

Figure footnotes:

[1] Phase is defined by the bilateral water quality plans: State of Queensland & Commonwealth of Australia (2003) *Reef Water Quality Protection Plan: for catchments adjacent to the GBR World Heritage Area (GBRWHA) October 2003*; State of Queensland & Commonwealth of Australia (2009) *Reef Water Quality Protection Plan: for the GBRWHA and adjacent catchments*; State of Queensland & Commonwealth of Australia (2013) *Reef Water Quality Protection Plan 2013: Securing the health and resilience of the GBRWHA and adjacent catchments*.; State of Queensland & Commonwealth of Australia (2018a). *Reef 2050 Water Quality Improvement Plan 2017-2022*.

[2] Reef regulations under the *Environmental Protection Act 1994 (Qld)* were passed in 2009 (*Great Barrier Reef Protection Amendment Act, 2009*) and enhanced in 2019 (*Environmental Protection (Great Barrier Reef Protection Measures) and Other Legislation Amendment Bill, 2019*).

Urban land

Urban areas cover less than 0.7% of the GBR catchment area. Stormwater runoff from urban and industrial land use and wastewater treatment releases contribute 7% of the dissolved inorganic nitrogen (DIN) flowing to the GBR and close to 2% of the sediment (Queensland Government, 2022). Management of urban runoff is the responsibility of government, the development and construction industry, and water service providers with support from peak bodies such as the Local Government Association of Queensland (LGAQ) and NRM organisations. In the GBR catchment area, local Government is responsible for managing wastewater treatment and stormwater compliance with State Government legislation. Around $3.5 million of the $270 million of investment in terrestrial land management for water quality outcomes is focused on the urban sectors role in water quality. Actions to manage urban water quality include:

- Urban stewardship initiatives.
- Updating of the Queensland Governments State Planning policy and Reef Protection regulations, with the latter requiring all new, expanded or intensified point source activities (such as treatment works) to meet discharge standards OR purchase credits from point source offsets.
- Developers can use off-site urban stormwater management solutions if onsite options are not available.
- Capacity building – for example, the Queensland Government funds the Erosion and sediment control (ESC) urban stormwater (USW) capacity building program delivered by the Queensland Water Regional Alliance Program (QWRAP) which is a collaboration between 30 councils, LGAQ and the Queensland Water Directorate (Qldwater).
- Onsite training and resources for local government sediment and erosion compliance inspections.
- The development of the Urban Water Stewardship Framework (part of the Queensland Reef Water Quality Program) which can be used to rate how urban initiatives contribute to water quality outcomes from on-ground sediment and nutrient management activities. The framework focuses on erosion and sediment control during construction of urban development, stormwater runoff in established areas and operation and maintenance of sewage treatment plants and associated sewer networks. This has been applied for the first time in 2020-2021 to 13 local councils within the GBR. Within this framework are initiatives to understand the quality of water in local waterways that flow to the GBR such as the:
  - Gladstone Healthy Harbour Partnership (GHHP, which reports on community stewardship and produces annual reports on the health of the Harbour).
  - Wet Tropics Waterways (producing the Urban Water Stewardship Report 2021).
  - Dry Tropics Partnership for Healthy Waterways (producing the Dry Tropics Report Cards).
  - Fitzroy Partnership for River Health Report Cards.
  - Mackay Whitsunday Isaac Healthy Rivers to Reef.

Reef Councils also have a Reef Council's Rescue Plan, a two-phase plan that aims to overcome existing barriers to creating a better business as usual for Reef Councils and their communities and deliver benefits to the GBR through three initiatives:

1) Cleaner Wastewater[13] (which has received $1.15 million of Queensland Government investment).
2) Cleaner Stormwater.
3) Cleaner road runoff.

[13] with five council applications assessed for further life cycle assessment – Burdekin macroalgae treatment process; Douglas upgrade to full recycling capacity; Fraser Coast irrigation of hardwood plantation; Generic lagoon treatment from a membrane polishing plant; Mackay, offsets including farm fertiliser management.

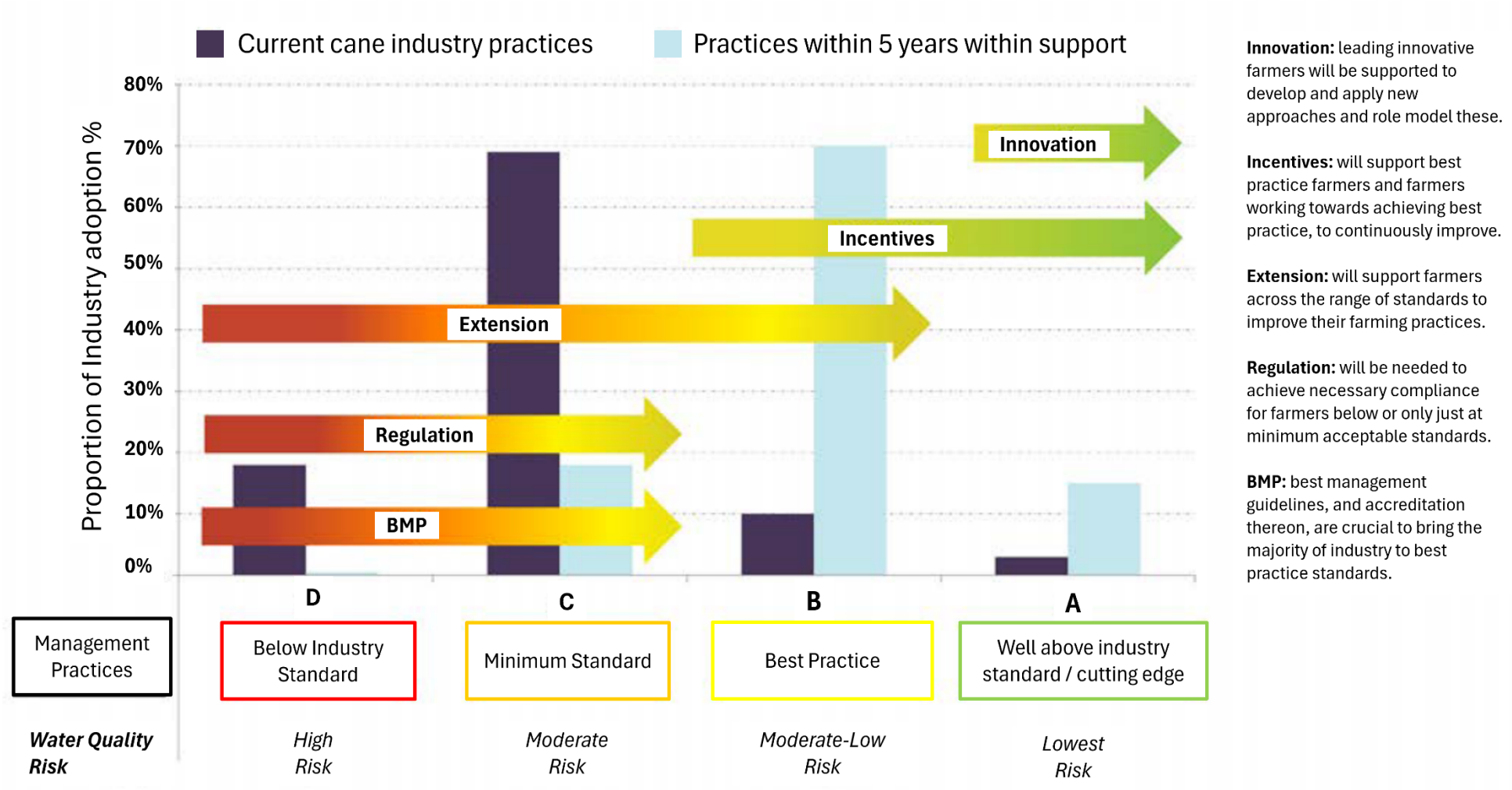


Figure 2. Mix of implementation types for improving water quality from sugarcane land. Source: Queensland Government (2016).

1.1 Question

Primary question	**Q7.1** What is the mix of programs and instruments (collectively and individually) used in Great Barrier Reef catchments to drive improved land management actions for Great Barrier Reef water quality benefits and how effective are they?

To address this question the authors reviewed government and non-government programs and instruments designed explicitly to improve water quality on the GBR. The focus is on programs and instruments designed to improve land management for water quality outcomes from agricultural land (including land managed privately and by corporate entities). While it is acknowledged that there is a broad and longstanding system of governance for land management for water quality outcomes for the GBR catchment area (see Taylor and Eberhard (2020) for an overview and review of these), this review focused on programs in the procedural and funding capacity sense rather than from the perspective of governance capacity. Land uses include grazing, sugarcane, horticulture, banana, irrigated and dryland cropping and urban. The scope includes programs that were active from January 2015 (to align with Reef 2050 Plan and 2017 SCS) with programs and instruments in place now having started by January 2020. The review includes information available to the end of March 2023. The programs include government and non-government programs such as public (Australian, State and regional government) and private administered GBR water quality focused programs (and associated projects) which used facilitative, incentive based or coercive instruments to influence for improved land management on private agricultural and urban land for water quality outcomes in the GBR catchment area. The review is constructed through a number of sub questions:

- What is the mix of programs and instruments implemented at an **Australian government** level to drive improved land management actions for GBR water quality benefits?
- What is the mix of programs and instruments implemented at **a mix of Australian and Queensland** government levels to drive improved land management actions for GBR water quality benefits?
- What is the mix of programs and instruments implemented at a **Queensland government** level to drive improved land management actions for GBR water quality benefits?
- How effective were these at achieving (floor and ceiling measures of effectiveness):
  - The objectives set for them?
  - A measured water quality outcome?
- What do we know about **how** effective the programs and instruments have been?

1.2 Conceptual diagram

Figure 3 provides a conceptual overview of the question in terms of understanding the geographic focus, industries/land uses considered in the analysis, as well as how programs and instruments relate and the measure of effectiveness.

Detail on the measures of effectiveness is provided in Figure 4.

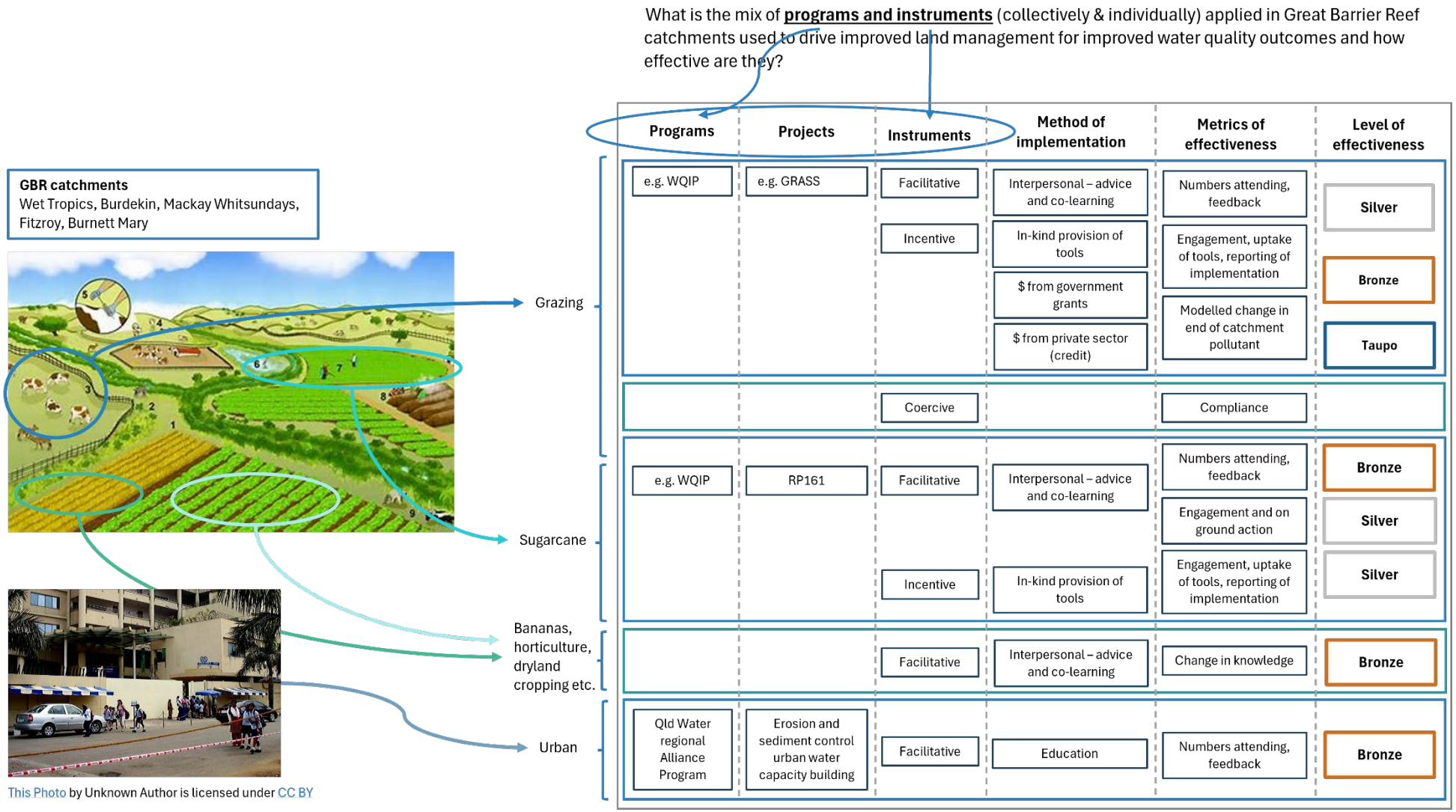


Figure 3. Conceptual framework for understanding programs, instruments and levels of effectiveness (illustrative only).

1.3 Links to other questions

This synthesis of evidence addresses one of 30 questions that are being addressed as part of the 2022 SCS. The questions are organised into eight themes: values and threats, sediments and particulate nutrients, dissolved nutrients, pesticides, other pollutants, human dimensions, and future directions, that cover topics ranging from ecological processes, delivery and source, through to management options. As a result, many questions are closely linked, and the evidence presented may be directly relevant to parts of other questions. The relevant linkages for this question are identified in the text where applicable but the primary question linkages are listed below.

Links to other related questions	**Q7.2** What are the behavioural (attitudinal), economic, social and cultural factors that hinder or enable the uptake of management practices that aim to improve water quality outcomes for the Great Barrier Reef?

2. Method

A formal Rapid Review approach was used for the 2022 Scientific Consensus Statement (SCS) synthesis of evidence. Rapid reviews are a systematic review with a simplification or omission of some steps to accommodate the time and resources available[14]. For the SCS, this applies to the search effort, quality appraisal of evidence and the amount of data extracted. The process has well-defined steps enabling fit-for-purpose evidence to be searched, retrieved, assessed and synthesised into final products to inform policy. For this question, an Evidence Summary method was used.

2.1 Primary question elements and description

The primary question is: ***What is the mix of programs and instruments (collectively and individually) used in Great Barrier Reef catchments to drive land management practices that aim to improve water quality outcomes for the Great Barrier Reef and how effective are they?***

Components of this question are unpacked using the CIMO framework in Table 1.

S/PICO frameworks (Subject/Population, Exposure/Intervention, Comparator, Outcome) can be used to break down the different elements of a question and help to define and refine the search process. The S/PICO structure is the most commonly used structure in formal evidence synthesis methods[15] but other variations are also available (e.g., CIMO framework used here).

- **Subject/Population:** Who or what is being studied or what is the problem?
- **Intervention/exposure:** Proposed management regime, policy, action or the environmental variable to which the subject populations are exposed.
- **Comparator**: What is the intervention/exposure compared to (e.g., other interventions, no intervention, etc.)? This could also include a time comparator as in 'before or after' treatment or exposure. If no comparison was applicable, this component did not need to be addressed.
- **Outcome**: What are the outcomes relevant to the question resulting from the intervention or exposure?

[14] Cook CN, Nichols SJ, Webb JA, Fuller RA, Richards RM (2017) Simplifying the selection of evidence synthesis methods to inform environmental decisions: A guide for decision makers and scientists. *Biological Conservation* 213: 135-145 https://doi.org/10.1016/j.biocon.2017.07.004

[15] https://libguides.jcu.edu.au/systematic-review/define and https://guides.library.cornell.edu/evidence-synthesis/research-question

Table 1. Description of question elements for Question 7.1 using a CIMO framework.

Question CIMO element	Question term	Description/ answer
Context	Which individuals, group, systems or relationships are you focusing on?	**What:** Government and non-government programs and instruments designed explicitly to improve land management actions for water quality benefit on the GBR will be the focus. **Where:** For all GBR NRM regions - Cape York, Wet Tropics, Burdekin, Fitzroy, Burnett Mary and Mackay Whitsunday. **Who:** 1. Addressing water quality from agricultural land: • This includes programs and instruments designed to improve land management actions for GBR water quality benefits from agricultural land. • This includes land managed privately and by corporate entities. • This includes land used for grazing, sugarcane, horticulture, banana and for irrigated and dryland cropping. 2. Addressing water quality from urban land: • This includes programs and instruments designed to improve land management actions for water quality benefits from urban land.

Question CIMO element	Question term	Description/ answer
Intervention	Which event, action or activity are you investigating the effects of?	Given the delivery of the last SCS in 2017, the focus was on programs and instruments that: Were active in or from January 2015 (align with Reef 2050 Plan and last SCS). With current programs and instruments in operation since January 2020 with the review to include information available to December 2022. A summary of the type of program and projects/instruments is provided in Figure 3. **Intervention includes government and non-government programs** such as: 1. Public (Australian, State and regional government) and private administered GBR water quality focused programs (and associated projects) which use extension/information and/or financial reward/penalty to motivate for land management actions which benefits water quality on the GBR. Note a financial reward may be: a. a payment from government through a competitive or non- competitive means. b. a payment from a buyer other than government (credit scheme). c. financial reward through means other than a payment (rate rebate, financial security due to insurance against loss, access to loans at better rates due to land management action etc.). • d. financial penalty due to lack of action (taxes and fines). 2. Regulations that have been implemented (in urban and rural settings) to generate an improvement in land management for water quality outcomes in GBR catchments
Mechanisms	Which responses to the intervention explain how it leads to the outcome? Which circumstances cause the response? In which circumstances are these responses avoided?	Responses to the intervention are: 1. Improved land management actions (urban or agricultural). Because we are focused on improved land management for a water quality outcome, improved agricultural land management can be viewed as action to move towards A level practice in the Water Quality Risk Frameworks which are specified for sugar cane, grazing, horticulture, grains and banana (Management practices | Reef 2050 Water Quality Improvement Plan (reefplan.qld.gov.au)) 2. Land remediation or rehabilitation actions on-ground (urban or agricultural land).

Question CIMO element	Question term	Description/ answer
Outcome	Which effects of the intervention you have chosen to focus on? How are you defining and measuring these effects?	**Outcome** is understanding **how** effective these programs and instruments were/are. Effectiveness is firstly defined according to program logic in Eberhard et al. (2021b) (i.e., RP 225) **as the relationship of outputs to program objectives.** Therefore, the first focus for understanding the effectiveness of the program/policy mix requires understanding the objectives of the program and/or instrument and assessing if the objectives were achieved (this is considered 'floor' level of assessing effectiveness). The question relates to water quality improvement. Therefore, the second/ceiling level to understanding effectiveness of the program/instrument mix is to understand the extent to which an improvement in water quality was achieved/known. The question asks "HOW effective". Therefore, a scale is used to understand effectiveness between the floor and the ceiling when evaluating literature. The components of the scale are described in the definitions.

Table 2. Definitions for terms used in Question 7.1.

Definitions	
Programs	**Programs** are the larger procedural and funding provider of usually a number of projects. For example, the Reef 2050 Water Quality Improvement Plan (WQIP) is the program, Grazing And Sustainable Solutions (GRASS) is the project under which landholders are encouraged to adopt land management practices for GBR water quality benefit through the instruments of extension and financial incentives.
Projects	One stream of application to achieve the program goals. One project may seek to achieve objectives through a number of i**nstruments.**
Instruments	Instruments are the means by which governments seek to influence behaviour and generate a land management improvement. Instruments include facilitative, incentive based and coercive instruments.
Facilitative	Extension is the primary instrument in facilitative interventions. Put simply, agricultural extension services can be defined as "services through which the adoption and application of new knowledge, technologies, and practices are promoted" (Mushtaq et al., 2017). Pannell et al. (2006), in the context of adoption of conservation practices by landholders, take a broader definition to include "public and private sector activities relating to technology transfer, education, attitude change, human resource development, and dissemination and collection of information" (2006:1408). However, Coutts et al. (2017) in their background paper to strengthening extension and education for practice change in the GBR, define extension as "the process of encouraging and supporting voluntary change on farm to improve production, profitability, environmental and/or social outcomes [including] increasing awareness, understanding, skills, motivation and pathways to change." This final definition highlights the orientation of extension in the GBR towards voluntary change and in supporting multiple objectives both on and off-farm. While

Definitions	
	each of these definitions differs to some degree, **what they share is the recognition of extension as fundamentally an act of communication tied to an intent to guide, influence or engage**. There are different models of extension (technology transfer, adoption, adaptation, co innovation). There are also different methods of extension implementation – private consultants, agricultural peak industry bodies, public research and education institutions (universities, government science departments).
Incentive based	These are implemented with the intention to substitute for missing monetary signals that are generated within markets for other goods and services. Taxes on pollution, subsidies to produce environmental outcomes and payments for ecosystem services are all examples of incentive-based interventions. Market-based or market-like instruments fall within the incentive category of intervention. These forms of intervention encourage certain behaviours through market signals rather than explicit directives such as regulation (Stavins, 2003). Market-based instruments can be price based (pay for a good either through a competitive (tender) or non-competitive process), quantity based, where regulation is used to set a baseline or target quantity of a product (such as water quality trading) or can operate through removing obstacles to the formation of a market (certification). Market based instruments often require support through government processes. For example, a cap-and-trade instrument requires regulation on a cap and enforcement of this to generate the demand for a market transaction. The incentive may also be indirect such as through the provision of services for free (such as in-kind labour to assist in completing applications for grants (such as with GRASS).
Coercion	Coercive instruments – usually regulatory instruments – the sticks – involve formal rules and directives that order or require certain actions. Regulatory instruments can prohibit something absolutely, or can prohibit with exemptions permissions (e.g., permits, licenses), or obligation to notify. The logic of regulation is that rules or penalties will motivate behaviour that complies with the regulatory instrument.
Effectiveness	Eberhard et al. (2021b) (i.e., RP 225) defined effectiveness as the relationship of outputs to program objectives.
Sub definitions of effectiveness	Because the question asks HOW effective, this review seeks to fill in the gap between the floor (measures against objectives) and the ceiling (measure of outcomes in terms of improved water quality) with a gradated scale of levels for measuring effectiveness (see Figure 4). This scale was informed by the international literature on effectiveness of programs and policies for water quality outcomes (primarily focused on agricultural lands) synthesised in Eberhard et al. (2021a). It is important to note that: • A study may report on an intervention using one or a number of levels. These levels are not additive, but it remains that the basic measure of effectiveness is a gain in Knowledge, Attitudes, Skills and Aspirations (KASA) and the best level of measuring effectiveness is known or modelled water quality improvement. There are a number of levels between this floor and ceiling. • A study may report on an effectiveness measure (such as number of landholders adopting a new management practice (silver), which is considered to be a good measure of effectiveness, but the number may

Definitions	
	actually be very low – i.e., measured at silver level but showing a poor result. Where this occurs in the evidence, it is highlighted.
Bronze level of effectiveness	**Bronze** – level of effectiveness is measured based on the program and instruments impact on the 'human dimension capacity to change' with metrics of this (Knowledge, Attitudes, Skills and Aspirations (KASA)) developed by Bennett et al. (2018) and Hobman and Taylor (2018). **For facilitative instruments an effective impact on KASA** may be numbers attending a field day, numbers seeking follow up consultation, amount of feedback from experience. **For in kind incentive based, KASA measures** might be numbers of property maps drawn up, farm management plans drawn up, and/or hours of extension which will qualify a landholder for a financial incentive. **For financial incentives** this might be numbers that expressed an interest (EOI), numbers applying, numbers of landholders contracted.
Silver level of effectiveness	A silver level of measuring effectiveness measures adoption of practice such as: • Number of landholders adopting a change or doing an action. • And/or number of hectares change occurred on. **BUT** it isn't known what they were doing before nor if they have adopted on one paddock or across the whole property, nor how long the adoption will last.
Gold	A gold level of measuring effectiveness measures: • How land management changed (what landholders were doing before (ABCD) and what they are doing now (ABCD).
Platinum standard	A platinum level of measuring effectiveness measures: • Intention to maintain adoption. • Extent of adoption across the business.
Taupo standard	The environmental benefits are known or can be modelled as per the cap and trade scheme applied with success for water quality improvement in Lake Taupo in New Zealand (see Spicer et al., 2021).

