2022 Scientific Consensus Statement

Question 7.2 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?

Question 7.2.1 What factors influence disadoption of management practices in agricultural industries and are there examples from elsewhere on how to address it?

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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.

[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

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 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**

[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

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 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

Questions

Primary Question 7.2 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?

Secondary Question 7.2.1 What factors influence disadoption of management practices in agricultural industries and are there examples from elsewhere on how to address it?

Background

In Chapter 4 of the 2017 Scientific Consensus Statement (SCS), Eberhard et al. (2017b) describe tackling the complexity of improving water quality outcomes for the Great Barrier Reef (GBR) as a 'wicked problem'. Their reasons for this include: it is a complex system operating at multiple scales; stakeholders have different opinions about GBR water quality issues; the science is contested; water quality is only one part of multiple issues affecting GBR health; and improving runoff from land requires behavioural change by many individual landholders. Eberhard et al. (2021) propose that the policy instruments available to facilitate behaviour change to adopt management practices that will improve water quality include financial instruments, regulations, suasive instruments (extension), and procedural instruments (or governance) that support the implementation of the above instruments. These instruments are supported by research, development, monitoring and evaluation.

The questions for this synthesis are mainly related to the suasive instruments (extension), although they also depend on the implementation of the procedural instruments and the supporting research, development, monitoring and evaluation processes.

Methods

The framework guiding this review was used to assess what might enable and improve uptake of management practices that will improve GBR water quality. This is a systems framework that investigates all system levels including governance, policy, industry, community, research, development and extension, landowners and management practices (see Figure 2).

- 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[5]. 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 Review method was used.
- An initial scoping study was undertaken using references collected from Chapter 4 of the 2017 SCS, additional references from the main author's personal library and then using Google Scholar to search for the main authors the previous processes had identified. The keywords from these were used to do counts and percentages of words from the title, abstract and keywords used in the references.
- Formal search terms were then developed using the CIMO model (Context, Intervention, Mechanisms, Outcome). Searches were conducted using the Web of Science and Scopus databases, with additional references obtained from institutional databases, from professional networks and third parties.
- For the main question, studies conducted outside the GBR catchments were excluded because the enabling and governance environment for the development and

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[5] 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

implementation of the policy and procedural instruments, including the supporting research, development and scaling processes are significantly different. For the secondary question relating to disadoption, the search was extended to the whole of Australia, but not to other countries for a similar reason.
- A total of 2,592 (94%) of studies were identified through online searches for peer reviewed and published literature, while 170 (6%) of studies were identified manually through the other methods. Of the studies initially identified as relevant using the exclusion criteria on the title and abstract, 57% came from manual sources, with 174 judged as eligible to progress to the second screening. Following a second screening based on the full text, 106 studies remained.

Method limitations and caveats to using this Evidence Review

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

- Only GBR derived studies were included for the main question and Australian studies for the secondary question.
- Only two academic databases were searched.
- Studies before 2000 were not included because of the considerable changes that have occurred in the enabling environment, governance systems, policy environment, industry and research development and extension systems, landholder systems and importantly the land management practices since then.
- Only studies written in English were included.

Key Findings

Summary of evidence to 2022

In total, 106 studies were eligible for the primary and secondary question. The focus for the search to answer the primary question was limited to studies that included GBR catchments. For the secondary question that specifically considers disadoption of management practices, the search was widened to encompass studies in Australia outside the GBR. The key reason studies were excluded from other locations was that the enabling environment and context for policies and programs targeting water quality in the GBR are substantially different from that which applies to other parts of Australia and the differences are even greater in other countries.

- Landholder perceptions of a wide range of characteristics that inhibit or enable the uptake of management practices to improve GBR water quality were identified. Some of these are immutable, while others can be influenced by policy and extension. Consequently, the effect of each was generally specific to the context of the practice and varied from landholder to landholder. No studies were found that identified practice-specific factors that enabled or hindered the adoption of urban water management practices to improve GBR water quality.
- While the characteristics of individuals and typologies of individuals are associated with the adoption of management practices, their effects vary and need to be assessed for contextual relevance as landholders are not homogeneous. Best practice would be to develop and test them with the different audiences.
- Landholder distrust and suspicion of certain groups including government and scientists involved in Great Barrier Reef research, program delivery organisations, program managers and delivery staff is a key factor hindering uptake of management practices. To overcome this distrust, management practices and programs for agricultural and urban land managers would be more efficacious if they were developed, tested, scaled, monitored and evaluated using collaborative processes that actively involve key actors in the relevant communities, value chains and innovation systems.
- While real and perceived economic factors are important to landholder decision making, even profitable practices can take time to be adopted because of the interactions within

and between economic factors and landholders, research, extension, industry and community attitudes and systems. Less profitable practices are likely to take even longer and will require further development of approaches, supporting policies and instruments.
- While there is some evidence that factors such as levels of human capital, economies of size, presence of trusted advisors and bottom-up development practices may be associated with improved uptake, they should not be considered in isolation.
- Social resilience, and innovative and adaptive capacity may be factors that hinder or enable the uptake of urban management practices, but there is very limited evidence about this.
- A series of principles have been identified from the literature to guide the design and implementation of innovation and scaling processes that can be adapted to apply to all research, development and extension projects aimed at changing both land management and urban water management practices to improve water quality outcomes for the GBR.
- Program evaluation from the micro to the macro levels is still weak and requires guidelines and funding that puts a greater focus on outcomes and impacts beyond the life of programs or projects. Ideally, evaluation would be part of the planning process, extend beyond the lifespan of the program, and include changes in behaviour, and human and social capital that may have ongoing benefits.
- No studies were found that measured the levels of disadoption of management practices for the GBR or more broadly in Australia since 2020 or identified the factors that hinder or enable disadoption of management practices.

Recent findings 2016-2022

- In their synthesis report for 2017 SCS Waterhouse et al., 2017, p. 13 concluded: “Collaborative processes to deliver interventions and improve trust in decisions and data are essential”. Despite improvement since 2017, this remains the case for policy development and implementation at all levels. Governance is a ‘wicked’ problem, therefore despite the complexity, time and cost involved, it requires high levels of engagement, partnering and collaboration, along with transdisciplinary and multidisciplinary planning, research and development processes.
- While perceptions of mistrust between farmers, government and scientists existed prior to the 2017 SCS, it appears this lack of trust increased after the introduction of the Reef Protection Regulations in 2019 and was noted several times in the Senate Inquiry into regulation of farming practices (Reef and Rainforest Research Centre & James, 2021). Since then, multiple studies have acknowledged and investigated this issue and have concluded that mistrust is a major factor hindering the uptake of management practices to improve water quality outcomes.
- Recent literature documents the benefits of embracing collaborative principles in innovation and scaling processes that build trust and improve the design, implementation and scaling of management practices to improve water quality outcomes for the GBR. Greater involvement of farmers, value chain actors and community could be fostered to build capacity, but collaboration needs to be maintained across time, locations, communities and organisations. Similarly, at the macro governance and policy level, the literature suggests that collaborative transdisciplinary or multidisciplinary research and planning processes are likely to improve outcomes, particularly if they have the consent and cooperation of the targets for these policies.

Significance for policy, practice, and research

Many of the issues listed below were raised in the 2017 SCS, but the evidence supporting them has increased. The significance of the findings for policy, management and practice include:

- The governance system for the GBR is a critical determinant of the innovation processes used, the management practices they develop, and hence the uptake of their recommended management practices.

- Therefore, management practices that are designed to be adopted by landholders to improve water quality outcomes, should be developed, tested and scaled using collaborative processes that actively involve key actors in the relevant value chains, innovation systems and communities. This will also help reduce the inherent distrust and suspicion by the farming sector of government, scientists involved in GBR research, GBR program delivery organisations, program managers and delivery staff.
- Practice, landholder specific and micro-level factors have been extensively investigated. Economic factors are relevant but the perceptions of these vary between researchers and farmers and within farming communities, so that even profitable practices may take time to adopt. Less profitable practices are likely to take even longer and will require enhanced approaches and policies that also integrate extension with incentives and regulation.
- While characteristics of practices, individuals and typologies of managers are associated with the likelihood of a practice being adopted, they should not be considered in isolation to their context and the processes used to engage with the managers. A focus on participatory and collaborative processes is likely to reduce the constraints of these characteristics, because all are involved in the planning, implementation and evaluation of relevant practices.
- Insufficient experimentation and evaluation of water quality programs means that collaborative monitoring and evaluation (M&E) processes for all levels including the macro governance system, the innovation process system and the industry, community and landholder systems should be reviewed, developed and evaluated. These processes could be part of the planning process for the project or program, extend beyond the participants involved in them and the end of a program or project and consider the social and social capital changes, including their effect on levels of trust.
- Mixes of instruments (e.g., regulation, incentives) could be collaboratively designed, implemented and evaluated alongside or in coordination with extension approaches to improve their efficiency and effectiveness.
- Evidence for disadoption and the reasons for disadoption have not been studied.

Key uncertainties and/or limitations

Factors that lead to uncertainties or limitations of the evidence include:

- This is a very broad topic covering multiple systems levels, industries, types of agricultural businesses and urban environments, manager characteristics, regions, agro-climatic environments and management practices.
- Change occurs in an enabling environment that governs or moulds it, but this environment is itself influenced or moulded by change and peoples' interactions and responses to the change. Consequently, the issues are extremely complex.
- Studies of practice or individual characteristics provide context specific and sometimes inconsistent evidence, which makes it hard to make causal statements about links between the characteristics and adoption of a practice or practices.
- Evaluations of outcomes and impact from the micro to the macro level are narrow, use inconsistent methodologies and are almost exclusively short term.
- Studies before 2000 were not included because of the considerable changes that have occurred in the enabling environment, governance systems, policy environment, industry, research, development and extension systems, landholder systems and management practices since then.
- Effects of governance, policy and innovation processes are less uncertain.
- Very limited evidence on factors influencing uptake in urban environments, particularly at the practice to meso-level.
- No peer-reviewed studies were found that investigate disadoption.

Evidence appraisal

The overall relevance for the body of evidence was rated 7.1, which is rated High. Of the 106 articles included in the review of Question 7.2, 68% were given a High score for overall relevance to the question, 34% had a High score for spatial relevance, and 25% had a High score for temporal relevance. These scores are expected given the range of studies involved and do not indicate any limitations for relevance.

Given the authors knowledge of the total potential pool of available evidence, 106 is considered a High number of studies in answering Question 7.2, although there was a lack of detailed studies in some relevant areas of the framework: insufficient, systematic and peer reviewed studies on the governance issue, none on the intersection between politics and policy advice, while evaluation studies from the micro to the macro levels were also weak, so it was difficult to evaluate the outcomes and impacts of many projects. The studies addressed an extremely diverse range of questions and used an extremely diverse range of theoretical and methodological approaches. Even when addressing a particular topic there was often a broad range of theories and methods used.

An additional reliability assessment (assessment of the internal validity) was made of all 106 studies used for the primary question. No studies were removed from the synthesis due to the assessment. Of the 106, 83% raised no concerns, while minor concerns were indicated for seven studies, mostly due to low numbers interviewed, although these were qualitative studies that provided rich data, so this is not an important issue. A further eight studies were rated as having some concerns, which were due to: the model not being evaluated against empirical data or at an early stage of development (6) and potential conflict of interest (2). For the latter, this was not perceived to be a major problem as the findings tended to be consistent with findings from other studies addressing similar issues.

For Question 7.2.1, which specifically addresses disadoption, only four studies were found in Australia since 2000, most of these were for the grains industry and none discussed disadoption in the GBR. No GBR (or Australian) studies measured levels of disadoption of agricultural or urban practices or evaluated the reasons for disadoption.

1. Background

The current progress towards achieving the targets set out in the Reef 2050 Water Quality Improvement Plan has been slow, and at the current trajectory, it is unlikely that the targets will be met (Australian Government & Queensland Government, 2020). This is concerning because it puts the Great Barrier Reef (GBR) under even more pressure, especially when considering other environmental factors such as climate change. If the ecosystems of the GBR are to be restored, it is crucial that greater effort is made to improve the quality of the GBR's water. Therefore, it is important to identify the levers or mechanisms that can accelerate the adoption of management practices aimed at reducing the threats linked to poor water quality.

In Chapter 4 of the 2017 Scientific Consensus Statement (SCS), Eberhard et al. (2017b) describe tackling the complexity of improving water quality outcomes for the GBR as a 'wicked problem'. Their reasons for this include: it is a complex system operating at multiple scales; stakeholders have different opinions about GBR water quality issues; the science is contested; water quality is only one part of multiple issues affecting GBR health; and improving runoff from land requires behavioural change by many individual landholders. Eberhard et al. (2021) propose that the policy instruments available to facilitate behaviour change to adopt management practices that will improve water quality include: financial instruments, regulations, suasive instruments (extension), and procedural instruments (or governance) that support the implementation of the above instruments. These instruments are supported by research, development, monitoring and evaluation. However, they also suggest that: psychological approaches have received limited application (except for Canechanger); there is a deficiency in coordination, collaboration and training in advisory systems; there are gaps between advisory services and the research and development system; evaluations rely on participation and satisfaction levels rather than outcomes and impacts; and substantial gaps in knowledge about the interaction of policy instruments and their impacts make it difficult to measure effectiveness and impact.

The questions for this synthesis are mainly related to the suasive instruments, although they also depend on the implementation of the procedural instruments and the supporting research, development, monitoring and evaluation processes.

1.1 Questions

Primary question	**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?
Secondary question	**Q7.2.1** What factors influence disadoption of management practices in agricultural industries and are there examples from elsewhere on how to address it?

In interpreting the primary and secondary questions of Question 7.2, the following terms will be interpreted broadly: uptake, factors, hinder, enable and management practices. The reasons for the broad interpretation are expanded later in discussion of the frameworks used when undertaking the review. The frameworks incorporate the various systems levels (macro, meso and micro) affecting the management practices, governance systems and innovation processes used to develop and promote management practices.

An important part of Question 7.2 is 'management practices that aim to improve water quality outcomes for the Great Barrier Reef'. A 'management practice' is construed to include technologies, practices or techniques (e.g., weed control, fencing riparian areas, irrigation efficiency, record keeping), institutional practices (ways of thinking and working in an organisation, e.g., how the innovation process and the factors that affect adoption are defined), and social changes (e.g., changes in the services, theoretical frameworks and processes that more effectively meet a social need). Once again, this idea is expanded in the GBR frameworks guiding this review. Implicit in the concept is that 'management practices' arise from interactions between a network of actors, not a linear pipeline. In the literature for the GBR, most of the 'management practices' for agriculture are those described in the Water Quality Risk Frameworks (WQRF) (Australian Government & Queensland Government, 2022), while management practices for urban water are defined in the Urban Water Stewardship Framework (UWSF) (Australian Government & Queensland Government, 2018). Both systems rank practices using a four-point ABCD framework from "superseded approaches" to "innovative practice". It is worth noting that implicit in the question and the WQRFs and UWSF is that some management practices are better than existing practices. This raises the question of who determines what is defined as better or more innovative. As Vanclay (2004, p. 215) suggest, "many practices actively promoted by extension in the past have significantly contributed to degradation", so the question of who decides what is 'better', whether it is 'better' for the proposed target adopter, and the practices and criteria for assessing its 'improvement' are critical to this review.

Uptake or adoption is defined as the process of discovery, decision and action that an individual or group applies when taking up new practices or innovations (as defined above) (adapted from Wilkinson, 2011, p. 39). It is rarely a binary process, rather it is a continuous process that is rarely complete and can be reviewed and adapted as new information, experiences and circumstances occur (Montes de Oca Munguia et al., 2021; Pannell et al., 2006; Pannell & Claassen, 2020; Vanclay, 2004; Wilkinson, 2011). It is normally thought of as occurring in stages such as: awareness, initial evaluation, trial, and partial adoption, adoption, non-adoption or disadoption. Depending on the practice, context and other factors, this process may occur slowly, quickly, skip stages, or stop at any of the stages. The more complicated the practice, the more likely it is to be partially or incompletely adopted or parts of it adapted or evolved to suit the individual and local context. Intensity of adoption may vary, for example from use across the whole of a farm to being used for only selected soils, crops or seasons.

Tully (1964) and Vanclay (2004) also point out that adoption occurs in a social context, whether that be farmers discussing with neighbouring farmers, or researchers discussing with researchers, or farmers discussing with farmers, researchers and others. More recently Glover et al. (2019) and Leeuwis & Aarts (2021) have critiqued the idea that adoption is an individual process, particularly for complex technological change, because its narrow technocentric, binary and black box thinking fails to consider the social and institutional components of innovation. The focus on the individual has spawned a plethora of social-psychological studies of the determinants of adoption (or non-adoption) that ignore vertical, horizontal, intra-individual and time related interdependencies and institutional influences involved with complex change (Leeuwis & Aarts, 2021). They conclude that adoption can sometimes be a collective rather than an individual process, which has implications for scaling of technologies beyond the initial innovators. Since it also ignores outcomes and impacts of adoption it does not include other consequences such as "unintended benefits, costs and risks, distributional questions and especially the ways in which the target population, or other people, may be creatively appropriating and adapting the technology" (Glover et al., 2019, p. 172). Nor for that matter does it consider changes in social and human capital.

Non-adoption and disadoption are at two ends of the continuum of the stages of adoption. Non-adoption may occur because a person or organisation is not aware of the innovation, has become aware of the innovation but has rejected it for various reasons without investigating further, or has investigated it further and then decided to reject it (Montes de Oca Munguia et al., 2021; Pannell et al., 2006; Vanclay, 2004; Wilkinson, 2011). For the purposes of this study, disadoption includes rejection of an innovation after a trial adoption (either partial or complete) through to disadoption after initially deciding to take it beyond the trial stage at a small or a large scale, or for a short or lengthier period. This decision may occur because of individual decisions or be due to one or more social and institutional interdependency factors.