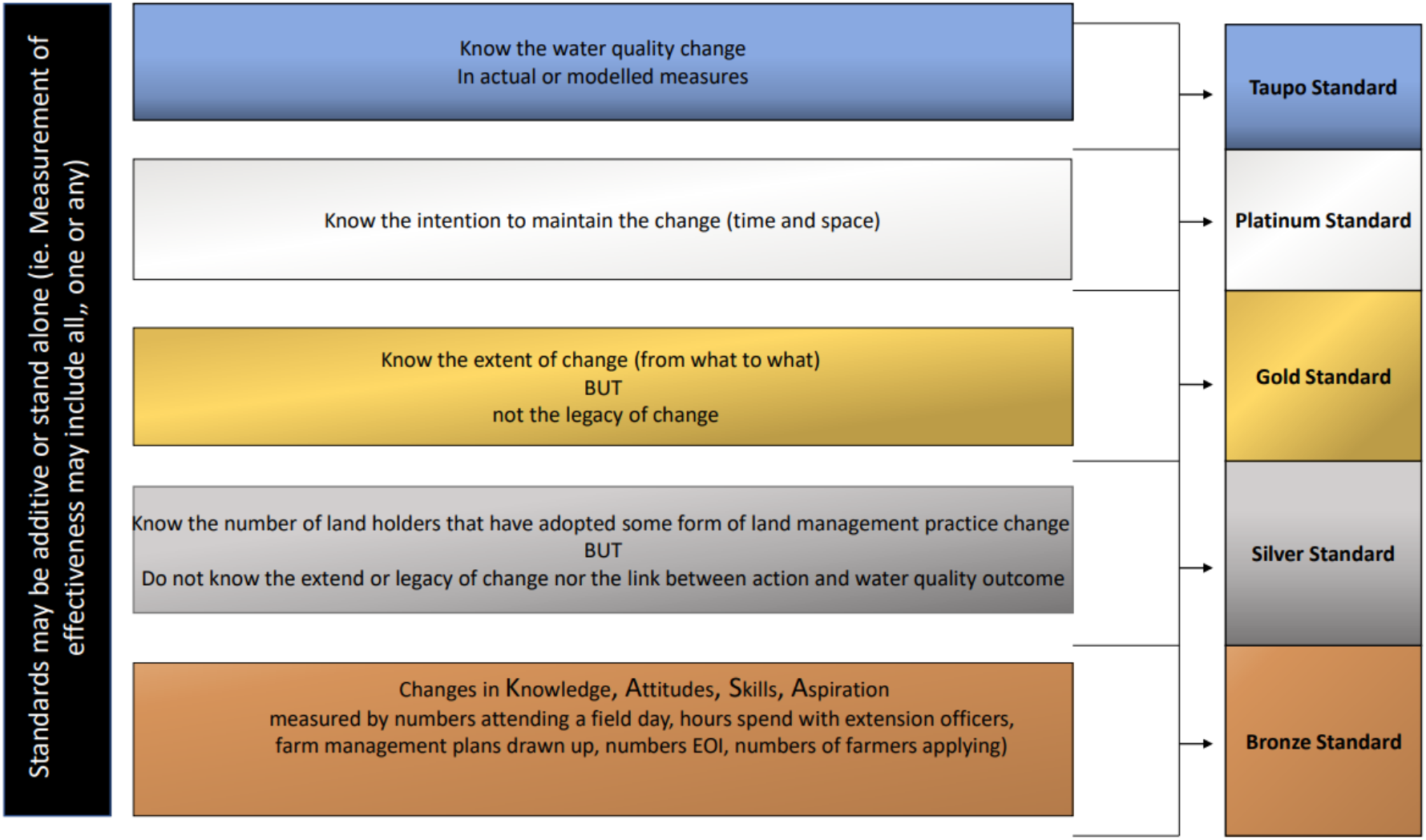


Figure 4. Conceptual framework of effectiveness measure. Adapted from Pradhan et al. (2017).

2.2 Search and eligibility

The Method includes a systematic literature search with well-defined inclusion and exclusion criteria.

Identifying eligible literature for use in the synthesis was a two-step process:

1. Results from the literature searches were screened against strict inclusion and exclusion criteria at the title and abstract review stage (initial screening). Literature that passed this initial screening step were then read in full to determine their eligibility for use in the synthesis of evidence.
2. Information was extracted from each of the eligible papers using a data extraction spreadsheet template. This included information that would enable the relevance (including spatial and temporal), consistency, quantity, and diversity of the studies to be assessed.

a) Search locations

Searches were performed in:

- Web of Science (WoS) (primary).
- Scopus (small number due to small returns and many duplicates with primary search).
- Cross-reference with known databases of land management improvement initiatives such as the Department of Environment and Sciences (DES) CORAL database, Queensland Government publication portal, Great Barrier Reef Foundation' (GBRF) Reef Water Quality Projects, as well as information held on NRM organisations websites such as the Burnett Mary Regional Group, Wet Tropics and Burdekin Dry Tropic Major Integrated Projects (MIPs), Reef Trust independent audit, reports from gully remediation projects and National Environmental Science Programme's Tropical Water Hub (NESP TWQ).
- Use of search term across special issues such as the Rural Extension and Innovation Systems Journal.

b) Search terms

Table 3 shows a list of the search terms used to conduct the online searches.

Table 3. Search terms for CIMO elements of Question 7.1.

Question element	Search terms
Context	Land, management, water, quality, improved, Great Barrier Reef, urban, agriculture, regulation, sugarcane, cane, grazing, graziers, beef, cattle, horticulture, grain, bananas, urban, regional
Intervention	Cane, changer, change, pioneer, paddock, reef, landholder grass, grant, extension, incentive, best management practice, BMP, (various names of programs and projects)
Mechanisms	Effective(ness), outcomes, adoption, improve(d,s), change(d, s)
Outcome	Water quality, adopt(ion), effective(ness), outcome(s), uptake

c) Search strings

Table 4 shows a list of the search strings used to conduct the online searches.

Table 4. Search strings used for electronic searches for Question 7.1.

Search strings (date limited (2015-2023))
(land NEAR/3 manage* AND (“Great Barrier Reef" OR reef)) AND catchment*"[a]
(land NEAR/3 manage* AND ("Great Barrier Reef" OR reef)) AND catchment* AND water AND qual*
“land management” AND “water quality” AND “Great Barrier Reef”[b]
effective* AND "land management" AND "water quality" AND "Great Barrier Reef" AND agric* [bc]
adoption AND "land management" AND "Great Barrier Reef" AND catchment*[b]
improved AND "land management" AND "Great Barrier Reef"[b] AND effec* [d]
adoption AND "land management" AND "Great Barrier Reef" [b]
improved AND "land management" AND "Great Barrier Reef" AND adopt* [b]
“land management” AND change AND "Great Barrier Reef" AND water AND quality AND improv* [b]
paddock AND reef AND effectiv*[b]
landholder* AND driv* AND change* AND "Great Barrier Reef"[b]
effect* AND Banana AND BMP AND "Great Barrier Reef" [b]
effect* AND sugar AND BMP AND "Great Barrier Reef" [b]
effect* AND grazing AND BMP AND "Great Barrier Reef" [b]
Effect* AND horti* AND BMP AND “Great Barrier Reef” [b]
Land AND condition AND monitoring AND "Great Barrier Reef" [b]
grass* AND "Great Barrier Reef" AND "water quality" [b]
nutrient AND management AND planning AND Great Barrier Reef [b]
Catalyst AND "Great Barrier Reef"
Cane AND Changer AND "Great Barrier Reef" [b]
manag AND urban AND water AND quality AND "Great Barrier Reef" [b]

Notes:
[a] started with "land" AND "Management" AND "Great Barrier Reef" OR "Reef" OR "GBR" AND "Catchment*" but needed to refine results.
[b] best results on topic search as opposed to title.
[c] searched with and without agric on topic search.
[d] added in a separate search.

d) Inclusion and exclusion criteria

Table 5 shows a list of the inclusion and exclusion criteria used for accepting or rejecting evidence items.

Table 5. Inclusion and exclusion criteria for Question 7.1 applied to the search returns.

Question element	Inclusion	Exclusion
Context	GBR and GBR catchment names Sugarcane, grazing, grains, cropping, horticulture, urban Landholders, land managers, local council, regional governance bodies	Catchments not in the GBR Carbon, carbon burning, land clearing, vegetation regulation Public coastal land Other lands (such as native forest, national parks, Indigenous Protected Areas etc.)
Intervention	Cane, changer, pioneer, paddock, reef, landholder, change, grass, grant, extension, incentive, BMP, (various names of programs and projects), landholder(s).	Network Governance as an intervention. Program and instruments that are designed to stop or reduce a negative impact (e.g., land clearing is not included). Programs and instruments that are not designed explicitly with a water quality benefit as an objective.
Mechanism		
Outcome	Engagement in program or instrument when implemented; adoption of change (landholder numbers adopting, land area change has occurred on, type of improvement, type of change, change in pollution levels, water quality change. Mentions socio economic, behavioural economics, human behaviour.	Pure production economics (i.e., gross margin implications of an intervention). Biophysical if not linked to an intervention.
Language	English	Non-English
Study type	Reporting on an intervention, reporting on research to assist with an intervention in the future, modelling about potential or hypothetical/model-based result from an intervention now or in the future.	Reporting only on economic implications of adoption (e.g., gross margin impacts of BMP adoption). Reporting only on biophysical impacts of intervention (e.g., change in pollution not linked to change in land management).
Timeframe	Published between January 2015 and 31 March 2023.	Published before 2015 or after 31 March 2023.

3. Search Results

A total of studies 612 studies were identified through online searches for peer reviewed and published literature. In total 210 studies were assessed as part of the first screening. From those, 86 studies were eligible for inclusion in the synthesis of evidence. Initial searches on WoS and Scopus (searching on topic as opposed to title produced a higher quality result) resulted in very few results (Table 6 and Figure 5) and all of them duplicates so the decision was made not to duplicate the effort by using both search mediums. Instead, search effort was invested into investigating reports available through the Queensland Government's CORAL database as well as databases of information provided as a part of the NESP and GBRF.

Table 6. Search results table, separated by A) Academic databases, B) Search engines (Google Scholar) and C) Manual searches. The search results for A and B are provided in the format X (Z) of Y, where: X (number of relevant evidence items retained); Y (total number of search returns or hits); and Z (number of relevant returns that had already been found in previous searches).

Date	Search strings	Sources	
A) Academic databases		Web of Science	Scopus
	"land NEAR/3 manage" AND "Great Barrier Reef" OR "reef" AND "catchment*"*[c]	*10 (0) 55*	*7 of 18*
	"land NEAR/3 manage" AND "Great Barrier Reef" OR "reef" AND "catchment*" AND "water" AND "qual*"*[c]	*0 (11) 11*	*8 of 25*
	"land NEAR/3 manage" AND "Great Barrier Reef" OR "reef" AND "catchment*" AND "water" AND "qual*"*[b]	*43 (14) 233*	
	(land management) AND (water quality) AND (Great Barrier Reef)[b]	*32 (0) 130*	
	"effective" AND "land management" AND "water quality" AND "Great Barrier Reef"*[b]	*11 (0) 24*	
	"effective" AND "land management" AND "water quality" AND "Great Barrier Reef" AND "agric*"* [b]	*0 (13) 13*	
	"adoption" AND "land management" AND "Great Barrier Reef" AND "catchment"*[b]	*0 (5) 5*	
	"improved" AND "land management" AND "Great Barrier Reef"[b]	*1 (7) 8*	
	"improved" AND "land management" AND "Great Barrier Reef" AND "effec"*[b]	*1 (1) of 1*	
	"improved" AND "land management" AND "Great Barrier Reef" AND "adopt"*[b]	*0 (5) of 5*	
	land management AND "change" AND "Great Barrier Reef" AND "water" AND "quality" AND "improv"*[b]	*2 (7) of 9*	
	paddock AND "reef" AND "effectiv"*[b]	*1 (1) of 2*	
	"Land" AND "condition" AND "monitoring" AND "Great Barrier Reef" [b]	*10 (3) of 13*	
	landholder AND driv* AND change* AND "Great Barrier Reef"*[b]	*1 (5) of 6*	
	effect AND Banana AND BMP AND "Great Barrier Reef"* [b]	*1 too old not included*	
	effect AND sugar AND BMP AND "Great Barrier Reef"* [b]	*1 (0) of 1*	

Date	Search strings	Sources	
	effect AND grazing AND BMP AND "Great Barrier Reef"* [b]	*0 (1) of 1*	
	"grass" AND "Great Barrier Reef" AND "water quality"* [b]	*1 (18) of 19*	
	nutrient AND management AND planning AND Great Barrier Reef [b]	*0 of 6 (nonrelevant according to search criteria)*	
	"Catalyst" AND "Great Barrier Reef"	*0 (1) 1*	
	"Cane" AND" Changer" AND "Great Barrier Reef" [b]	*1 (0) 1*	
	"manag" AND "urban" AND "water" AND "quality" AND "Great Barrier Reef" [b]	*10 (0) 22*	
	"knowledge" AND "land manag" AND "water quality" AND "great barrier reef"*	*0 (2) 2*	
	"attitude" AND "land manag*" AND "water quality" AND "great barrier reef"*	*0*	
	"skill" AND "land manag*" AND "water quality" AND "great barrier reef"*	*0 (1) 1*	
	*"aspi**" AND "land manag*" AND "water quality" AND "great barrier reef"*	*0 (1) 1*	
	"KASA" AND "Great Barrier Reef"	*0*	
	"water quality' AND regul AND "Great Barrier Reef"*	*0 (20) 20*	
B) Search engines (Google Scholar: "improved" AND "land management" AND "Great Barrier Reef" AND "adopt* [b])			
	"GBR" water quality" AND urban	*0 (20) 20*	
	Effectiveness of programs for water quality improvement in the GBR	*2 (0) 2*	
	Total items online searches		***612***
C) Manual search			
Date		Number of items added	
Oct 2022 and Feb 23	*CORAL database*	*39*	
Oct 22 and Feb 23	*GBRF RTP websites*	*Enabled addition of programs and instruments for part 1 and one peer reviewed piece of literature.*	
Oct 22	*Terrain MIP*	*4 items found only 1 peer reviewed*	
Oct 22 and April 23	*Urban water quality*	*6 reports on partnerships + the report card for each catchment (6) + 3 reports on the report cards 15(0)15*	
Feb 23	*NESP TWQ*	*7 (0) 7*	
	Total items manual searches		***57***

Notes:
[a] started with "land" AND "Management" AND "Great Barrier Reef" OR "Reef" OR "GBR" AND "Catchment*" but needed to refine results.
[b] best results on topic search.
[c] best results on title search.

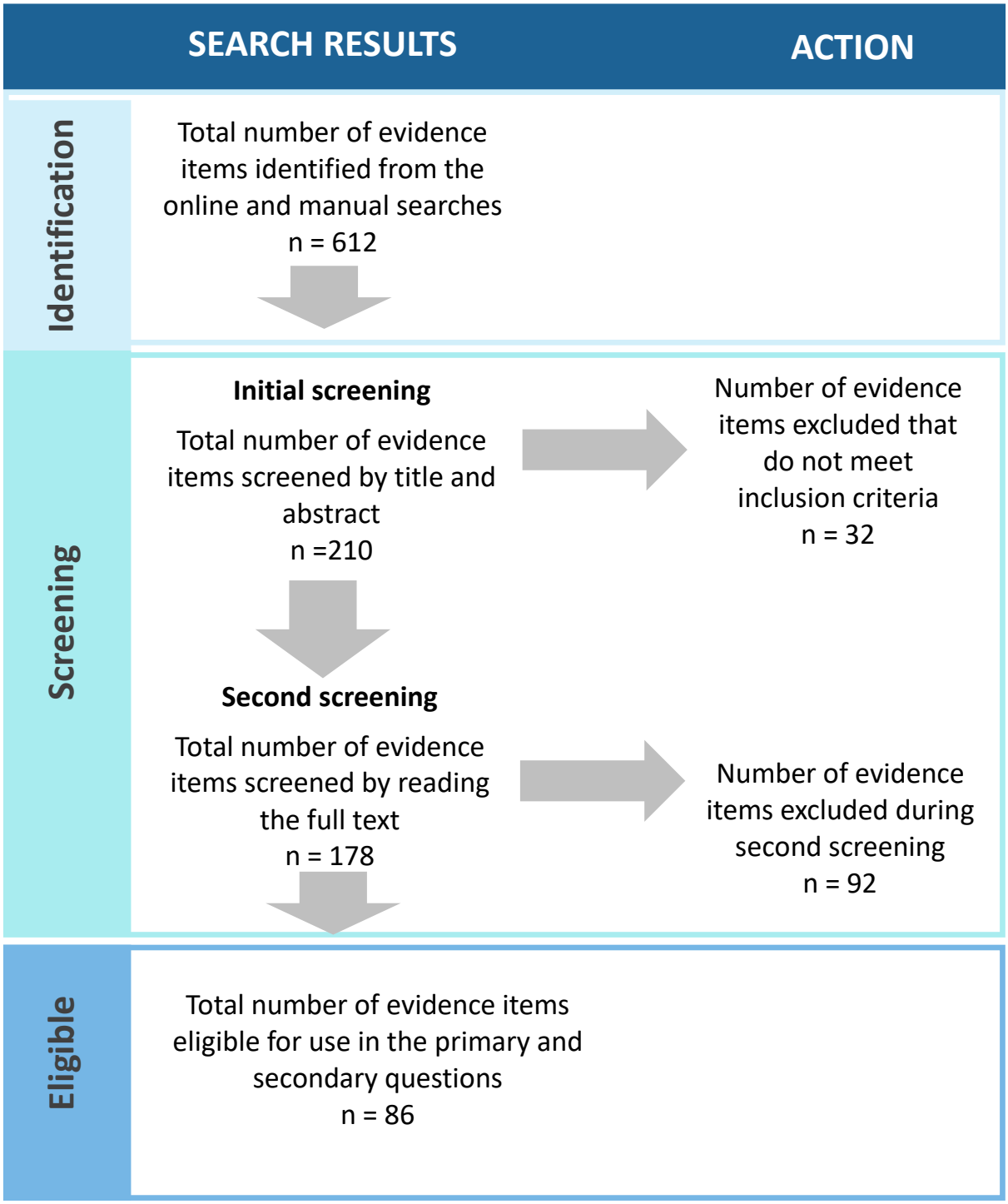


Figure 5. Flow chart of results of screening and assessing all search results for Question 7.1.

4. Key Findings

4.1 Narrative synthesis

The synthesis of evidence is written in two parts. Part 1 is the summary study characteristics and synthesis of evidence related to the first part of the question - *What is the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?* This part is also organised to discuss the programs and instruments applied from the Australian Government, as a mix between Australian and Queensland Government, and those applied from the Queensland Government.

Part 2 is the summary study characteristics and synthesis of evidence related to the second part of the question – *and how effective are they?*

Each Part is structured by presenting the study characteristics followed by the synthesis of evidence.

Part 1 -What is the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?

4.1.1 Summary of study characteristics – Overview of Australian Government Programs and instruments (agricultural and non-regulatory)

The two key pathways for Australian Government investment into agricultural land management for GBR water quality improvement since 2015 has been through the **Reef Trust Program** and the **Reef Trust Partnership Program**[16]. There has also been investment into research about instruments. This literature is included in Part 2 of the synthesis of evidence.

Reef Trust Program

The Reef Trust program is the Australian Government's flagship investment program to support the delivery of the Reef 2050 Long Term Sustainability Plan. The Australian Government has committed over $3.2 billion to the Reef Trust, some of this investment is focused on water quality improvement (The Reef Trust - DCCEEW accessed 20/02/2023)[17]. Of the 86 peer reviewed evidence items retrieved in the search, 6 of these reported on the mix or a component of the Reef Trust investment (Table 7).

Table 7. Peer reviewed evidence focusing on Reef Trust.

Reference	Focus
Alluvium (2023)	Many applications of Reef Trust Phase 1 through to 7.
Wilkinson et al. (2017)	Priorities and progress of gully erosion.
Wilkinson et al. (2019)	Technical findings of Reef Trust Gully Erosion Program.
Eberhard et al. (2021a)	Mentions Reef Trust Reverse Tenders.
Pickering et al. (2019a)	Behavioural skills training for extension linked to Reef Trust funded Project Uplift.
Connellan et al. (2022)	Link to Reef Trust 4.03 Enhanced Efficiency Fertiliser (EEF) Cane Farmer Trials.

Reef Trust Partnership Program

The **Reef Trust Partnership Program** (the Partnership) is the other key program for Australian Government investment in supporting land management for water quality benefits to the GBR. The Partnership is a AUD$443 million six-year grant between the Australian Government Department of

[16] There is reference to the Australian Government Reef Program with reference to Water Quality Grants and partnerships, but this appears to be outdated with respect to the GBR and focused on the National Landcare Program.

[17] The offsets component of Reef Trust is not included as this is a mitigation measure for an impact rather than a program with instruments to generate an improvement in management for a water quality outcome.

Climate Change, Energy, the Environment and Water (previously the Department of Agriculture, Water and the Environment) which managed Reef Trust Funding on behalf of the Australian Government, and the GBRF. The partnership has also been established to support the delivery of the Australian and Queensland Governments Reef 2050 Long Term Sustainability Plan. The Partnership has invested in water quality projects to the tune of AUD$200.6 million and under the headings of:

	Included in this report
Water quality early investments	
Water quality regional programs	
Innovation and systems change	
Conservation and protection of less disturbed catchments	
Traditional Owner-led water quality activities	
Technical advisory	

Only activities with a purple mark are reported here. Of the 50 peer reviewed articles retrieved in the search, 6 of these reported on the mix or a component of the Reef Trust Partnership investment (Table 8).

Table 8. Peer reviewed evidence focusing on Reef Trust Partnership.

Reference	Focus
Pickering et al. (2019b)	Project CaneChanger
Pickering et al. (2019a)	Cane to Creek
Vilas et al. (2020)	Cane to Creek
Rouse and Davenport (2017)	Project Catalyst
Alluvium (2023)	In terms of the adoption of Catalyst more broadly.
Rolfe et al. (2021)	Project Pioneer

4.1.2 Synthesis of evidence –Australian Government Programs and instruments.

Table 9 through to Table 18 synthesise the Reef Trust investment and then the Reef Trust Partnership investment focused on driving **agricultural land management actions for GBR water quality benefits**. The tables synthesise the:

- Project name and delivery organisation
- Delivery instrument (financial instrument etc.)
- Targeted agricultural industry
- Industry of focus
- Action type (management practice focus etc.)
- Catchment(s) of focus
- Pollutant focus
- Timeframe of implementation

These synthesis tables also highlight the extent and quality (in terms of level of peer review) of information available about Reef Trust and Reef Trust Partnership Programs projects. Figure 5 provides important information for understanding the Tables.

Industry	Key	Quality of reports
Sugarcane	SC	No Reports available
Grazing	GZ	Info/Reports available BUT not peer reviewed
Horticulture	HC	Reports available AND peer reviewed
Banana	BN	
Cropping	CP	

Figure 6. Key to understanding summary tables.

Table 9. Australian Government Reef Trust (Phase 1 – only those focused on agricultural land management). Note: B'kn = Burdekin, MWS = Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Is this a scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Reef Trust Tender – Wet Tropics (1.01)	Mgmt practice change	Financial: Tender/ reverse auction							SC	DIN	$5 m	2014/15-2017/18	Terrain NRM	Alluvium (2023)	No
Promotion of A class grazing management practices (1.02)	Mgmt practice change	Extension							GZ	Sediment	$3 m	2014/15-2016/17	Qld Govt	Alluvium (2023)	No
														Info on website at Promotion of A-class Grazing | Project | MERIT (ala.org.au)	No

Table 10. Australian Government Reef Trust (Phase 2 – only those focussed on agricultural land management). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Fifty percent reduction in gully erosion from high priority subcatchments in the Normanby (2.01)	• Mgmt practice change • Landscape repair	Technical support and on-ground works							GZ	Sediment	~$708K	2017-2022	Cape York NRM	Alluvium (2023)	No
														more info at: capeyorknrm.com.au	No
Gully prevention and remediation over 11,000 ha on Normanby River, Kings Plains (2.02)	• Mgmt practice change • Landscape repair	Technical support and on-ground works							GZ	Sediment	~$300K	2016-2019	The trustee for the South Endeavour Trust	Alluvium (2023)	No
														more info at: capeyorknrm.com.au	No
Technical support for Reef Trust Gully Erosion Control Programme (2.03)	Technical assistance	Technical support and on-ground works							GZ	Sediment	~$500K		CSIRO	Alluvium (2023)	No
														Wilkinson et al. (2019), Wilkinson et al. (2017)	Yes
Point Source Sediment Management in the Burdekin Dry Tropics NRM region – East Burdekin (2.04)	• Mgmt practice change • Landscape repair	Technical support and on-ground works plus extension							GZ	Sediment	~$900K	2016-2019	NQDT	Alluvium (2023)	No
														Wilkinson et al. (2019), Wilkinson et al. (2017)	Yes
														More at Point Source Sediment	No

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
														Management | NQ Dry Tropics	
Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management - Theresa (2.05)	• Mgmt practice change • Landscape repair	Technical support and on-ground works plus extension							GZ	Sediment	~$700K	2016-2019	FBA	Alluvium (2023) Wilkinson et al. (2019), Wilkinson et al. (2017)	No Yes
Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management - Fitzroy (2.06)	• Mgmt practice change • Landscape repair	Technical support and on-ground works plus extension							GZ	Sediment	~$700K	2016-2019	FBA		
Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management - Mackenzie (2.07)	• Mgmt practice change • Landscape repair	Technical support and on-ground works plus extension							GZ	Sediment	~$700K	2016-2019	FBA		
Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management - Isaac (2.08)	• Mgmt practice change • Landscape repair	Technical support and on-ground works plus extension							GZ	Sediment	~$700K	2016-2019	FBA		
Don River Catchment Sediment Reduction	• Mgmt practice change	Technical support and on-ground							GZ	Sediment	~$960K	2016-2019	Greening Aust		

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Project: Improving GBR water quality (2.09)	• Landscape repair	works plus extension													
Gully management in highly erodible subcatchments of the Mary River (2.10)	• Mgmt practice change • Landscape repair	Technical support and on-groundworks plus extension							GZ	Sediment	~$800K	2016-2019	MRCCC		
Point Source Sediment Management in the Burdekin Dry Tropics NRM Region (2.11)	• Mgmt practice change • Landscape repair	Technical support and on-groundworks plus extension							GZ	Sediment	~$900K	2016-2019	NQDT		
Reef Trust Tender (2.12)	• Mgmt practice change	Financial: Tender/ reverse auction							SC	DIN	$3m	2015-2020	NQDT	Alluvium (2023)	No
														Mentioned in Eberhard et al. (2021a)	Yes
														Mentioned in Waterhouse and Pineda (2021)	No
														More info at Reef Trust Tender | NQ Dry Tropics	No

Table 11. Australian Government Reef Trust (Phase 3 – only those focussed on agricultural land management). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific Paper?	Other info
			Cape York	Wet Tropics	B'kin	MWS	Fitzroy	Burnett Mary								
Project Catalyst - revamp farm management practices (3.01)	• Mgmt practice change	extension (trials)							SC	DIN	$3m	2016-2019	Catchment Solutions	Alluvium (2023)	No	
														Rouse and Davenport (2017)	Yes	
														More info at Project Catalyst – Introducing the people with passion for Project Catalyst.	No	
Reef Alliance* – Growing a Great Barrier Reef - Improving Horticulture practices (3.02)	• Mgmt practice change	Financial: Targeted incentives							HC	DIN, sediment, Pesticide	$2.4m	2016-2019	QFF	Alluvium (2023)	No	Website not working.
Reef Alliance - Growing a great Barrier Reef - Improving cane practices (3.03)	• Mgmt practice change	Extension and financial incentives							SC	DIN	$17m	2016-2019	QFF	Alluvium (2023)	No	
														Reef Alliance Program – Growing a Great Barrier Reef – Burdekin Cane Project | NQ Dry Tropics		QFF website not working for BM or WT cane
Reef Alliance - improving dairy practices (3.04)	• Mgmt practice change	Extension and financial incentives							GZ (DAIRY)	DIN	$500K	2016-2019	QFF	Alluvium (2023)	No	Website not working

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific Paper?	Other info
			Cape York	Wet Tropics	B'kin	MWS	Fitzroy	Burnett Mary								
Reef Alliance - improving grain practices (3.05)	• Mgmt practice change	Extension and financial incentives							CP (GRAIN)	Sediment	$3.6m	2019-2019	QFF	Alluvium (2023)	No	Website not working
Reef Alliance - improving grazing practices (3.06)	•Mgmt practice change (hillslope)	Extension and financial incentives							GZ	Sediment	$21m	2016-2019	QFF	Alluvium (2023)	No	Website link for Burdekin only
Sustainable Cane Practices (3.07)	• Mgmt practice change	Extension and financial incentives							SC	DIN	$4 m	2016-2019	Reef Catchments	Alluvium (2023)	No	
														More info at Reef Trust 3 - Reef Catchments Reef Trust 3 - Reef Catchments	No	
Project Pioneer (3.08)	•Mgmt practice change (hillslope)	Extension							GZ	Sediment	~$3 m	2019-2019	Resource Consulting Services	Alluvium (2023)	No	
														Rolfe et al. (2021)	Yes	
														More info at Project Pioneer | Regenerative Land and Business Management	No	

*There are other reports available but not peer reviewed

Table 12. Australian Government Reef Trust (Phase 4 – only those focussed on agricultural land management). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific Paper?
			Cape York	Wet Tropics	B'kin	MWS	Fitzroy	Burnett Mary							
Wet Tropics repeated tenders (4.01)	• Mgmt practice change	Financial: Reverse auction/tender		■					SC	DIN	$6.7m	2016-2023	Terrain NRM	Alluvium (2023)	No
														Factsheets etc at Reef Trust IV: Repeated Tenders Improve Cane Farm Productivity (terrain.org.au)	No
Dry Tropics repeated tenders (4.02)	• Mgmt practice change	Financial: Reverse auction/tender			■				SC	DIN	$7.3m	2016-2023	NQDT	Alluvium (2023)	No
														Mentioned in Eberhard et al. (2021a)	Yes
														Rundle-Thiele et al. (2021) (cited in Waterhouse et al., 2021)	Yes
														Factsheets etc at Reef Trust Tender | NQ Dry Tropics	No
Cane Farmer trials (EEF60) (4.03)	• Mgmt practice change	EOI to take part in extension through trials		■	■	■	■	■	SC	DIN	$5m	2017-2021	Qld Canegrowers	Alluvium (2023)	No
				■	■	■	■	■						Connellan et al. (2022)	No
														Waterhouse and Pineda (2021)	No
														More info at Introducing EEF60: cane farm fertiliser trials - Canegrowers	No
GBR Riparian Zone Mgmt - Mary Catchment Riparian Project (4.04)	• Mgmt practice change	Targeted extension and technical support (landscape repair)						■	GZ, SC, Dairy	Sediment	$3m	2017-2022	Mary River Catchment Coord committee (MRCCC)	Alluvium (2023)	No
Stream bank remediation in priority areas (4.05)	• Mgmt practice change • Landscape repair (gully and streambank)	Technical support, financial support for actions,	■						GZ	Sediment	$4m	2017-2022	Cape York NRM	Wilkinson et al. (2019), Wilkinson et al. (2017)	Yes
Gully and stream bank erosion							■				$3.8m		Catchment Solutions		

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific Paper?
			Cape York	Wet Tropics	B'kin	MWS	Fitzroy	Burnett Mary							
control program (4.06)															
Stream bank and gully erosion (4.07)											$3.8m		FBA		
Herbert River remediation (4.08)											$2.9m		D: Terrain NRM		
Gully restoration in the GBR (4.09)											$3.7m		D: NQDT		
Laura gullies project (4.10)											$2m				
Burdekin gully remediation (4.11)											$2m		NQDT		
Controlling streambank erosion in the Mackay Whitsunday region (4.12)											$4m		Reef Catchments		
Technical support	Technical												CSIRO		

Table 13. Australian Government Reef Trust (Phase 5 – only those focused on agricultural land management). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Delivered by:	Information available:	Scientific Paper?
			Cape York	Wet Tropics	B'kin	MWS	Fitzroy	Burnett Mary							
Project Uplift Farming Systems Initiative (Sufgarcane SRA farming systems) (5.01)	• Mgmt practice change	Extension support to implement farming systems							SC	DIN, sediment, pesticide	$4.5m	2017-2022	MSF Sugar	Alluvium (2023)	No
														Pickering et al. (2019a)	Yes
														Project-Uplift-Fact-Sheet-Final.pdf (sugarresearch.com.au)	No

Table 14. Australian Government Reef Trust (Phase 6 – only those focused on agricultural land management). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust $	Timeframe	Partnership (P) with/delivered by (D)	Information available:	Scientific Paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Delivering tailored solutions (CR161) Complete Nutrient Management in Cane	• Mgmt practice change	Extension and technical support							SC	DIN, sediment, pesticide	$3.3m	2018-2022	Qld Govt DES	Alluvium (2023)	No

Table 15. Australian Government Reef Trust (Phase 7 – only those focused on agricultural land management). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	Reef Trust Investment	Timeframe	Delivered by:	Information available:	Scientific Paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Improving water quality in the Burnett River Catchment (7.01)	• Mgmt practice change • Landscape repair (gully and streambank)	Extension and on ground works							GZ	Sediment	2021	2021-2023	BMRG	Alluvium (2023) More info at Burnett River Water Quality Project - Burnett Mary Regional Group (bmrg.org.au)	No No
Improving water quality in the Fitzroy Basin (7.02)	• Mgmt practice change (hillslope)	Extension and on ground works							GZ	Sediment	$5.7m	2021-2023	FBA	Alluvium (2023)	No
Broadscale adoption of tried and tested - Precision ag used to reduce nutrients and pesticides entering the water (7.03)	• Mgmt practice change	Extension and support to produce property management plan							SC	DIN	$4m	2021-2032	NQDT	Alluvium (2023)	No
Streambank remediation in the Burdekin catchment (7.04)	• Mgmt practice change • Landscape repair (gully and streambank)	Extension and support for on-ground works							GZ	Sediment, particulate phosphorus and DIN	$2.9 m	2021-2023	NQDT	Alluvium (2023)	No
Maximising ecosystem biodiversity on the O'Connell and Proserpine basins (7.05)	• Mgmt practice change	Extension and support for on-ground works							GZ, SC	Sediment, DIN, Pesticides	$5.4m	2021-2023	Reef Catchments	Alluvium (2023)	No
Place based program in the Murray and Mossman Catchment (7.06)	• Mgmt practice change for intensive ag	Extension and trialling							SC	DIN	$5.6 m	221-2023	NQNRM Alliance	Alluvium (2023)	No

Table 16. Reef Trust Partnership Program Water Quality Early investments (agricultural land only).

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Cane Changer 2	Mgmt practice change for SmartCane BMP adoption and accreditation	Extension							SC	DIN	$1.4m	Qld CaneGrower Association	Pickering et al. (2019b) More info at: Early Investment Grants - Great Barrier Reef Foundation Project Cane Changer	Yes No No	
Cane to Creek	Mgmt practice change, peer to peer learning	Extension							SC	DIN and pesticides	$2.2 m	SRA	Pickering et al. (2019b) Vilas et al. (2020)	Yes Yes	
Early career extension officers	Mgmt practice change through additional extension services	Training for extension							SC	DIN	$1.2 m	QFF			
Gully erosion control in the Mary River Catchment	• Mgmt practice change • Land restoration (gully)	Support for on-ground works in landscape repair							GZ	Sediment	$646K	MRCCC	Early Investment Grants - Great Barrier Reef Foundation		
Innovative gully project (Phase 3)	Gully remediation Piloting Reef credits for gully restoration	Extension and on-ground restoration							GZ	Sediment	$2m	Greening Australia			Possibly part of Reef Aid
Bluewater	Mgmt. practice change	extension							SC	Pesticides	$1.2m	Farmacist Pty Ltd			
Evidence approach to improving water quality	?	?							SC	Fertiliser and pesticide	$900k	BRIA irrigators			
	Mgmt. practice change								SC	DIN	$2.4m	Catchment solutions	Rouse and Davenport (2017)	Yes	

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Project Catalyst extension													More info at www.projectcatalyst.net.au	No	
Project Pioneer Extension	Mgmt. practice change								GZ	sediment	$2.8m	RCS	Rolfe et al. (2021)	Yes	
													More info, factsheets etc at Project Pioneer | Regenerative Land and Business Management		
Reef Alliance Phase 2	Mgmt practice change								SC, GZ	DIN and sediment	$3.5m	QFF	QFF welcomes funding for Reef projects - Queensland Farmers' Federation		
Reefwise Grazing	Mgmt. practice change	Extension and incentives							GZ	Sediment	$650K	NQDT	Reefwise grazing of Burdekin Rangelands | NQ Dry Tropics		

Table 17. Reef Trust Partnership Water Quality Regional Programs (agricultural land only). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Upper Herbert Water Quality Program	• Mgmt practice • Engineered solutions	Extension and on ground works							GZ	sediment	$3.45m	Terrain NRM	More info at: Upper Herbert Sediment Reduction Project: Terrain NRM	No	2021-2024
Lower Herbert Water Quality Program									SC	DIN	$16.2m	Canegrowers			
-Project CaNE	Mgmt. practice change	Extension/ agronomic services									$7.1m of above	Herbert cane Productivity service		No	
- Nutrient data hub	Mgmt. practice change	knowledge									$2m of above	Liquiforce		No	

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
- Catalyst	Mgmt. practice change	Extension and adoption of BMP									$1.4m of above	Catchment solutions	More info at www.projectcatalyst.net.au	No	
- Modernising mill mud	Trialling technology										$630K of above	Agrogroup		No	
- Major Grants	Mgmt practice change	Financial incentives									$2.1m of above	Herbert river cane growers assoc	MAJOR GRANTS PROJECT - Canegrowers Herbert River (herbertrivercanegrowers.com.au)	No	
Upper and East Burdekin Water Quality Program	Mgmt practice change	Extension and financial incentives							GZ	Sediment	$5.1M	NQDT	More info at Herding change | NQ Dry Tropics		2021-2023
Lower Burdekin Water Quality Program									SC	DIN	$20.4m	NQDT	Lower Burdekin Water Quality Program | NQ Dry Tropics		
- Burdekin irrigation project	Transition to sustainable technology	Extension (?)										SRA			
- Farmacist - nutrients	Data for precision ag	Extension (?)										Farmacist			
- Farmacist – pesticide (project Bluewater 2)	Mgmt. practice	extension										Farmacist			
- Constructed wetland treatment program	Land restoration								SC	DIN		Greening Australia			
- Reef Credits	Financial – purchase of credits	Financial /trialling							?	?		Green Collar			
Bowen Broken Bogie Water Quality Program															

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
$25.9m **NQDT**															
Accelerated grazing support in the BBB – extension of LDC*	Mgmt practice remediation	Extension and property management planning									$5m of the above	NQDT			
BBB gully remediation	Mgmt practice remediation	Extension, on ground works and piloting Reef Credits									$1.8m of above	Greening Australia			
Extension of the Landholders Driving Change MIP*	Mgmt practice remediation	Extension and property management planning										NQDT			
Mackay Whitsundays water quality program											**$22M**	**Reef catchments**			
Bluewater 2 -	Mgmt practice	Extension							SC	pesticide	$4.4M	Farmacist	Home (farmacist.com.au)		
Precision ag	Mgmt practice above reg	Extension and data							SC	DIN	$2.7m	Farmacist			
Major grant project – grower incentives	Equipment purchase	Financial assistance								DIN and pesticide	$2.5m	Reef catchments	Major Grants - Reef Catchments		
Cane to creek										DIN and pesticide	$2.1m	SRA	Pickering et al. (2019b)	Yes	Results of initial study
													Vilas et al. (2020)	Yes	
													SRA to build industry knowledge on interactions between on-farm practice and		

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
													water quality in the Central Region - Sugar Research Australia		
Catalyst broader adoption	Mgmt practice	extension							SC	DIN	$1.7m	Catchment solutions	Alluvium (2023)	No	Linked to this report but may not be the same impleme ntation
													Rouse and Davenport (2017)	Yes	
Nutrient data hub	Mgmt. practice	knowledge							SC		$1.2m	liquiforce			
Mackay Irrigation project	Mgmt. practice	Extension and data							SC	DIN and pesticide	$1.2m	Canegrowers			
Nutrient mgmt. plans	Mgmt. practice	Extension and data							SC	DIN and pesticide	$1.1m	Mackay productivity services	Mackay Area Productivity Services | Productivity Board | Alexandra (maps.org.au)		
Fitzroy Water Quality Program															
Fitzroy Alliance gully rehab	Rehabilitation Mgmt practice	On ground works							GZ	Sediment	$5m	Verterra			
FBA sediment reduction	Rehabilitation Mgmt practice	On ground works							GZ		$4.1m	FBA			
Streambank gully erosion solutions	Rehabilitation	On ground works							GZ		$3.4M	Catchment Solutions			
Water quality improvements	Rehabilitation	Extension for practice							GZ		$1.7m	FBA			

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?	Other info
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
	Mgmt practice	change, on ground works													
Mackenzie water quality program	Rehabilitation Mgmt practice								GZ		$1.6m	Greening Australia			
Mary River Water Quality Program	Rehabilitation of eroding riverine areas								GZ	DIN and pesticides	?	BMRG			
Mulgrave Russell Regional Water Quality Program															
Precision to decision	Mgmt practice	Base data and extension							SC		$300K	Farmacist			
Water quality monitoring and remediation	Mgmt practice and remediation	Extension and on ground works							SC, BN		$1.5m	JCU			
Tully Johnstone Regional Water Quality Program*															
Cassowary Coast Reef Smart Farming	Mgmt practice	extension							SC, BN		$5.9m	Canegrowers			
Nutrient data hub	Mgmt. practice 6ES	knowledge							SC		$800K	Liquiforce			
Tully Johnston water quality program - Water quality monitoring and remediation	Mgmt practice and remediation	Extension and on ground works							SC		$800K	JCU	Tully Johnstone Regional Water Quality Program - Great Barrier Reef Foundation		

* Extension of the Major Integrated Projects (MIP) (Wet Tropics and Burdekin) which were originally funded by the Queensland Government Reef Water Quality Program, extension funded by Australian Government through Reef Trust

Table 18. Reef Trust Partnership Innovation and system change (agricultural land only). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	RTP $	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary						
Reducing herbicide use on sugarcane farms with precise robotic weed control	Techno-logy trial	trial							SC	herbicide	$400K	JCU	AI to improve Reef water quality by reducing herbicide use on farms - Great Barrier Reef Foundation	
Trialling the use of drones in riparian restoration	Techno-logy trial	trial								Sediment	$400K	Greening Australia	Trialling the use of drones in riparian restoration - Greening Australia - Greening Australia	
Understanding the role of regenerative grazing management practices in improving land condition and water quality	?	?							GZ	sediment	$400K	CSIRO	Innovation and Systems Change - Great Barrier Reef Foundation	
On-ground testing and modelling of effectiveness of enhanced efficiency fertilisers									SC	DIN		SRA and CSIRO	Connellan et al. (2022)	No
Development of banana yield monitoring system and a refined input management program	?	?							BN	nutrients	$300K	Farmacist	Innovation and Systems Change - Great Barrier Reef Foundation	
Sensor for DIN	Techno-logy trial	trial							SC	DIN	$350K	IntelliDesign	Innovation and Systems Change - Great Barrier Reef Foundation	
Incentive8	Trial tool								SC	DIN	$400K	JCU	Innovation and Systems Change - Great Barrier Reef Foundation	
Modifying machinery to plant multispecies cops in sugarcane farms for improved soil health and water quality	Modifying equipment	trial									$250K	Farmacist	Innovation and Systems Change - Great Barrier Reef Foundation	
E shepherd virtual fencing	Trial								GZ	Sediment			eShepherd (gallagher.com)	
Understanding nutrient export	On-ground	Trial and assessment							GZ	Sediment			Reports available – addressed in questions related to gully remediation effectiveness - see EHP large publication TEMPLATE (barrierreef.org)	

Not including: Network of seaweed biofilters – Stage 1 (Concept)

4.1.3 Summary of study characteristics – Overview of Queensland Government Programs and instruments (agricultural and non-regulatory).

The key pathways for Queensland Government investment into GBR water quality improvement has been through the Reef Water Quality Program. This program funds practice change and science projects to help producers better manage agricultural land. Practice change projects work with producers to improve farming practices that reduce runoff from agricultural properties. Science projects deliver valuable knowledge-based practical tools and advice for landholders and their advisers (from Practice change and science projects | Environment, land and water | Queensland Government (www.qld.gov.au) accessed 20/02/23). The review of programs and instruments focuses on those applied directly to drive land management practice change to improve water quality outcomes for the GBR. There are many science projects and literature purely based on the science of water quality change (for example there are a number of published biophysical science papers written based off the work conducted for the Wet Tropics MIP) which are not included as a part of this analysis, these have been included in addressing other biophysical science questions of the 2022 SCS. Projects excluded from analysis are noted at the end of the tables.

Of the 86 peer reviewed evidence items returned from the extensive literature search, 14 related to applications of the Queensland Water Quality Protection Program (Table 19).

Table 19. Peer reviewed evidence focusing on application of the Queensland Water Quality Program, specifically for generating practice change for GBR water quality improvement.

Reference	Focus
Soil, Catchment and Riverine Processes Group (2022)	Horticulture and cropping
Alluvium (2023)	Reef Trust Phase 1 through to 7
	Cane BMP
Connellan et al. (2022)	Link to Reef Trust 4.03 EEF Cane farmer Trials
Baker et al. (2021)	Better Beef for the Reef
Coggan et al. (2022)	Grazing Sustainable Solutions (GRASS) and NQDT Landholders Driving Change (LDC) Major Integrated Project (MIP) (Phase 1)
Di Bella et al. (2015)	Nitrogen Use Efficiency
Wilkinson et al. (2017)	Priorities and progress of gully erosion
Wilkinson et al. (2019)	Technical findings of Reef Trust Gully Erosion Program
Waterhouse et al. (2021)	Burdekin MIP (Phase 1)
Deane et al. (2018)	Cane BMP
Kealley et al. (2022)	
Kealley et al. (2021)	
Kealley and Quirk (2016)	
Pickering et al. (2019b)	

4.1.4 Synthesis of evidence –Queensland Government Water Quality Program.

Table 20 synthesises the investment focused on driving **agricultural land management actions for GBR water quality benefits** from the WQIP. The tables synthesise the:

- Project name and delivery organisation
- Delivery instrument (financial instrument etc)
- Targeted agricultural industry
- Industry of focus
- Action type (management practice focus etc)
- Catchment(s) of focus
- Pollutant focus
- Timeframe of implementation

As per the summary tables for the Australian Government programs and instruments, these synthesis tables also highlight the extent and quality (in terms of level of peer review) of information available about WQIP projects and delivery instruments. Figure 5 provides important information for understanding the Tables.

Table 20. Queensland Government Reef Water Quality Program (only that related to agricultural land management for water quality outcomes from 2015 onwards). Note: B'kn = Burdekin, MWS = Mackay Whitsunday.

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Agricultural Work Placement Program												2020-2022	Rural Jobs and Skills Alliance (led by QLD Farmers' Federation)	Agricultural extension work placement program | Environment, land and water | Queensland Government (www.qld.gov.au)	
Enhanced Extension coordination Project 2017-2021	Extension training											2017-2021			
RP240 Improving knowledge and research for horticulture and cropping activities		extension										2020-2022		Soil, Catchment and Riverine Processes Group (2022)	No
	BMP adoption								HC, CP						
	BMP adoption								CP (grains)						
	My BMP adoption								CP (cotton)						
	WQIP, Reef Assured adoption								BN						
RP 234: A land condition monitoring program for GBR catchments (LCAT)									GZ			2020-2021			
RP192 Six easy steps toolbox development for refined on farm nutrient management	Toolbox	extension							SC, HC			2018-2020	SRA		
RP132G Accelerating the use of FORAGE and other complementary tools to support grazing land practices		extension							GZ						

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
RP155C Sub-soil constraints mapping to inform nutrient management in cropping industries									GZ				Farmacist		
TF 6.6.2: Innovative agriculture: Remote livestock management systems and satellite pasture data trial												2017-2020		TF6.6.2 Innovative Agriculture: RLMS & Satellite Pasture Data Trial | Project | BioCollect (des.qld.gov.au)	
TF 6.1 Reef Trust - Enhanced Efficiency Fertiliser Project									SC	DIN		2017-2020		TF6.1 Reef Trust - Enhanced Efficiency Fertiliser Project | Project | BioCollect (des.qld.gov.au)	
														Connellan et al. (2022)	No
T11.8 Better Beef for the Reef									GZ	Sediment				Baker et al. (2021)	Yes
														TF11.8 Better Beef for the Reef | Project | BioCollect (des.qld.gov.au)	
T11.3.4 Grass roots project									GZ				RCS	RCS: Grassroots Project (rcsaustralia.com.au)	
TF 11.12 RP 176G Northern grazing demonstration project									GZ	Sediment		2017-2021	Qld Govt DAF	TF11.13 RP176G Northern grazing demonstration project | Project | BioCollect (des.qld.gov.au)	
RP 223C Russell Mulgrave complete nutrient management									SC	DIN		2020-2022	Farmacist	RP223C Russell Mulgrave Complete	

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
planning for cane farming 2020-2022														Nutrient Management Planning for Cane Farming - Farmacist | Project | BioCollect (des.qld.gov.au)	
RP 222C Russell Mulgrave complete nutrient management planning for cane farming SRA Note: considered accredited and low risk re regulation compliance	Mgmt practice	Tailored extension							SC	DIN		2020-2022	SRA	RP222C Russell Mulgrave Complete Nutrient Management Planning for Cane Farming - SRA | Project | BioCollect (des.qld.gov.au)	
RP232 Fine-scale water quality monitoring in high risk catchments									SC	DIN		2019-2022			
GRASS (FBA, NQDT, BMRG, DAF) Note: considered accredited and low risk re reg compliance.									GZ	Sediment		2019-2023	FBA	GRASS - FBA | Project | BioCollect (des.qld.gov.au) GRASS - NQDT | Project | BioCollect (des.qld.gov.au) GRASS - BMRG | Project | BioCollect (des.qld.gov.au) GRASS - DAF | Project | BioCollect (des.qld.gov.au)	
														Coggan et al. (2022)	Yes
RP 201C AND TF 11.14 AND RP167C Sandy Creek on farm change for water quality									SC	DIN		2019-2022		http: reefcatchments/sandy creek	
														Factsheets on website	

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
RP 210, RP 161 Tailored nutrient and farm management solutions for the Herbert Note: considered accredited and low risk re regulation compliance									SC, HC	DIN and pesticide		2019-2021		RP210 Tailored nutrient and farm management solutions for the Herbert Catchment area | Project | BioCollect (des.qld.gov.au) HR2R-Sandy-Creek-case-study-101017.pdf (healthyriverstoreef.org.au)	
														Alluvium (2023)	No
RP 200C Burnett Mary Delivering tailored solutions												2019-2021			
RP 202C Managing the cane trash blanket as an asset									SC	DIN		2019-2020	DES		
RP 209H Burnett Mary delivering tailored solutions Horticulture									HC	DIN, sediment and pesticide		2018-2021	Verterra		
Cane BMP Phase 3 Note: considered accredited and low risk re regulation compliance									SC	DIN		2019-2023	Canegrowers	Smartcane BMP – Best Management Practices For The Cane Industry	
														Deane et al. (2018)	Yes
														Kealley et al. (2022)	Yes
														Kealley et al. (2021)	Yes
														Kealley and Quirk (2016)	Yes