Question 7.2.1 also includes the word 'elsewhere' which implies considering the literature on disadoption outside the GBR area. In considering this issue, this review will focus mainly on other Queensland and Australian examples as the enabling environment, the national social-economic and political environment and the agroclimatic and ecological environment are very important in determining adoption processes.

1.2 Conceptual diagrams

Many investigations of the factors that hinder or enable the uptake of management practices in the GBR focus on narrow aspects of the adoption and innovation processes, with a particular focus on the barriers and enablers of technology adoption by farmers or for a particular industry (e.g., Benn et al., 2010; Bohnet, 2015; Deane et al., 2018; Eberhard et al., 2021; Fielke et al., 2021; Greiner, 2016). Others discuss governance and processes used to promote change (Bennett et al., 2018; Dale et al., 2016; Eberhard et al., 2017a; Vella & Baresi, 2017). While they provide valuable insights into factors influencing adoption or governance in their areas, they do not address the complexity of the systems interactions that influence the uptake of management practices that will improve GBR water quality. Indeed, most of the research focus is on why farmers are not adopting the innovations and 'improved' practices developed by the existing innovation processes and not on all levels of the governance and innovation processes that affect adoption. There is currently very little research to explore the adoption of management practices that improve water quality beyond the agricultural sector when considering the role of other industries and/or communities.

The frameworks below are an initial step designed to help overcome this weakness by portraying the complexity of the system, so that future work does not oversimplify the system. They incorporate insights from an ecological systems theory framework, agricultural innovations systems (AIS) theory and a framework for assessing macro, meso and micro level governance and innovation processes affecting adoption of innovations that will improve GBR water quality.

An adapted ecological systems framework

The overarching framework for this question is based on ecological systems theory (Bronfenbrenner, 1992) to help categorise the various system levels, and the actors and factors that influence human behaviour at the various levels (Figure 1). This systems-thinking approach demonstrates that people do not exist in isolation but rather that people, and their behaviours and the outcomes of those behaviours, are shaped by interactions within and between the levels of the system in which they exist. The strength of this approach is that it applies equally across agriculture, as well as the broader urban industry.

The system levels of the framework are:

- The practice or behaviour characteristics (e.g., how compatible, complex or triable the practice is).
- The micro-system level (i.e., individual or ‘actors’ demographic factors, including relevant land or house characteristics and their attitudes, motivations and capacity, as well as the individual’s immediate environment which includes their relationships with other people such as family, peers and neighbours).
- The meso-system level (i.e., social structures that influence the micro-system and implement the programs determined at the macro-system level, for example, industry, Research, Development and Extension (RD&E) agencies, and community).
- The macro-system level (i.e., all socio-economic and cultural elements, for example, how the environment changes, policy and legislation, politics, mass media and global markets).

Within each of these levels, behavioural, attitudinal, social and cultural factors (often, collectively referred to as the “human dimensions”) that hinder or enable uptake will be explored.

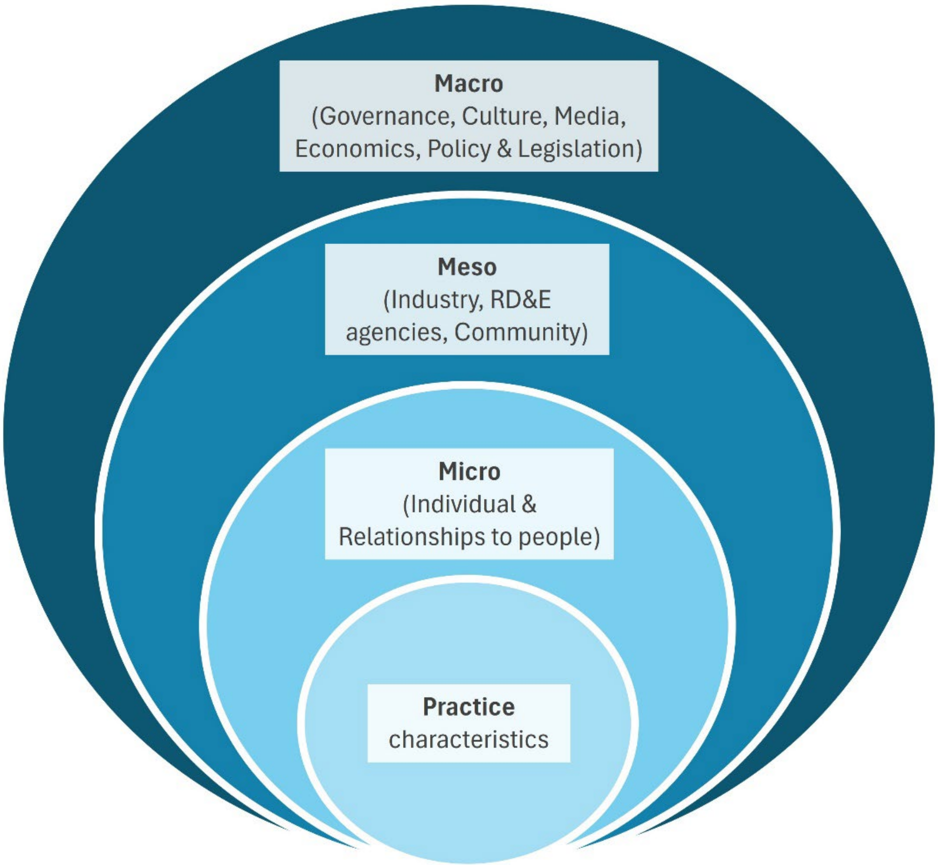


Figure 1. An adapted ecological systems framework to classify the system levels that hinder or enable the uptake of management practices. Adapted from Bronfenbrenner (1992).

An agricultural innovation system for GBR value chains

Change in agricultural systems occurs within an agricultural innovations system (AIS), which incorporates the components that influence and are influenced by the AIS (de Boon et al., 2022; Rajalahti, 2012). For the purposes of this study, an AIS is defined as: "A network of actors or organisations, and individuals, together with supporting institutions and policies in the agricultural and related sectors, that brings existing or new products, processes, and forms of organisation into social and economic use" (Tropical Agriculture Platform, 2016, p. x). This is similar to the definitions used by Mytelka (2000), The World Bank (2006) and Rajalahti (2012). An innovation system can be defined at a national, regional or local level, depending upon the purpose to which it is being put. An AIS also involves the learning and development that occurs when organisations and individuals engage in generating, adapting and diffusing new knowledge, products, processes and forms of organisation, along with the formal and informal governance systems, institutions (rules, norms, conventions) and policies that determine how the interactions take place (de Boon et al., 2022; Rajalahti, 2012; The World Bank, 2006). A simplified model for an AIS is outlined in Appendix 2 (Figure 4) and includes the key actors and institutions for the main agribusiness value chains in the GBR system.

A framework for assessing governance and innovation processes affecting uptake of management practices that will improve GBR water quality

While an AIS model incorporates the key actors and institutions involved in the GBR agricultural value chains that are influenced by and influence the change process, its main focus is the meso-level networks of actors and institutional structures (de Boon et al., 2022). It does not include a framework for diagnosing the operations of the innovation processes that shape change within the agricultural industries or urban systems that affect water quality in the GBR. Because of the complexity and unpredictability of the GBR innovation system, potential consequences of management practices are difficult to foresee and may have positive or negative effects on different actors within the GBR system. Innovation processes are driven by the political power dynamics, and these dynamics influence the philosophies, approaches and processes used to drive behaviour change (de Boon et al., 2022). Therefore, the normative and power dynamics within AIS of the GBR and the processes that derive from these are important to explore when assessing the factors that hinder and enable change within the relevant sectors.

In the last century and this century many paradigms of innovation and change have been used in Australia and elsewhere (Anderson et al., 2006; Black, 2000; Blackburn, 1994; Coutts et al., 2005; Jennings et al., 2011; Pound & Conroy, 2017; Rogers, 1995) ranging along a directive-non-directive continuum, from transfer of technology or top-down models, to farmer-first, bottom up or participatory models. Each paradigm for change involves an inherent philosophy and theory of change and associated processes and techniques.

The paradigms used for the innovation processes, including the research, development and extension phases, can be critical enhancers and barriers to the level and speed of change (de Boon et al., 2022; Michie et al., 2011; Paschen et al., 2021; Toillier et al., 2020; Tully, 1966; Williams et al., 2021). Because of the potential importance inherent in the innovation processes used in the GBR to facilitate and constrain practice change, the ecological systems framework is strengthened by a framework that expands on the governance system, the context of the key actors, and the innovation processes that are governing, moulding, enhancing and constraining the water outcomes on the GBR due to the GBR agricultural and urban innovation processes (Figure 2). This framework uses the principles developed by de Boon et al. (2022) in their governance framework for agricultural innovation, but includes concepts derived from Birner et al. (2009), Bryant (1989), Coggan et al. (2021b), de Boon et al. (2022), Dessart et al. (2019), Michie et al. (2011), Murray-Prior (2020), The World Bank (2012), Tully (1966) and Williams et al. (2021). In the context of this study, the definition of governance used by Eberhard et al. (2017b, p. 33) is used: “Governance refers to the wide variety of decision-making processes leading to various environmental, social and economic outcomes within society. The processes include the decisions involved in policy development and implementation, including policy instruments such as regulation, cooperation and market approaches”.

The five main dimensions of this framework are: the macro context and the enabling environment; the macro governance system; the meso-micro context; the innovation processes; and the innovations and their characteristics developed by the innovation processes (particularly those relevant to changing management practices to improve water quality emanating from agricultural industries). The policies, investments, regulations, and socio-economic and political factors or the macro context and enabling environment govern and mould the macro governance system, the meso-micro context and the innovation processes relevant to changing management practices affecting GBR water quality. In this framework, the meso-micro context combines the meso level of industry and community, with the micro level of individuals or landholders from the ecological systems framework. Detailed explanations of these five dimensions can be found in Appendix 3.

Outcomes of the innovation and scaling processes

The innovation and scaling processes produce innovations that are direct and indirect drivers of change in all five dimensions of the framework (de Boon et al., 2022).The process, knowledge and innovation stocks are the amounts of these at a particular time. Change in turn produces new stocks, which become flows of innovations, which will have intended and unintended outcomes and impacts. Together they mould and govern the ability of the system to adapt to and cope with the interaction of human induced change in the production and environmental systems and ultimately the state of the GBR ecosystems.

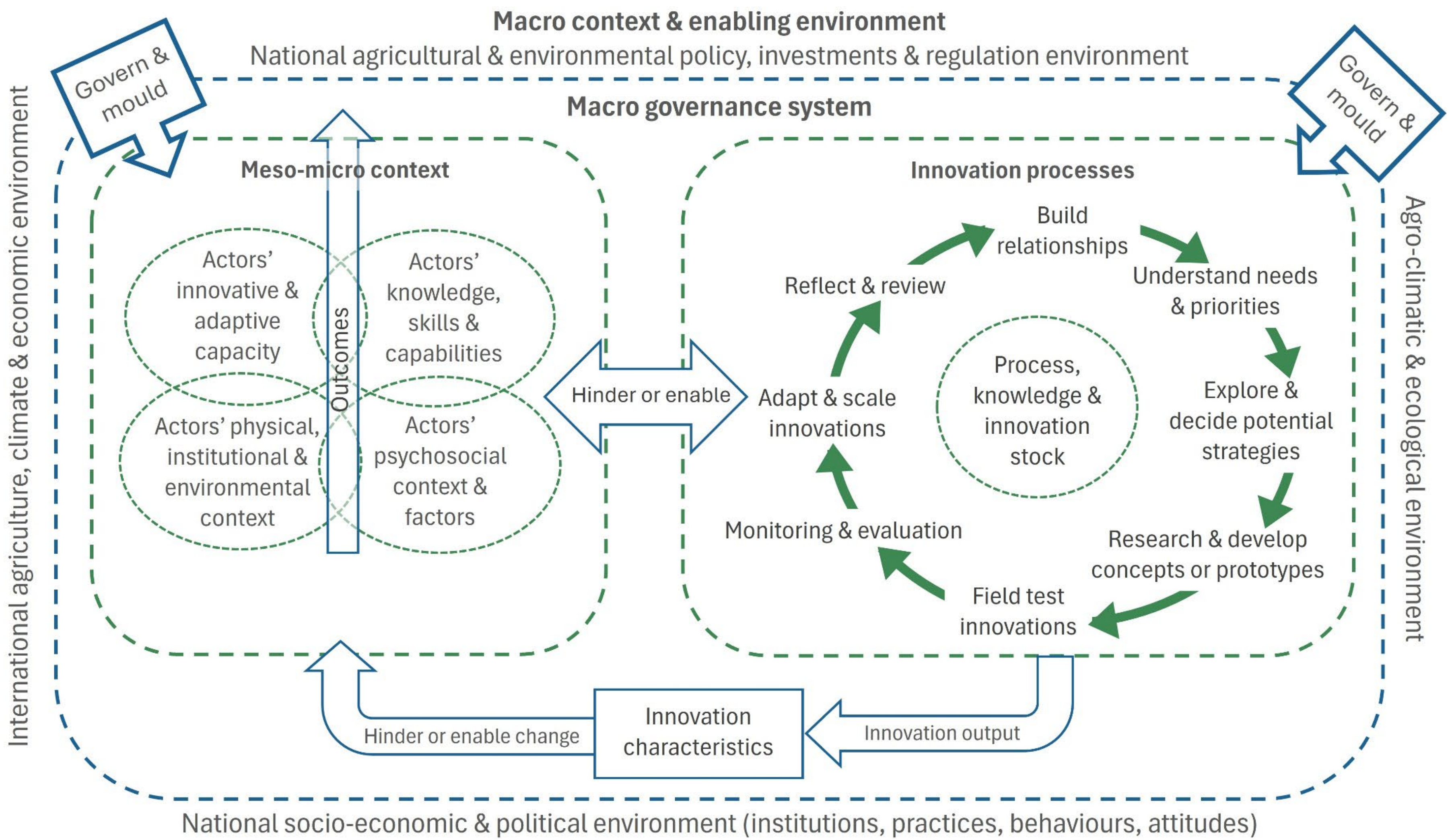


Figure 2. A framework for assessing governance, context and innovation processes affecting uptake of management practices that will improve GBR water quality. Adapted from de Boon et al. (2022), but including concepts from Birner et al. (2009), Bryant (1989), Coggan et al. (2021b), de Boon et al. (2022), Dessart et al. (2019), Michie et al. (2011), Murray-Prior (2020), The World Bank (2012), Tully (1966), Williams et al. (2021).

Insights for addressing Question 7.2 from the ecological systems model and the framework for assessing factors affecting uptake of management practices that will improve GBR water quality

Incorporating the ecological systems framework into the procedure for assessing factors that hinder or enable uptake of improved practices in the GBR improves the analysis in a couple of ways. First it facilitates mapping and analysis of the relevant chain actors and components of the key agribusiness (and broader industry systems) relevant to the GBR at the start of the process, thereby providing a wider-angle and more holistic view of the system. Second, it forces a consideration of the implications of the macro and meso level enabling environment and governance, with their policies, institutions, investments and regulations on the innovation processes and their interactions with the key actors in the system. Third, it would emphasise that change to factors influencing water quality consider their effects on the efficiency and effectiveness of the relevant industry systems (agribusiness and broader industry in the urban sectors) and their value chains, not just on the GBR. The relationships and information flows between the actors in the systems might also be considered when promoting change. A final strength of this framework is its alignment to other, highly relevant models and conceptual frameworks which can inform this topic.

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	**Q7.1** 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? Question 7.2 is indirectly related to questions 3.5, 4.6 and 5.3 which address the question of “effective management practices” for reducing sediment and particulate nutrient loss, dissolved nutrient loss, and pesticide risk because it considers these practices from a landholder perspective. **Q3.5** What are the most effective management practices (all land uses) for reducing sediment and particulate nutrient loss from the Great Barrier Reef catchments, do these vary spatially or in different climatic conditions? What are the costs and cost-effectiveness of these practices, and does this vary spatially or in different climatic conditions? What are the production outcomes of these practices? **Q4.6** What are the most effective management practices for reducing dissolved nutrient losses (all land uses) from the Great Barrier Reef catchments, and do these vary spatially or in different climatic conditions? What are the costs of the practices, and cost-effectiveness of these practices, and does this vary spatially or in different climatic conditions? What are the production outcomes of these practices? **Q5.3** What are the most effective management practices for reducing pesticide risk (all land uses) from the Great Barrier Reef catchments, and do these vary spatially or in different climatic conditions? What are the costs of the practices, and cost-effectiveness of these practices, and does this vary spatially or in different climatic conditions? What are the production outcomes of these practices?

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[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 Review method was used.

2.1 Primary question elements and description

The primary question is: ***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?***

The secondary question is: ***What factors influence disadoption of management practices in agricultural industries and are there examples from elsewhere on how to address it?***

A description of the question elements for Questions 7.2 and 7.2.1 is provided in Table 1. Definitions of relevant terms used for these questions are in Table 2.

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[7] but other variations are also available. For example, the CIMO[8] framework used here replaces Subject/Population with Context, and Comparator with Mechanisms. Its components are:

- **Context:** Which individuals, groups, systems or relationships are you focusing on?
- **Intervention**: Which event, action or activity are you investigating the effects of?
- **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?
- **Outcome**: Which effects of the intervention you have chosen to focus on? How are you defining and measuring these effects?

[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

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

[8] https://libguides.library.cqu.edu.au/c.php?g=949210&p=6881304

Table 1. Description of question elements for Questions 7.2 and 7.2.1 using CIMO.

Elements (CIMO)	Question terms	Description
Context	GBR, except for disadoption Otherwise not explicit; those who adopt, disadopt define & promote adoption of 'management practices'.	***Which individuals, group, systems or relationships are you focusing on?*** ***<u>Agriculture</u>*** • For Q7.2 the agricultural industries in catchments that flow into the GBR system, with sugarcane, grazing & bananas being the main industries. • For Q7.2.1 the agricultural industries in Queensland and Australia. • Managers of agricultural properties of those industries. • Managers of agricultural value chain businesses. ***<u>Urban</u>*** • Catchments that flow into the GBR system. • Managers of urban water/council operators that deal with point source and diffuse (i.e., developing urban and established urban) pollutants. • Managers of urban water within the urban development and construction sector. • Urban water service providers. ***<u>Other</u>*** • Policy makers & funders of GBR RD&E on 'improved practices'. • Traditional & social media networks.
Intervention/ Phenomenon	Not explicit or implicit	***Which event, action or activity are you investigating the effects of?*** • Context & enabling environment operations. • Governance system operations. • Innovation processes & associated programs and projects including RD&E.
Mechanisms	'Behavioural (attitudinal), economic, social and cultural factors that *hinder or enable* uptake of practices that aim to improve water quality outcomes'.	***Which responses to the interventions explain how it leads to the outcome? Which circumstances cause the response? In which circumstances are these responses avoided?*** • Barriers or enablers of adoption of management practices or innovations in all elements of the GBR AIS. • Behavioural, attitudinal, economic, social and cultural factors. • Includes reasons for behaviours & decisions about the enabling environment, governance, meso-micro context, innovation processes & innovation characteristics that affect levels of adoption and disadoption.

Elements (CIMO)	Question terms	Description
Outcome	Explicitly 'uptake of management practices that aim to improve water quality outcomes for the GBR' for 7.2 and disadoption in 7.2.1.	***Which effects of the interventions have you chosen to focus on?*** • In terms of agricultural management practices (explicit) affecting water quality of the GBR (implicit), will focus on higher levels of the Bennett (1979) hierarchy of evidence for evaluations of interventions, including: reactions to the various interventions; changes in knowledge, attitudes, skills and aspirations; changes in behaviour; and end results. However, more recently end results have been divided into outcomes and impacts and include social, environmental and economic outcomes and impacts. • Evaluations of the effectiveness and efficiency of macro, meso and micro level governance and innovation processes of the AIS affecting adoption of innovations that will improve GBR water quality (implicit). ***How are you defining and measuring these effects?*** • Outcome evaluations normally consider the outcomes or results of an intervention, (as indicated in the hierarchy above) at various scales in time and space. However, impact evaluation normally involves measuring the causal impact of an intervention on an outcome or outcomes of interest (Glewwe & Todd, 2022; Winters et al., 2010). In international development the definition used by the World Bank is (Glewwe & Todd, 2022, p. 6): "An impact evaluation is a study that attempts to measure the causal impact of a project, program, or policy on an outcome of interest to governments and other interested parties". • Currently adoption of agricultural management practices and the impact on water quality is currently measured via the Water Quality Risk Frameworks. • There is not currently an equivalent urban water quality monitoring program, although some of the regional report cards monitor water quality that would be impacted by urban water practices under the UWSF. • In this study we will consider both soft evidence (non-causal outcomes) and hard evidence (causal impacts) of interventions and programs.

Table 2. Definitions for terms used in Questions 7.2 and 7.2.1.

Definitions	
Innovation	Includes technologies, improved practices, management practices or techniques (e.g., weed control, fencing riparian areas, irrigation efficiency, record keeping), institutional practices (ways of thinking and working in an organisation, e.g., how the innovation process and the factors that affect adoption are defined), and social (e.g., changes in the services, models and processes that more effectively meet a social need).
Adoption	The process of discovery, decision and action that an individual or group applies when taking up new practices or innovations.
Disadoption	Includes rejection of an innovation after a trial adoption (either partial or complete) through to disadoption after initially deciding to take it beyond the trial stage at a small or a large scale or for a short or lengthier period.
Management practices	***Agriculture*** The adoption of improved management practices specific to agricultural industries located in GBR catchments is defined and reported using industry specific management practice frameworks called Water Quality Risk Frameworks. These ABCD management practice frameworks were first developed in 2008 to represent different levels or standards of management practice within different industries (i.e., sugar, grains, horticulture, bananas and grazing) for different water quality parameters (i.e., sediment, nutrients and pesticides). The terminology commonly used to describe the management practices in the frameworks were A = innovative practices; B = best management practice; C = minimum standard practices; D = superseded practices. The 2013 Paddock to Reef program Water Quality Risk Frameworks replaced the ABCD frameworks with an equivalent risk to water quality: A = Lowest risk; B = Moderate-Low risk; C = Moderate risk; D = High risk. ***Urban*** The adoption of improved management practices specific to the urban water sector located in GBR catchments is defined and reported using an industry specific management practice framework called the Urban Water Stewardship Framework (UWSF). The framework covers on-ground management activities linked to erosion and sediment control, stormwater management, and operation and maintenance of wastewater treatment plants and the sewer network. It also covers activities related to policy, planning and governance, capacity building, training, research and development, and monitoring and evaluation, which underpin on-ground management practices. The UWSF has adopted the same ABCD framework as developed in 2008 to represent different levels or standards of management practice within different agriculture industries. Thus, the terminology used to describe the management practices in the UWSF are A = innovative practices; B = best management practice; C = minimum standard practices; D = superseded practices.
Improved	Improved normally means better than existing practices or innovations. This raises the question of who determines what is defined as 'improved'. As Vanclay (2004, p. 215) expound, "many [improved] practices actively promoted by extension in the past have significantly contributed to degradation", so the questions of who decides what is 'improved', whether it is 'improved' for the proposed target adopter, and the criteria for assessing its 'improvement' are critical to this review.
Human Dimensions	In the sense that human behaviour will impact on water quality outcomes, these include social, cultural, institutional and economic factors: from the aspirations and capacities of landholders, industries and communities to their stewardship practices and broader governance of the GBR.

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.

An initial scoping search was undertaken using the following approaches:

- References were collected from Chapter 4 of the 2017 Scientific Consensus Statement (Eberhard et al., 2017b), mainly from Section 5 (The Great Barrier Reef governance system) and Section 6 (Agricultural Practice Change) and were assessed based on their eligibility and relevance to questions 7.2 and 7.2.1 and whether they could be obtained easily.
- Additional recent references were assessed for eligibility and relevance from the author's personal library and professional networks and added to the list.
- *Google Scholar* was then used to conduct searches on the names of the main authors identified from the above sources and using some of the main keywords used in the references already identified.

In total, 174 references were located in the initial scoping. From these, the title, abstract and lists of keywords were exported from Endnote to an Excel spreadsheet, which was used to do counts and percentages of keywords from the title, abstract and author keywords. These keywords were used to help develop the initial search strings related to the question elements that were used in the next stages of the search.

a) Search locations

Following the initial scoping search, the more detailed searches were performed on:

- The primary databases of Web of Science and Scopus.
- References used in previous (2008 and 2013) SCS.
- Searches of institutional databases containing relevant and peer reviewed reports and papers (AIMS, NESP, CORAL, MERIT, CSIRO, UQ, JCU, GU and QUT).
- Additional references obtained from professional networks and third parties.

b) Search terms

The initial 174 references were examined for keywords in the title, abstract and author keywords, which were then combined with the CIMO model to develop the search terms in Table 3 to conduct the online searches.

Table 3. Search terms for different question elements for Question 7.2 based on the CIMO framework.

Element	Search terms
Context	• Great Barrier Reef, GBR, sugar cane, beef, banana, grazing, horticulture • farmer, grazier, farm manager, extension, advisory services, research, agribusiness, media, governance, policy, development, OGBR, GBRMPA, Great Barrier Reef Foundation • urban, development and construction industry, water utility, council, local government
Intervention/ Phenomenon	• program, project, innovation process, enabling environment, govern, policy, planning, strategy, development, capacity
Mechanisms	• participation, collaboration, co-design, co-innovation, community, partner • innovation, improved practice, management practice, adopt, disadopt, diffusion, intend, learning, barrier, impede, enable, driver, trust, extension, advisory, communication, sources, research, cultural, social, social capital, motivation, risk, norm, belief, knowledge, attitude, skills, aspirations, framing
Outcome	• knowledge, skills, attitude, behaviour, change, adoption, disadoption, practice change, outcome, impact, process, monitoring, evaluation, environment, sustainability, social, economic, typology, segmentation, water quality

c) Search strings

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

Table 4. Search strings for Question 7.2 based on the search terms for the CIMO framework.

No	Search strings: Question 7.2 Agriculture
1	((gbr OR “Great Barrier Reef”) AND (farm* OR graz* OR “sugar*cane” OR beef OR banana OR horticult*) AND (adopt* OR non*adopt* OR dis*adopt* OR innovat* OR “practice change” OR "behavio?r change" OR “management practice”) AND (knowledge OR skill* OR attitude* OR risk OR norm* OR fram* OR cultur*OR economic* OR barrier OR enable*)) AND PY=(2000-2022)
2	((gbr OR “Great Barrier Reef”) AND (adopt* OR non*adopt* OR dis*adopt* OR innovat* OR “practice change” OR "behavio?r change" OR “management practice”) AND (knowledge OR skill* OR attitude* OR risk OR norm* OR fram* OR cultur*OR economic* OR barrier OR enable*)) AND PY=(2000-2022)
3	((gbr OR “Great Barrier Reef”) AND (farm* OR graz* OR “sugar*cane” OR beef OR banana OR horticult*) AND (adopt* OR non*adopt* OR dis*adopt* OR innovat* OR “practice change” OR "behavio?r change") AND (participat* OR collaborat* OR communit* OR partner* OR co-design OR co-innovat*)) AND PY=(2000-2022)
4	((gbr OR “Great Barrier Reef”) AND (adopt* OR non*adopt* OR dis*adopt* OR innovat* OR “practice change” OR "behavio?r change") AND (participat* OR collaborat* OR communit* OR partner* OR co-design OR co-innovat*)) AND PY=(2000-2022)
5	((gbr OR “Great Barrier Reef”) AND (extension OR innovat* OR adopt* OR non*adopt* OR dis*adopt* OR “practice change” OR "behavio?r change") AND (governance OR policy OR development OR program OR enabl* OR process) AND (“Office of the Great Barrier Reef” OR “Marine Park Authority” OR “Great Barrier Reef Foundation” OR government)) AND PY=(2000-2022)
6	((gbr OR “Great Barrier Reef”) AND (farm* OR graz* OR “sugar*cane” OR beef OR banana OR horticult*) AND (adopt* OR non*adopt* OR dis*adopt* OR innovat* OR “practice change” OR "behavio?r change") AND (outcome OR impact OR monitor* OR evaluat*)) AND PY=(2000-2022)
7	((gbr OR “Great Barrier Reef”) AND (media OR news OR communicat* OR inform*) AND (perception* OR impact OR anthropogenic OR policy OR trust OR “climate change”)) AND PY=(2000-2022)
No	**Search strings: Question 7.2 Urban**
8	((gbr OR "great barrier reef") AND (urban OR develop* OR "local government" OR council) AND (innovat* OR adopt* OR non*adopt* OR dis*adopt* OR "practice change" OR "behavio?r change" OR "management practice" OR stewardship) AND (knowledge OR skill* OR attitude* OR risk OR norm* OR social OR fram* OR cultur*or AND economic* OR barrier OR enable*)) AND PY=(2000-2022)
9	((gbr OR "great barrier reef") AND (urban OR develop* OR "local government" OR council) AND (governance OR policy OR project OR development OR program OR enabl* OR process) AND ("office of the great barrier reef" OR "reef trust" OR "marine park authority" OR "great barrier reef foundation" OR government)) AND PY=(2000-2022)
10	((gbr OR "great barrier reef") AND (urban OR develop* OR "local government" OR council) AND (innovat* OR adopt* OR non*adopt* OR dis*adopt* OR "practice change" OR "behavio?r change" OR "management practice" OR stewardship) AND (outcome OR impact OR monitor* OR evaluat*)) AND PY=(2000-2022)
No	**Search strings: Question 7.2.1 Agriculture**
1	((Australia OR Queensland) AND (farm* OR graz* OR “sugar*cane” OR beef OR banana OR horticult*) AND (non-adopt* OR non*adopt OR disadopt*) AND (knowledge OR skill* OR attitude* OR risk OR norm* OR fram* OR cultur*OR economic* OR barrier OR enable*)) AND PY=(2000-2022)
2	((Australia OR Queensland) AND (non-adopt* OR non*adopt OR disadopt*) AND (knowledge OR skill* OR attitude* OR risk OR norm* OR fram* OR cultur*OR economic* OR barrier OR enable*)) AND PY=(2000-2022)
3	((Australia OR Queensland) AND (farm* OR graz* OR “sugar*cane” OR beef OR banana OR horticult*) AND (non-adopt* OR non*adopt* 0R disadopt*) AND (governance OR policy OR development OR program OR enabl* OR process)) AND PY=(2000-2022)
4	((Australia OR Queensland) AND (non-adopt* OR non*adopt* OR disadopt*) AND (governance OR policy OR development OR program OR enabl* OR process)) AND PY=(2000-2022)

d) Inclusion and exclusion criteria

The eligibility criteria (see Table 5) for determining the inclusion or exclusion of papers identified with the search terms shown in Table 4 are based on the CIMO framework and mainly deal with excluding papers more relevant to Questions 7.1 (Coggan et al., this SCS) and 7.3 (Espinoza et al., this SCS).

Table 5. Inclusion and exclusion criteria for Question 7.2 applied to the search returns.

Question element	Inclusion	Exclusion
Context	a) Study includes GBR catchments. b) Studies of disadoption can also include environmental & sustainable practices in other countries. c) Focus on studies after 2000. d) Managers of agricultural properties & agricultural value chain businesses. e) Managers of urban water. f) Development and construction industry. g) Employees of GBR RD&E agencies. h) Policy makers & funders of GBR RD&E on 'improved practices'. i) Traditional & social media sources discussing GBR water quality.	a) Studies that do not include GBR catchments excluded except for disadoption, exclude studies that do not include Australia*. b) Tourism & other GBR industries not related to: AIS, urban water, development & construction. c) Management of other land (e.g., forest, national parks).
Intervention/ Phenomenon	a) Research & development policies, programs, processes and outputs. b) Extension including: technology transfer, education & training, communication & information access, demonstrations, & voluntary facilitation & empowerment programs.	a) Positive & negative incentive mechanisms; legal & regulatory mechanisms; infrastructure (e.g., engineering); water market reform (e.g., Burdekin). b) Interventions not targeting AIS or urban system changes.
Mechanisms	a) Studies relating to reasons for behaviours & decisions about the enabling environment, governance, meso-micro context, innovation processes & innovation characteristics that affect levels of adoption and disadoption. b) Studies relating to barriers or enablers of adoption of 'improved practices' or innovations including behavioural, attitudinal, social and cultural factors.	a) Not behavioural (attitudinal), economic, social and cultural factors as barriers or enablers. b) Studies of excluded interventions /phenomena or with included interventions/phenomena.
Outcomes	a) Changes in the upper levels of Bennett's hierarchy for evaluation (e.g., KASA, practice change, outcomes) and evaluations and impacts related to adoption and disadoption of management practices to improve GBR water quality due to the included interventions. b) Changes in macro, meso and micro level governance and innovation processes of the AIS affecting outcomes and impacts relating to the adoption of innovations that will improve GBR water quality.	a) Evaluation of excluded interventions /phenomena affecting GBR water quality, including affecting levels of adoption of 'improved' management practices.
Peer Review	Peer reviewed papers as defined.	Non peer reviewed literature.
Language	English	Written in languages other than English.

* Other countries excluded because their enabling environments are different to the Australian context, particularly the GBR enabling environment, and adding them would result in hundreds of largely irrelevant papers.

3. Search Results

A total of 2,592 (94%) of studies were identified through online searches for peer reviewed and published literature, while 170 (6%) of studies were identified manually through expert contact and personal collection. However, of studies initially identified as relevant 57% came from manual sources, with 174 judged as eligible for inclusion in the synthesis of evidence after a first screening (Table 6) (Figure 3).