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
														Pickering et al. (2019b)	Yes
														Alluvium (2023)	No
Banana BMP phase 2			Not specified						BN, CP, HC			2018-2023			
RP192 ^6easy steps tool box development for refined on farm nutrient management									SC, HC			2018-2020		SIX EASY STEPS TOOLBOX - Sugar Research Australia	
RP 198 Development of a generic pesticide selectin support tool									SC	Pesticide					
RP 206 Dalrymple Landcare Grant	Mgmt practice	Extension							GZ	sediment		2018-2023			
TF 11.5.3a Springvale erosion management plan implementation	Remediation	On ground works							GZ	Sediment		2018-22			
RP 191B Banana nutrient trials	Trials	trials							BN	nutrients		2018-23			
RP 199G Forage budgeting in the Fitzroy	Mgmt practice	extension							GZ	sediment					
TF 11.5.3c Springvale erosion mgmt. plan – seed bank	On ground works	Seed bank							GZ	Sediment		2018-19			
RP10C Safegauge for nutrients	Info	Info							SC	DIN		2011-2021			
TF 11.3.3 Pathways to water quality improvements in Mytrle Creek subcatchment									SC	DIN		2018-2021	SRA	Home - Sugar Research Australia	
RP 196 TF11.3.1 delivering tailored solutions to Mackay Whitsunday growers to improve nutrient management	Mgmt practice	Extension							SC	DIN		2018-22	Farmacist	RP196 TF11.3.1 Delivering tailored solutions to Mackay-Whitsunday growers to improve nutrient	

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
Note: considered accredited and low risk re regulation compliance														management | Project | BioCollect (des.qld.gov.au)	
RP 193G Forage Budgeting	Mgmt Practice	Info/ extension							GZ	sediment					
RP 120 Improving NUE for sugarcane with constrained yield potential	Mgmt practice/ trial	trial							SC	NUE		2019-2020		Possibly linked to Di Bella et al. (2015) but nothing on this program specifically	Yes
TF11.3.2 Janes Creek achieving whole system water quality improvement in the Mackay									SC	DIN		2018-21	DES	Janes Creek Landholders' Project - Reef Catchments	
TF 6.6.3 radishes for water quality	Mgmt Practice	trial							HC	Nutrients		2017-2020			
TF 6.6.2	Mgmt practice	Trial							GZ	Sediment		2017-2020			
TF6.6.1 Synchronised controlled release fertiliser	Trial	Trial							SC						
RP 219 Farming in reef Catchments rebate scheme									GZ, BN, SC			2018-2022		Programs & services | Queensland Rural and Industry Development Authority (qrida.qld.gov.au)	
Hort 360 GBR BMP Horti BMP	Mgmt practice	Extension BMP							HC other			2018-2023	Growcom	Hort360 – The health check card for your farm business	

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
RP 166C Enhanced efficiency fertiliser deep draining monitoring	Mgmt practice								SC			2016-2020			
RP 169 C Connecting Burdekin cane farmers to their wetlands	Mgmt practice													one page pdf report cards available https://www.nqdrytropics.com.au/projects/waterways-wetlands-and-coasts-program/connecting-burdekin-cane-farmers-to-their-local-wetlands-2016-2019/	
TF 11.3.5 Fitzroy River Catchment erosion gully restorations	On-ground words								GZ					Connected to: Wilkinson et al. (2019), Wilkinson et al. (2017)	Yes
11.5.2 Springvale erosion mgmt. plan	On-ground works								GZ			2016-2018		TF11.5.2 Springvale Station Erosion Management Plan | Project | BioCollect (des.qld.gov.au)	
TF 6.3 Innovative gully remediation	On-ground works - remediation								GZ					https://www.greeningaustralia.org.au/projects/rebuilding-eroding-land-2/	
RP105G Spatial arrangement and seasonal dynamics of cover in grazing lands	Tools for better planning								GZ	sediment					

Project	Action type	Delivery instrument	Region						Industry	Pollutant focus	$	Time frame	Delivered by:	Information available:	Scientific paper?
			Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary							
TF 8.2.1 Burdekin MIP (phase 1 2017-2021)*	Mgmt practice	Extension, incentives							GZ	Sediment		2017-2022		Waterhouse et al. (2021)	No
														Coggan et al. (2022)	yes
TF 8.3.1 WTMIP – Wet Tropics MIP (phase 1 2017-2021)*	Mgmt. practice	Extension for on ground change Financial incentive (Reef Credits)										2017-2022		TF8.3.1 WTMIP - Wet Tropics Major Integrated Project | Project | BioCollect (des.qld.gov.au) Reef Credit as Market-Based Incentive Mechanism – Eco Markets Australia	
														Waltham et al. (2021)	Yes

* Phase 2 funded by GBRF Reef Trust Partnership and included in Table 17

Not included:

- RP 225, 226, 227, 228 etc human dimension research (supporting but not directly seeking to influence land management practice for water quality benefit)
- TF 6.5.4 Denitrification bioreactor trial (wet tropics)
- Farmers for the future
- Reef Islands Initiative
- RP128G Sources of available particulate nutrients and organics phase 1 and 2
- TF 7.5 Enhancing management practice adoption monitoring and reporting
- TF 7.2 Enhanced condition enhanced monitoring
- TF 7.1 GBR catchment loads monitoring
- TF6.6.5 Bentonite and limestone use in sugarcane for improve soil and water quality
- TF 6.5.5 Validation of water quality improvement from constructed wetlands treatment trains in Mackay
- TF 6.5.3 Bioreactors
- RO 155C soil constraint mapping
- TF 6.5.2 constructed wetlands
- RP 112G Mapping erodible soils in grazing lands – Fitzroy (dataset)
- RP 143C Qualify residual soil nitrogen in sugarcane beds in Burdekin
- NESP 3.1.5 Ecotoxicology of pesticides on the GBR

4.1.5 Summary of study characteristics–Programs and instruments for urban land management focused on GBR water quality.

Of the 86 pieces of peer reviewed information, 37 relate to the management of water quality from an urban environment. One of these is a scientific journal article whilst the remainder are peer reviewed reports.

Management of urban runoff is the responsibility of government, the development and construction industry, and water service providers with support from peak bodies such as the Local Government Association of Queensland (LGAQ) and NRM organisations. In the GBR catchments, local government is responsible for managing wastewater treatment and stormwater compliance in line with State Government legislation.

Under the Reef 2050 Long Term Sustainability Plan (funded by Australian and Queensland Governments), Regional Report Card partnerships have been formed and named: Gladstone Healthy Harbour Partnership; Wet Tropics Waterways; Dry Tropics Partnership for Healthy Waterways; Mackay Whitsunday Isaac Healthy Rivers to Reef Partnership; and Fitzroy Partnership for River Health. Technical reports and findings from these partnerships are summarised in Table 21. The Regional Report Cards developed as a part of the partnerships inform the state and condition for freshwater basin, estuarine, inshore marine and offshore marine environments at a regional scale.

By monitoring freshwater water quality along with many other ecosystem health indicators within basins, coastal and marine areas, the reports provide tools to inform policy and guide future initiatives in the GBR catchment area. However, each partnership has their own indexes and scoring ranges which hinders comparisons between them.

Besides the annually released Regional Report Cards, partnerships also report on (n=40) initiatives being implemented in their regions with the objective to improve the quality of water in local waterways that flow to the GBR and adjacent estuarine and marine environments in Water Stewardship Reports (Table 21). These local initiatives include government, local communities (which includes Traditional Owners), industry stakeholders and rural landholders, among others. The form of intervention described in these initiatives varies from extension, financial incentive and education and between industries and locations. This review focused on the initiatives to improve water quality that are identified in the report cards, however the reports can be broader in scope and may also include initiatives to monitor seagrass habitats, seagrass monitoring or reducing the use of freshwater from agriculture, for example.

In addition to the regional report cards and stewardship reports, a more recent scheme is the Urban Water Stewardship Framework (UWSF) which exists under the Queensland Reef Water Quality Program. The framework focuses on erosion and sediment control during construction of urban development, stormwater runoff in established areas and operation and maintenance of sewage treatment plants and associated sewer networks. The framework aims to provide valuable information to local governments, such as areas where improvements can be made and how to enhance urban water management practices and contribute to the preservation of the GBR.

4.1.6 Synthesis of evidence – Programs and instruments for urban land management focused on GBR water quality

Table 21 synthesises investment and information available related to the Urban Water Stewardship Framework and the Regional Report Cards. The table synthesises the:

- Project name and delivery organisation
- Time frame of implementation
- Action type (management practice focus etc.)
- Catchment(s) of focus

These synthesis tables also highlight the extent and quality (in terms of level of peer review) of information. Figure 7 provides important information for understanding the Table 21.

Quality of reports
No Reports available
Info/Reports available BUT not peer reviewed
Reports available AND peer reviewed

Figure 7. Key for understanding urban reports.

Table 21. Queensland Government Program: Reef Water Quality Protection Program (URBAN). Note: B'kn = Burdekin, MWS -= Mackay Whitsunday.

Project	Action type	Region						Time frame	Delivered by:	Information available:	Scientific paper?	Other info
		Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary					
RRC06 Urban Water Mgmt Practice and Stewardship Framework for report cards 1								2018-2020		Mentioned in Flint et al. (2021)	Yes	
										RRC06 Urban Water Management Practice and Stewardship Framework for Report Cards | Project | BioCollect (des.qld.gov.au)	no	
								2018-2021	Dry Tropics Partnership for healthy waterways	Dry Tropics Partnership for Healthy Waterways (2021b)	no	
								2020-2021	Wet Tropics Waterways Partnership	Wet Tropics Waterways (2021)	no	
Healthy Water Partnerships								2020-2021	Fitzroy Partnership for river health Partnership	Fitzroy Partnership for River Health (2022a)	no	
								2019-2020		Fitzroy Partnership for River Health (2021a)	no	
								2020-2021	Mackay Whitsunday Isaac healthy rivers to Reef Partnership	Mackay Whitsunday Isaac Healthy Rivers to Reef Partnership (2021b)	no	
								2021-2022		Mackay Whitsunday Isaac Healthy Rivers to Reef Partnership (2022a)	no	

Project	Action type	Region						Time frame	Delivered by:	Information available:	Scientific paper?	Other info
		Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary					
								2020-2021	Gladstone Healthy Harbour Partnership	Gladstone Healthy Harbour Partnership (2022b)	no	
								2019-2020		Gladstone Healthy Harbour Partnership (2021b)	no	
RRC05 Dry Tropics Partnership for healthy waterways	Regional report cards							2018-2019	Dry Tropics Partnership for healthy waterways	Whitehead (2020)	no	
								2019-2020		Whitehead (2021)	no	
								2020-2021		Whitehead (2022)	no	
								2020-2021		Dry Tropics Partnership for Healthy Waterways (2021a)	no	
								2019-2020		Dry Tropics Partnership for Healthy Waterways (2020)	no	
								2018-2019		Dry Tropics Partnership for Healthy Waterways (2019a)	no	
								2017-2018		Dry Tropics Partnership for Healthy Waterways (2019b)	no	
RRC04 Fitzroy Partnership for river health	Regional report cards							2020-2021		Fitzroy Partnership for River Health (2022b)	no	
								2019-2020		Fitzroy Partnership for River Health (2021b)	no	
								2018-2019		Fitzroy Partnership for River Health (2020)	no	
								2017-2018		Fitzroy Partnership for River Health (2019)	no	
RRC03 Wet Tropics Waterways Partnership	Regional report cards							2020-2021	Wet Tropics Waterways Partnership	Wet Tropics Waterways (2022b)	no	
								2020-2021		Wet Tropics Waterways (2022a)		
RRC02 Gladstone Healthy Harbour Partnership	Regional report cards							2021-2022	Gladstone Healthy Harbour Partnership	Gladstone Healthy Harbour Partnership (2022a)	no	
								2020-2021		Gladstone Healthy Harbour Partnership (2021a)	no	

Project	Action type	Region						Time frame	Delivered by:	Information available:	Scientific paper?	Other info
		Cape York	Wet Tropics	B'kn	MWS	Fitzroy	Burnett Mary					
								2019-2020		Gladstone Healthy Harbour Partnership (2020)	no	
								2018-2019		Gladstone Healthy Harbour Partnership (2019)	no	
								2017-208		Gladstone Healthy Harbour Partnership (2018)	no	
								2021-2022		Gladstone Healthy Harbour Partnership (2022c)	no	
								2020-2021		Gladstone Healthy Harbour Partnership (2021c)	no	
										Mentioned in Flint et al. (2021)	Yes	
RRC01 Mackay Whitsunday Isaac healthy rivers to Reef Partnership	Regional report cards							2020-2021	Mackay Whitsunday Isaac healthy rivers to Reef Partnership	Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2022b)	no	
								2019-2020		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2021c)	no	
								2018-2019		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2020b)	no	
								2017-2018		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2019b)	no	
								2020-2021		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2021a)	no	
								2019-2020		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2020a)	no	
								2018-2019		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2019a)	no	
								2017-2018		Mackay Whitsunday Isaac healthy rivers to Reef Partnership (2018)	no	
RP218 Wastewater Stewardship Strategic assessment								2019-2020		Reef Councils Major Integrated Project STP Upgrade Considerations (qldwater.com.au)		

1. Gladstone and Mackay do not have a report for UWSF but the results are within the other water stewardship reports

4.1.7 Summary of study characteristics–Regulation for agricultural land management focused on GBR water quality.

Of the 86 pieces of peer reviewed literature suitable for assessment, 28 mention regulation somewhere in the document. However, only three papers go into detail about the implementation and effectiveness of regulation. These are Deane et al. (2018), Eberhard et al. (2021a) and Hamman et al. (2022). Of these, Hamman et al. (2022) provides the most focus on regulations.

Part 2 - How effective are the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?

4.1.8 Summary of study characteristics – How effective?

Studies found were classified according to whether they related to agricultural land practices or urban land; agricultural land was then further sub-divided according to type of agriculture – grazing, sugarcane, etc. Studies within each category were further classified by the instrument used to drive the change in practice. Studies were also classified as:

Observational:	Reporting results of direct assessment of the instrument through primary data collection.
Secondary:	Reporting some insights gathered from review of other assessments (not collecting primary information).
Secondary/conceptual:	Reporting on a trial or analysis of a new concept or critique of method
Modelled	Reporting a hypothetical scenario based on modeled data (this could sometimes provide insight into effectiveness).
Technical support:	Reporting on effectiveness of technical support for program (not detailed in this question).

Agricultural land use - Grazing

Studies relating to the grazing industry (n=20) are summarised in Table 22, indicating the type of instrument(s) considered in each study, and whether the study used primary information (n=12) or was based on modelling (n=4) or based on observation from a role of technical support within a program (n= 2). As can be seen, the programs studied in these papers can be categorised into two groups: i) those predominantly focused on facilitative instruments, either alone or in conjunction with financial instruments; and ii) papers focusing on on-ground works, where significant investment is made to remedy large gullies on the land, with works mainly funded, and in many cases, directly managed by the program rather than the individual landholder. The reported effectiveness of these two categories is considered separately in the section below. Hamman et al. (2022) also discusses regulation in relation to grazing, but discussion of regulation is not included further here. [18]

[18] 28 studies refer to regulation however only Hamman et.al (2022) provide detail about the use of regulation as a tool to generate land management practices for water quality outcomes. Hamman makes some mention of change in compliance (so potentially improved effectiveness) but effectiveness of regulation is not assessed in detail.

Table 22. Summary of relevant grazing focused papers by instrument.

Reference	Instrument type:			Is there a focus on on-ground works	Observational or Modelled study
	Facilitative	Incentive (Financial)	Coercive (Regulation and compliance)		
Alluvium (2023)	X	X		Multiple projects – overall number of gullies/ properties unspecified	Secondary
Barbi et al. (2015)	X				Observational
Brown (2017)	X				Observational
Coggan et al. (2022)	X	X			Observational
Hamman et al. (2022)			X		Secondary
Long (2017)	X				Observational
Moravek et al. (2017)	X				Observational
Moravek and Nelson (2015)	X				Observational
Baker et al. (2021)	X				Observational
Rolfe et al. (2021)	X	X			Observational
Rust and Star (2018)				6 properties	Observational (cost effectiveness)
Star et al. (2015)	X				Modelled
Star et al. (2017)	X				Modelled
Star et al. (2018)*					Modelled
Star et al. (2019)				75 landholders	Modelled
Queensland Audit Office (2015)	X				Secondary
Waterhouse et al. (2021)	X	X		19 gullies (plus 5 streambank & 5 erosion control projects)	Observational
Wilkinson et al. (2017)				170 gullies	Technical support
Wilkinson et al. (2019)				210 gullies	Technical support
Willis et al. (2017)	X				Observational

* Include sugar cane landholders in addition to graziers

Agricultural land use – Sugarcane

Of the 86 peer reviewed pieces of evidence, 27 related to sugarcane (Table 23). Of these, most analysis was focused on the implementation (n=8) or conceptual development of facilitative type instruments (n=7). Four were modelled studies and eight were secondary reviews. There were a number of studies that assessed the actual or potential application (and design) of financial incentive instruments.

Table 23. Summary of relevant sugarcane focused papers by instrument.

Reference	Instrument type:			Focus on:		Study type
	Facilitative	Incentive (Financial)	Coercive (Regulation and compliance)	On ground works	Tech/new method	
Wegscheidl et al. (2015)	X					Observational
Royle and Di Bella (2017)	X					Observational

Reference	Instrument type:			Focus on:		Study type
	Facilitative	Incentive (Financial)	Coercive (Regulation and compliance)	On ground works	Tech/new method	
Waltham et al. (2021)						Modelled
van Grieken et al. (2019)		X				Modelled
Di Bella et al. (2015)	X					Observational
Davis et al. (2021)	X				X	Secondary - conceptual
Deane et al. (2018)	X	X				Observation
Rolfe et al. (2018)		X				Secondary-conceptual
Davis et al. (2019)	X				X	Secondary–conceptual
Eberhard et al. (2021a)		X				Secondary
Hamman et al. (2022)			X			Secondary
Rouse and Davenport (2017)	X					Observational
Queensland Audit Office (2015)	X					Secondary
Vilas et al. (2020)	X				X	Secondary
Kealley et al. (2022)					X	Secondary/conceptual
Kealley et al. (2021)					X	Secondary/conceptual
Kealley and Quirk (2016)	X					Observational
Pickering et al. (2019b)	X					Observational
Pickering et al. (2019a)					X	Secondary
Connellan et al. (2022)	X					Observation
De Valck et al. (2022)		X				Modelled
Oza et al. (2021)				X		Modelled
Alluvium (2023)	X	X (4 tenders, one grant)				Secondary
Waterhouse and Pineda (2021)	X	X			X	Secondary
Smart et al. (2020) (cited in Waterhouse et al., 2021)		X			X	Secondary/conceptual
Thorburn et al. (2020)		X			X	Secondary/conceptual
Rundle-Thiele et al. (2021) (cited in Waterhouse et al., 2021)		X				Secondary

Agricultural land use - Other

Beyond grazing and sugarcane, there have been a small number of studies (n=6) that have focused on other agricultural industries, these studies are summarised in Table 24. These studies focused either on facilitative instruments alone, generally in conjunction with BMP programs, or a combination of facilitative and financial incentive instruments. Most of these studies reported observational results (n=4) with two studies reporting on modelled results. The reported effective of these programs are considered separately below.

Table 24. Summary of relevant papers to other agriculture by instrument.

Reference	Type of 'Other Agriculture' included	Instrument type:			Observational or Modelled study
		Facilitative	Incentive (Financial)	Coercive (Regulation and compliance)	
Alluvium (2023)	Crops (Grains)	X	X		Observational
	Horticulture	X	X		Observational
	Dairy	X	X		Observational
Eames and Collins (2017)	Crops (Grains)	X			Observational
Harvey et al. (2018)	Horticulture (bananas)	X			Observational
Holligan et al. (2017)	Horticulture (bananas)	X	X		Modelled
Owens et al. (2017)	Crops (Grains)	X			Modelled
Soil, Catchment and Riverine Processes Group (2022)	Crops (Note 1)	X			Observational
	Crops (Cotton)	X			Observational
	Horticulture (Note 2)	X			Observational

Note 1: Crops included cereals and pulses; Note 2: Sought to include bananas, macadamias, avocados, vegetables and pineapples, but most of the available data related to bananas.

Non-agricultural (urban) land use

Beyond agriculture there have been 15 peer reviewed studies focusing on initiatives to change urban water management such that it improves GBR water quality. The majority of evidence available to assess the effectiveness of urban focused programs is included within the Urban Water Framework, Regional Report Card initiative. Two journal papers which contained some information about urban water programs, their implementation and their effectiveness were found. Flint et al. (2021) includes an assessment of mud crab health as a way of understanding changes in urban water quality in Gladstone Harbour and Smart et al. (2020), exploring the potential for point and non-point source nutrient trading, highlights that an innovative finance scheme such as this is one has the potential to be a cost-effective way to motivate for improved land management for urban water quality improvement

4.1.9 Synthesis of evidence – How effective have program and instruments been? (Agricultural land use – Grazing)

Evidence on effectiveness of interventions for grazing are discussed within the categories of:

Facilitative instruments for land management:	• Were objectives met? • Effectiveness in terms of Bronze, Silver, Gold, Platinum and Taupo indicators. • Other measures of effectiveness (cost effectiveness). • Insights on effectiveness from modelled studies.
Instruments to generate on-ground works:	• Effectiveness in terms of Bronze, Silver, Gold, Platinum and Taupo indicators. • Other measures of effectiveness (cost effectiveness). • Insights on effectiveness from modelled studies.

Facilitative instruments, either used alone or in conjunction with financial instruments for land management

The selected papers (n=11) covered a wide range of GBR programs, including the Reef Trust suite of programs and projects (Alluvium, 2023), Project Pioneer (Rolfe et al., 2021), Better Beef for the Reef (Baker et al., 2021), Burdekin MIP (Coggan et al., 2022; Waterhouse et al., 2021), GRASS (Coggan et al., 2022), and Better Economic & Financial Futures (Barbi et al., 2015), with a number of projects relating to

the Grazing BMP program (Brown, 2017; Long, 2015; Moravek & Nelson, 2015; Queensland Audit Office, 2015; Willis et al., 2017). All of these programs included a focus on the importance of facilitative instruments such as extension in influencing grazing land management practices, with a number of the grazing programs also including financial incentives such as grants alongside the extension services offered. The work also focused on a variety of catchments across the GBR region, with some studies reporting on work in more than one catchment, the regions covered by the studies were as follows: Cape York (Rolfe et al., 2021), Burdekin (Brown, 2017; Coggan et al., 2022; Long, 2017; Moravek et al., 2017; Waterhouse et al., 2021; Willis et al., 2017), Fitzroy (Barbi et al., 2015; Brown, 2017; Coggan et al., 2022; Long, 2017; Rolfe et al., 2021) and Burnett Mary (Baker et al., 2021; Brown, 2017; Long, 2017; Rolfe et al., 2021). Two papers reported on all regions across the GBR (Alluvium, 2023; Queensland Audit Office, 2015).

How effective these programs and instruments have been, assessed using the bronze to Taupo framework, is discussed below. The effectiveness assessment only applies to literature that presented an observational study of a program and/or instrument.

Floor level of effectiveness - did the program/instrument meet objectives?

A number of observational studies provided reflection into if the program/instrument achieved a baseline or floor level of understanding effectiveness along the lines of – did the implementation of the instrument achieve the objectives? [19] These, and their findings are reported in Table 25.

Table 25. In the peer reviewed literature, is there information about the floor level of effectiveness of land management interventions - were objectives set and met?

Program assessed	Reference	Instrument type	Objective of the intervention	Did it meet its objectives?
CQ BEEF	Barbi et al. (2015)	Facilitative /Extension	Did CQ BEEF impact ground cover	Assessed this, did not meet ground cover.
Grazing BMP	Brown (2017)	Facilitative /Extension	Objective of the instrument was to assist graziers identify improved practices to enhance profitability and sustainability of grazing businesses.	Yes: in terms of sustainability: *84% considered changes to their business; *73% had commenced or completed changes;*30% adopted improved strategies to maintain land declining in condition *The percentage of respondents using land condition monitoring increased from 5.4% prior to attending Grazing BMP workshops and extension activities to 19.6% after participation in the Grazing BMP program.
	Long (2017)		Not noted in paper	Not noted in paper
	Moravek et al. (2017)		The aim of the instrument was to support beef producers to adopt grazing systems that are productive and profitable with	Yes, notes percentage of respondents, by management category, who indicated a practice change – 51% indicated a practice change in grazing land

[19] Most, if not all, the programs and instruments implemented in GBR catchments will have monitoring and evaluation procedures and documentation. This information does not meet the requirements of the review in that these reports are not considered to be independently peer reviewed. Therefore, information about meeting objectives in such reports are not included here unless already included in the peer reviewed evidence.