Table 6. Search results table, separated by A) Academic databases, B) Search engines 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 (as per Table 4)	Sources*	
A) Academic databases		Web of Science	Scopus
Question 7.2			
10/2022	*1*	*32(18) of 72*	*21(4) of 54*
10/2022	*2*	*41(8) of 266*	*26 (0) of 140*
10/2022	*3*	*19 (0) of 28*	*13 (2) of 21*
10/2022	*4*	*25(0) of 86*	*18(1) of 70*
10/2022	*5*	*15(0) of 43*	*14(0) of 54*
10/2022	*6*	*23 (0) of 49*	*19 (0) of 50*
10/2022	*7*	*33 (8) of 579*	*33 (3) of 354*
12/2022	*8*	*96(6) of 115*	*91(1) of 101*
12/2022	*9*	*22(0) of 22*	*46(12) of 112*
12/2022	*10*	*137(3) of 162*	*119(0) of 127*
Question 7.2.1			
10/2022	*1*	*5(5) of 6*	*3(0) of 3*
10/2022	*2*	*4(0) of 17*	*3(0) of 8*
10/2022	*3*	*5(0) of 5*	*0*
10/2022	*4*	*4(0) of 20*	*2(0) of 28*
B) Search engines (Google Scholar)			
	N/A		
	Total items online searches	***2,592 (94%)***	
C) Manual search			
Date	Source	Number of items added	
Feb-Sep 22	*SCS 2017 Chapter 4*		
Feb-Sep 22	*Google searches on authors in SCS 2017 Chapter 4*		
Feb-Sep 22	*Personal collection searches*		
Feb-Sep 22	*Personal contacts*		
Feb-Sep 22	*Total items initial manual searches*	*88 of 144*	
Dec 22	*Personal contacts*	*2(2)*	
Jan 23	*Personal contact*	*2(2)*	
Feb/Mar 23	*Stakeholder literature*	*13(7) of 22*	
	Total items manual searches	***170 (6%)***	

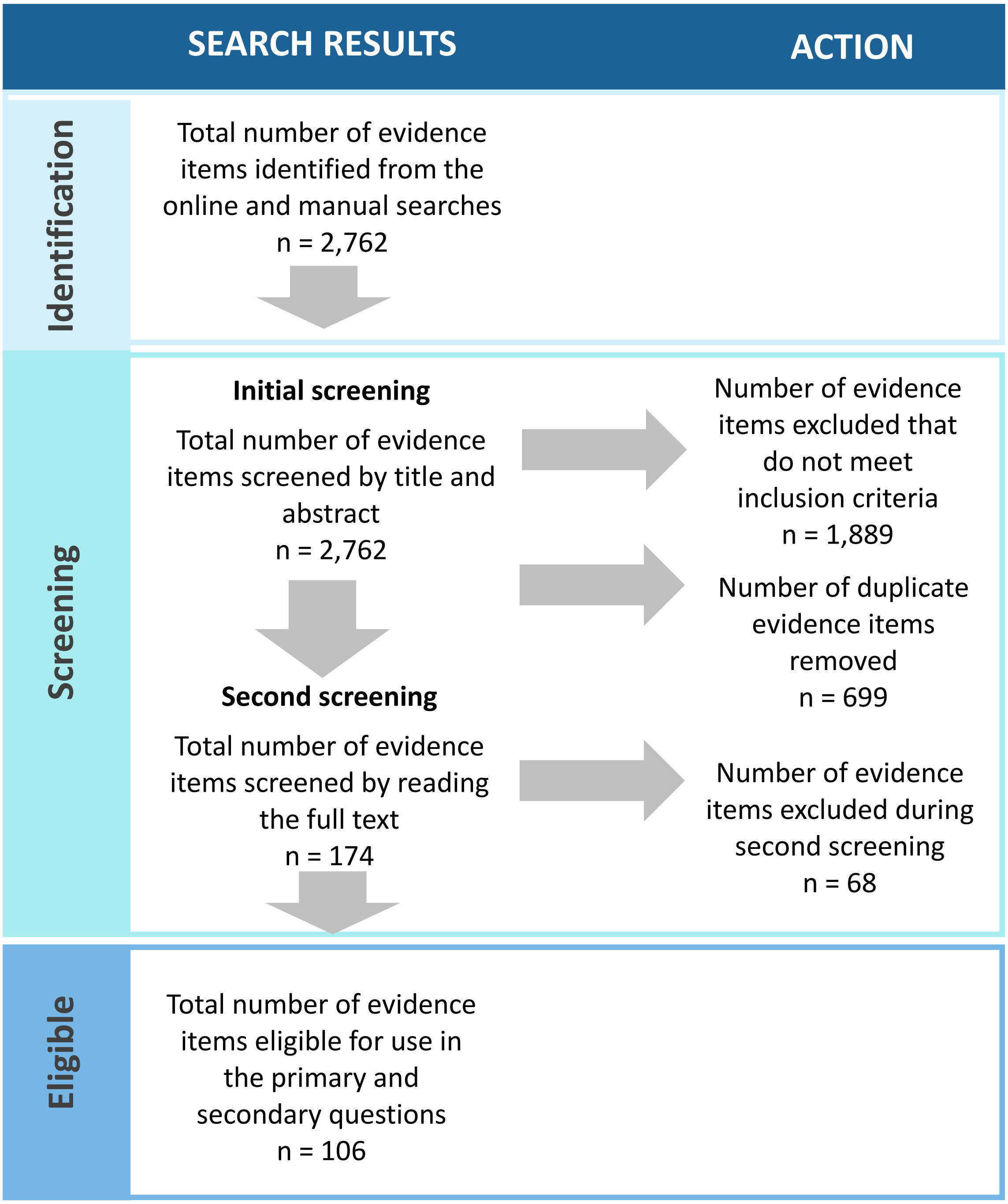


Figure 3. Flow chart of results of screening and assessing all search results for Questions 7.2 and 7.2.1.

4. Key Findings

This section relates to the information and evidence extracted from the final list of studies (body of evidence) that was used to answer the primary and secondary questions. In undertaking this narrative, the frameworks outlined in Figures 1 and 2 have been used. The questions are discussed using the systems levels of:

- The practice or behaviour characteristics (e.g., how compatible, complex or triable the practice is).
- The micro-system level (i.e., individual or 'actors' demographic factors, including relevant land or house characteristics and their attitudes, motivations and capacity, as well as the individual's immediate environment which includes their relationships with other people such as family, peers and neighbours).
- The meso-system level (i.e., social structures that influence the micro-system and implement the programs determined at the macro-system level, for example, industry, RD&E agencies and community).
- The macro-system level (i.e., all socio-economic and cultural elements, for example, how the environment changes, policy and legislation, politics, mass media and global markets).

4.1 Narrative synthesis

4.1.0 Summary of study characteristics

In total, 106 studies were eligible for the primary and secondary questions. The focus for the search to answer the primary question was limited to studies that included GBR catchments. The key reason studies were excluded from other locations was that the enabling environment and context for policies and programs targeting water quality in the GBR is substantially different from that which applies to other parts of Australia and the differences are even greater in other countries.

For the secondary question that specifically considers disadoption of management practices, the search was widened to encompass studies in Australia outside the GBR. International studies were not included because their context and enabling environments are substantially different. Only four extra studies were found that mentioned this issue (Llewellyn, 2007; Llewellyn et al., 2012; Pannell et al., 2006; Robertson et al., 2012). However, no studies have directly investigated the issue of disadoption. Disadoption was considered theoretically in some studies, but none collected or analysed quantitative or qualitative data that measured factors leading to disadoption of recommended management practices. None of the studies eligible for the primary questions collected or analysed data on disadoption.

The studies for the primary question have been categorised by GBR location and industry (Table 7) and by study type and industry (Table 8). Around one third of studies focused on the sugarcane industry, with half these being in the Wet Tropics region, while 16% focused on the grazing industry, with these being mostly in the Burdekin/Bowen and Fitzroy regions. Only one study directly related to the Mackay Whitsunday region and none were found that focused on the Cape York and Burnett Mary regions. Around 42% of studies considered issues across the GBR, but these cross-regional studies mostly focused on either urban water quality or governance issues relating to both urban or agricultural issues. Two-thirds of the studies categorised as urban had the broader focus. The 'Other' category includes studies mostly at the macro system level that aim to provide guidance to policy makers, evaluate governance, policies and processes used for decision making. Four studies investigate the use of media by all sides in the policy and governance debates. About one quarter of the studies assess meso-level factors and provide guidance or evaluate the process used for governance and planning.

Table 7. Distribution of studies by region, agricultural industry and urban issues.

Region/Industry	Agriculture/Horticulture					Other*	Total	Urban
	Sugarcane	Grazing	Bananas	Cropping	Multiple			
Wet Tropics	16	0	1	0	2	7	***26***	5
Burdekin/Bowen	3	8	0	0	0	3	***14***	3
Mackay Whitsunday	1	0	0	0	0	0	***1***	0
Fitzroy	0	5	0	0	2	0	***7***	0
Burnett Mary	0	0	0	0	0	0	***0***	0
Multiple	7	2	0	0	1	1	***11***	1
GBR	7	1	0	0	7	28	***43***	17
Total	***34***	***16***	***1***	***0***	***12***	***39***	***102***	***26***

* Not directly related to a particular industry, often related to macro or meso urban or agricultural context, enabling environment and governance issues.

The most common study type involved mixed methods, with some of these involving primary data sources only, while others incorporated primary and secondary data sources (Table 8). Slightly over one third of studies used secondary data sources, split between modelling (conceptual & bioeconomic), reviews and analysis of secondary data sources. Studies in the 'Analysis' category involve analysis of secondary data for issues such as governance, policy and use of media for campaigns. Urban studies also involved both primary and secondary data sources, although conceptual models were more common for the urban studies. Mixed methods were more commonly used in sugarcane industry studies, while studies of grazing industries tended to use quantitative methods.

Table 8. Distribution of studies by study type, agricultural industry and urban issues.

Study type/Industry	Agriculture/Horticulture					Other*	Total	Urban
	Sugarcane	Grazing	Bananas	Cropping	Multiple			
Qualitative data	6	2	0	0	0	8	***15***	8
Quantitative data	4	8	0	0	5	0	***18***	0
Mixed methods data	15	3	1	0	3	8	***30***	6
Review	3	1	0	0	2	3	***9***	2
Conceptual model	1	0	0	0	1	9	***11***	6
Bioeconomic model	4	1	0	0	0	2	***7***	1
Analysis	1	1	0	0	1	9	***12***	3
Total	***34***	***16***	***1***	***0***	***12***	***38***	***102***	***26***

* Not directly related to a particular industry, often related to macro or meso urban or agricultural context, enabling environment and governance issues.

4.1.1 Summary of evidence to 2022

In this section the evidence to answer questions 7.2 and 7.2.1 is provided. It uses the frameworks provided in Figures 1 and 2 to structure its presentation. In both frameworks a key relationship is between practice characteristics and the meso-micro context in Figure 2. From this starting point the discussion will consider issues relating to the management practices, the meso-micro context (i.e., of landholders, industry, communities), the innovation processes (involving landholders, industry, communities and the RD&E system) and the macro level context, enabling environment and governance system. The discussions of the meso-micro context and innovation processes for urban water management are discussed separately to that for agricultural land users as different systems are involved. However, the discussion is combined for the macro level context, enabling environment and governance system.

Characteristics of management practices hindering or enabling their uptake

In this section the characteristics of management practices for agricultural land users are discussed separately to urban water managers.

Management practice characteristics hindering or enabling their uptake by agricultural land users

A range of studies have reported on the characteristics of agricultural management practices that hinder or enable their uptake. They range from: bio-economic models (Canegrowers, 2020; Kandulu et al., 2018; Poggio et al., 2018; Star et al., 2015; van Grieken et al., 2013); quantitative surveys that were analysed statistically using either principal components analysis, regression or other statistics (Herr et al., 2004; Rolfe & Gregg, 2015; Rolfe & Harvey, 2017); mixed methods studies combining qualitative and quantitative methods (Coggan et al., 2017; NQ Dry Tropics, 2016; Wegscheidl et al., 2015); studies using qualitative methods (Bohnet et al., 2011; Lankester et al., 2009; Vilas et al., 2020); and studies based on reviews and analysis of data from other studies (Christiansen & Hunt, 2000; Coggan et al., 2021b; Eberhard et al., 2017b; Farr et al., 2019; Harvey et al., 2016; Kealley & Quirk, 2016; Kraak & Drew, 2015).

Three of the bio-economic models investigate the economics for sugarcane farmers of different nitrogen (N) rates (Canegrowers, 2020; Kandulu et al., 2018; van Grieken et al., 2013). Poggio et al. (2018) investigated the economics of investing in Smartcane Best Management Practice (Smartcane BMP) changes, while Star et al. (2015) investigated profitability of Natural Resource Management (NRM) frameworks for grazing in the Fitzroy catchments. The investigations of different N rates used varied in their approaches but their findings were similar for reductions in N up to those recommended by the "SIX EASY STEPS" approach (Canegrowers, 2020; Kandulu et al., 2018; van Grieken et al., 2013). These studies caution that promoting N rates to farmers that are much lower than for "SIX EASY STEPS" may reduce farm yields and profitability, something also implied in the review by Harvey et al. (2016). This creates a risk of forcing sugarcane farmers out of production with consequent negative effects on mill viability and their associated regional communities (Canegrowers, 2020; van Grieken et al., 2013). Without policy that reduces this effect, the more likely outcome is that the lower rates required will not be adopted.

Another hindering factor suggested by Kandulu et al. (2018) is that because fertiliser cost is a relatively low percentage of expected returns, farmers often use N rates that maximise returns in good years because this is a low risk decision. While Poggio et al. (2018) concluded that the economic benefits for sugarcane farmers in the Wet Tropics of adopting Smartcane BMP changes were positive, there was a big range in these benefits (\$25-\$220 ha^{-1} yr^{-1}). Similarly, the changes resulted in reduced environmental impacts but there was also a big range in reductions from 2-31% for nitrogen and 9-78% for pesticides. They suggest taking a whole farm perspective to manage risks and that adopting BMP practices can lead to positive economic and water quality outcomes. In the context of grazing systems, the complex and dynamic nature of decision making, coupled with uncertainties associated with weather, may hinder adoption of optimal levels of pasture utilisation suggested by the NRM frameworks (Star et al., 2015).

While historically there has been considerable research into the characteristics of management practices that affect their rate of adoption (e.g., relative advantage, compatibility, trialability, observability, complexity) (Pannell et al., 2006), the focus here is on management practices targeted at improving water quality outcomes for the GBR. Most of the studies in this section provide information that is very context specific, for example in the sugarcane industry:

- Costs of adoption: Adoption of some Smartcane BMP practices by sugarcane farmers across a range of regions was found to be hindered by high fixed costs, production costs and cost of capital investment for some practices but not others (Rolfe & Harvey, 2017). They concluded "measures to improve BMP adoption are complicated by heterogeneity in adoption drivers between practices and across groups of landholders, creating challenges to find effective strategies to encourage adoption" (p. 276).
- Compatibility with farming system: Adopting green cane trash blankets in the Burdekin is constrained by the flat, furrow-irrigated paddocks (Christiansen & Hunt, 2000), which slows water flow and increases water infiltration for this farming system.
- Economies of size effects: Adoption of some precision technologies for pesticide spraying was only economic for larger farms and when used as part of an integrated weed

management program, for specific weeds and coverage (Harvey et al., 2016). Similarly, NQ Dry Tropics (2016) found economies of scale occur for practice shifts and suggest that practice class shifts for herbicides may cost growers, except for C to B in one of the regions, but that costs will be higher in another part of the region.
- Technology characteristics interacting with context: Adoption of the 1622WQ application that was developed to help sugarcane farmers recognise the link between rainfall, fertiliser application and nitrogen pollution required real time information to be effective, but its adoption was limited by extension officers and farmers unease and discomfort with digital technologies, poor internet connectivity leading to slow operations, lack of suitable platforms for the technology, poor data quality and problems with designing the application to make it accessible and relevant to a broad range of potential users (Vilas et al., 2020).

While for the grazing industry:

- Interaction between management practice, property context and decision makers: The characteristics of seven recommended riparian management practices (e.g., fencing riparian areas, fire management, weed control) that hindered or enhanced their adoption varied from practice to practice depending on the practice, property characteristics and factors influencing the decision makers (Lankester et al., 2009).
- Interaction between management practice and influence of a factor: Adoption of four key recommended management practices by graziers in the Fitzroy and Burdekin catchments (pasture spelling, rotational grazing, sustainable stocking rates, frontage management) were influenced by assessment of risk, relative advantage, trialability, complexity, flexibility and complexity, but the effect of these factors varied for each practice (and decision maker context) (Rolfe & Gregg, 2015).
- Transaction cost complexities: While Coggan et al. (2021a) found graziers did not perceive there to be high transaction costs of adopting some recommended land management practices, some practices required highly specific skills that they were not motivated to develop.

A review of adoption of management practices in the sugarcane and grazing industries by Coggan et al. (2021b) reinforces the effect of the interaction between context and the characteristics of an innovation on the extent and rate of adoption of the management practices. Transaction costs, capital costs, operating costs, perceptions of input, outcome and financial riskiness, uncertainty about weather, and relative advantage on a range of measures are all relevant, but the extent of relevance varies from practice to practice and context to context. For instance, the transaction costs of learning about best management practices for sugarcane were found to be inversely correlated with the asset specificity of the practice change, perhaps because the change involved more complex system changes (Coggan et al., 2017).

Conclusions about characteristics of agricultural management practices hindering or enabling their uptake

There are many studies that identify the behavioural, economic, social and cultural factors that hinder or enable the uptake of management practices that aim to improve water quality outcomes for the GBR. In brief:

- Economic factors and perceptions of economic factors (e.g., profitability; transaction, capital and operating costs; riskiness and uncertainty; economies of size), were important to decision making by landholders about adoption of recommended management practices. Even profitable practices can take time to be adopted because of interactions between the economic factors and other factors such as compatibility with the farming system, the level and complexity of skills required, and the decision maker and property characteristics.
- The benefits and costs of recommended practices as calculated by research and extension, are not necessarily consistent with the reality for many farmers and even less consistent

with their perceptions of the benefits and costs. Involving next users and end users in establishing these is important to reducing misperceptions on both sides.
- However, which factors were relevant differed from study to study, from practice to practice, context to context and landholder to landholder. Therefore, it is difficult to make general statements about the adoptability of practices based on their characteristics.
- In summary, landholder perceptions of a wide range of factors were identified as key drivers of adoption but the effect of each was specific to a practice in their context, while varying from landholder to landholder and context to context.

Management practice characteristics hindering or enabling their uptake by urban managers

No articles were found that identify the characteristics of practices that inhibit or enable their adoption in the context of urban water management within the GBR context. Nonetheless, it is recognised that urban communities and non-agricultural land users also contribute to sediment, nutrient, and water quality within the GBR ecosystem (Bartley et al., 2017; NQ Dry Tropics, 2016). Management practices that aim to improve water quality outcomes in urban areas target diffuse source pollution (for example, stormwater pollution management such as vegetated treatment systems) and point source pollution (for example, wastewater management approaches) (Eberhard et al., 2017b). Urban water management practices to improve GBR water quality often take a 'total water cycle' approach that aims to consider all elements of the water cycle (i.e., potable water, wastewater and stormwater). Opportunities for specific urban management actions are highlighted in regional-scale Water Quality Improvement Plans, for example: NQ Dry Tropics (2016). In addition, the Urban Water Stewardship Framework recently developed by the Queensland Government (Australian Government & Queensland Government, 2018), is a tool that can be used to assess and report on the level of management practice adoption by local governments in urban areas. A core objective of the framework is to drive adoption through the identification of areas for potential improvement and to guide the development of regional water quality improvement plans. It is intended that urban water management practice level results will be included in regional report cards.

Factors associated with actors in the meso-micro context that hinder or enable the uptake of agricultural management practices

In this section we consider those factors associated with actors (i.e., farmers, extensionists, researchers and policy makers) in the meso-micro context that hinder or enable the uptake of management practices. They include the actors' physical, institutional and environmental context plus their innovative and adaptive capacity. While some factors are located at the meso level (e.g., availability of machinery and services to implement a practice change), most change that directly affects practices for GBR water quality is located at the micro level because it involves a change in landholders' psychosocial context and their knowledge, skills and capabilities, which are important for behaviour change. Change also involves the innovation processes, mainly the Research, Development and Extension (RD&E) system, which mostly occur at the meso (i.e., community and institutional level). It also needs to be recognised, as mentioned in the framework (see Figure 2), that some factors are more directly relevant to a particular practice (e.g., knowledge, skills and capacity of farmers, extensionists, researchers and policy makers) and hence more easily changed. Others are relatively remote from decisions to adopt a specific practice, are quite stable and therefore difficult to change (e.g., personality, risk tolerance, resistance to change, values and farming vision).

The role of trust in hindering or enabling the uptake of agricultural management practices

One of the key factors that has affected adoption of recommended management practices and was discussed in at least 20 studies at the meso-micro level was trust. Most of the studies examined the effect of mistrust or scepticism of landholders towards information about the effects of their practices on GBR water quality and the benefits of practice changes advocated by government, regulators, advisors, scientific experts and GBR institutions (Coggan et al., 2021a). There are also different types of trust (e.g., companion, community, commitment and competence) that affect relationships and are relevant at all levels of the system and between all stakeholders. At the farm level it is summed up in this quote (Emtage & Herbohn, 2012b, p. 358):

> "Trust of other people and organisations plays an important role in determining how landholders will respond to public policies and programs designed to improve natural resource management, particularly their appraisal of information sources."

As both Coggan et al. (2021a) and Reef and Rainforest Research Centre & James (2021) emphasise in their synthesis reports, trust between farmers, extensionists and researchers is critical to a successful process for developing and promoting management practices to improve water quality. It takes time to build, is easy to destroy, and is affected by past experiences with scientists and policy makers (Arklay et al., 2018; Benn, 2015; Cleary et al., 2022; Coggan et al., 2021a; Davis et al., 2021; Emtage & Herbohn, 2012a; 2012b; Fielke et al., 2021; Hay et al., 2019; Lockie et al., 2002; Jakku & Thorburn, 2010; Reef and Rainforest Research Centre & James, 2021; Rundle-Thiele et al., 2021b; Taylor & van Grieken, 2015; Vella & Dale, 2014; Vilas et al., 2020). In their synthesis of findings from the National Environmental Science Program Tropical Water Quality Hub that relate to the social dimensions of trust, Reef and Rainforest Research Centre & James (2021, p. 48) conclude:

> "Trust … is the glue that holds the people involved with effective projects together. Strong levels of trust improve communication and increase levels of cooperation. By increasing trust, you increase the speed of transactions and reduce their cost. Without it, behaviour change in reef water quality projects will be nigh-on- impossible to achieve."

Past experience with government policies and regulations was identified by multiple authors as being a barrier to accepting the link between their practices and GBR water quality and to adopting recommended management practices (Coggan et al., 2021a; Emtage & Herbohn, 2012a; Hay et al., 2019; Reef and Rainforest Research Centre & James, 2021; Taylor & van Grieken, 2015; Vella & Dale, 2014). The introduction of legislation to prohibit some practices was an important factor in reducing trust in government and those promoting practice change, which in turn became a barrier to landholders adopting recommended practice changes. More recently, campaigns by some farmer leaders, industry bodies, scientists and media have decreased trust in science and government, which in turn has increased resistance to adopting recommended management practices (Cleary et al., 2022; Emtage & Herbohn, 2012a; Reef and Rainforest Research Centre & James, 2021). Others have identified a lack of trust in scientists and government without identifying what caused it (Benn, 2015; Coggan et al., 2021a; Emtage & Herbohn, 2012a; 2012b; Hay et al., 2019; Jakku & Thorburn, 2010; Reef and Rainforest Research Centre & James, 2021; Rundle-Thiele et al., 2021b).

Several projects have focused on building trust, which has helped overcome existing levels of mistrust, therefore increasing uptake of management practices by landholders and increasing their interest in promoting them more broadly to neighbours (Davis et al., 2021; Fielke et al., 2022; Jakku & Thorburn, 2010; Pickering et al., 2018; 2019b; Reef and Rainforest Research Centre & James, 2021; Vella & Dale, 2014; Vilas et al., 2020). The benefits of this practice have been documented by Rundle-Thiele et al. (2021b), who in their evaluation of nine GBR programs identified trust as an enabler of practice change in 100% of projects. While this may take time, it can help "establish trust and confidence in scientists", which is summed up by this quote from a Mackay farmer (Jakku & Thorburn 2010, p. 679):

> "When we started out I was little bit sceptical of [the scientists]. ...The relationship has just grown through the whole project and we've got respect for each other, that's for sure."

Alternatively, not listening to farmers and information overload can irritate farmers, which leads to a lack of trust (Fielke et al., 2022; Hay et al., 2019). In the framework in the current synthesis, building trust depends on the innovation processes used, which will be discussed in detail later.

Other individual meso-micro factors hindering or enabling the uptake of agricultural management practices

This section combines the other individual meso-micro factors affecting uptake of recommended management practices by landholders. In total, 29 studies were identified that addressed this issue but they used a wide range of approaches in the design and analysis of the data. Sixteen used quantitative survey data (four to segment respondents or develop typologies, seven used various statistical methods, five used psychology theories), three used choice experiments, three were reviews or synthesis studies, two used bioeconomic models, two involved mixed methods, two analysed qualitative data and one was a proof of concept model with preliminary results.

Various indices were used in the typology models to segment farmers, including level of engagement and interest in desired behaviours, landholders' management objectives, trust of others, information sources, management criteria, strategies for time use and allocation, and factors limiting ability to manage (Bohnet et al., 2011; Emtage & Herbohn, 2012b, 2012a; Rolfe & Gregg, 2015; Rolfe & Harvey, 2017). While they found that these criteria were linked to adoption or non-adoption of management practices and that typologies based on these could help explain adoption in some circumstances, the groupings varied by indices used as drivers of adoption. Therefore, as for the characteristics of a practice, this makes them difficult to use for general conclusions about likelihood of adoption. Instead, drivers and segments tended to be context and practice specific. For example, motivations, use of information, participation in social groups, previous behaviour, perceptions of risks, financial constraints, social factors, industry factors, market uncertainty, climate uncertainty, perceptions of profitability were associated with adoption (or non-adoption) of some practices in some contexts, the conclusion drawn from these studies is that factors that hinder or enable adoption will vary depending on the underlying goals and values of landholders, their perceptions of the relationship between their activities and water quality and a range of other factors specific to their context and the practice. After all, changing their management practices proposed by others to improve water quality, requires landholders to change farming practices they have developed over time based on their experience.

Of the seven studies using quantitative data (mostly derived from primary surveys), four used a combination of principal components analysis (PCA) and other statistical techniques (Greiner & Gregg, 2011; Greiner & Miller, 2008; Greiner et al., 2009; Lockie et al., 2002), one used multiple regression models (Herr et al., 2004), one descriptive statistics (Pickering et al., 2018), and one statistical and regression techniques on survey data combined with other evaluation data (Moravek et al., 2017). The studies using PCA analysis (Greiner & Gregg, 2011; Greiner & Miller, 2008; Greiner et al., 2009; Lockie et al., 2002) used similar analytical techniques to the typology models but with slightly different aims, with all four looking at adoption of conservation practices by graziers. These studies aimed to link adoption of a list of key management practices to various indices of farmer or community characteristics. Positive correlations were found between many indicators and adoption rates: e.g., pro-conservation goals; external incentives; recognition by peers, community and regional industry organisations; perceived risk taking; stewardship aspirations; and some of the capacity for change indicators. The relationship between these indices and particular practices was inconsistent, which indicates a complex interaction between landholders' financial and non-financial motivations, socio-economic factors, barriers to adoption, community factors, and perceptions of policy instruments. Moreover, the magnitude of many of the statistically significant indicators and the adoption of a particular practice or a suite of practices was small (e.g., Greiner et al., 2009; Lockie et al., 2002), suggesting limited value for policy making if considered in isolation. To overcome this Lockie et al. (2002) suggests focusing more on the broader system within which major stakeholders and landholders exist rather than focusing just on individual landholders.

Of the five studies using psychology theories, four used the Theory of Planned Behaviour framework (TPB) (Fielding et al., 2005; Hasan et al., 2021; Hay et al., 2019; Rundle-Thiele et al., 2021a), while the other integrated social identity theory with the TPB (Fielding et al., 2008), to investigate factors affecting the adoption or intention to adopt management practices to improve GBR water quality by sugarcane farmers, graziers and horticulturalists.

Hasan et al. (2021), Hay et al. (2019) and Rundle-Thiele et al. (2021a) found that some measures of social norms were statistically significant factors linked to behaviour. Attitudes about having their efforts recognised and relationships with other growers were found to have statistically significant links to fertiliser practice change by Hasan et al. (2021) (although this varied by regression model). Hay et al. (2019) found fertiliser application behaviour had a statistically significant, direct and indirect effect relationship to two lifestyle indicators, but only an indirect effect relationship to maintaining good relationships with other farmers, sharing new ideas with others and having efforts recognised by others. Conversely, one of the lifestyle indicators had a positive and statistically significant relationship with run-off handling practices, while the other lifestyle indicator and maintaining good relationships with other farmers were not statistically significant. Rundle-Thiele et al. (2021a) and Hasan et al. (2021) found that early adopters were less concerned with what other farmers think, but what other farmers think may be more relevant to later adopters as a practice is promoted across the wider community. Other factors that are not part of the TPB, such as participation in workshops, cane growing experience, social and environmental goals, characteristics of the practice, and financial motivations were sometimes associated with adoption, although these effects varied between studies or were not measured consistently making it difficult to generalise about their effect on uptake of practices.

In the two studies that investigated management of riparian zones, stronger intentions by graziers to manage the zones were associated with: past behaviour; more positive attitudes towards riparian zone management; sense of control; and a greater sense of normative support for a practice, including support from catchment groups and government (Fielding et al., 2005; 2008). Social norms of the landholder community (standard codes of behaviour) rather than subjective norms (beliefs about whether most people approve or disapprove of a behaviour) were found to be a better predictor of behaviour. These studies also support the contention mentioned earlier that socio-demographic variables and financial concerns are not always good predictors of behaviour. It appears beliefs about a management practice and other social factors may be more important in influencing adoption than the costs of a practice as determined by researchers.

Two smaller qualitative studies of adoption of recommended riparian management practices (Barbi et al., 2015; Lankester et al., 2009) examined the reasons for adopting or not adopting these practices. Twelve of the 18 in the Lankester et al. (2009) study had adopted some of the seven recommended practices, while the others had not adopted any or had implemented more general management practices. As was found in the quantitative studies, the reasons for adoption and non-adoption varied with practice. These reasons were categorised into five influencing factors (social, property size, property tenure, environmental, financial) but were not linked to individuals or practices. Environmental goals were intertwined with production goals, although most of those who adopted a practice had perceived a private or financial benefit of a practice, partly due to a perceived relative advantage or ability to trial. Some participants expressed scepticism about scientific explanations that sediment runoff from grazing was affecting the GBR, which acted as a constraint to change. A key suggestion of the study was that specific practices are not suitable for all areas and that perhaps promoting management ‘principles’ rather than specific ‘practices’ may be more likely to enhance adoption. In an evaluation of extension and adoption of best management practices, Barbi et al. (2015) suggest that multi-faceted extension approaches had a positive effect on adoption. Interestingly they measured ground cover using satellite imagery from 1991 to 2014 and concluded there was a disparity between adoption of management practices and ground cover. They suggest that perhaps ground cover targets are a more suitable metric than adoption of best management practices. This is related to the suggestion to focus on principles rather than practices by Lankester et al. (2009). Because these were small qualitative studies, more comprehensive studies are required to test the hypothesis that it is better to focus on principles rather than practices.

The three choice experiments involved owners and managers of rangeland grazing enterprises, with the intention of assessing: the effect of bounded rationality on decision making under uncertainty involving the ABCD land condition framework (Gregg & Rolfe, 2016); the effect of bounded rationality (myopia) and behavioural aspects (salience) involving the ABCD land condition framework (Gregg & Rolfe, 2018); and the effect of outcome risks or input risks associated with projects to reduce gully erosion and sediment runoff (Star et al., 2019). Bounded rationality (placing lower weights on future outcomes by discounting them more than would occur if they had pure time preferences) and behavioural effects (overweighting of consumption now) were found to have accounted for poorer decision performance and profitability suggesting that managers have cognitive difficulties coping with the complex decision environments involved (Gregg & Rolfe, 2016; 2018). While behavioural effects were less important as factors influencing land condition, both myopic and salience behaviours significantly affected land condition and decision performance (Gregg & Rolfe, 2018). This may provide an explanation for some of the findings in other studies that landholders do not always make economically rational decisions (according to the principles of classical decision theory).

Interestingly, while Gregg & Rolfe (2016) suggest that the grazing managers showed low levels of risk aversion, Star et al. (2019) found that higher levels of both conservation risk and input risk reduced participation (in the choice alternatives), with greater conservation output risk producing greater reductions in participation than greater input cost risk. This contradiction may arise due to the way risk is measured and the different designs of the experiments. Star et al. (2019) also suggest that the winners curse problem (essentially fear of paying too much) and a reluctance to invest in a project that fails (akin to the bias of preferring inaction to action) may also reduce participation rates in conservation programs. These studies indicate that while grazing managers may show low levels of risk aversion, the underlying drivers are more complex. Both managers aversion to risk (where they can ascribe subjective probabilities to outcomes) and aversion to ambiguity (where the probabilities of outcomes, or even the outcomes themselves, are unknown) may influence uptake of some management practices.

While the bio-economic model developed by Star et al. (2015) that focused on modelling the trade-offs between grazing pressure, profit, management practices and subsequent outcomes in water quality for grazing enterprises in the Brigalow Blackbutt and Brigalow Gidgee land types uses a very different method, it reaches similar conclusions to other studies about the complexity of managing for private benefits in these environments. The dynamic nature of decision making and the uncertainty associated with outcomes of these decisions due to climate cycles and uncertainty about climate change are key factors that may be hindering decision making (Star et al., 2015; 2019). Implications arising from these studies for improving adoption include: suites of practices and policy mechanisms may help reduce the effects of complexity risk and uncertainty on decision making, and consideration needs to be given to the use of demonstration sites that manage and monitor the effects in prolonged dry seasons; and combining these sites with peer-to-peer learning.

The three review and two mixed methods studies (Cleary et al., 2022; Coggan et al., 2021a; 2021b; Kealley & Quirk, 2016; Waterhouse et al., 2017) use mainly secondary data to investigate the human dimensions of factors that hinder or enable the uptake of management practices. However, the issues they cover, the approaches they use, and their foci are different in many respects. Their findings tend to be broad as they attempt to provide conclusions across industries and regions.

Cleary et al. (2022) used data from the 2021 Future of Farming Survey of sugarcane farmers and insights from previous typology research, to develop typologies of landholders. The typologies developed are very general and include five segments: Traditionalists, Experimenters/diversifiers, Enterprise farmers, Conservationists, and Lifestyle/hobby farmers. They acknowledged that “while different profiles of landholders exist, it is not recommended that these profiles be applied in a prescriptive or rigid way” (p.33) and that “farmer types are not mutually exclusive” (p. 42). As identified in the other typology studies, while there might be correlations between these segments and generic adoption of BMPs, the results are likely to be associated with different levels of adoption, this just means some segments are more likely than others to adopt some practices, and this will not be consistent across practices and contexts. Cleary et al. (2022) also used a qualitative survey involving 10 local experts to identify factors likely to shape change at the individual/micro system, mesosystem and macrosystem levels. These factors identified at the micro-meso level are similar to those identified in the other studies. The segments were used to develop engagement approaches for different segments, but at this stage the efficacy of these approaches has not been tested. A few important conclusions are made: one-size-does not fit all; engagement approaches should be flexible and responsive to the different audiences, contexts, practices and dynamics of the systems; engaging with landholders should take a holistic approach to land management, address landholders’ barriers and challenges and take into account their knowledge, experience and motivations.

On the other hand, the mixed methods study by Kealley & Quirk (2016) argued that the factors that hindered the adoption of Smartcane BMP practices by sugarcane farmers were inertia, disengagement (no urgency), unaware or disbelieving that there were any core business benefits, don’t believe the science about their responsibility, and reject the advice given by outsiders. A range of factors were found to enhance adoption including their personal perceptions, business drivers, government policy, access to support, and linkages with peers and industry.

In the review and synthesis studies by Waterhouse et al. (2017), Coggan et al. (2021a) and Coggan et al. (2021b), the meso-micro factors linked to adoption were similar and included: farmer characteristics, demographic and situational circumstances, social processes, characteristics of the innovation and learning process. These categories of factors are consistent with the framework guiding this study (compare Figure 2-1 in Coggan et al. (2021a) with Figure 2). The main conclusions arising from their studies, apart from recognising that there has been little investment in the human dimensions of factors affecting water quality in the GBR, is that there needs to be a change in innovation processes used to conduct the research, development and extension for the GBR to shift power towards farmers to reduce the barriers to adoption (discussed later).