Program assessed	Reference	Instrument type	Objective of the intervention	Did it meet its objectives?
			improved water quality outcomes for the GBR.	management, 38% in animal management and 50% in business management over the years 2013-2015.
	Moravek and Nelson (2015)		Adoption of grazing BMP for water quality outcomes	76.1% of producers who participated in one or more of the projects activities had made a practice change (but what practice and for how long was not reported)
	Queensland Audit Office (2015)		1,500 modules completed in self-assessment.	1,789 achieved self-assessment.
			360 business completing all modules.	783 businesses certified completed.
			30 businesses accredited.	10 accredited (so therefore considered to be partial success).
	Willis et al. (2017)		Objective of the instrument was to encourage beef producers to adopt practices that result in productive and profitable grazing systems that also have improved water quality outcomes for the GBR.	Did well on delivery of modules but not well on accreditation.
Better Beef for the Reef	Baker et al. (2021)	Facilitative /Extension	Objective of the instrument was to engage with previously unengaged farmers to achieve reduced sediment runoff, and increase on-farm profitability, productivity ad sustainability.	Yes, 85% of unengaged farmers improved knowledge or skills in sustainable land management, and implemented a practice change (which can be measured in P2R[20]).
Project Pioneer	Rolfe et al. (2021)	Facilitative /Extension	Objective of the instrument was to improve property management capacity, profitability and reduce sediment entering the GBR.	Yes, but noted difficulty to measure accurately with climate impacts and short timeframes. Water quality change modelled using P2R.
Burdekin MIP (Landholders Driving Change (LDC))	Waterhouse et al. (2021)	Facilitative /Extension, financial incentives and on-ground works	Demonstrate the ability of land management and catchment remediation efforts to reduce sediment and associated particulate nutrient loads exported from the Burdekin River to the GBR.	Yes – demonstrated a reduction in sediment but reported as a 44% contribution to all of Burdekin's reduction in sediment load which in total was less than 1% of the targeted end of catchment load reduction.

[20]P2R is the Paddock to Reef Program Integrated Monitoring, Modelling and Reporting Program often referred to as Paddock to Reef or P2R. For more information see Paddock to Reef | Reef 2050 Water Quality Improvement Plan (reefplan.qld.gov.au)

Bronze level of effectiveness – human dimensions and KASA

Studies focusing on grazing included those with a very small number of participants through to larger studies. For example, Baker et al. (2021) report on the results of funding on-farm demonstration sites (although also engaged more widely on other aspects of the work), and Rolfe et al. (2021) whose surveys had 18 and 23 respondents in 2017 and 2019 respectively. Others reported on the large numbers that have engaged with BMP programs, for example, it was reported that by 2016, 1,652 grazing businesses had completed at least one BMP module (Brown, 2017), with other studies lying between these extremes.

Improvements in one or more dimensions of landholder's knowledge, attitudes, skills and aspirations were noted by quite a number of studies. Studies linked to BMP programs were able to report increased knowledge and skills in terms of completing BMP modules (Brown, 2017; Queensland Audit Office, 2015) and engaging in the program (Long, 2017; Moravek et al., 2017). Specifically, Willis et al. (2017) report 80% KASA improvement from BMP programs, and Baker et al. (2021) reported an 85% improvement. The need for further learning was also highlighted, with Long (2017) reporting that 78% were seeking training and/or information on multiple topics. Rolfe et al. (2021) analysed surveys collected from landholders in 2017 & 2019, which also asked questions referring to practices from five years earlier and reported increased landholder engagement and improved understanding (hence knowledge) of their business, and improved skills in managing risk, all of which should improve management practices and promote future adoption of best management practices. One study highlighted that extension programs have provided graziers with knowledge to understand the importance of ground cover (Barbi et al., 2015) and noted that a suite of extension activities across different management practices are required, enabling graziers to select the activities that are appropriate for their needs.

The Burdekin MIP program was also noted to have promoted knowledge and skills amongst participating landholders (Coggan et al., 2022; Waterhouse et al., 2021). Of the landholders in the program, 90% were reported as having positive attitudes towards improved practices; further the design of the program and the mix of tailored extension and incentive investments were credited with encouraging previously low or unengaged landholders to engage. Coggan et al. (2022) described how landholders engaged in the GRASS program had reported that the improved land practices required specific knowledge and skills best provided by experts and thus recommended that a public provider of services such as contour mapping could be required to address the gap.

Alluvium (2023) reports on the achievements of the suite of Reef Trust projects offered. This study reports on improvements to the KASA of the engaged landholders, provided through many different events, including workshops, field days, one-on-one extension training, development of case studies, and video presentations. Also, similar to Coggan et al. (2022), reports on the importance of project teams/extension officers working in long-term partnerships over long-term timeframes to ensure desired outcomes from training and extension services provided.

Focusing on Grazing BMP projects, Queensland Audit Office (2015) reported that the program had met two of three targets, with self-assessment completion of modules, and number of graziers certified for completing five modules being above target. While only ten graziers were fully accredited, compared to a target of 30, 100% of these had been audited to confirm the accreditation.

Silver and gold level of effectiveness – landholders adopt some change in behavior

Rolfe et al. (2021) demonstrated that the Project Pioneer program resulted in adoption of improved practices, comparing those practices that were most used five years ago to those that are most used currently. The authors argue that the fact that land condition and pasture budgeting were now identified as the most important ways of setting stocking rates indicates that participants were moving towards more technical and best practice approaches, and thus the program has achieved gold level effectiveness – change achieved from specific practices to improved specific practices. As an example of this, landholders felt that as a result of involvement in Project Pioneer, they had made the most changes

in paddock spelling, data records for pasture, financial management and people management (forward planning).

Brown (2017), from a phone survey of 92 graziers who had completed the whole BMP program, reported that 73% had commenced or completed changes to the land management practices, and also reported some information on the changes that had been adopted, such as an increase from 5% to 20% of graziers who engage in land condition monitoring. Sixty-one graziers had been accredited by the BMP program, which required their practices to be audited and changes confirmed. In further evidence relating to the effectiveness of BMP programs, Willis et al. (2017) reported with 95% confidence that 65-87% of the beef producers who undertook activities achieved real change.

Similarly, Moravek et al. (2017) reported with 95% confidence that 78% of those graziers engaging in extension and/or workshops had changed their practices and reported that "Producers who interacted with DAF officers on grazing land management (GLM) topics were significantly more likely to make a GLM practice change than those who did not engage in GLM extension activities" (page 74). However, no information was provided on what they had changed from or changed to. Findings were echoed by Long (2017), reporting that 85% of those that were engaged had made at least one change to their practices. Broad information is provided on the types of changes, such as 15% have implemented changes in herd management, but specific details of previous or current practices are not supplied.

Other studies also reported that practice changes had been implemented but provided limited details. Baker et al. (2021) reported 17 farmers adopted practices measurable under P2R but did not provide information regarding what these farmers had changed from or to.

Coggan et al. (2022) reported that programs had encouraged landholders to trial new practices, such as pregnancy scan technology, water telemetry, weep wipe, weed mister and fire management planning, promoted by the 'Exploring New Incentives' component of the Burdekin MIP. The program overall engaged with landholders in a range of different projects, facilitating improved practices relating to grazing land management (GLM) wire and water projects, revegetation, and utilising a grader to reduce run off (Waterhouse et al., 2021).

Interestingly, it was noted by one study that the type of interaction – extension, workshops, or combination of both – were equally as likely to promote practice change (Moravek et al., 2017) while another noted that one-on-one extension activities were particularly effective for long term practice change whilst workshops and field days had only limited effectiveness in engaging 'unengaged' landholders (Baker et al., 2021). Coggan et al. (2022) described how the transaction costs involved in adopting a new practice can be reduced by involvement in a program that provides both extension and financial incentives (grants), as the mix of offerings can together address multiple barriers to adoption, rather than just focusing on knowledge or capital investment barriers.

Platinum levels of effectiveness

While studies cannot prove that changes will continue to be adopted in the future, in some instances they are able to provide evidence that ongoing change is likely. Rolfe et al. (2021) states that increased landholder engagement and improved understanding of their business and engagement in future programs should underpin ongoing adoption. Coggan et al. (2022) note the importance of establishing and nurturing relationships between extension officers and landholders, as this reduces the transaction costs and breaks down barriers to adoption, and continuing to adopt, new improved land management practices. Waterhouse et al. (2021) did not explicitly discuss intentions to continue with the improved practices adopted but did refer to intentions for further adoption of new improved practices in future, whilst Alluvium (2023) did report that as a result of the projects landholders will be more committed to water quality improvements in future.

Other studies made no mention on intentions to maintain changes, and thus do not provide evidence of meeting the platinum effectiveness threshold.

Taupo level of effectiveness

The Burdekin MIP project was reported to be effective at the Taupo scale, as the various land management projects (excluding on-ground gully remediation works discussed separately below) was reported to have removed 2,831 tonnes of sediment per year from the system for GLM wire and water projects, and 1,383 t yr^{-1} by the grader project.

Various Reef Trust projects also reported the amount of sediment removed from the system as a result of the project, thus indicating effectiveness at the Taupo scale. Across projects 1.02, 3.06, 3.08, and 4.04 it was reported that a total of 72,285 t yr^{-1} of sediment had been removed, with two further projects (7.02 and 7.05) not included in that total due to the projects still being active which meant that savings were hard to assess (Alluvium, 2023).

A number of the programs reported on provide information to the Paddock to Reef (P2R) Grazing Water Quality Risk frameworks, which allows links between land management practices and the condition of the resource – that is improved practices should reduce sediment and improve water quality over time. Accordingly, by linking results to P2R, certain studies are able to report that the programs have been effective at improving water quality and thus achieved Taupo level effectiveness (Baker et al., 2021; Rolfe et al., 2021).

Other studies made no mention of how the program reported on could be related to water quality changes, and thus do not provide evidence of meeting the Taupo effectiveness threshold (Brown, 2017; Coggan et al., 2022; Long, 2017; Moravek et al., 2017; Willis et al., 2017). The programs reported on in these papers may actually be part of the P2R system, however this was not specifically stated in the papers cited.

Barbi et al. (2015) reported the starting practice in terms of the water quality risk framework but did not report on changes in practices, instead seeking to report on the impact of practices, comparing the ground cover of properties engaged in a particular extension program with the ground cover of a control that were not engaged in the program. No clear correlation was found between ground cover and management practices, suggesting improved practices may not be sufficient to achieve water quality targets, however the authors of the study do qualify their results as based on small sample size and potential bias introduced by their sample selection methodology. Table 28 provides a summary of knowledge about effectiveness of interventions for land management change for GBR water quality outcomes for grazing.

Overall understanding of effectiveness - grazing.

The most peer reviewed evidence about effectiveness exists for the application of extension. Peer reviewed evidence about extension in grazing (n=12) primarily reports effectiveness at a lower level (KASA) (n=9) with a smaller cohort (n=6) providing insight into the extent of land management practice change as a result of the extension intervention (medium level of understanding of effectiveness). Five pieces of evidence linking extension to some change in water quality improvement (Taupo standard) were recorded. Within this cohort of papers, three reported on extension with financial instruments and two were included in the cohort which reported on the known, modelled or potential improvement in water quality improvement (one study reported on extension plus financial instruments but did not focus on understanding effectiveness in terms of water quality change). It is important to note here that this is an underrepresentation of the understanding of effectiveness as one study includes analysis of 25 applications of extension (some with financial support attached) for grazing, all of which report on a modelled change in water quality (see Table 26). Understanding of the effectiveness of on-ground works is of a high standard with most studies reporting an understanding of change in water quality connected to works.

Table 26. Summary of knowledge about effectiveness of grazing interventions for land management change for GBR water quality outcomes (based on peer reviewed evidence).

Intervention name	Instrument	Reference	Based on the evidence did it achieve objectives?	Does the study report on:					
				KASA (Bronze)	Bronze plus (participation)	Silver (number adopting change)	Gold (extent of change)	Platinum (longevity)	Taupo (water quality change)
CQ Beef	Extension	Barbi et al. (2015)	No	Not assessed	Not known	Not known	Know what they changed from and to in terms of ground cover.	Not reported	Not reported
Grazing BMP	Extension	Brown (2017)	Partial based on best evidence from Queensland Audit Office (2015)	Knowledge and skills	Yes, numbers completing modules and accredited are reported		Yes, for some land management practices	Not reported	No – reports in terms of ABCD land condition not P2R water quality risk framework.
		Long (2017)		Not assessed	Yes	No- plans to change	No	No	No
		Moravek et al. (2017)		Yes – a big focus		No	No	No	No
		Willis et al. (2017)		Yes	Yes, in terms of modules completed		No	No	No
		Queensland Audit Office (2015)		Yes	Yes, in terms of modules completed		No	No	No
Better beef for the reef	Extension	Baker et al. (2021)	Yes	Yes	Yes	Yes	No	No	Partial – reports that 17 practices that were measurable under P2R were adopted but does not say what they

Intervention name	Instrument	Reference	Based on the evidence did it achieve objectives?	Does the study report on:					
				KASA (Bronze)	Bronze plus (participation)	Silver (number adopting change)	Gold (extent of change)	Platinum (longevity)	Taupo (water quality change)
									were so cannot extrapolate further.
Project Pioneer	Extension	Rolfe et al. (2021)	Yes but challenges with reporting	yes	yes	yes	yes	Mentioned	Yes, through P2R with some assumptions. These could be extrapolated further if required (and was done by Alluvium (2023) (see below).
		Alluvium (2023)	yes	yes	yes	yes	yes	yes	Yes, notes adoption of P2R area of practice change at 598,990 ha equating to a sediment saving of 12,736 t (total).
Burdekin MIP	Extension, financial instruments and on-ground works	Waterhouse et al. (2021)	Yes, in terms of demonstrating land management and sediment reduction (based on Waterhouse et al. (2021)	Yes	yes	yes	yes	No	Yes, know tonnes of reduction for each intervention type. Up to July 2021, the LDC project is reported to have reduced fine sediment by 10,600 t yr^{-1}.
		Coggan et al. (2022)		Partial	Not the focus of the study				
Reef Trust	Various (covers 25 applications)	Alluvium (2023)	yes	yes	yes	yes	yes	yes	See Table 27

*Table 27. Sediment reduction from Reef Trust grazing investment (as reported in Alluvium (2023)) * (G) = based on good evidence, (M)=based on moderate quality evidence, (P)=based on poor evidence.*

Intervention name	Instrument	$ invested	Reported P2R area of practice change (ha)	Reported tonnes of sediment saved**	Reported cost effectiveness
RT 1.02 Promotion of A class Grazing (Fitzroy and Burdekin)	Extension – mgmt. practice change	$3m	44,085	2,046	$1,466/t (G)
RT 2.01 Fifty percent reduction in gully erosion from high priority sub catchments in the Normanby (Cape York)	Direct invite and support to delivery partner to deliver targeted landscape repair through technical support and on-ground works.	$708,248	360	556	$1,187/t (G)
RT 2.02 Gully prevention and remediation over 11,000 ha on Normanby River, Kings Plain (Cape York)	As above	$304,400	44,139	18,030	$16/t (G)
RT 2.04 Point Source Sediment Management in the Burdekin Dry Tropics NRM region - East Burdekin	As above	$906,000	Not reported	80	$10,220/t (G)
RT 2.05 Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management – Theresa (Fitzroy)	As above	$702,884	6,473	56	$11,776/t (G)
RT 2.06 Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management - Fitzroy	As above	$702,884	1,090	1,906	$336/t (G)
RT 2.07 Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management – Mackenzie (Fitzroy)	As above	$702,884	1,504	181	$3,534/t (G)
RT2.08 Gully Remediation in the Fitzroy by Revegetation and Grazing Land Management – Isaac (Fitzroy)	As above	$702,884	1,598	179	$3,684/t (G)
RT 2.09 Don River Catchment Sediment Reduction Project: Improving GBR water quality (Burdekin)	As above	$962,550	262	51	$17,805/t (G)

Intervention name	Instrument	$ invested	Reported P2R area of practice change (ha)	Reported tonnes of sediment saved**	Reported cost effectiveness
RT 2.10 Gully management in highly erodible sub-catchments of the Mary River Catchment	As above	$808,760	172	810	$924/t (G)
RT 2.11 Point Source Sediment Management in the Burdekin Dry Tropics NRM Region	As above	$906,000	2,114	565	$1,478/t (M)
RT 3.06 Reef Alliance – Growing a Great Barrier Reef GRAZING (all GBR catchments)	As above	$21,592,000	1,373,024	46,569	$423/t (G)
RT3.08 Project Pioneer: Innovation in Grazing Land Management (all GBR catchments)	As above	$2,908,000	598,990	12,736	$228/t (G)
RT 4.04 GRZ'M. Great Barrier Reef Riparian Zone Management - a Mary project	As above	$3,027,000	7	11,934	$210/t (G)
RT 4.05 streambank remediation in priority areas (Cape York)	As above	$4m	23	482	$7,067/t (G)
RT 4.06 Fitzroy subcatchment gully and stream bank erosion control program	As above	$3,891,070	2,296	6,648	$496/t (G)
RT 4.07 Stream bank and gully erosion control through improved practices in the Fitzroy	As above	$3,867,325	819	6,037	$584/t (G)
RT 4.08 Improving reef water quality through Herbert River catchments & gully remediation (Wet Tropics)	As above	$2,974,773	631	828	$3,067/t (G)
RT 4.09 Gully restoration in priority reaches to improve water quality in the GBR (Burdekin)	As above	$3,770,000	225	3,512	$1,038 (G)
RT 4.10 Laura Gullies Project, fix up and skills for the future (Cape York)	As above	$2,065,000	7,770	1,222	$1,466/t (G)
RT 4.11 Stomping out Sediment in the Burdekin - livestock impact for gully remediation	As above	$2m	1,186	1,664	$1,033/t (G)
RT 4.12 High priority stream bank erosion control in the Mackay Whitsunday	As above	$4m		8,295	$411/t (G)

Intervention name	Instrument	$ invested	Reported P2R area of practice change (ha)	Reported tonnes of sediment saved**	Reported cost effectiveness
RT7.01 Improving land management practices and water quality in the Burnett River catchment	Extension and financial support for actions	$6,099,986		15,000	Not available
RT 7.02 Water quality and soil improvements in grazing and cropping enterprises in the Fitzroy	Extension and financial support for actions	$5,700,000	Not finished	Not finished	Not available
RT 7.04 Streambank remediation in the Burdekin catchment	Extension and support for on ground works	$2,900,000		6,178	Not available
RT7.05 Targeted support to maximise soil, biodiversity and vegetation outcomes in the O'Connell and Proserpine Basins of the Mackay Whitsundays	Extension and support for on ground works	$5,612,947		1,500	Not available

* Note, many of these are for investment in on-ground works (see also Table 28)

** Alluvium (2023) highlight assumptions and other factors that influence the quality of the data used in load reduction estimate. These need to be considered when interpreting effectiveness.

Other measures of effectiveness - Cost effectiveness of interventions

The cost effectiveness of the Burdekin MIP interventions was evaluated, finding that GLM support programs ranged from $2.20/tonne/year to $223/tonne/year, providing an average cost of $27/tonne/year (Waterhouse et al., 2021). The Grader projects was reported to have been consistently cost effective, with 22 out of 25 projects costing less than $40/tonne/year of sediment reduced.

The cost effectiveness of various Reef Trust projects was also evaluated, with costs per tonne per year of sediment reduction ranging from $210/tonne/year for project 7.04 through to $1,466/tonne/year for project 1.02 (mean of projects 1.02, 3.06, 3.08 and 4.04 being just over $1,000/tonne/year, median of $326/tonne/year) (Alluvium, 2023) (also see Table 27).

Modelled studies

The modelling studies (n=4) were not linked to any specific program or intervention, but instead sought to model different aspects of potential interventions to improve water quality (and intervention design) or to assist with prioritisation of future intervention actions, either by geography or by behaviour change achieved.

A modelling study focusing on drivers of change in graziers agricultural management practices found that it is the interaction of identified financial returns, and attitudes to risk and uncertainty of landholders, that are key influencers of decisions to adopt improved practices (Star et al., 2015). This study focused on graziers in the Fitzroy basin, exploring drivers that may affect decisions to shift from lower categories of practices (51.79% of graziers practices were at B level, 33.6% at level and 7.0% at D level per the Second Report Card 2010, with only 7.61% at A level). To shift more graziers towards the higher-class practices requires an improved understanding of the relative profitability of the specified practices over the long term, and an understanding of the risk and uncertainty related to these returns; thus providing insights into efficient policy delivery and resource targeting to optimise returns. **The study concludes that offering a bundle of practices to adopt may address uncertainty and variability, allowing flexibility in response to the risk appetite and attitudes of individual graziers.**

A modelling study focusing on geography sought to assist the allocation of future investments, and to understand the likely cost effectiveness of such investments, to help achieve Reef 2050 Plan targets (Star et al., 2017). Focusing on graziers within the Fitzroy basin, Star et al. (2017) demonstrated an approach of integrating data to prioritise neighbourhood catchments to achieve the Reef Plan target of a 20% reduction in anthropogenic sediment loads. The method relies on a function which integrates a number of parameters to allocate scores to each of the neighbourhood catchments in terms of potential sediment savings, effectiveness and the modelled cost, where the higher the score the more cost-effective working in that catchment is to achieve sediment outcomes considering the factors of cover, management practice adoption, delivery ratio and cost. The costs included both modelled profit impacts from reduced stocking rates, plus costs of delivering extension services to achieve the improved practices, based upon previous research that demonstrated extension could shift 11% of landholders from C to B. **The approach demonstrated in this study could be used to identify the most cost-effective catchments for targeting with extension programs in future.**

The effectiveness of different behaviour change interventions (graziers and sugarcane) on sediment and DIN loads to the GBR was explored in another modelling study, which developed Source Catchment models to estimate pollutant reductions at the end of the catchment. The objective of this was to assist in the prioritisation of water quality interventions (Star et al., 2018). While not linked to any specific program, the model sought to provide an improved approach for evaluating the relationships between policy actions, investments and expected environmental benefits for future programs. Based upon 47 river catchments within the GBR region, the model included 235 different sediment reducing actions and 57 different DIN reduction actions, sought to assess the effectiveness of different interventions taking account of marine protection values, costs of action, and risk. **The study highlighted the high heterogeneity in the performance of different management interventions in different places in delivering improvements for the GBR per dollar spent, thus emphasising the importance of seeking pollutant reductions where the most effective outcome can be achieved rather than simply targeting an industry or a catchment.** For example, costs per tonne of sediment reduced were estimated

between $3.09 (minimum in Wet Tropics) to $79,065.76 (maximum in Burdekin), whilst cost per kg of DIN reduction ranged from $124 (minimum in Burdekin) to $184 (maximum in Burnett Mary) with a mean of $160.10.

On ground works

Gully erosion can be addressed by a number of strategies, including decreasing stocking rates on grazing land, revegetation of erosion features and the implementation of specific infrastructure including fencing and earthworks (Rust & Star, 2018). The first two of these strategies can be promoted by facilitative, financial and regulatory instruments, as discussed above. However, the latter refers to on-ground works, the focus here. On-ground gully remediation works seek to stabilise the gully, that is that the site is returned to a condition where no greater sediment is generated compared to surrounding land (Rust & Star, 2018).

The studies providing evidence regarding on-ground works for this synthesis include case studies reporting on specific gully remediation activities at specific locations (5 studies – one (Alluvium 2023) which reports on 21 applications of assistance for on-ground works to manage for gully and streambank erosion) and 1 study using modelling to explore a barrier to participation in gully remediation activities.

Programs for on-ground works focus on site specific gully remediation projects and involve a selected numbers of sites which have been identified as having significant gullies in need of remediation (Alluvium, 2023). The remedies applied are tailored to address the specific requirements of each site based on biophysical features such as soil type, peak water flows, the location of the gully in the landscape, and the slope of the gully and surrounding land. Remedies include revegetation and establishing permanent structures, seeking to divert or disrupt water flows, to reinforce and protect soils, to increase ground cover and to install stock exclusion measures. The site-specific nature of the works restricts opportunities to synthesise projects findings by remedy, as each site within each project will employ a different mix. However, some clear conclusions can be drawn from the evidence available.

Firstly, the projects can all be described as having been effective as all have resulted in some remediation of gullies, which has reduced sediment loads and thus contributed to improved water quality. However, there are great variations in the quantity of sediment reduction from project to project, and across individual gullies within projects, due to the site-specific nature of both the sediment load prior to remediation and to the remediation works required. Seeking to apply the bronze – Taupo effectiveness framework to such projects is therefore complex.

Bronze level of effectiveness – human dimensions and KASA

The first step in effective sediment reduction from gully remediation depends on the appropriate selection of sites; this 'appropriateness' depends upon the willingness of landholders to participate in addition to the biophysical characteristics of the site. Thus, landholder attitudes and aspirations have an important role to play in the participation decision. Having agreed to participate, the opportunities for building knowledge and skills vary from project to project. Some projects are funded and managed by external contractors to complete the works with little landholder involvement, while others offered opportunities for landholders to contribute alongside external contractors, and a third type supported the landholders to complete the works themselves offering full or part funding plus extension (Alluvium, 2023; Waterhouse et al., 2021; Wilkinson et al., 2017; 2019). Many projects also involved landholders in hosting community days to provide opportunities to share the learnings from their projects with others.

Wilkinson et al. (2019) noted that many landholders were initially reticent about engaging in erosion control projects, not seeing them as a business priority or not knowing how to tackle them. Studies described how a number of Reef Trust projects sought to work with landholders to build KASA, encouraging reticent landholders to become supportive participants, and successfully built capacity within the local communities in the GBR catchment area to implement erosion control measures (Wilkinson et al., 2017). Knowledge and skills were reported as developed by the Reef Trust via multiple field days promoting peer to peer learning, plus the development of multiple written case studies and videos (Alluvium, 2023). The Burdekin MIP was also reported as successfully encouraging previously unengaged landholders to engage, and building aspirations, with a reported increase from 25% to 60%

in the number of landholders seeking to move to best practice for managing streambank erosion within the next 5 years (Waterhouse et al., 2021).

Silver to Platinum levels of effectiveness

These levels of effectiveness are particularly relevant for on-ground works for gully remediation, as participating sites move from un-remediated to remediated as a consequence of the intervention rather than requiring a change in landholder behaviours over time.

Taupo level of effectiveness

Studies focusing on the on-ground gully remediation works all provided information that links the program intervention to improved water quality by estimating the quantity of sediment removed from the system on an annual basis as a consequence of the works. The sediment savings are estimated using a modelling tool such as the sediment savings calculator developed as part of the Gully Toolbox developed as part of the Reef Trust program (Alluvium, 2023; Wilkinson et al., 2017; 2019). The effectiveness of the works in terms of tonnes of sediment saved vary considerably. For example, Reef Trust Phase II Gully Remediation works was reported as reducing sediment loads by 5,400 t yr^{-1} from across 210 gullies, noting that 80% of the savings were derived from 12% of the individual gully sites (Wilkinson et al., 2019). Further, Wilkinson et al. (2019) report that the magnitude of fine sediment reduction tended to increase with gully area, such that site sediment savings >10 t yr^{-1} were more typical to result from gullies larger than >1 ha in area, while site sediment savings were typically <0.1 t yr^{-1} for gullies <0.1 ha in area. Over all phases of the Reef Trust program, many successful gully restoration projects were completed or are still in progress, with gully restoration projects (some of which also include extension and capacity building elements) reported as saving over 66,000 t yr^{-1} [based upon summing separate gully remediation projects reported within Alluvium (2023)].

The Burdekin MIP project reported estimated sediment savings using two alternate methods/tools – the Alluvium investment tool applied at the site level and the Source Catchment Model via the P2R program which provides a more sophisticated representation of the system at the basin/catchment level (Waterhouse et al., 2021). Based on the individual site model, the gully remediation projects removed 6,064 t yr^{-1} of sediment from 19 completed gully remediations (Waterhouse et al., 2021).

Table 28. Summary of knowledge about effectiveness of on-ground works grazing interventions for GBR water quality outcomes (based on peer reviewed evidence).

Program	Reference	Based on the evidence did it achieve objectives?	Does the study report on:					
			KASA (Bronze)	Bronze plus (participation)	Silver (number /area adopting change)	Gold (extent of change)	Platinum (longevity)	Taupo (water quality change)
Reef Trust II	Wilkinson et al. (2017)	Not relevant to this approach	Acknowledges this		yes	Not relevant measures for gullies, go from un-remediated to remediated	Expected but not known	Yes
	Wilkinson et al. (2019)				yes			Yes
	Alluvium (2023)		Yes	no	Yes			Yes – see Table 28
	Waterhouse et al. (2021)		yes	yes	yes			Yes

Other measures of effectiveness - Cost effectiveness of interventions

Beyond the estimated sediment reductive achieved, studies sought to evaluate the cost effectiveness of gully remediation projects focusing on the site remediation costs. By seeking to better understand variations in cost effectiveness across sites, and thus the drivers of cost effectiveness, this can result in future resources being better directed, thus ensuring that future projects getting the best return (in terms of improved water quality and reef health) from the money invested.

Considerable variation was found in the cost effectiveness of the different projects. Focusing firstly on Reef Trust funded projects, an average cost of $700/tonne/year initially reported by Wilkinson et al. (2017) based on 170 gullies was reduced to $510/tonne/year based on the extended sample of 210 gullies report upon in Wilkinson et al. (2019). Across all phases of the Reef Trust project, average cost is around $725/tonne/year (Alluvium, 2023). Estimated costs per tonne per year reported for individual projects within the Reef Trust portfolio varied from a minimum of $16/tonne/year to a maximum of $17,805/tonne/year (Alluvium, 2023). Wilkinson et al. (2017) reported that at the scale of individual gullies, the cost-effectiveness tends to be better when treating gullies with area >0.1–1 ha, and thus recommended targeting gully remediation towards fewer sites with larger gullies. It was also recommended that emphasising only cheaper treatments for less active gullies is another way to improve cost effectiveness. Lower costs per tonne were reported for the Burdekin MIP, where gully remediations ranged from a minimum on $8.1/tonne/year to $370/tonne/year (noting that outliers were excluded from the reported range) (Waterhouse et al., 2021). This project used a 'hot spot' approach to identify key gullies for remediation and was focused on a small region within the Burdekin basin known as a significantly high source for sediment generation; the contribution of these factors to the cost effectiveness of the program is unknown. A small cost effectiveness study focusing on another region known to be high in sediment generation (Fitzroy basin) estimated cost effectiveness for six gullies to range between $66.93/tonne/year to $516.23/tonne/year (Rust & Star, 2018). This study also found evidence for a relationship between the volume of gully erosion addressed by a remediation project and the cost effectiveness of the site-specific work, suggesting economies of scale may have a role to play.

Modelled studies

The modelling study (n=1) was not linked to any specific program or intervention, but instead sought to model an important aspect of potential interventions, namely landholder participation. This study sought to explore a potential barrier to landholders participating in on-ground gully remediation works (Star et al., 2019). Using a choice modelling methodology with landholders within the Fitzroy Basin, Star sought to explore the impact of the 'winners curse', where perceived input cost risks and conservation outcomes risks cause landholders to be reluctant to be associated with programs supporting gully remediation. The model demonstrated that the 'winners curse' is an issue impacting adoption levels, with conservation outcome risk found to have a much higher effect than input cost risk. Based on these findings, further research into how such barriers can be overcome could be beneficial to increase future participation rates in such programs.

Statement about how effective for grazing

- Many programs implemented using extension/facilitation achieved engagement and/or skill improvement objectives but may have achieved less than objectives in accredited change (e.g., Queensland Audit Office (2015) reports an objective of 30 businesses accredited as a part of Grazing BMP and only 10 achieved accreditation.
- Understanding about cost effectiveness of programs has been conducted for Reef Trust investments. For these, cost effectiveness ranged from $16 t^{-1} of sediment removed through to $17,000 $^{t-1}$ removed.

4.1.10 Synthesis of evidence – How effective? (Agricultural land use – sugarcane)

Evidence on effectiveness of interventions for sugarcane are discussed within the categories of:

Facilitative instruments for land management:	• Were objectives met? • Effectiveness in terms of Bronze, Silver, Gold, Platinum and Taupo indicators • Other measures of effectiveness (cost effectiveness) • Insights on effectiveness from modelled studies • Methodological critiques

Out of the 86 peer reviewed studies, 12[21] directly assessed the implementation of a program or instrument implemented to generate land management change for a GBR water quality outcome and provide any evidence of effectiveness. This sparse literature showcasing an evaluation of effectiveness is consistent with findings from Eberhard et al. (2021a).

Facilitative instruments, either used alone or in conjunction with financial instruments

Floor level of effectiveness - did the program/instrument meet objectives?

Di Bella et al. (2015), Kealley and Quirk (2016), Pickering et al. (2019b), Rouse and Davenport (2017), Royle and Di Bella (2017) and Wegscheidl et al. (2015), and all provide observational review of the effectiveness of facilitative instruments. Alluvium (2023) provides analysis of 15 sugarcane focused Reef Trust funded interventions (2 of these being sugarcane and grazing) and does not report on baseline effectiveness (but does report on other areas of effectiveness discussed in later stages of this section). Most facilitative focused instruments were implemented with objectives around 1) participant numbers and 2) an intention to change.

Wegscheidl et al. (2015), reporting on the implementation of the Queensland Governments DAF extension (specifically as it was implemented throughout the Wet Tropics) had clear implementation objectives (600 canegrowers participating in extension activities, 50% surveyed improved their capacity to improve management practice and at least 20% of those engaged would achieve a practice change before June 2014) which they well and truly met (900 growers were engaged in extension, 96% evaluated reported an improvement in capacity and there was a 41% +/- 10% of growers engaged who made a practice change (at a 95% confidence interval)).

Royle and Di Bella (2017) had a primary objective of improved N management practices (rate, placement, timing); introduction of enhanced efficiency fertiliser (EEF) products and a move to sustainable farming systems (fallow management and planting systems). This was achieved with subsurface N application increased from 58% to 79% between 2012 and 2015 (increase of 21%); an increase in growers including a legume fallow (2.4% to 14.2% between 2012-2015) and a 10% increase in area planted to sustainable mound planting. It was also reported that of the 30 growers in hotspots that attended targeted extension and trials - 18 had data to reflect change. 10 of these had reduced N rates to equal or below the 6 Easy Steps program (6ES), a reduction of greater than 10 kg/ha.

Di Bella et al. (2015), reporting on the Herbert Water Quality Monitoring Program (which came before Project NEMO – nitrogen efficiency management on farm) reported objectives related to identifying sources of pollutants as a farm and subcatchment level and support farmers to improve management practices though targeted extension. Water quality monitoring occurred revealing levels often higher than national guidelines which then generated motivation in management practice change especially around application methods for nitrogen. Extension resulted in a shift in areas treated with surface application of nitrogen (shifting to subsurface) from 78% to 38%.

Rouse and Davenport (2017), reporting on Project Catalyst did not report on the setting or meeting of objectives.

[21] although the Australian Government study provided analysis of 15 Reef Trust funded applications

Kealley and Quirk (2016), reflecting on the implementation of SmartCane BMP, note an implementation target of 1,520 growers completing self-assessments and 380 of these achieving accreditation by end of 2014. They report that just under 500 businesses were benchmarked at the end of 2014 with 78 of these accredited at the end of 2016. Queensland Audit Office (2015) provide some additional statistics – 684 registered farmers completed at least one module at the end of 2014 and 4 accredited farmers completed one module (.01% of farms)

Pickering et al. (2019b) reporting on CaneChanger note the intention of uptake and report that at the commencement of CaneChanger there were 489 businesses benchmarked, representing 55% of the land area under sugarcane and 56 businesses accredited representing 12% of the land area under sugarcane, under Smartcane BMP. At the completion of CaneChanger phase 2 there were 792 businesses benchmarked representing 80% of the land area under sugarcane and 233 businesses accredited representing 35% of the land under sugarcane in Smartcane BMP across the wet tropics - this is reported as a 316% increase in BMP accreditations. It is important to note that Pickering et al. (2019b) acknowledge that other programs operating in the study area at the same time would have influenced these results but do not account for this in the reporting of results. The authors confidently assume that these reported uptakes are inflated.

The Alluvium (2023) study reports on 15 individual implementations of intervention for sugarcane funded by Reef Trust. While this study reports on objectives of interventions, the results focus on other criteria of effectiveness (such as nutrient reductions) and are discussed in the following sections.

Table 29. Is there information about the floor level of effectiveness of land management interventions - were objectives set and met?

Program assessed	Reference	Instrument type	Did it meet its objectives
DAF extension	Wegscheidl et al. (2015)	Extension	Yes
Herbert water quality monitoring program	Di Bella et al. (2015)	Extension	Yes
NEMO – nitrogen efficiency management	Royle and Di Bella (2017)	Extension	Yes
Project Catalyst	Rouse and Davenport (2017)	Extension	Not specified
SmartCane BMP	Kealley and Quirk (2016), Queensland Audit Office (2015) Deane et al. (2018)	Extension	No
SmartCane BMP (CaneChanger)	Pickering et al. (2019b)	Extension	Yes (but lots of contributing variables unaccounted for)
Enhanced Efficiency Fertiliser (EEF) (Reef Trust 4.03)	Connellan et al. (2022)	Extension	Yes
Reef Trust Reverse Tender (Burdekin)	Eberhard et al. (2021a)	Financial	Not assessed

Bronze level of effectiveness – human dimensions and KASA

While not always the primary objective of the intervention, many studies reporting on the overall effectiveness of an intervention implemented to drive land management practice that aims to improve water quality outcomes for the GBR, did provide a reflection on the impact of the intervention on a landholder's capacity to make a change – that is the landholders knowledge, attitudes, skills and aspirations (KASA).

For example, Wegscheidl et al. (2015) noted that at the end of 21 group-based extension activities run by Queensland DAF, 96% of participants reported an increase in knowledge and skills (with an understanding on in which areas landholders had gained the greatest knowledge). Di Bella et al. (2015)

highlights the importance of human capital and capacity to generate change. Di Bella et al. (2015) notes that as a result of the targeted extension of Herbert Catchment growers, land managers now have a sound knowledge concerning water quality. Di Bella et al. (2015) also reflects on the many different capitals that need to be in place to generate land management practice change and how the extension impacted upon these. Extension impacted on natural capital by improving: knowledge on land use and water quality; institutional capital by establishing investment for long-term water quality monitoring; and social capital by bringing together industry associations that do not normally work together.

Some interventions assessed within the Alluvium (2023) study reviewed the impact of the sugarcane focused intervention on KASA. For example, Reef Trust 1 Reef Trust Tender in the Wet Tropics note that many participating growers became project advocates, sharing their knowledge with other growers through formal and informal mechanisms and grower networks, particularly 'over the fence' conversations. Reef Trust 4 (Enhanced Efficiency Fertilisers (EEF)) notes the inclusion of knowledge generating activities such as shed meetings, farm tours and drone training to enhance the capacity of growers. Reef Trust Phase 5 (SRA farming practices) reported a perception that landholders improved their skills and knowledge.

The impacts on KASA were not assessed by Kealley and Quirk (2016), Pickering et al. (2019b) and Royle and Di Bella (2017) and only mentioned in a cursory fashion by Rouse and Davenport (2017).

Another base level evaluation of effectiveness is related to the numbers of participants engaged in an intervention (this is often listed in the intervention objectives). Whilst Rouse and Davenport (2017) do not report on intervention impacts on KASA they do note that 78 farmers were participating in the program when they conducted their study. Many statistics about numbers participating have already been discussed in the intervention objectives.

Some statistics on landholder participation in activities is reported for the Reef Trust assessment by the Australian & Queensland Government (2022). For example, Reef Trust 3 (updating farm management practices) noted that greater than 100 farming families actively participated in the project through innovation or early adoption trials and there were 2,978 participants who attended 67 events including Annual Grower Forums, Field Days, shed meetings, training sessions and bush trips during the project. This allowed for networking and peer to peer learning, and the project identified that peer to peer learning was the most effective method of influencing change with growers and their farming systems. Phase 4 (repeated tenders in the Wet Tropics – financial instrument) notes that 51 growers participated in workshops resulting in 14 successful applicants. The repeated tender in the Burdekin Dry Tropics resulted in agreements set up with 13 growers. Reef Trust 4 (EEF) achieved a nutrient management plan with all 62 participants. Reef Trust Phase 5 (SRA farming practices) reported participation by 70 farming entities.

Silver to Platinum levels of effectiveness (and sometimes Taupo)

Only a few studies reported at least a **silver level** of effectiveness – that is, reported number of landholders adopting a change.

Wegscheidl et al. (2015) reported that 41% +/- 10% of growers engaged in extension had made some form of practice change. 64% of 97 growers surveyed (62 growers) said they had made a change to their farming practices or business due to some form of extension activities. When assessing the level of change it was assumed by the study authors that growers were one step below the practice level they reported to be as a result of the extension. Whilst the intention to maintain the practice change is not known (so cannot report on **gold level** of effectiveness), change in management practice is reported against the water quality risk framework so is able to be mapped to a water quality outcome through Paddock to Reef modelling (**Taupo**). Management change from extension is reported as area change in Table 30.

Table 30. Area changed to best practice as a result of extension (from one step below in the P2R water quality risk framework).

Region/catchment	New area (ha) managed under best practice (from one step below in the P2R Water Quality Risk Framework)		
	Soil	Nutrient	Pesticide
Mackay Whitsunday	784	909	266
Burdekin	0.5	84	25
Herbert	70	168	49
Tully	498	478	160
Johnstone	785	862	253
Mulgrave-Russell/Barron	2,498	2,746	804
Mossman/Daintree	114	446	131
TOTAL	**4,749**	**5,692**	**1,688**

Source: Wegscheidl et al. (2015) (p. 5)

Number of landholders participating and adopting a change were reported for trial type interventions (such as Di Bella et al., 2015; Rouse & Davenport, 2017; Royle & Di Bella, 2017). Di Bella et al. (2015) also highlighted what participating landholders changed to (this was not the case for Rouse and Davenport (2017). For example, in Herbert Canegrower studies following the targeted extension style intervention, the rate of subsurface application of N had increased from 58% to 79.5% (2012-2015) and the area of land planted to legume crops during the fallow had increased from 2.4% to 14.2 % (2012-2015). Both papers assessing the Herbert trials acknowledged the need to link land management changes to water quality outcomes (Gold) but cite short trial timeframes as making this challenging. While not reporting on KASA achievements per se, Di Bella et al. (2015) notes the importance of different levels of capital in generating long-term change (Bronze), linking different forms of human and social capital as critical to maintaining change (platinum).

Most sugarcane interventions analysed in Alluvium (2022) reported at a **level beyond silver** (and so are addressed in the next section), and not much at silver. The exceptions for sugarcane were reporting on Reef Trust Phase 1 and 4 Wet Tropics Reef Tender and Reef Trust Phase 2 and 4 for the Burdekin Reef Tender. For Reef Trust 1 in Wet Tropics, 14 landholders were directly contracted to reduce fertiliser application with 19,278 ha being able to be recorded against P2R practice change specifications (which means water quality improvement can also be mapped – **Taupo**). For Reef Trust Phase 2 (Burdekin), it was reported that 16 landholders were contracted to reduce N (with level of DIN reduced also reported – Taupo). For Reef Trust Phase 4 saw another 14 landholders contracted for N reduction in Wet Tropics and 13 in the Burdekin. Eberhard et al. (2021a) note that for the Burdekin repeated tender this resulted in 5% of sugarcane farmers being contracted to reduce N application resulting in a 14% reduction in N use (but does not note change from or to or relate this to P2R water quality risk framework.

Taupo level of effectiveness

In addition to Wegscheidl et al. (2015), the only sugarcane study that reports a Taupo level of understanding of effectiveness is the Alluvium (2023) analysis of Reef Trust interventions. This analysis assesses 15 sugarcane focused interventions over the course of Reef Trust investment phases I to VII. The results of this are provided in Table 31.

Table 31. Summary of effectiveness from the evaluation of Reef Trust (from Alluvium, 2023).

Reef Trust Intervention*	Instrument	Reef Trust investment	Pollutant reduction (Taupo – know impact on water quality) **	Cost effectiveness (plus additional information)***
Phase 1. (1.01) Reef Trust Tender Wet Tropics	Competitive tender financial instrument	$1,704,313	31,167 kg of DIN	$49/kg DIN (based on strong level evidence)
Phase II (2.12) Reef Trust Tender Burdekin	Competitive tender financial instrument	$3,137,527	21,331 kg of DIN	$137/kg (based on moderate level of information)
Phase III – (3.01) Project catalyst revamp - Updated farm management practices (WT, B, MWS)	Extension/trials ($ provided to support trials)	$3m	12,906 kg DIN	$208/kg (based on average level of information)
Phase III – (3.02) Reef Alliance	Extension	$17,574,999	148,541 kg DIN	$106/kg (based on average quality information)
Phase III – (3.07) Sustainable Cane (MWS)	Extension and financial incentive	$4,425,000	8,294 kg of DIN	$476/kg (based on average level of information)
Phase IV – (4.01) repeated tender Wet Tropics	Competitive tender financial instrument	$6,719,020	76,764 kg of DIN	$77/kg (but based on poor quality of information)
(4.02) As above for Burdekin	As above	$7,381,889	28,841 kg of DIN	$225/kg (based on poor information quality)
Phase IV - (4.03) EEF cane farmer trials	Trials		Unknown	unknown
Phase V - (5.01) Project Uplift farming systems (WT, B, BM)	Extension and financial incentives	$4,520,780	52,532 kg of DIN	No cost-effective figure but considered a strong performance
Phase V1 – (6.01) Complete Nutrient Care, delivering tailored solutions	Extension building on RP 161	$5,700,000	5,175 kg of DIN	$554/kg (based on moderate information)

* Phase VII not reported as no results yet.
** Alluvium (2023) highlight assumptions and other factors that influence the quality of the data used in load reduction estimate. These need to be considered when interpreting effectiveness.
*** This value is not just a simple calculation of tonnes saved by dollars spent due to how present value was included in the calculation.

Table 32 provides a summary of knowledge about effectiveness of interventions for land management change for GBR water quality outcomes for sugarcane.

Overall understanding of effectiveness

Twelve[22] pieces of peer reviewed evidence related to the effectiveness of extension for water quality improvement from sugarcane growing businesses in the GBR catchment area. There is one standalone assessment of the effectiveness of a financial instrument. The Alluvium report also provides assessment of five applications of interventions using financial instruments (competitive tender and cost sharing arrangements). Very few sugarcane extension evaluations assess the effectiveness in terms of water quality impacts. Most only go as far as reporting on numbers of landholders adopting a change. Analysis of effectiveness of financial instruments report on water quality change.

[22] Note that one of these is the Alluvium report which includes an evaluation of 15 Reef Trust funded interventions.

Table 32. Summary of knowledge about effectiveness of sugarcane interventions for land management change for GBR water quality outcomes (based on peer reviewed evidence).

Intervention name	Instrument	Reference	Based on the evidence did it achieve objectives?	Does the study report on:					
				KASA (Bronze)	Bronze plus (participation)	Silver (number adopting change)	Gold (extent of change)	Platinum (longevity)	Taupo (water quality change)
DAF extension	Extension	Wegscheidl et al. (2015)	Yes	Yes	No	Yes	Yes	No	Yes because aligned to water quality risk framework and P2R
Herbert water quality monitoring program	Extension	Di Bella et al. (2015)	Yes	Yes	No	?	Yes	Acknowledged	No
NEMO – nitrogen efficiency management	Extension	Royle and Di Bella (2017)	Yes	Acknowledged	No	Yes	Yes	No	Acknowledged
Project Catalyst	Extension	Rouse and Davenport (2017)	Not specified	No	Yes	Yes	No	No	No
SmartCane BMP	Extension	Kealley and Quirk (2016)	No	no	yes	yes	No	No	no
		Queensland Audit Office (2015)		No	Yes	No	No	No	No
SmartCane BMP (CaneChanger)	Extension	Pickering et al. (2019b)	Yes (but lots of contributing variables unaccounted for)	No	Yes	Yes	No	No	No
SmartCane BMP	Extension	Deane et al. (2018)	No	No	No	Yes, but shows very low accreditation	No	No	No
EEF 60 (Reef Trust 4.03)	Extension	Connellan et al. (2022)	Yes – shows N uptake efficiency with no reduction in production	No	Yes (trial)	Trial	NA	NA	NA

Intervention name	Instrument	Reference	Based on the evidence did it achieve objectives?	Does the study report on:					
				KASA (Bronze)	Bronze plus (participation)	Silver (number adopting change)	Gold (extent of change)	Platinum (longevity)	Taupo (water quality change)
		Alluvium (2023)	yes	Yes	Yes	Yes	Yes	Yes	Yes
Reef Trust Reverse Tender (Burdekin)	Financial	Eberhard et al. (2021a)	Unknown	No	No	Yes	Yes	No	Yes
Reef Trust various and multiple interventions (n=15)	Various (n=15. 10 extension, 5 financial)	Alluvium (2023)	yes	yes	Yes	Yes	Yes	Yes	Yes (P2R) – see Table 31 for $/kg effectiveness figures

Other measures of effectiveness - Cost effectiveness of interventions (broadly).

Broader reflections on effectiveness of sugarcane programs and instruments were articulated in four pieces of evidence. Waterhouse et al. (2016) provides a broad discussion on improved land management programs and their effectiveness, stating that modelling would indicate that improved practices (relevant to sugarcane) has reduced N by 10% to 1,646 t yr^{-1} but notes that a large proportion of agricultural land in priority areas (up to 75 – 80% in some areas) is still managed to below best management standards. Deane et al. (2018) provides some broad comment about extension programs such as Smartcane BMP extension as well as enforcement of regulations and the potential for a future nutrient trading scheme. In this paper Deane et al. (2018) highlights that despite 60% of sugarcane land in Queensland having been through the self-assessment stages of SmartCane BMP, only 5% have been accredited.

Modelled studies

Modelled studies are those that provide an analysis of what could be in the future, providing information on the design of instruments for improved results. [23] There were 4 (n = 4) peer reviewed evidence items that fall into this category. van Grieken et al. (2019) assesses how different landholder types in the Wet Tropics might respond to an economic incentive, aligning change to the ABCD water quality risk framework. van Grieken et al. (2019) report that under a base scenario where government does not pay any share of land use change, 9% of the available sugarcane land is managed using aspirational practices (A) (reduced N, legume fallow, zero tillage); (B) best management practice is optimal on 66% of sugarcane land and it is optimal to manage 25% of the land using common (C) class practice. Further, a minimum CSR (cost share ratio - capital and transition costs are covered) of 90% is required to shift to 100% adoption of A class practices for large farms; medium sized farms will shift from B to A class management with a CSR of above 60%, 100% CSR is required to shift all medium farms to 100% adoption. Small farms mainly operate at C class management but about half shift to B class management when the CSR is above 20%. At 60% CSR, all land is B class, but 100% CSR is required to shift to A class. At 100% CSR, all sugarcane land is at A class and water pollution decreases by 56% from the base case.

De Valck et al. (2022) provides another modelling study, collecting data from 1,100 households to reflect on the potential for instruments that reflect consumer preferences for GBR friendly management practices in prices. Using the non-market valuation technique of Contingent Valuation, De Valck et al. (2022) show that households are willing to pay on average $24.50/year/household (~0.34% of an average weekly grocery bill) for GBR friendly sugar. De Valck et al. (2022) estimate that through a small sugar 'tax', such as the amount suggested, AUD$46.9m could be raised which could be used to support sugar growers improve management practices with GBR water quality outcomes. The ability for a scheme like this to work effectively will be heavily influenced by the design, especially the ability to circulate the money raised for GBR friendly sugar back into techniques to achieve GBR friendly sugar.