Conclusions about the meso-micro factors hindering or enabling the uptake of agricultural management practices

Conclusions arising from this analysis of the meso-micro factors hindering or enabling the uptake of management practices include:

- There is a range of levels of trust of farmers in government, scientists involved in GBR research, GBR program delivery organisations, program managers and delivery staff. However, multiple authors have found mistrust is a key factor hindering the uptake of management practices that will improve water quality entering the GBR by a significant proportion of farmers. Causes of this include: the way regulation has been legislated and implemented; insufficient effort to involve farmers and the community in many parts of the GBR governance and innovation processes; and short-term, unconnected projects that do not address the complexity of management decisions faced by farmers or allow the development of critical relationships (built on trust) between farmers, extension, research and program managers.
- Overcoming mistrust has been thoroughly addressed in many studies (e.g., Coggan et al., 2021a; Reef and Rainforest Research Centre & James, 2021; Rundle-Thiele et al., 2021b). They provide guidelines for changes in policy that may reduce mistrust including: shifting power in the RD&E system toward farmers; a focus on processes that establish a link between on-farm activities and water quality; focusing on communities and the broader system rather than on individual landholders to change beliefs about management practices; and perhaps focusing on principles that improve water quality rather than practices.
- While typology type studies can improve understanding of broad categories of issues that will be more important for some farmers, the research highlights that the influence of those factors varies from practice to practice, farmer to farmer, context to context and over time and therefore cannot be used prescriptively. The key implications are that “one-size does not fit all” and bundles of relevant practices, incentives, policy mechanisms and engagement strategies that are flexible, adaptable and responsive to different audiences and their context are required. Best practice would be to develop and test them with the different audiences.
- Similarly, the characteristics of individuals (i.e., their innovative and adaptive capacity; knowledge, skills and capabilities; goals and values; perceptions of the relationship between their activities and water quality; and physical, institutional and environmental context) many of which have been included in the development of typologies, are linked to their adoption of management practices. The main limitation of those studies is that the influences of those factors are highly variable. Also, because they involve correlational

methodologies, they should not be considered as a causal guide and need to be checked for local relevance when designing programs and projects.
- The effect of risk aversion on decision making is complex and can be considered more broadly to include ambiguity and uncertainty. Even so these effects vary widely with context.

Factors associated with actors in the meso-micro context that hinder or enable the uptake of urban management practices

Although individual and community efforts can contribute to pollutant reductions in urban areas, local governments have been designated the primary managers responsible for the control and management of urban pollutants (Dale et al., 2018). While no articles discuss micro or meso level factors specific to urban water management practices in the GBR catchment area, several articles were identified that consider the broader water management environment and are inclusive of factors relevant to the uptake of urban water management practices.

Social resilience in urban communities

Gooch et al. (2012) examined the concept of social resilience and its relevance to communities facing environmental stressors in the context of the threats to the GBR. Social resilience refers to a community's ability to withstand, respond to, and recover from disturbances. It recognises the interdependence between the health and well-being of communities and their surrounding natural environment. The authors reviewed the local government planning processes used to develop the Black Ross (Townsville) Water Quality Improvement Plan (located in the Burdekin region), which has a strong focus on urban water quality issues, to identify several domains specific to the human dimensions of social resilience. The research highlighted leadership, stewardship, social networks, and cross-scale government-community partnerships as key ingredients for enhancing social resilience. Their findings suggest that the local governments that represent these communities, as well as the communities themselves, require high levels of social resilience to adapt and adopt new management practices when responding to environmental threats, such as those facing the GBR. Hence, social resilience is an important factor to consider when planning for water quality management in urban communities.

Innovative and adaptive capacity in urban communities

While Gooch et al. (2017) noted that the ability to adopt new management practices relies on the capacity of the communities and groups involved and as identified in the previous Scientific Consensus Statement (Eberhard et al., 2017b), there remains a notable gap in knowledge regarding the specific capacity of local governments to implement improved management practices in urban areas.

In summary, beyond social resilience and adaptive capacity, no other articles were identified that discuss meso-micro level factors that could influence the uptake of urban water management practices in the GBR catchment area, which remains a critical knowledge gap.

Innovation processes and their effect on the uptake of management practices

As outlined in the framework for this synthesis (Figure 2), the innovation processes include the structures and processes that drive the development and scaling out of agricultural innovations aimed at improving water quality for the GBR. These processes occur at the micro or individual human behaviour level, the meso level or institutional context, and at the macro level or governance system in which the innovation processes take place and which are shaped by this system and feed back into the governance processes. While scaling out and adaptation of innovations is a stage in the innovation processes framework, it will be treated separately in this discussion because it involves management practices developed by a range of innovation processes. Conceptually the paradigms used for both the innovation process and scaling out can be placed on a directive-non-directive continuum and hence may hinder or enable uptake of the associated management practices. In addition, the innovation processes used for agricultural management practices will be discussed separately from the process that includes urban practices to improve water quality.

The effect of innovation processes on uptake of management practices

This section considers papers that deal mainly with the processes used at the meso-micro level to identify, develop, test and evaluate agricultural and urban management practices designed to improve water quality. In their synthesis report for the 2017 Scientific Consensus Statement, Waterhouse et al. (2017, p. 13) concluded:

> "Collaborative processes to deliver interventions and improve trust in decisions and data are essential. Local, trusted intermediaries and flexible incentives need to be fostered to improve participation in reef water quality programs."

Prior to 2017, six studies at the meso-micro level investigated or evaluated the effect of the design of innovation processes on uptake of management practices (Bagshaw & Lindsay, 2009; Di Bella et al., 2016; Greiner & Gregg, 2011; Jakku & Thorburn, 2010; Robinson et al., 2009; Thorburn et al., 2011). Since then, eight studies have evaluated the effect of innovation process design for individual projects (Arklay et al., 2018; Davis et al., 2021; Dunstan et al., 2021; Fielke et al., 2021; Roemer et al., 2021; Stitzlein et al., 2020; Tsatsaros et al., 2020; Vilas et al., 2020) and four studies have evaluated its effect on multiple projects (Coggan et al., 2021a; Reef and Rainforest Research Centre & James 2021; Rundle-Thiele et al., 2021b; Waterhouse et al., 2017). The key findings arising from these studies include:

- Co-design and co-production of knowledge processes (hereafter referred to as collaborative processes) between farmers, industry, scientists, policy makers and other relevant stakeholders have enabled greater acceptance of recommended management practices. In part this occurs because farm managers are involved in developing or refining the technologies and hence there is a greater likelihood of other managers adopting them (e.g., Davis et al., 2021; Tsatsaros et al., 2020).
- Collaborative processes resulted in increased trust between landholders, industry, extensionists, researchers and community, leading to increased adoption as discussed in detail previously (e.g., Coggan et al., 2021a; Davis et al., 2021; Fielke et al., 2021; Rundle-Thiele et al., 2021b).
- While collaborative processes in the projects investigated take time, they improved social capital (bonding, bridging and linking social capital) that help overcome distrust, reduce transaction costs, produce more relevant management practices and provide a foundation for trust and involvement in future projects (e.g., Bohnet & Smith, 2007; Coggan et al., 2021a).
- Where collaborative processes are involved, focus is taken off the individual and onto the system and the contributions of all participants, thereby reducing stigmatisation of one stakeholder group. In part this arises because all parties are aware of the reasons some technologies are not adopted or where changes (including adaptation) are required to reduce the factors hindering adoption (Moore et al., 2021; Pickering et al., 2017; Roemer et al., 2021).
- Transdisciplinary processes inherent in the approaches used in many of the studies led to more relevant practices, but also enhanced bonding, bridging and linking social capital, thus creating the potential for longer-term and more productive collaborations in future innovation processes (e.g., Davis et al., 2021; Di Bella et al., 2016; Waterhouse et al., 2017).
- Collaborative interactions lead to shared ownership of technologies, with better understanding of all participants about how they framed problems, solutions and messaging differently (e.g., Coggan et al., 2021a; Jakku & Thorburn, 2010; Roemer et al., 2021; Rundle-Thiele et al., 2021b; Tsatsaros et al., 2020; Vella & Dale, 2014).

One of the constraints to the use of collaborative processes observed by Coggan et al. (2021a) is that science metrics focus on reports and scientific publications not on building relationships. They also suggest short-term projects and contracts for extension staff do not allow time to build the relationships required to establish trust, which in turn can lead to improved outcomes and impact. Another problem identified was that monitoring and evaluation metrics often fail to measure the impacts of collaborative processes, for reasons that include: narrow focus on individuals' KASA change and adoption of a particular practice; limited focus on impacts of improved trust and relationships on adoption or adaptation of other practices; improvements in adoptability of management practices; improvements in innovation processes; benefits arising from the increased trust and advocacy of farmer participants for future projects; and little evaluation beyond the end of a project (Coggan et al., 2021a; Jakku & Thorburn, 2010; Reef and Rainforest Research Centre & James, 2021; Roemer et al., 2021; Rundle-Thiele et al., 2021a; Vilas et al., 2020; Waterhouse et al., 2017).

The few studies that reported on the use of collaborative processes at the more meso and macro levels were aimed mainly at improving the efficiency and effectiveness of planning for both urban and agricultural change (Greiner et al., 2005; Robinson et al., 2009; Tsatsaros et al., 2020; Vella & Dale, 2014). Vella & Dale (2014) report on the application of a collaborative planning process known as the Mossman Mill District Practices Framework. The framework was used to coordinate activities at a range of scales from farms, mill, industry, river catchment, NRM region and GBR region, with the aim of integrating resource condition targets, best management practices so that they could meet outcomes for NRM plans, legislative requirements and develop practical ways to audit compliance and agricultural resource conditions. They concluded that the biggest lesson was that "achieving and maintaining grassroots ownership of the framework is necessary from the outset so that the practice standards have real meaning" (p. 256). The complexity of processes and issues, unclear and varying expectations, conflicts between stakeholder groups, unequal knowledge-power dynamics, poor links between management changes and environmental outcomes, sustaining participation and insufficient forward planning capabilities were key constraints the processes needed to overcome (Robinson et al., 2009; Tsatsaros et al., 2020; Vella & Dale, 2014).

A study by Smajgl et al. (2009) combines a computable general equilibrium model with an agent-based model to provide integrated policy impact assessment at a micro to macro scale to support water policy decision making. Development of the model involved workshops with science experts and policy makers, but there was no evaluation of the use of the model by policy makers. While this used different methods and is at different scales to Vella & Dale (2014), they also conclude that the policy outcomes are uncertain and complex. A major difficulty was adapting the models to include multidisciplinary inputs at different scales.

Scaling processes and their effect on uptake of agricultural management practices

As outlined in the framework discussion, scaling (sometimes known as extension or diffusion) is the process of spreading a practice beyond the initial groups of stakeholders involved in the development stage. Ideally, this process should be integrated into the innovation process as shown in the framework, although it involves its own processes and methods and can occur from the micro to the macro scale depending on the practice change. Of the studies identified, 21 were categorised as including evidence on scaling outcomes and processes. All evaluated scaling of agricultural projects and none were identified that investigated urban scaling. Of these studies, eight involved surveys investigating landholders' decisions, eight involved multiple methods to evaluate projects, three were planning documents based on a range or sources and one was based on a literature review.

In scaling projects, one of the key issues raised by many studies is the need to shift the focus from individuals to engagement with the relevant populations of farmers and the associated relevant farmer leaders, farmer groups, industry extension, industry advocacy bodies, and regional organisations (Arklay et al., 2018; Cook et al., 2021; Greiner et al., 2009; Herd et al., 2022; Kealley & Quirk, 2016; Lockie et al., 2002; Moore et al., 2021; Pickering et al., 2017; 2018; Reef and Rainforest Research Centre & James, 2021; Wegscheidl et al., 2015). The reasons for this include:

- Peers and the community are an important part of the motivation to make changes in the grazing industry, but recognition needs to be linked to regional organisations and recognise different factors enabling and hindering change at that level (Cook et al., 2021; Gordon & Nelson, 2007; Greiner & Miller, 2008; Greiner et al., 2009; Lockie et al., 2002).

- Successful programs in the sugar industry should include and acknowledge the role of farmer, industry and intermediary participants and leaders, take account of the range of motivations and contexts for change, provide recognition to participants in the projects and the industry generally, and design programs for change at the individual and regional industry level (Cook et al., 2021; Hay et al., 2019; Herd et al., 2022; Kealley & Quirk, 2016; Moore et al., 2021; Pickering et al., 2017; 2018; Reef and Rainforest Research Centre & James, 2021; Taylor & van Grieken, 2015; Wegscheidl et al., 2015).
- Engagement is required to build relationships, trust and hence social capital across an industry and a region to enable adoption (Cleary et al., 2022; Cook et al., 2021; Kealley & Quirk, 2016; Pickering et al., 2017; 2018; Reef and Rainforest Research Centre & James, 2021; Rolfe et al., 2020; Taylor & van Grieken, 2015).
- Change takes time and can be complex. Persistence of these networks is required to provide ongoing support and to maintain the changes (Coggan et al., 2017; Greiner & Miller, 2008; Kealley & Quirk, 2016; Moore et al., 2021; Pickering et al., 2018; Reef and Rainforest Research Centre & James, 2021; Taylor & van Grieken, 2015).
- Social capital developed through effective engagement is an ongoing enabler of practice change promoted by future projects and programs at all levels of the GBR system from the farm to policy, by facilitating coordination, communication, collaboration, planning and implementation (Cook et al., 2021).
- A major advantage of the engagement process is that it can overcome some of the intrinsic (and extrinsic) barriers to a range of practices because the focus is on flexible, holistic, context relevant, tailored and multi-level system change rather than individual practice changes (Cook et al., 2021; Pickering et al., 2017; 2019b). For instance, Pickering et al. (2019b) found that farmers involved with the Cane Changer project had an increased sense of public recognition and personal responsibility toward improving water quality, which reduces one of the key factors hindering uptake of recommended management practices aimed at this. It also leads to increased levels of individual and collective efficacy and empowerment, which has the potential to enable future practice change (Cleary et al., 2022; Moore et al., 2021).

An important component of some studies that took an industry or regional focus was to build the capacity of key participants in the program to facilitate the change process (e.g., farmer leaders, extension and industry professionals) (Cook et al., 2021; Moore et al., 2021; Pickering et al., 2019a; Wegscheidl et al., 2015). The aims of these programs varied, but they acknowledged the need for there to be a sufficient cohort of leaders and facilitators in these programs who had the skills required for them to be effective. In the Cane Changer project, the emphasis of training was on understanding the psychology of themselves and others in the industry, the drivers and barriers to change, and communication strategies for promoting practice change (Moore et al., 2021).

Seven of the studies involved evaluations of scaling projects (Kealley & Quirk, 2016; Moore et al., 2021; Moravek et al., 2017; Pickering et al., 2019b; Reef and Rainforest Research Centre & James, 2021; Waterhouse et al., 2022; Wegscheidl et al., 2015), although with different aims and methods. Key recommendations of these studies included:

- Involve and coordinate with other programs and involve relevant farmers, farmer groups, industry organisations and companies, and private and public extension officers (Kealley & Quirk, 2016; Moore et al., 2021; Pickering et al., 2019b; Reef and Rainforest Research Centre & James, 2021; Wegscheidl et al., 2015).
- Design and implement the monitoring and evaluation process with this group from the beginning (Moore et al., 2021; Pickering et al., 2019b; Reef and Rainforest Research Centre & James, 2021; Waterhouse et al., 2022; Wegscheidl et al., 2015).
- Monitoring and evaluation should continue beyond the end of a project and consider other changes as there is often a time lag between interactions with a scaling project and practice change (Kealley & Quirk, 2016; Moravek et al., 2017; Waterhouse et al., 2022). In addition, there may be overlap in effects on adoption arising from different projects and adoption by

landholders due to producer-to-producer interactions not directly related to the project (Moravek et al., 2017). As indicated by Pickering et al. (2019b), changes in levels of trust and stewardship can have flow-on benefits for future projects promoting practice change.

Investigations of programs that included government grants suggest that these programs performed better when a number of recommended practices were linked or bundled together with their financing or incentives, received input and support from regional industry organisations and were supported by training, extension and relevant environmental services (Greiner & Miller, 2008; Greiner et al., 2009; Rolfe et al., 2020; Taylor & van Grieken, 2015; Waterhouse et al., 2022; Wegscheidl et al., 2015). In the evaluations of the schemes that combined grants with various extension support (Rolfe et al., 2020; Taylor & van Grieken, 2015; Waterhouse et al., 2017), the involvement of extension officers complemented the grants by offering technical advice and ongoing support to help overcome problems and help maintain and improve on changes. Rolfe et al. (2020) and Waterhouse et al. (2017) also emphasised the need to tailor training to enterprise and participant needs. Taylor and van Grieken (2015) found confusion over the aims of some grant programs, particularly where they coincided with announcements about regulatory programs. Furthermore, they reported there was some discontent about who got the grants with perceptions of favouritism, of the same people getting grants, or that people who were already using the practices were not recognised by these schemes.

Some studies investigated the impact of communication strategies on scaling and adoption. Hay et al. (2019) found that message complexity, message tone, and the relationship between verbal and visual imagery can influence its perception and have positive, negative or unintended consequences. Framing of messages was also found to have an effect, with positive framing of a diversity of farmers' stories being a factor that promotes change (Hay et al., 2019; Herd et al., 2022; Kealley & Quirk, 2016; Moore et al., 2021; Pickering et al., 2019b). A key element of the Cane Changer project was to destigmatise change by 'setting the record straight' (Moore et al., 2021; Pickering et al., 2019b). As a result of their deliberate strategy to promote positive stories across the industry, participants felt more positively recognised by the community and accepted a greater personal responsibility for water quality (Pickering et al., 2019b).

Consistent messaging from trusted sources and integrating these with social media strategies were also suggested as likely to improve uptake (Hay et al., 2019; Wegscheidl et al., 2015). This messaging should not be confined to farmers, but should also include industry advisors, industry advocates and regional partners (Herd et al., 2022; Wegscheidl et al., 2015). However, messaging also needs to be flexible and tailored for context so that it meets the needs of farmers with different motivations and goals (Cleary et al., 2022; Greiner et al., 2009; Hay et al., 2019; Pickering et al., 2017). Where possible messaging should also focus on the triple bottom line for landholders (Kealley & Quirk, 2016; Lockie et al., 2002; Wegscheidl et al., 2015).