Waltham et al. (2021) assesses the potential cost effectiveness of converting high DIN risk, low lying sugarcane land to wetlands. Oza et al. (2021) also assesses this future area for gaining N savings. Both of these studies have the potential to inform methodology development and targeting in the landscape for future application of land management instruments that seek to gain DIN reductions through wetland development or restoration. One such instrument that could take advantage of findings of these studies is Reef Credits.

Methodological critiques (secondary/conceptual)

Six (n=6) of the peer reviewed studies focused on critiquing methodologies for understanding effectiveness but by doing so provide insight into a number of programs and instruments. A number of these are related to technology. Linked to Project 25, Davis et al. (2019) reports on the results of 20 in-depth interviews to understand landholder perceptions of water quality information and their land

[23] Remembering that we did not include studies that provided an extensive analysis of the farm level economic impacts of adopting a BMP, of which there are a many.

management practices in the Russell Mulgrave subcatchment of the Wet Tropics. **Incidentally, Davis et al. (2019) reports that approximately 85% of landholders in this subcatchment are at C level practice in the ABCD water quality risk framework**. Landholders reported improved communication, improved trust, an environment with more direct oversight of monitoring data, and 'space' to learn and experiment as contributing factors to their engagement in Project 25. In a similar study, Vilas et al. (2020) reports on the results of landholder interviews following engagement in 1622WQ app, an app which provides landholders with real time and spatially relevant water quality information (also in the Russell Mulgrave). Vilas et al. (2020) reports that there are >1,100 users of the app within the 1,400 strong sugarcane grower cohort and seeks to understand where landholders are at when it came to comfort with technology. Reflecting on the use of the blockchain concept, Kealley et al. (2021) presents the technology required to facilitate and support understanding sugarcane provenance and reports on the testing of this with a small sample of growers, mills and end users (Kealley et al., 2022)

Different to the other methodological reviews is Rolfe et al. (2018). Using data from 530 farm level projects funded by Reef Rescue between 2013/14 to 2014/15, Rolfe critiques the methodology for establishing effectiveness. Overall, and using P2R, Rolfe et al. (2018) estimated that 337 of the projects resulted in 37,571 tonnes of sediment reduction, 242,150 kg of N reduction and 1,714 kg of pesticide reduction. Rolfe et al. (2018) estimated that the modelling of **187 (or 1/3) projects showed that they did not produce a system change that would result in a water quality improvement (Gold and Taupo level of measurement was applied with the results showing a poor outcome).** 22 projects were extension and not able to quantify benefit, further, 36% of projects using 32% of public funds were not modelled to generate any direct pollution benefits contrary to the purpose of the programs. Rolfe et al. (2018) also highlights some issues when it comes to assessing effectiveness using P2R data, primarily, that the P2R modelling assumes that project management actions are adopted immediately and continuously. It is also assumed that the management changes are 100% effective at achieving the modelled reductions.

In a critique of alternative methods for determining effectiveness, Rolfe et al. (2018), while using a disaggregated approach[24], shows that for Reef Rescue investment for sediment, the best 50%of projects cost $9.00/ tonne, while the worst 50%of projects cost $177/tonne. Put another way, the first 25%of projects (by cost-effectiveness) achieved 72% of benefits, the second 25% of projects achieved an additional 18% of benefits, whereas the third and fourth quartiles of projects achieved only 9% and 1%, respectively. For DIN, the best 50% of projects cost $2.92/kg, while the worst 50% of projects cost $87/kg. Put another way, the first 25% of projects (by cost-effectiveness) achieved 86% of benefits, the second 25% of projects achieved an additional 10% of benefits, whereas the third and fourth quartiles of projects achieved only 4% and 1% respectively. For pesticides: the first 25% of projects achieved 70% of benefits, the second 25% achieved an additional 19% of benefits whilst the 3rd and 4th quartiles of projects achieved only 9% and 1% respectively.

Rundle-Thiele et al. (2021) referring to work by Windle and Rolfe (2011) highlight the results of a retrospective evaluation of effectiveness of the reverse tender scheme in the Burdekin that pre-dated that funded by Reef Trust. This work highlighted that these early reverse tenders were cost-effective (at an average of $7.74/kg DIN at end-of-catchment in 2018 -i.e., ranging from $0.80- $35.60/kg DIN at end-of-catchment). Waterhouse and Pineda (2021) do note that it is difficult to compare the cost-effectiveness of different mechanisms, such as Reverse Tenders and Reef Credits versus grant- and extension-based programs, due to intrinsic differences in their design and expected outcomes. Referring to the work of Rundle-Thiele et al. (2021), Waterhouse and Pineda (2021) note that in the first group (Reverse Tenders and Reef Credits), it seemed appropriate to evaluate the cost-effectiveness solely within the scheme's duration, in terms of the costs incurred relative to the end-of-catchment DIN reductions delivered, where incurred costs should ideally include the costs of scheme administration as well as direct payments to farmers. In contrast, grant- and extension-based programs can potentially be evaluated in terms of the cost-effectiveness of each program overall ($ spent per total DIN reduction delivered), or the cost-effectiveness of individual interventions within programs ($ spent per farm per

[24] The disaggregated approach is presented as the better approach as it is more consistent with economic analysis and analyses pollutants separately, allowing benchmarking of costs per pollutant.

DIN reduction delivered from that farm). However, grant- and extension-based programs seek to encourage practice change through diffusion (i.e., practice change inspired by the program), which is notoriously difficult to quantify. Thus, when the cost-effectiveness of these types of schemes is evaluated solely in terms of outcomes delivered by scheme participants within the duration of the scheme, it is very likely that the cost-effectiveness achieved by these types of schemes will be lower than that of contracted 'payment for delivery' schemes like the Reverse Tenders evaluated by Rundle-Thiele et al. (2021).

In terms of evaluating new techniques for encouraging nitrogen reduction by sugarcane farmers, Smart et al. (2020) models DIN reductions with a hypothetical DIN permit trading market between sugarcane farmers. Smart et al. (2020) highlights that trades are driven by variation in DIN losses and gross margins on different soil types under different N application rates. In a further exploration of innovative ways to motivate for DIN reduction from sugarcane growers, Thorburn et al. (2020) evaluates the potential for an insurance product as an enduring instrument, that does not depend on public funding, to help farmers manage the risk of reducing N applications below current rates.

Statement about how effective for cane

Since there is extensive variation in what has been measured to gauge effectiveness as well as variations in the method to measure effectiveness, it is not possible say what approach is most effective where and when. Some observations:

- Similar to grazing, many programs implemented focused on extension/facilitative and focused on engagement and/or skill improvement objectives. Most achieved their implementation objectives but the exception to this was the assessment of SmartCane BMP where accreditation was well below the objective.
- As for grazing, the most understanding about cost effectiveness of sugarcane focused programs has been conducted for Reef Trust investments. For these, cost effectiveness ranged from $49/kg of DIN removed through to $554/kg of DIN removed.

4.1.11 Synthesis of evidence – How effective? (Agricultural land use – Other agriculture; beyond grazing and cane)

Facilitative instruments used alone, and in conjunction with financial incentive instruments

One observational study (n=1: (Soil, Catchment and Riverine Processes Group, 2022)) focused on the practices used by different agriculture industries within the GBR catchment area via the lens provided by the relevant voluntary Best Management Practice framework e.g., Grains BMP, myBMP for the cotton industry, and Banana Best Management Practices, Hort360. This paper provides a summary of the state of knowledge on the number of landholders involved in each industry, and also provides information on the typically used practices alongside commentary on likely changes in use of practices over time (Soil, Catchment and Riverine Processes Group, 2022). As such the study could provide a useful baseline for comparison with other studies at a later date. However, the study does not explore reasons why practices are adopted, or how programs may influence those behaviours, and thus does not provide evidence of effectiveness of any programs; and accordingly, this study is not further discussed here.

Other observational studies (n=3) (Alluvium, 2023; Eames & Collins, 2017; Harvey et al., 2018) looked at facilitative and financial incentive instruments used together, when BMP or other extension programs are used alongside grant programs to further encourage changes in KASA and in land management practices. In these studies, while all participating landholders have the opportunity to access extension and financial support, not all landholders access the financial incentives. For example, of the 295 growers reported on by Eames and Collins (2017) as completing Grains BMP program, only 184 had accessed funding to support their implementation of improved practice. The available studies provide insufficient information to separately report on the effectiveness of the extension component relative to the financial incentive component of the programs.

Floor level of effectiveness - did the program/instrument meet objectives?

Eames and Collins (2017) present the objectives and reconcile achievement against these for a BMP focused initiative for the grains industry in the Fitzroy. The objectives of this initiative were to assist grain growers identify pathways to BMP adoption that are practical, profitable and sustainable, develop skills to enable long-term practice change and demonstrate the alignment between land management and regional water quality targets. In 2017, Eames and Collins reported that 274 on-ground projects had been implemented by 84 grain growers at a cost of $10.3 million (but with 70% of this cost as grower in-kind contribution). Alluvium (2023) report that the Reef Alliance improving grains practices (RT 3.05) project which aimed to reduce sediment through improved farming practices, delivered 732 tonnes of sediment savings at $4,390/t (the results of the dairy focused Reef Alliance project were not reported). The Mary Catchment Riparian Project (RT 4.04) for sediment reduction from streambank management from the grazing, sugarcane and dairy industry delivered 11,934 tonnes of sediment at $210/tonne.

Bronze level of effectiveness – human dimensions and KASA

For landholders in the grains industry, participation in Grains BMP requires completion of a number of modules delivered via self-assessment workshops, field days and other group and individual training opportunities (Eames & Collins, 2017), and seeks to build knowledge and skills in aspects of land management that can improve farm profits and environmental outcomes (Eames & Collins, 2017; Soil, Catchment and Riverine Processes Group, 2022). Focusing on the Fitzroy Basin, Eames and Collins (2017) found that 298 out of 600 growers have completed the program since it began in 2008, which provides some evidence that the program was effective in encouraging participation in these KASA building programs.

Working with banana growers, Harvey et al. (2018) reported on a study where DAF economists worked one-on-one with landholders to build plans for their properties, thus promoting KASA for the participating landholders in addition to promoting change. However, this was a very small case study with only three participating growers.

Engagement activities were also reported by other studies, specifying numbers of landholders who participate but not specifying whether this engagement actually resulted in improved KASA of those landholders (e.g., by reporting BMP module completion rates), thus effectiveness of the programs at bronze level has not been reported (Alluvium, 2023)

Silver and gold level of effectiveness – landholders adopt some change in behaviour

Eames and Collins (2017) report of the success of BMP programs in effective behaviour change and provided details on the behaviours that the cropping landholders had changed from and to, providing evidence of gold level effectiveness. Examples include that across 15% of the land GPS guidance was implemented, and across 15% of the land practice has changed from random wheel traffic to controlled wheel traffic.

The three case studies on banana growers reported that all involved adopted specified new and improved practices, but details were not provided of their previous practices prior to change (Harvey et al, 2018).

Alluvium (2023) reported that 77 grain growing landholders demonstrated practice change across almost 70,000 hectares, as did 164 horticultural landholders over 5,617 hectares, and 57 dairy practices across 2,899 hectares.

Platinum levels of effectiveness

The studies do not report on whether landholders are likely to maintain the change in behaviour reported at silver or gold level above.

Taupo level of effectiveness

One study reported there had been improved water outcomes for sediment, nutrients and/or pesticides from the behaviour changes of grains growers, but the study did not quantify the benefit (Eames & Collins, 2017). Similarly, banana grower case studies reported water quality benefits in terms of reduced sediment (TSS & PN), reduced fertiliser loss (DIN) and reduced pesticides, but the improvement was not quantified (Harvey et al., 2018).

Other studies did attempt to quantify the impact of the program in improving water quality, to indicate program effective at the Taupo level, but such quantification was not always possible. Savings of 732 tonnes of sediment per year were reported as due to behaviour changes by cropping landholders due to the Reef Trust program (Alluvium, 2023). However, the same report disclosed that the impact on water quality of some other projects within the Reef Trust program were unknown: that is there is no evidence of Taupo level effectiveness for the projects focused on the dairy industry and on horticulture.

Other measures of effectiveness - Cost effectiveness of interventions, and ability of programs to leverage government spend to generate investment by landholders

The cost effectiveness of programs was only reported for one program by one study, with Alluvium (2023) reporting that as part of the Reef Trust program, 732 tonnes of sediment savings had been achieved by grains landholders at a cost of $4,390/t/year; the report assessed this cost to be higher than the average cost, so not particularly effective on this measure.

The Reef Trust program was found to be effective in using program funds as leverage to generate investment from landholders, finding that for that for every $1 invested by the project, grains landholder invested $2.984, whilst horticultural landholders would invest $1.96, and dairy landholders would invest $8.24 (Alluvium, 2023). Eames and Collins (2017) also reported successful use of programs to leverage landholder investment, with 69% of funding for the grain program they invested representing in-kind contributions from growers.

Modelled studies

The modelling studies (n=2) were not linked to any specific program or intervention, but instead sought to model improvements to water quality that would arise from changes in landholders adopting differing levels of practices in accordance with the Grains Best Management Practice framework (Owens et al., 2017) or adopting banana industry best practices (Holligan et al., 2017).

For grains, the paddock scale modelling indicated that there was great potential for improving water quality, particularly by reducing sediment loads, that could result from improved practices for dryland grain cropping (Owens et al., 2017). The study concluded that paddock modelling provided a useful tool for exploring land management options and situated the work within the context of Grains BMP, however the study did not explore how the facilitative instruments available within the BMP could be best used to achieve the modelled improvements in practices.

For bananas, the detailed modelling using a stepwise incremental improvement in practices across the industry also indicated that there was great potential for improving water quality (DIN and TSS), and for improving economic outcomes within the banana industry (Holligan et al., 2017). The study concluded that modelling was useful to help policy to encourage practice change, noting a mix of extension, grants and other incentives and regulation could be used. The study discusses how the choice of policy is complex, and further so because some farms have already made changes to better practices, thus suggesting the easiest and most attractive changes may already have been made.

Statement about how effective for other agriculture in GBR catchments

Like the studies focused on grazing or sugarcane, effectiveness was well understood for objectives such as increased engagement and improvement in skills. It was less common for studies to report on a water quality impact. Where it was noted, it was only quantified in the study conducted by Alluvium (2023).

Alluvium (2023) report that the Reef Alliance improving grains practices (RT 3.05) project which aimed to reduce sediment through improved farming practices, delivered 732 tonnes of sediment savings at $4,390/t (the results of the dairy focused Reef Alliance project were not reported). The Mary Catchment Riparian Project (RT 4.04) for sediment reduction from streambank management from the grazing, sugarcane and dairy industry delivered 11,934 tonnes of sediment at $210/tonne.

4.1.12 Synthesis of evidence – How effective? (Regulation – all agricultural land uses)

The early days of attempting to contain the water quality impacts of agricultural land use was fragmented and stopped short of introducing specific regulations to control nutrient use of the agricultural industry (Hamman et al., 2022). Hamman et al. (2022) provides a historical overview of regulation which is not repeated here (see Table 33). Hamman et al. (2022) does note that the threats from the United Nations Educational, Scientific and Cultural Organisation (UNESCO), International Union for Conservation of Nature (IUCN) and the World Heritage Committee to place the GBR on the World Heritage in danger list has provided a catalyst for regulation backed up with compliance and enforcement. This move towards improved implementation of existing regulation was supported by the 2016 GBR Water Science taskforce. Hamman et al. (2022) highlights that regulatory non-compliance has shifted from 55% in 2016-2019 to 30% (2022) with increased follow up visits and support. A new regulatory package came into effect in September 2019 enabling the declaration of minimum practice standards for commercial sugarcane, grazing and horticultural practices across the GBR catchment area and declaring these activities as environmentally relevant activities. The 2019 regulations aim to provide for measures to improve water quality entering the GBR. The effectiveness of this regulation has not yet been assessed.

Table 33. Summary of regulation on the GBR. Source: Hamman et al. (2022).

Regulatory Framework	Legislative Instruments	Objectives	Key Components and Concepts
Planning	Planning Act 2016, Regional Planning Interests Act 2014, Coastal Protection and Management Act 1995.	Integrated system of land use planning and development assessment underpinned by principles of ecologically sustainable development (ESD).	Requirement for a development approval for assessable (and regional) development. Offences for non-compliant development, including clearing vegetation without a permit. Restrictions on removing sand and quarry material in the coastal zone.
Major Projects	State Development and Public Works Organisation Act 1972, Economic Development Act 2012.	Facilitation of major public and private infrastructure projects through the declaration of explicitly controlled areas. Driven by desire for economic progress.	Declaration by the state of Coordinated Projects and State Development Areas which fast track development. Declaration of Priority Development Areas (PDAs) within which community objection rights are limited and local planning instruments are overridden.
Mining	Mineral Resources Act 1989, Petroleum and Gas (Production and Safety) Act 2004.	To encourage the economic development of minerals and gas in the state, whilst minimizing conflicts with other land uses.	Requirement for mining/petroleum lease and other licences for operating resource activities. Extraction and exploration also requires compliance with environmental protection and water use legislation.
Water Use	Water Act 2000.	Sustainable management of Queensland's water resources, including underground water reservoirs. Driven by the principles of ESD.	Requirement for water licence to extract underground water and riverine protection permits required for destruction of vegetation in a watercourse, lake or spring.
Pollution	Environmental Protection Act 1994.	Protection of the environment from air, water and soil pollution.	Requirement for Environmental Authority to undertake activities such as mining, aquaculture, intensive animal husbandry, chemical and petroleum production, and food processing.

Regulatory Framework	Legislative Instruments	Objectives	Key Components and Concepts
Waste	Waste Reduction and Recycling Act 2011.	Waste avoidance and reduction, minimise the impact of waste on the natural environment	Provides for the introduction of a levy for certain waste as well as reporting and waste tracking requirements. Certain disposal practices are also banned.
Vegetation	Forestry Act 1957 Vegetation, Management Act 1999.	Management and ecologically sustainable use of the state's forested areas and regional ecosystems (woody vegetation).	Establishes a framework for regional ecosystems including 'relevant purposes' for which a landholder can clear their land. Works in tandem with the Planning Act 2016 to require assessment and approval.
Port Development	Sustainable Ports Development Act 2015, Transport Infrastructure Act 1994.	Management of port-related development in and around the GBR World Heritage Area.	Declaration of priority ports along GBR coast. Prohibition of capital dredging outside of priority ports. Requirement for Master Plan for each port. Restricted entry for port land.
Nature Conservation	Marine Parks Act 2004, Nature Conservation Act 1992.	Conservation and sustainable use of wildlife and protected areas in Queensland (national parks, reserves, marine parks etc.).	Offence to take or interfere with native wildlife (plants and animals). Restriction on activities within protected areas such as national parks, marine parks.
Cultural Heritage	Torres Strait Islander Cultural Heritage Act 2003, Aboriginal Cultural Heritage Act 2003, Native Title (Queensland) Act 1993.	Protection of cultural heritage places and artefacts throughout the state. Recognition of native title interests in land and waters.	Duty of care established not to harm Aboriginal or Torres Strait Islander cultural heritage. Requirement to negotiate with (and where required, compensate) native title holders.

4.1.13 Synthesis of evidence – How effective? (Programs for urban land use)

Partnership reports provided information on 36 initiatives underway across the partnerships with a line of sight to improving water quality in the GBR. Despite the 36 initiatives, only a few reported on impact to water quality in the GBR.[25] For example, Fitzroy Partnership for River Health (2021a) reports that the Rockhampton Regional Council's 'River to Reef' initiative, which saw renewal and upgrade works in the sewage treatment plant, reduce ammonia released to the estuary by 90%. Similarly, the 'Aluminium Stewardship Initiative (ASI)' implemented by the Rio Tinto Alumina (RTA) Yarwun, where the development of a High Efficiency Sediment program had 'improved the water quality runoff and the ecological surveys up and downstream of the refinery showed no evidence of impacts', however, these results were not reported (Gladstone Healthy Harbour Partnership, 2021b).

The urban stewardships framework assessments were conducted for the first time in 2020-2021 to 13 local councils within the GBR in accordance with the Urban Water Stewardship Framework Implementation Manual Version 2.0 (Department of Environment and Science, 2020). The Dry and Wet Tropic partnerships provided urban stewardships framework reports, and the Mackay Whitsunday Isaac and the Gladstone partnerships reported their results in the water stewardship reports (Dry Tropics

[25] This is the case because whilst many had a line of sight to improving GBR water quality, their reporting focused on other indicators such as human dimensions, wetland water quality etc. Some examples of these include litter initiatives such as the "Litter Education and Awareness Program (LEAP)" implemented by the Gladstone Regional Council and partners, or the "What's down our drains?" initiative implemented by the Rockhampton Regional Council, both aimed to reduce the amount of litter but ultimately to engage with local population and promote awareness (Gladstone Healthy Harbour Partnership, 2022b; Fitzroy Partnership For River Health 2022a). Additionally, some initiatives collaborated with Traditional Owners, for example the "Port Curtis Coral Coast Traditional Use Marine Resources Agreement (PCCC TUMRA)" overseen by the Gidarjil Development Corporation Ltd (Gidarjil) provided training to Gidarjil Land and Sea Rangers in monitoring methods. The data collected from these can be used to support the Reef Water Quality Report Card (Gladstone Healthy Harbour Partnership, 2022b).

Partnership for Healthy Waterways, 2021b; Gladstone Healthy Harbour Partnership, 2021b; Mackay Whitsunday Isaac Healthy Rivers to Reef Partnership, 2021b; Wet Tropics Waterways, 2021).

Based on the 2020-2021 assessment, overall, all regions were given a "C" grade, which means that the regions meet the current minimum industry standards, equating to an overall moderate risk to water quality (Table 34). The point source indicator category received a 'B' for the Wet Tropics and the Mackay Whitsunday Isaac region, showcasing that these regions are currently applying the best practice with consequent low risk to water quality.

Table 34. Urban Water Stewardship Framework Ratings: A (Above best practice; score greater than 17.5, very low water quality risk level); B(Current best practice; Score between 12.5 and 17.4; low water quality risk level); C (Minimum standard; Score between 5.1 and 12.4; Moderate water quality risk level); and D (Outdated practice, score between 0 and 5; High water quality risk level).

Urban Water Stewardship Framework (2020-2021)[1]				
	Wet Tropics	Mackay Whitsunday Isaac region	Gladstone	Dry Tropics
Overall	C	C	C	C
Developing Urban	B	C	C	C
Policy, planning and governance	C	C	C	null
Infrastructure management and maintenance	B	C	C	null
Social approaches	C	C	C	null
Monitoring and evaluating	B	C	B	null
Established urban	C	C	C	C
Policy, planning and governance	B	D	C	null
Infrastructure management and maintenance	C	C	C	null
Social approaches	C	C	C	null
Monitoring and evaluating	C	C	C	null
Point Source	B	B	C	C
Policy, planning and governance	B	A	B	null
Infrastructure management and maintenance	B	B	C	null
Social approaches	B	B	C	null
Monitoring and evaluating	B	A	B	null

1. No information about Urban Water Stewardship frameworks was found for the Fitzroy.

4.1.14 Key conclusions

Question Part 1: What is the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?

- From 2017-2022 the Australian and Queensland State Governments invested A$390m for on-ground initiatives focused on assisting agricultural landholders adopt land management practices to generate a water quality benefit in the GBR.
- The majority of this investment was focused on extension (51%), followed by financial instruments WITH extension (36%). A very small amount of the total funding for change has been applied to financial instruments in the absence of extension (3%), regulation and compliance (4%) and physical works such as on-ground gully remediation (5%) (Eberhard et al., 2021a).
- A$3.5m has been invested by the Queensland Government through the Queensland Reef Water Quality Program to support industry and councils in the GBR catchment are to reduce urban runoff to the GBR.
- The two key pathways for **Australian Government investment** into agricultural land management for GBR water quality improvement have been the **Reef Trust Program** and the

Reef Trust Partnership Program. [26] There a has also been investment into research about instruments.

  - The Australian Government has committed over $3.2 billion to the Reef Trust, some of this investment is focused on water quality improvement. Of the 86 peer reviewed evidence items retrieved in the search, approximately 7 reported information on a mix or a component of the Reef Trust investment. **There is extensive non-peer reviewed information available, but this could not be reported in the SCS due to the methodology used which required all evidence items to be peer reviewed. Table 9 to Table 18 reflect this.**
  - The Partnership is a AUD$443 million six-year grant between the Australian Government Department of Climate Change, Energy, the Environment and Water (previously the Department of Agriculture, Water and the Environment) which managed Reef Trust Funding on behalf of the Australian Government, and the GBRF. Only programs under early investments, water quality regional programs, innovation and systems change and technical advisory are reported in this synthesis. Of the 86 peer reviewed evidence items used in the synthesis, approximately 9 of these reported on the mix or a component of the Reef Trust Partnership investment. **There is extensive non-peer reviewed information available, but this could not be reported in the SCS due to the methodology used which required all evidence items to be peer reviewed. Table 9 to Table 18 reflect this.**

- The key pathways for Queensland Government investment into GBR water quality improvement from **agricultural land** has been through the Reef Water Quality Program. This program funds practice change and science projects to help producers better manage agricultural land. Practice change projects work with producers to improve farming practices that reduce runoff from agricultural properties. Science projects deliver valuable knowledge-based practical tools and advice for landholders and their advisers.
  - Of the 86 peer reviewed evidence items that met the eligibility criteria, 15 related to applications of the Queensland Water Quality Protection Program. **There is extensive non-peer reviewed information available, but this could not be reported in the SCS due to the methodology used which required all evidence items to be peer reviewed. Table 20 and Table 21 reflect this.**
- The **urban** water stewardship framework exists under the Queensland Reef Water Quality Program. The urban water partnerships have produced 12 technical reports and 3 additional reports documenting health of key assets in and around the waterways of the GBR.
- There is very little peer reviewed evidence reporting on the effectiveness of regulation. There is no peer reviewed literature reporting on the effectiveness of the most recent (2019) regulation.