Planning for scaling agricultural programs and project

Five frameworks are documented that provide approaches for boosting the effectiveness of scaling agricultural programs and projects to improve water quality in GBR catchments. Three have been developed for or with sugarcane farmers: Cleary et al. (2022) advanced approaches to practice change to help optimise engagement across the GBR sugarcane regions; Herd et al. (2022) provide a framework for strategies in the Mackay Whitsunday and Lower Burdekin sugarcane regions; Pickering et al. (2019b) and Moore et al. (2021) document the process used and evaluated for Project Cane Changer which was conducted with sugarcane farmers in six districts of the Wet Tropics region. Two did not focus on a particular industry or location: Reef and Rainforest Research Centre and James (2021) provide some recommendations for designing and leading scaling projects to build trust into projects, while Cook et al. (2021) outline a comprehensive project plan to enhance regional extension coordination and capacity building in the GBR II Project across multiple industries in all GBR catchments.

Cleary et al. (2022) developed typologies from the 2021 Future of Farming survey data of landholder characteristics (farm size, off-farm income, succession planning and personal values), insights from previous typology research and interviews with ten local experts. They suggest four approaches for engaging with landholders that can be tailored for different landholder profiles:

- Telling the whole story: To be holistic when engaging with landholders and not to focus on one thing.
- Profitability and productivity: Do not forget they are running a business, so profitability and productivity are critical.
- The good growers: Landholders want to do the 'right thing' so acknowledge effort and progress. Connect with tangible environmental improvements, their legacy and empower them and their community.
- Hope for the future: Present change that empowers landholders to future proof their property and to put them in control.

Herd et al. (2022) developed their framework for three core practice areas relevant to their regions (nutrients, pesticides, irrigation), based on a review of the literature, reports on recent behavioural change interventions, and around 20 interviews. They incorporate insights from a socio-ecological model, not unlike the framework used for this question and suggest four steps in a process to develop strategies for each region:

1. Select and prioritise landholder types for each region: They use typologies similar to those used by Cleary et al. (2022) and suggest they be used to identify, prioritise and select landholder types relevant to practice change.
2. Develop journey maps for each region: Using a model of stages of behaviour change and knowledge of the landholder types, to select interventions to target key influences and moderating factors for each landholder type and their stage of behaviour change.
3. Selection of behaviour change interventions and development of the practice change strategies: Interventions are to be developed for intermediaries and landholders based on a behaviour change intervention ontology and principles for selecting interventions to enable changes in the three core practice areas.
4. Design of evaluation, and delivery of monitoring, evaluation and learning plan: This is proposed to be an emergent design using a 'representative' sample of growers. The plan is to be based on a theory of change, have key evaluation questions, and test and refine strategies with landholder and intermediary input.

The Project Cane Changer approach (Moore et al., 2021; Pickering et al., 2019b) was developed using behavioural science principles designed to increase the uptake of Smartcane BMP benchmarking and accreditation and is the only one of the four project designs that has been evaluated. It involved four steps or strategies (Moore et al., 2021; Pickering et al., 2019b):

1. Coordinate and engage: Identify and engage local leaders (including farmers, industry and extension) to be in leadership groups to take ownership and drive the project and with them develop implementation plans.
2. Commit and capture: With the leadership groups, analyse the underlying drivers and barriers to change, the impact of groups, norms and leaders. Then invite farmers to commit to change, while acknowledging the changes they have already made.
3. Build capacity: Build the skills and capacity of leaders to enable them to support the change process, foster engagement and heighten innovative thinking.
4. Reinforce behavioural change: Communicate individual and project accomplishments to the key groups and the public to normalise and destigmatise change.

In a review designed to identify principles that will improve trust between scientists and farmers, Reef and Rainforest Research Centre and James (2021) conclude by providing recommendations for project leaders when leading and designing scaling projects:

1. Team selection: Begin by engaging people early, preferably while developing the funding proposal to increase ownership of a potential project. Consider the overall system when identifying the discipline backgrounds and skills required.

2. Participatory and collaborative project design: Ensure shared understanding of the situation from multiple perspectives and improve ownership by involving contributors in setting objectives and program logic.
3. Project planning: Take time and allow funding while planning to develop trusting relationships and include processes to maintain these.
4. Project implementation: Take time to develop strong interpersonal relationships with target audiences and communities before delivering activities. Begin with low-risk interactions, recognise the expertise of all involved and communicate shared values.
5. Monitoring and evaluation: Use monitoring and evaluation to track performance over time and drive continual improvement. Continually reflect, review and revise program logic and monitor group processes.

Cook et al. (2021) outlines a project plan to improve the efficiency and effectiveness of extension programs targeted to improve water quality in GBR catchments for the GBR II project. Its key focus areas are derived from internal and external evaluations of previous projects and additional insights from independent reviews and strategic engagement plans. The focus areas, objectives and actions are combined into four pillars.

1. Collaboration: Industry bodies are integral to GBR extension programs. This involves: flexible, holistic and codesigned programs; understanding producer context and barriers; effective cross-stakeholder and cross-regional networks; and holistic evaluation.
2. Coordination: Regional extension planning, and coordination is strong. This involves: stakeholders clearly understanding and agreeing on objectives and strategies to engage producers; effective planning and coordination within and across platforms to implement strategies collaboratively; and effective cross regional platforms connected through coordinated networks.
3. Community: The power of community is mobilised through peer-to-peer learning. This includes: effective peer-to-peer learning opportunities to build capability and social capital; and expand and connect producer peer-to-peer learning networks to mobilise community power while providing potential links to unengaged producers.
4. Capacity: There is sufficient extension capacity in public and private extension networks. This requires: sufficient extension officers with appropriate skills and expertise; and applying a range of extension approaches suited to different purposes and types of producers working synergistically.

Key principles for the design and implementation of innovation processes derived from the studies of innovation and scaling processes

Some key principles are derived from these studies that should be included in the design, implementation and evaluation phases of all research, development and extension projects (or programs as appropriate) aimed at changing management practices to improve water quality outcomes for the GBR. They can be adapted as required to the projects from the micro to the macro level. The principles include:

- Engage and coordinate from the beginning: Engage with relevant stakeholders (farmers, agribusiness, councils, NRM bodies, research and development organisations, private and public extension professionals, government and semi-government policy agencies) to establish the leadership groups and relationships necessary to develop the project. Consider the system when establishing a leadership group from these and establish links with other relevant participants, groups and stakeholders. Start by publicly and privately acknowledging progress that has already been made and shun stigmatising some groups of landholders.
- Collaborative design: Collaboratively co-design the project so that it is transdisciplinary, flexible, holistic, and takes account of the context and barriers to changing practices and processes necessary to meet the projects goals. Ensure there is shared understanding, ownership and commitment to the project and its goals by the leadership groups and as

many other participants as possible. Time is required if the relationships and trust necessary for this to occur are to develop.

- Coordination: Establish and develop coordination processes within the project and with other relevant research and scaling projects and agencies.
- Understand underlying factors: With the leadership groups, understand the underlying factors that hinder or enable the uptake of recommended management practices throughout the innovation system and governance and enabling environment, not just at the farm level. Include factors that influence the triple bottom line.
- Collaborative monitoring and evaluation (M&E): Establish a collaborative M&E process during the planning process that continues during and after the project. This will start with collaborative principles, but will emerge, develop and change following regular appraisals to reflect and evaluate its logic. Focus beyond project practice changes at the farm level to monitor and evaluate changes in the innovation processes, meso-micro context and governance and extend the M&E beyond the life of the project. Ensure results are shared with the farmers involved.
- Implement with the community: Take the time to establish and maintain trusting relationships and acknowledge that this will have benefits beyond the project. Design interventions with the project leadership team and the broader community and at scale, but don't forget flexibility to allow for different individual contexts, goals, knowledge, skills and capabilities.
- Reinforce and empower: Reinforce change and empower participants by taking a positive attitude and acknowledging and communicating effort and progress to the project participants, the broader community and other relevant scaling projects and agencies.
- Build capacity: Build capacity as part of the project. With project leaders, identify participant needs to engage with and support the project and build their capacity to enhance the change process during and beyond the project. Depending on the project objectives this may include farmers, farmer leaders, industry intermediaries and leaders, extension and research professionals.

Macro context, enabling environment and governance factors affecting uptake of management practices to improve water quality outcomes

Governance was defined in the outline of the framework for this study to include the decisions involved in policy development and implementation. In this section, the literature on macro context, enabling environment and governance factors that affect the uptake of management practices to improve water quality outcomes is discussed. The role of the media as part of the enabling environment affecting governance and influencing the uptake of management practices is included. While historically there has been little analysis of how factors at the macro or institutional level enable or hinder adoption for the GBR (Coggan et al., 2021b), there has been an increasing list of publications directly addressing this issue for the GBR since the last SCS.

The effect of macro governance structures and processes on the uptake of management practices

Fifteen studies were identified that directly addressed the issue of governance at the macro or meso level that can apply to both urban and agricultural management practice adoption. Effective governance, from the local to the international level, is critical to decision making for the human dimensions that influence outcomes for the GBR (Gooch et al., 2017). Dale et al. (2016) utilised Governance Systems Analysis (GSA) to evaluate the GBR governance system from 2013 to 2016. They assessed 40 subdomains of governance that influence GBR outcomes, ranging from international to local levels, and identified subdomains at high risk of failure that would require transformational change to manage declining outcomes for the GBR. Property Planning and Management, as part of the Agricultural Development Domain, was rated a high risk as were various economic development subdomains, in particular those relating to plans to increase agriculture in Northern Australia. A lack of formal trilateralism between the three levels of government and a lack of engagement or partnering with major stakeholders were also considered weaknesses of the Long Term Sustainability Plan subdomain, which was rated a high risk when published.

In another study, Dale et al. (2018) applied the GSA framework to evaluate policies and programs implemented at the catchment scale to facilitate the implementation of water quality outcomes within the GBR catchments. While the Urban Water Management subdomain rated low on only one design principle and significant progress was noted in upgrading sewage discharge treatment into the GBR, five conditions necessary for more effective diffuse source urban pollution management were identified (Dale et al., 2018, p. 75). These conditions include the integration of the protection of aquatic ecosystems in urban land-use and development control planning, the use of innovative offset measures and developer contributions to local/regional waterway management, the careful location of urban development with regard to sediment stores to prevent sediment unlocking, mobilisation, and transfer, the incorporation of water-sensitive urban design in new development areas, and the retrofitting and softening or hardening of existing urban development, drainage, and riparian systems. Conversely, the Pastoral and Agricultural Farming Systems subdomain, rated low on five out of eight principles. This was related to its complex origins, and consequent fragmented approaches and drivers. They regarded reform as critical in this subdomain.

While Olvera-Garcia and Neil (2020) claim collaborative governance approaches have been used for GBR water quality planning since the early 2000s, earlier papers document and analyse a propensity for higher levels of government to exclude farmers and local institutions from cooperative or collaborative processes for decision making about governance. For instance, Benn et al. (2010), Benn (2015) and Taylor (2010) suggest government policy makers tended to control access to technical and scientific knowledge and to frame the policy debate without consulting or considering knowledge from farmers or industry about why adoption of recommended management practices was slower than required or why the science might not provide the complete picture. Government sometimes argued that cooperative processes were not achieving changes quick enough (Taylor, 2010), even though there were sometimes economic reasons for farmers not adopting the practices (Benn et al., 2010).

Dale et al. (2016) suggest a need for government to move from consultation to partnership with the major GBR stakeholders, who at this time were consulted but not engaged or partnered with in the development and implementation of policy. Some stakeholders perceived this dearth of engagement negatively. In the early 2000s many farmers did not accept the science related to their role in contributing to poor GBR water quality. When this coincided with threats and implementation of legislation to prohibit some practices (Taylor, 2010; Vella & Dale, 2014), farmers, farmer organisations and others took strategic decisions to oppose changes and this combination reinforced rejection of the effects of agriculture on GBR water quality and the practicality of the recommended management practices being proposed by the government (Benn, 2015; Benn et al., 2010; Lane & Robinson, 2009; Taylor, 2010). No evaluations were found that explicitly assessed the effect of regulations on uptake of practices.

Another early discussion that relates to insufficient engagement, was about a lack of integration between policy and institutional arrangements and a lack of horizontal and vertical integration between different agencies (Hill et al., 2015; Lane & Robinson, 2009; Vella & Dale, 2014). A lack of integration between the various departments with responsibilities for the GBR, with the consequent reduction in coherent policies and programs, led Benn et al. (2010) to call for one department to deal with agri-environmental policies. This concurs with the earlier discussion about landholders getting inconsistent messages from intermediaries and scientists, or not knowing which hat NRM and government intermediaries were wearing (e.g., Hay et al., 2019; Pickering et al., 2019b; Taylor & van Grieken, 2015).

In the 2017 SCS Eberhard et al. (2017b, p. 4) suggest that "Great Barrier Reef governance is a 'wicked' policy problem requiring adaptive, participatory and transdisciplinary approaches". In their summary of the 2017 SCS, Waterhouse et al. (2017) also conclude collaborative processes are essential. There is evidence that these approaches are increasing and beginning to bear fruit. During the period of turmoil over GBR policy and legislation (e.g., a threat by the Premier in 2003 to implement regulation (Taylor, 2010)), Vella and Dale (2014) found that the partnership and engagement processes involved with the development of the Mossman Mill District Practices Framework, resulted in sufficient trust and goodwill to maintain grassroots support. Similarly, Lane and Robinson (2009), in a case study analysis of a large-scale collaboration and coordination effort to address water quality in the GBR, concluded that the development of horizontal and vertical collaborative partnerships among diverse actors was promising, although this may be partial and would vary with context, goals and scale. Hill et al. (2015, p. 272) suggest that collaboration can help with management of six dimensions of risk involved with collaboration: “knowledge asymmetries; institutional diversity and fragmentation; uncertainty; ‘‘invisible’’ slow-changing variables; power imbalances; and socio-economic marginalisation and disadvantage”, while leveraging knowledge and working with institutions at the scale where they have the comparative advantage to achieve impact. Similarly Tan and Humphries (2018) argue that since 2007, there have been ‘exemplary attempts’ to reduce power imbalances and use collaborative approaches with involvement of regions, Traditional Owners and multiple stakeholders. Despite key enablers such as a high level of scientific consensus, co-operation and buy-in from governments and stakeholders, and the UNESCO listing supported by global and local networks, they conclude that the major barrier to ‘transformational adaptive governance’ is competing political ideologies around land clearing and climate change.

Nevertheless, these changes towards participatory and collaborative processes may be patchy. Eberhard et al. (2017a) concluded there was little evidence of a transfer of power to other agencies, from “government to governance”. Rather federal and state governments were using consultative processes to link to stakeholder forums rather than to engage them in decision making – a participant-governed network. Greater engagement has occurred, but the consultative structures and processes have largely been used to augment the normal hierarchical processes, not replace them. This is consistent with the findings of Olvera-Garcia and Neil (2020) who concluded that regional level collaborations helped with achieving water quality outcomes. However, despite nested collaborative arrangements being in place, power inequalities between regional and higher-level institutions and deficiencies of consensus building at the state and federal levels of government reduce collaboration and hence reduce possible environmental outcomes.

A recent review by Taylor and Eberhard (2020) emphasises that knowledge exchange rather than knowledge transfer is more likely to build trust and commitment. In listing policy instruments that influence adoption they conclude that the capacity of regional partnerships and delivery networks is fragile and that there is insufficient experimentation and evaluation of water quality programs to facilitate adaptive management. In addition, they suggest there has not been sufficient attention to involving other crucial actors in the value chains and community who have a role in hindering or enabling practice change and that there is a need to foster capacity and maintain collaboration in and with this broader range of actors.

Macro planning processes and their role in managing water quality for the GBR

Water quality planning for the GBR is implemented through two mechanisms: the Reef 2050 Water Quality Improvement Plan (Australian Government & Queensland Government, 2018) and through regional Water Quality Improvement Plans (e.g., NQ Dry Tropics, 2016). However, as noted in a previous SCS (Eberhard et al., 2017b), one of the key challenges for GBR planning was that the implementation of these plans was not directly resourced. Instead, they were used to inform investments via water quality programs, which were typically highly constrained by programmatic specifications and limited local experimentation. Additionally, the planning and management of terrestrial and marine systems were not connected, with substantial overlap, duplication and a lack of policy and institutional integration, even though implementation requires coordinated governance across multiple fragmented levels of government (Vella & Baresi, 2017; Vella & Dale, 2014; Vella & Forester, 2017). To address these challenges, Gordon (2007) suggests that regional planning approaches adopt a localised, whole-of-system, adaptive management approach, where the socio-economic system feeds back to managers further up the catchment.

Additionally, planning involves the translation of knowledge into the actions needed to achieve a goal, and therefore, sound planning decisions rely on the successful integration and translation of many different forms of knowledge (Kroon et al., 2009). However, this becomes increasingly challenging with the emerging focus on decentralised approaches to planning, such as those in the

GBR context. To illustrate, in their analysis of the development of the Tully Water Quality Improvement Plan, Kroon et al. (2009) noted several planning challenges associated with:

- Integrating scientific knowledge with local perspectives and values.
- Fragmented, uncertain, and/or biased information that can lead to poor decision making.
- The long-time frames needed to generate and develop knowledge.
- The translation of different sets of knowledge into management programs and responsibilities.
- Sustained participation over time by some stakeholder groups.

However, they also noted that the "establishment of a durable partnership [can enhance] knowledge integration at the catchment scale, and provided a framework for coordinating and integrating large amounts of fragmented and uncertain information from research, community, government, and industry" (Kroon et al., 2009, p. 1186). A process to establish and maintain such partnerships was also at the core of the Adaptive Management Framework proposed by Bennett et al. (2005) to develop and implement strategies for a Reef Water Quality Protection Plan.