Question Part 2: How effective are the mix of programs and instruments (collectively and individually) used in GBR catchments to drive improved land management actions for GBR water quality benefits?

Studies found were classified according to whether they related to agricultural land practices or urban land; agricultural land was then further sub-divided according to type of agriculture – e.g., grazing, sugarcane. Studies within each category were further classified by the instrument used to drive the change in practice (extension, financial instrument, combination, regulation). Studies were also classified as:

Observational	Reporting results of direct assessment of the instrument through primary data collection.
Secondary	Reporting some insights gathered from review of other assessments (not collecting primary information).

[26] There is reference to the Australian Government Reef Program with reference to Water Quality Grants and partnership, but this appears to be outdated with respect to the reef and focussed on the National Landcare Program.

Secondary/conceptual	Reporting on a trial or analysis of a new concept or critique of method.
Modelled	Reporting a hypothetical scenario based on modelled data (this could sometimes provide insight into effectiveness).
Technical support	Reporting on effectiveness of technical support for program (not detailed in this question).

Effectiveness was measured using several levels:

Baseline effectiveness	Objectives were set and reported against.
Bronze level of measuring effectiveness	Information was available on the impact of the intervention on knowledge, aspirations, skills and attitudes (KASA) of landholders.
Silver level of measuring effectiveness	Information was available about adoption of practice in terms of number of landholders adopting a change.
Gold level of measuring effectiveness	Information was available about how land management change (before and after intervention).
Platinum level of measuring effectiveness	Information was available about intention to maintain practice change.
Taupo level of measuring effectiveness	Information was available about water quality improvement outcome.

- Despite the level of investment in land management activities with the objective to improve GBR water quality, there is little PEER REVIEWED (n=86) information about the implementation, or the effectiveness of the programs and instruments invested in.
- Of the 86 peer reviewed evidence items, 19 related to grazing; 27 related to sugarcane, 6 related to other agricultural land uses and 37 related to urban land use (some evidence items relate to more than one industry).
- The quality of peer reviewed information on effectiveness is also variable, with some papers reviewed at a level that could be considered questionable (i.e., as a practice paper with internal editorial review rather than a research paper with two external reviews). For example, 3 out of the 19 peer reviewed evidence items for grazing initiatives were ranked as 'less rigorous' and 3 out of 27 evidence items were ranked this way for sugarcane.
- Reef Trust investment has had the most rigorous assessment in terms of effectiveness through the recent Alluvium study.

- For grazing:
  - Nine peer reviewed evidence items reviewed the effectiveness of extension-based interventions; three reviewed extension and financial instrument combinations; one assessed regulation.
  - Twelve peer reviewed evidence items gave measures of effectiveness from a review of the implementation of a program or instrument designed to influence land management for a GBR water quality outcome.
  - Four provided modelled results of potential effectiveness based on application variables or instrument design, two reflected on implementation from a technical support perspective and one related to regulation.
  - Apart from the cost effectiveness assessment of a large proportion of Reef Trust investment (Alluvium, 2023), three evidence items assessed implementation effectiveness at a Taupo level of understanding effectiveness – that is linking change to

water quality either through actual measures or through the P2R water quality risk framework (which is based on many assumptions)
  - Most evidence items provided an assessment of effectiveness at a KASA level of understanding effectiveness, some assessed at a silver and gold level of understanding effectiveness.
  - While some studies acknowledged the need to understand the legacy of adoption, none reported assessing this.
  - Due to the fact that there is extensive variation in what has been measured to gauge effectiveness as well as variations in the method to measure effectiveness, it is not possible to identify what approach is most effective where and when. Some observations:
    - Many programs implemented using extension/facilitative approaches achieved engagement and/or skill improvement objectives but may have achieved less than objective accredited change (e.g., Queensland Audit Office (2015) reports an objective of 30 businesses accredited as a part of Grazing BMP with only 10 achieving accreditation).
    - The most rigorous and consistent assessment of effectiveness applies a cost effectiveness methodology to Reef Trust investments. For these, cost effectiveness ranged from $16/tonne of sediment removed through to $17,000/tonne removed.
- For sugarcane:
  - Eleven evidence items reviewed extension-based interventions; four reviewed extension and financial instrument combinations; one assessed regulation; eight critiqued intervention instruments and or assessed new methods.
  - Eight evidence items provided measures of effectiveness from a review of the implementation of a program or instrument designed to influence land management for a GBR water quality outcome.
  - Four evidence items provided modelled insight into the potential effectiveness on application variables or instrument design and 11 evidence items provided effectiveness insight based on analysis of concepts more broadly.
  - Apart from the cost effectiveness assessment of Reef Trust investment (Alluvium, 2023), which assessed the cost effectiveness of numerous Reef Trust investments, only two evidence items reported water quality impacts of the intervention.
  - Very few evidence items assessed the impact on KASA but reported more on silver and gold levels of understanding effectiveness (numbers adopting and extent of land management change).
  - Once again, while some studies acknowledged the need to understand the legacy of adoption, none assessed this.
  - Since there is extensive variation in what has been measured to gauge effectiveness as well as variations in the method to measure effectiveness, it is not possible to identify what approach is most effective where and when. Some observations:
    - Similar to grazing, many programs used extension/facilitation to generate change and focused on engagement and/or skill improvement objectives. Most achieved their objectives. The exception to this was the assessment of SmartCane BMP where effectiveness, measured as accreditation, was well below the objective.
    - As for grazing, the greatest understanding about cost effectiveness of programs has been conducted for Reef Trust investments. For these, cost effectiveness ranged from $49/kg of DIN removed through to $554/kg of DIN removed.
- For urban:
  - Twelve out of the 15 evidence items were peer reviewed technical reports associated with the implementation of the partnerships program. There were three additional evidence items about the partnerships program.

- Besides the annually released regional report cards, and despite 36 initiatives underway to improve GBR water quality, only a few partnerships report on the effectiveness of initiatives being implemented in their regions in terms of improvement in water quality. It is noted that many of these initiatives do have other objectives on which effectiveness is reported (such as changes in measures within the domain of human dimensions).
- Despite the 36 initiatives, only a few reported on impact to water quality on the GBR. The Urban Water Stewardship Framework assessments provide more of a performance assessment of urban initiatives to water quality outcomes. A "C" ranking was achieved overall, indicating that the regions as a whole meet the current minimum industry standards.

4.1.15 Significance of findings for policy, management and practice

1. Quantity and quality of peer reviewed evidence
   - Despite the extent of investment in programs and instruments in the GBR catchment area to drive land management practices that aim to improve water quality outcomes for the GBR, only 86 pieces of peer reviewed evidence could be found to provide any insight into effectiveness.
   - The quality of peer reviewed evidence was variable.
   - There is an extensive quantity of evidence available about the performance of projects implementing a range of instruments, but the majority of this evidence is not peer reviewed – that is, it exists in non-peer reviewed reports, factsheets and web pages and could not be used as a part of the Scientific Consensus Statement.

   Significance: additional support for obtaining high quality peer review of findings is required.

2. There are different ways to assess effectiveness. In many cases the material that we reviewed for this synthesis may have been completely appropriate and fit for purpose for the original evaluation of effectiveness but may not have been up to standard for our assessment of effectiveness as effectiveness of an intervention was considered with reference to an improvement in water quality for the GBR. Therefore assessing effectiveness occurred on a scale starting from: 1) if the objectives of the intervention were met; 2) if it was known if and how the intervention or initiative impacted on human capacity to change (Bronze); 3) if the impact on adoption of practice was known (Silver); 4) if the extent of change in practice was known (Gold); 5) if the legacy of the change was known (Platinum) and 6) if the impact on GBR water quality was known (or could be modelled through P2R) (Taupo). Based on the review, the most comprehensive understanding of effectiveness (using our scale) occurred for Reef Trust projects (26 grazing and 15 sugarcane focused interventions). Evaluating effectiveness is very nuanced and there are many other factors that could be included in an effectiveness evaluation. For example, natural capital, social capital, human capital, are co-benefits that may arise as a result of engagement in a water quality improving activity.

   Significance: If an understanding of effectiveness across interventions is desired, a standard and coordinated approach to evaluating and reporting all aspects of effectiveness needs to be established, supported, followed, reported on and peer reviewed.

4.1.16 Uncertainties and/or limitations of the evidence

- Despite the extent of investment in programs and instruments in the GBR catchment area to drive land management practices that aim to improve water quality outcomes for the GBR, only 86 pieces of peer reviewed evidence could be found to assess effectiveness. Of these, 27 (41%), were from journals with a high quality peer review process, 10 (15%) were from a journal with a less rigorous peer review process and 6 (9%) were conference proceedings. The remaining 50% (43) were peer reviewed reports.
- Within the evidence collected, methodologies to determine effectiveness vary. This variation includes measures and assumptions in the generation of an effectiveness measure. Information was collected from a range of outputs reporting on effectiveness but not necessarily using a common method to generate measures of effectiveness. It is not possible to compare effectiveness measures when methodologies are different.

- Evidence from before 2015 was not included.
- Evaluations of regulatory effectiveness have not yet been conducted.
- Evaluations of procedural governance (as a type of program) was not included in the evaluation. Without knowledge of the importance of procedural instruments, effective investments might be made in an inefficient way within catchments. Future evaluations within the SCS also need to assess the effectiveness of procedural governance. This is particularly important when seeking to understand the effectiveness of new approaches to packaging investment such as that applied by the MIPs.

4.2 Contextual variables influencing outcomes

For Part 1 of this question, contextual variables could influence where programs and instruments were applied and what was applied. The spatial application of the mix of programs and instruments is fairly well distributed across Wet Tropics, Burdekin, Fitzroy and Mackay Whitsunday regions. Cape York and Burnett Mary tend to be less focused upon. Prioritising catchments for investment is influenced by the type of industries and the impact of land use on GBR water quality as well as spatial proximity to the GBR. In terms of the types of programs and instruments applied, there tends to be a heavy focus on facilitative instruments some with and some without financial assistance. This is likely due to a long history of extension support in the agricultural sector and possibly a focus on influencing KASA in the first instance. Facilitative instruments are often a core stepping off point for effective implementation of financial incentive-based instruments. The fact that the majority of instruments applied to bring about changes in land management have been facilitative instruments (and possibly with a first focus on influencing KASA) could have had an influence on the effectiveness assessment when assessed in terms of the change in water quality outcomes.

4.3 Evidence appraisal

Relevance

The scale described in Table 35 was used to assess the relevance of the study.

Table 35. Evidence appraisal scoring system.

Score	Rating	Reason
Relevance of the study approach/reporting of results to the primary question		
1	Low	Info/discussion but not detail on either mix and/or effectiveness.
2	Moderate	Detail on program or programs and detail on effectiveness of a program but doesn't cover all categories of effectiveness.
3	High	Includes detail of one or more programs or interventions plus all components of categories of effectiveness.
Spatial generalisability of the study to the primary question		
1	Low	Just one region and/or one program.
2	Moderate	Covers 2 regions but not very generalisable.
3	High	More than 2 regions and/or some discussion about generalisability across regions.
Temporal generalisability		
1	Low	One year of data, or project only ran for 1 year.
2	Moderate	Data collected over a 2 - 3 year period or at more than one point in time. Or project ran for 2-3 years.
3	High	Data collected over a >3 year period or at >3 points in time. Or project ran for more than 3 years.

Due to the difference in quality and reliability for the evidence from non-urban and urban focused studies, the appraisal scores were separated for the two categories of focus.

Agriculture (non-urban)

Relevance of the study approach and reporting of results for the overall body of literature was Moderate with a score of 1.6. The individual scores for relevance of the study approach/reporting of results that this score was calculated from included an adjustment (down) if the paper was a practice and not a research paper so as to reflect concern about the quality of the review process for some of the items used as evidence.

The spatial relevance was rated as Moderate (score 2.0) and the temporal relevance of the body of evidence was Moderate (score 2.3). The relevance of the overall body of evidence was on the high side of Moderate with a score of 5.9.

Urban

Relevance of the study approach and reporting of results for the overall body of literature for non-agricultural studies (urban) was Moderate with a score of 2 out of 3.

The spatial relevance was rated as High (score 3.0) and the temporal relevance of the body of evidence was High (score 3.0). The relevance of the overall body of evidence was High with a score of 8.

Consistency, Quantity and Diversity

As no single method was used in the literature to assess effectiveness, it is not feasible to make an accurate statement about the consistency of evidence but given this variability, the authors consider it to be Low to Moderate.

In the authors experience and knowledge of the total potential available pool of evidence relating to the question, the quantity of evidence items eligible for inclusion was Low.

For the two main industries – sugarcane and grazing, the evidence presents a fairly robust mix of direct observation, conceptual review, modelled analysis and overarching review. For example, for sugarcane: of the 86 peer reviewed pieces of evidence, 27 related to sugarcane. Of these, most analysis was focused on the implementation (n=8) or conceptual development of facilitative type instruments (n=7). Four were modelled studies and eight were secondary reviews. For grazing, the study used primary information (n=11), was based on modelling (n=4), or was based on observation from a role of technical support within a program (n= 2).

Table 9 to Table 21 demonstrate that the 86 pieces of evidence used is not likely to be representative of all the evidence that is available about effectiveness. However, as noted throughout this report, the quantity of available peer reviewed evidence is low and there is extensive non-peer reviewed information available about the performance of programs and instrument.

Confidence

Based on the above assessment, the overall confidence in the body of evidence was Moderate to Limited. For agriculture, this resulted from Moderate relevance, and Low/Moderate consistency (Table 36). For urban, this resulted from High relevance, and Low/Moderate consistency (Table 37).

Table 36. Summary of results for the evidence appraisal of the whole body of evidence used in addressing Question 7.1 - Agriculture. The overall measure of Confidence (i.e., Limited, Moderate and High) is represented by a matrix encompassing overall relevance and consistency.

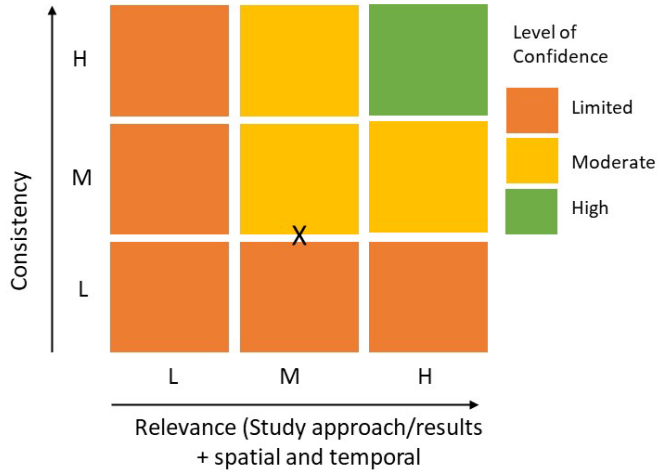
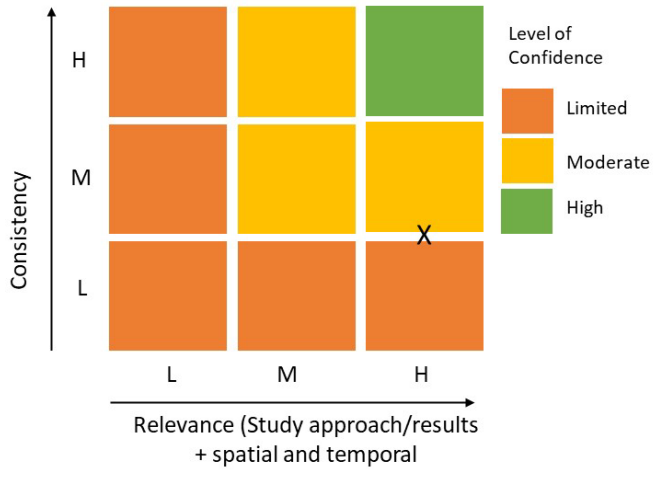
Indicator	Rating	Overall measure of Confidence
Relevance (overall)	Moderate	
-To the Question	Moderate	
-Spatial (if relevant)	Moderate	
-Temporal (if relevant)	Moderate	
Consistency	Low to Moderate	
Quantity	Low	
Diversity	Moderate	

Table 37. Summary of results for the evidence appraisal of the whole body of evidence used in addressing Question 7.1 - Urban. The overall measure of Confidence (i.e., Limited, Moderate and High) is represented by a matrix encompassing overall relevance and consistency.

Indicator	Rating	Overall measure of Confidence
Relevance (overall)	High	
-To the Question	Moderate	
-Spatial (if relevant)	High	
-Temporal (if relevant)	High	
Consistency	Low to Moderate	
Quantity	Low	
Diversity	Moderate	

4.4 Indigenous engagement/participation within the body of evidence

No Indigenous engagement occurred in the drafting of the response of this question, however a number of peer reviewed items reporting on implementation and/or effectiveness of water quality improvement initiatives that included Indigenous engagement, were included:

Non-Urban (agriculture)

- Laura Gullies Project (Reef Trust 4.10) - The project built on effective local Indigenous ranger and corporate capacity to manage erosion threats on Crocodile & Welcome Stations, and the Ang-Gnarra Aboriginal Lands Trust. Erosion control activities included destocking cattle from riparian areas and gullies, native revegetation of gully areas, weed and fire control, porous

check dams in gullies, rock chutes at advancing young head cuts, and treatment of road gullies with water diversion banks. This project specifically trained six Indigenous staff in excavator use.

Urban

- There are Indigenous project partners (Woorabinda Aboriginal Shire Council and the Barada Barna Aboriginal Corporation) for the Fitzroy Partnership for River Health Water Stewardship initiatives changing Fitzroy Basin's water future 2022.

4.5 Knowledge gaps

A summary of knowledge gaps for Question 7.1 is presented in Table 38.

Table 38. Summary of knowledge gaps for Question 7.1.

Gap in knowledge (based on what is presented in Section 4.1)	Possible research or Monitoring & Evaluation (M&E) question to be addressed	Potential outcome or Impact for management if addressed
Knowledge of effectiveness beyond number of participants and change in capacity of participants (KASA).	Starting land management practice level in ABCD water quality risk management framework language (or language consistent with modelling water quality improvement) (what landholders changed from). New level of land management practice (what landholders changed to). Over what amount of land. Commitment to change (legacy/ adoption/ dis-adoption). Impact of change on the pollutant of interest.	Knowledge of effectiveness in terms of type and extent of change as well as potential water quality impact.
Consistent approach to measuring this across programs and instruments.	Standard/consistent measures, guidance on what and how to collect these and support to collect these.	Ability to comparatively assess effectiveness.
Understanding of co-benefits generated from engagement in programs and instruments and an understanding of how these can assist in supporting land management initiatives which generate a water quality outcome for the GBR.	Questions which cover – additional gains in natural capital, physical capital, social capital and human capital.	More rounded understanding of effectiveness especially in relation to indicators for longevity of adoption. This will also create greater depth on the understanding of effectiveness.
Real time lag of water quality outcome from land management practice change (modelled in P2R as instant and complete change).	Effectiveness in water quality change.	Adjustment of understanding of impact of land management change to water quality outcome.

5. Evidence Statement

The synthesis of the evidence for **Question 7.1** was based on 86 studies conducted across the Great Barrier Reef catchment area and published between January 2015 and 31 March 2023. The synthesis includes a *Moderate to High* level of diversity of study types (for the 52 studies reporting on programs in the agricultural sector this included 80% observational from primary and secondary data and 20% modelled studies) and has a *Limited to Moderate* confidence rating (based on *Low* to Moderate consistency and *Moderate* (agriculture) and *High* (urban) overall relevance of studies).

Summary of findings relevant to policy or management action

The Australian and Queensland Governments have sought to improve Great Barrier Reef water quality through investment in a range of initiatives focused on the management of private land under the Reef Trust Program, Reef Trust Partnership (Australian Government) and the Reef Water Quality Program (Queensland Government, agricultural and urban land). This investment is estimated at AUD$1.1 billion over the last 20 years, with approximately AUD$390 million of this for on-ground projects from 2017-2022. Investment has focused specifically on the instruments of extension (51%), followed by financial instruments with extension (36%). Less investment has been allocated directly to physical works such as on-ground gully remediation (5%), regulation and compliance (4%) and financial instruments in the absence of extension (3%). Despite the magnitude of the investment, there is no standard way to understand and report on effectiveness of these programs in generating water quality benefits. It is therefore not possible to draw, from the available peer reviewed literature, defining conclusions about which instruments are consistently effective at driving changes to land management practices to improve water quality outcomes, including when and where they have been most effective. The quality of the limited peer reviewed evidence is also variable. Further, a significant proportion of available evidence examining the performance of Great Barrier Reef water quality improvement projects and programs exists in non-peer reviewed outputs. Ensuring that studies are formally peer reviewed and published will support more transparent and accessible program evaluations, and better consistency and comparability among assessment approaches all of which will contribute to informing future investments.

Supporting points

- Programs and instruments used in the Great Barrier Reef catchment area to drive improved land management actions for water quality benefits are largely funded by the Australian and the Queensland Governments, and sometimes a combination of these. Most of the investment has been in the sugarcane and grazing industries.
- In the agricultural industries, land management actions for water quality benefits have primarily been generated through facilitative instruments (extension), incentive-based instruments (primarily financial incentives) and regulation/coercion. For urban land, actions have been motivated mostly through facilitative instruments and regulation.
- The synthesis assessed the effectiveness of programs and instruments using criteria for whether a program or instrument achieved its objectives and graded these based on indicators of effectiveness. The highest assessment level for effectiveness was when a water quality outcome was known or modelled. Additional information such as cost-effectiveness, insights from modelled studies and literature that critiqued the effectiveness of different methods was also included. Relevant observations include:
  - Most peer reviewed evidence focuses on the effectiveness of extension (primarily in grazing and sugarcane) and is based on assessment of landholder uptake of program objectives (which range from landholder interest in a program through to land management practice change) more so than a measured water quality outcome. For other agricultural industries (bananas for horticulture and cotton and grains for cropping), the effectiveness of the intervention was well understood for program objectives such as increased engagement and skills improvement, but it was less common for studies to report on water quality outcomes.

  - Studies that evaluated the effectiveness of financial instruments tended to include water quality outcomes in effectiveness measures more so than assessments of extension. For example, a recent study evaluated 23 projects funded by the Reef Trust and reported on pollutant reduction, cost-effectiveness and other measures of success.
  - The most well-developed and consistently applied understanding of the cost-effectiveness of water quality outcomes has been conducted for Reef Trust investments. The Reef Trust assessment reports that for grazing, cost-effectiveness ranged from AUD$16 to AUD$17,000 per tonne of fine sediment removed. For sugarcane, cost-effectiveness ranged from AUD$49 to AUD$554 per kg of dissolved inorganic nitrogen removed. Effectiveness was only assessed in terms of the estimated pollutant load reductions and did not include other benefits such as broader social change or capacity building.

- There is very little peer reviewed evidence on the effectiveness of regulation more broadly. There is no peer reviewed evidence on the effectiveness of regulations specifically aimed at improving the quality of water entering the Great Barrier Reef, including the (2019) Reef protection regulations established under the *Environmental Protection (Great Barrier Reef Protection Measures) and Other Legislation Amendment Bill 2019*.
- For urban land uses, Regional Partnerships and the associated Regional Report Card initiatives are creating a forum for benchmarking urban water management activities. The Urban Water Stewardship Framework can be used to rate relative risk to water quality from urban water management activities and identify what aspects need improvement. A “C” ranking was achieved for overall urban water management in 2021, indicating that as a collective, councils were meeting current minimum industry standards, but were not yet at best practice management level.
- An evaluation of the effectiveness of broader procedural governance was not included.

6. References

The 'Body of Evidence' reference list contains all the references that met the eligibility criteria and were counted in the total number of evidence items included in the review, although in some cases, not all of them were explicitly cited in the synthesis. In some instances, additional references were included by the authors, either as background or to provide context, and those are included in the 'Supporting References' list.

Body of Evidence

Alluvium (2023). Final Report: Part A: An evaluation of the Australian Government Reef Trust water quality investments. *Australian Government*. https://www.dcceew.gov.au/sites/default/files/documents/alluvium-part-a-evaluation-report.pdf

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Appendix 1: 2022 Scientific Consensus Statement author contributions to Question 7.1

Theme 7: Human dimensions of water quality improvement

Question 7.1 What is the mix of programs and instruments (collectively and individually) used in Great Barrier Reef catchments to drive improved land management actions for Great Barrier Reef water quality benefits and how effective are they?

Author team

Name	Organisation	Expertise	Role in addressing the Question	Sections/Topics involved
1. Anthea Coggan	CSIRO	Economist	Lead Author	All sections, all topics
2. Diane Jarvis	JCU	Economist	Contributor	Searches and data extraction Analysis and writing (esp evidence synthesis around grazing)
3 Mara Emmerling	CSIRO/JCU	Student	Contributor	Synthesis of programs and instruments for each region and industry. Evidence collection, inclusion of evidence on data extraction spreadsheet.
4. Ella Schirru	CSIRO/JCU	Student	Contributor	Synthesis of programs and instruments for each region and industry. Evidence collection, inclusion of evidence on data extraction spreadsheet.
5. Bianca Molinari	C_2O Consulting		Contributor	Investigation of urban programs and instruments, Integration of information about programs into tables and drafting of text about evidence synthesis and effectiveness.