A Bayesian network model developed incorporating expert knowledge derived from a participatory modelling approach investigated the potential impact of key policy instruments on practice adoption and the influence of practice and landholder characteristics (Mayfield et al., 2023). It was used to estimate and compare adoption percentages for five instruments (extension, grants, regulations, governance, and communication informed by behavioural insights). It was validated for adoption of fertiliser and riparian vegetation practices in 14 different scenarios. The model findings imply that integrating policy instruments (grants, extension and regulations) may generate stronger adoption than single instruments. While population data and implementation rates were not used for validation, such tools provide an opportunity to scrutinise the effect of policy instruments in situations where constantly evolving policy mixes make empirical impact assessment difficult.

Vella and Forester (2017) specifically investigated the challenges faced by GBR planners and identified sluggish bureaucracies, value conflicts and captured interests, a lack of coordinated leadership, and ineffective public participation as key obstacles to overcoming conflicts and developing strategies for good GBR policy. To overcome these barriers to action, the planners built systematic capacity, created partnerships, and put in place collaborative systems through both formal and informal processes (Vella & Baresi, 2017; Vella & Forester, 2017).

Studies that address other macro-level planning issues include:

- Weak evaluation: In their synthesis report of the 2017 SCS, Waterhouse et al. (2017) found there had been insufficient monitoring, evaluation or reporting of social, economic, governance or institutional indicators that would help improve effectiveness of these programs. In the previous SCS Eberhard et al. (2017b) noted the lack of systematic evaluations of planning and governance performance creates uncertainty when identifying barriers and enablers to adoption at the macro level. More recently, Eberhard et al. (2021) in a critical review of policy instruments, suggest that weak program evaluation is still the case even though they accessed programmatic grey literature. They also conclude most extension projects rely on weak descriptive measures, such as participation and satisfaction, which do not address the medium to longer term outcomes for the projects. It appears that evaluation of the macro and meso level evaluations of innovation processes and governance are still to be addressed.
- Need to take transdisciplinary or multidisciplinary approaches: While Eberhard et al. (2021) calls for the use of multidisciplinary approaches to develop and evaluate policies, Waterhouse et al. (2017) takes it further by calling for the use of transdisciplinary approaches to develop, test and evaluate practices and processes. These approaches can be used at meso levels, but because of the complexities involved with policy, are perhaps very relevant at the macro level.
- Develop strategies to take advantage of conservation opportunities: Moon et al. (2014) use a multidisciplinary conceptualisation of conservation opportunity to identify three types of

opportunity that can be leveraged to facilitate conservation action: 1) Potential opportunities (are available but not yet ready, so barriers must be removed to enable change to occur); 2) Traction opportunities (arise because of unpredictable shocks, events or changes to the system that policy and conservation entrepreneurs can position themselves to capitalise on); and 3) Existing opportunities (existing opportunities that exist but may not have been taken advantage of for a range of reasons). Moon et al. (2014) document and discuss examples of these conservation opportunities since the 1970s. They suggest the framework can be used to identify opportunities to bring about change.

Media and its effect on uptake of management practices

Recognising the media's potential as an 'agent of change', five studies were identified that examined media narratives and discourses related to the GBR (Eagle et al., 2018; Foxwell-Norton & Konkes, 2019; 2021; Foxwell-Norton & Lester, 2017; Konkes & Foxwell-Norton, 2021). Foxwell-Norton and Lester (2017) and Foxwell-Norton and Konkes (2019) compared the early campaigns for the GBR in the 1960s, 1970s and 1980s with the more recent campaigns associated with putting the GBR on the List of World Heritage in Danger. While the methods for use of media have changed, so has the role of media in the debate, with 'protection' of the GBR shifting from a positive frame to a more contested frame. Coverage of environmental protection for the GBR is overshadowed by political and extractive industry sources arguing for 'economic development' but using the language of 'sustainable development, with a noted decline in the voices of scientists and other counter voices arguing from an ecological perspective. Foxwell-Norton and Lester (2017) identified a more recent trend in which the broader media landscape has empowered participatory politics to wrestle public debate from existing sites of cultural and economic power, such as mainstream commercial media, industry, and governments. Nonetheless, they acknowledged that uncertainty remains regarding the impact of this shift, as recent Australian traditional media has tended to favour industry and development over conservation of the GBR. Konkes and Foxwell-Norton (2021) identified another shift in recent media coverage towards a sensationalised view of the potential future health of the GBR as dying, which may lead to a decline in local mitigation strategies for water quality as these are seen as less relevant in the context of overwhelming climate change effects.

Additionally, Foxwell-Norton and Konkes (2021) reviewed the role of media in fostering action towards the GBR and found that media content favouring politics and debates related to climate science and reef science has allowed sceptics to discredit scientists and others as 'alarmists'. An example of this is the debate over the review and synthesis processes for the GBR (e.g., Larcombe & Ridd, 2018; Schaffelke et al., 2018), which has pitted scientists against each other with some media and industry advocates taking sides in the debate and supporting one side against the other. Konkes and Foxwell-Norton (2021) critique both sides in this debate to show how efforts to communicate science using media logic can result in misuse of information in politicised debates. However, Foxwell-Norton and Konkes (2021) also noted a recent trend of scientists engaging directly with the media, including through social media and alternative channels that are not reliant on mainstream news media.

Conclusions about the macro factors hindering or enabling the uptake of agricultural and urban management practices

Conclusions about the macro factors hindering or enabling the uptake of management practices include:

- Most research concludes that governance of the GBR is a 'wicked' policy problem that requires high levels of engagement, partnering and collaboration to successfully improve water quality despite the complexity of such processes, the expense and the time it will involve.
- While recent levels of engagement, partnering and collaboration have improved since the early 2000s (e.g., the Major Integrated Projects), much of this has been horizontal collaboration (e.g., at the regional level), and there is good evidence that there are still power imbalances between local and regional, and between state and federal institutions

which means that many of these processes are consultative rather than collaborative. Funding for horizontal and vertical collaboration needs to continue to enhance the development and implementation of good policy to improve water quality.

- Policy decisions in one area (e.g., regulatory instruments) have had negative effects on the effectiveness of other instruments (e.g., grants and extension), creating a need for greater integration between policies and institutions involved in developing and implementing these policies.
- Policy decisions will be more likely to be implemented effectively if they have the consent and cooperation of the targets for those policies (e.g., landholders or councils) as they will be able to rely on industry, media and political support to resist unwanted change. Intermediaries in the value chains also need to be considered here. Media can intensify the levels of conflict.
- Transdisciplinary or multidisciplinary research and planning processes, which are collaborative, are likely to improve outcomes where they are used at all levels of decision making from the macro through to the micro.
- There is insufficient, systematic and peer-reviewed literature on the effectiveness of governance, planning and innovation processes that affect the uptake of management practices to improve GBR water quality. This could also include investigating mixes of instruments with extension to allow experimentation and customisation.

4.1.2 Recent findings 2016-2022 (since the 2017 SCS)

- In their synthesis report for the 2017 SCS Waterhouse et al. (2017, p. 13) concluded: "Collaborative processes to deliver interventions and improve trust in decisions and data are essential". Despite improvement since 2017, this remains the case for policy development and implementation at all levels. Governance is a 'wicked' problem that requires high levels of engagement, partnering and collaboration, along with transdisciplinary or multidisciplinary research and planning processes, despite complexity, time and cost involved.
- While perceptions of mistrust between farmers, government and scientists existed prior to the 2017 SCS, it appears this lack of trust increased after the introduction of the Reef Protection Regulations in 2019 and was noted several times in the Senate Inquiry into regulation of farming practices (Reef and Rainforest Research Centre & James, 2021). Since then, multiple studies have acknowledged and investigated this issue and have concluded that mistrust is a major factor hindering the uptake of management practices to improve water quality outcomes.
- The recent literature documents the benefits of embracing collaborative principles in innovation and scaling processes that improve the design, implementation and scaling of management practices to improve water quality outcomes for the GBR, while helping improve farmers' trust in recommended management practices. Similarly, at the macro governance and policy level, the literature suggests collaborative transdisciplinary or multidisciplinary research and planning processes are likely to improve outcomes, particularly if they have the consent and cooperation of the targets for these policies.

4.1.3 Key conclusions

- Landholder perceptions of a wide range of characteristics that inhibit or enable the uptake of management practices to improve GBR water quality were identified. Nevertheless, the effect of each was generally specific to a practice in their context, while varying from landholder to landholder and context to context. No studies were found that identified factors that enabled or hindered the adoption of urban water management practices to improve GBR water quality.
- While the characteristics of individuals and typologies of individuals are associated with the adoption of management practices their effects vary and need to be assessed for contextual relevance. Many farmers lack trust in government, scientists involved in GBR

research, GBR program delivery organisations, program managers and delivery staff. Hence it is a key factor to be addressed by programs and projects if its effects on uptake of management practices are to be reduced.
- Social resilience, innovative and adaptive capacity may be factors that hinder or enable the uptake of urban management practices, but there is very limited evidence about this.
- A series of principles have been identified from the literature to guide the design and implementation of innovation and scaling processes that can be adapted to apply to all research, development and extension projects aimed at changing management practices to improve water quality outcomes for the GBR. They include: Engage and coordinate from the beginning; Collaborative design; Coordination; Understand underlying factors; Collaborative M&E; Implement with the community; Reinforce and empower; and Build capacity.
- Program evaluation from the micro to the macro levels is still weak and requires guidelines and funding that puts a greater focus on outcomes and impacts beyond the life of programs or projects. Ideally, evaluation would be part of the planning process, extend beyond the lifespan of the program, and include changes in behaviour, and human and social capital that may have ongoing benefits.
- In their synthesis report for the 2017 SCS Waterhouse et al. (2017, p. 13) concluded: "Collaborative processes to deliver interventions and improve trust in decisions and data are essential". Despite improvement since 2017, this remains the case for policy development and implementation at all levels. Governance is a 'wicked' problem that requires high levels of engagement, partnering and collaboration, along with transdisciplinary or multidisciplinary research and planning processes, despite complexity, time and cost involved.
- No studies were found that measured the levels of disadoption of management practices for the GBR or more broadly in Australia since 2020. If disadoption is an issue, then work should be funded to investigate the extent that it is an issue and what causes it.

4.1.4 Significance of findings for policy, management and practice

The significance of these findings about the factors hindering or enabling the uptake of management practices can be summarised as follows:

- The macro context, enabling environment and governance systems that govern and mould the innovations processes used to develop the management practices can be a major factor hindering or enabling the uptake of the management practices.
- If management practices developed for the GBR by the RD&E system (or innovation system) are to be adopted by independent managers to lead to improvements in water quality outcomes, it would be beneficial if they were developed, tested and scaled using collaborative processes that actively engage key actors in the relevant value chains and innovation systems.
- Innovation processes that incorporate collaborative processes and actively involve key actors in the relevant value chains and innovation systems are required to overcome the inherent distrust and suspicion of government, scientists involved in GBR research, GBR program delivery organisations, program managers and delivery staff.
- Practice, landholder specific and micro-level factors have been extensively investigated. While characteristics of practices, individuals and typologies of managers are associated with the likelihood of their adoption, they should not be considered in isolation to their context and the processes used to engage with the managers.
- Collaborative M&E processes for all levels including the macro governance system, the innovation process system and the meso-micro context system should be reviewed, developed and evaluated. These processes should be part of the collaborative planning process for the project or program, extend beyond the participants involved in them and consider the social changes including their effect on levels of trust.
- Evidence for disadoption and the reasons for disadoption have not been studied.

Many of these issues were raised in the 2017 Scientific Consensus Statement, but the evidence supporting these findings has only increased.

4.1.5 Uncertainties and/or limitations of the evidence

Factors that lead to uncertainties or limitations of the evidence include:

- This is a very broad topic covering multiple industries, types of agricultural businesses and urban environments, manager characteristics, regions, agro-climatic environments and management practices. In addition, the systems level analysis goes from the micro practice and individual level through to the macro governance, media, policy, political and legislative levels and uses many different theoretical, methodological and analytical approaches to investigate these issues.
- Change occurs in an enabling environment that governs or moulds it, but this environment is itself influenced or moulded by change and peoples' interactions and responses to the change. Consequently, the issues are extremely complex.
- Studies of practice or individual characteristics and their influence on practice adoption provide conflicting evidence.
- Evaluations of outcomes and impact from the micro to the macro level are narrow, inconsistent and almost exclusively short term.
- Studies before 2000 were not included because of the considerable changes that have occurred in the enabling environment, governance systems, policy environment, meso-micro context and management practices since then.
- Effects of governance, policy and innovation processes are less uncertain.
- Very limited evidence on factors influencing uptake in urban environments.
- No peer-reviewed studies were found that investigate disadoption.

4.2 Contextual variables influencing outcomes

The main contextual variables influencing the relationship were: climate change, political conflict, complex planning, and heterogeneity of context on factors affecting uptake (Table 9).

Table 9. Summary of contextual variables for Questions 7.2 and 7.2.1.

Contextual variables	Influence on question outcome or relationships
Climate change (or climate variability)	Political conflict and change in framing of the debate about factors affecting the GBR (Eagle et al., 2018; Eberhard et al., 2017a; 2021; Foxwell-Norton & Konkes, 2019; 2021; Foxwell-Norton & Lester, 2017; Konkes & Foxwell-Norton, 2021; Larcombe & Ridd, 2018; Tan & Humphries, 2018). Increased uncertainty for decision making (Coggan et al., 2021b; Eberhard et al., 2017a; Gregg & Rolfe, 2016; 2018; Herr et al., 2004; Kandulu et al., 2018; Rolfe & Gregg, 2015; Star et al., 2015; 2019).
Political conflict	Conflict over planning processes: power relationships, collaborative, regulatory approaches (Benn, 2015; Benn et al., 2010; Kroon et al., 2009; Lane & Robinson, 2009; Olvera-Garcia & Neil, 2020; Tan & Humphries, 2018; Taylor, 2010; Tsatsaros et al., 2020; Vella & Dale, 2014; Vella & Forester, 2017). Loss of trust arising from a range of issues from government regulations to political and media agendas (see discussions and references in the section of the role of trust).

Contextual variables	Influence on question outcome or relationships
Complex planning	Difficulties integrating planning across locations, communities, institutions, levels of governments (Bohnet, 2015; Bohnet & Smith, 2007; Cleary et al., 2022; DAF, 2021; Dale et al., 2016; 2018; Eberhard et al., 2021; Gooch et al., 2012; 2017; Harvey et al., 2016; Kroon et al., 2009; Mayfield et al., 2023; Moon et al., 2014; Tan & Humphries, 2018; Taylor, 2010; Taylor & Eberhard, 2020; Tsatsaros et al., 2020; Vella & Baresi, 2017; Vella & Dale, 2014; Vella & Forester, 2017; Waterhouse et al., 2017).
Heterogeneity of context on factors affecting uptake	Differences in location, time, industry, manager KASA, location, innovation processes, population assessed, research theory and method, political and enabling environment policies and context all interact and alter the effect of variables on uptake (multiple references).

4.3 Evidence appraisal

Relevance

The relevance of the overall body of evidence was 7.1, which is in the High range. The relevance of each individual indicator was 2.5 (out of 3.0) for the relevance of the study approach and reporting of results to the question, 2.3 for spatial relevance, and 2.3 for temporal relevance. Of the 106 articles included in the review of Question 7.2 "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?", 68% were given a High score for overall relevance to the question, while 24% were given a Moderate score. For spatial relevance, 34% had a High score and 62% had a Moderate score, while for temporal relevance, 25% had a High score and 63% had a Moderate score. These scores to be expected from the range of studies involved and don't indicate any limitations for relevance. However, for Question 7.2.1 "What factors influence disadoption of management practices in agricultural industries and are there examples from elsewhere on how to address it?", there is no relevant information that directly addresses the question of disadoption in the Australian literature.

Quantity, Consistency and Diversity

Given the authors knowledge of the total potential pool of available evidence, 106 is considered a High number of studies in answering Question 7.2, although there was a lack of detailed studies in some relevant areas of the framework. As is concluded in the narrative synthesis, there are insufficient, systematic and peer reviewed studies on the governance issue, and none on the intersection between politics and policy advice. Evaluation studies from the micro to the macro levels were also weak, so it is difficult to evaluate the outcomes and impacts of many projects.

Given the broad nature of the primary question, the studies addressed an extremely diverse range of questions and used an extremely diverse range of theoretical and methodological approaches. Even when addressing a particular topic there was a diverse range of theories and methods used.

However, for Question 7.2.1, only four studies were found in Australia since 2000 that discussed disadoption, most of these were for the grains industry and none discussed disadoption in the GBR. No GBR (or Australian) studies measured levels of disadoption of agricultural or urban practices or evaluated the reasons for disadoption.

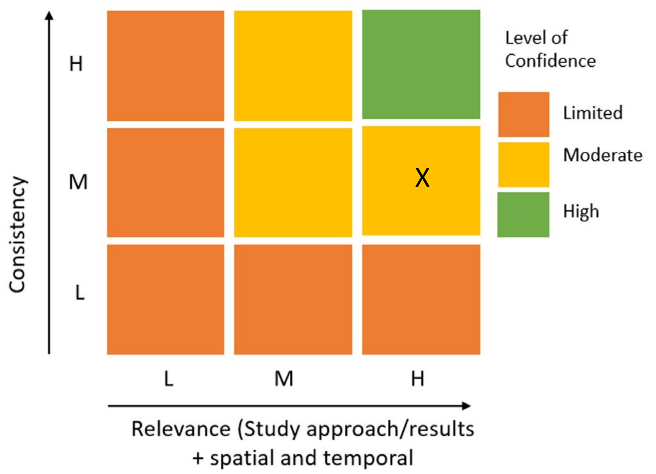
Additional Quality Assurance (Reliability)

A rapid internal validity assessment was made of all 106 studies used in the synthesis for the primary question to identify any obvious potential bias and to identify studies most influential in drawing conclusions from the body of evidence. No studies were removed from the synthesis due to the internal validity assessment. Of these, 85% raised no concerns, while minor concerns were indicated for seven studies, mostly due to low numbers interviewed, although these were qualitative studies that provided rich data, so this is not an important issue. A further eight studies were rated as having some concerns, which were due to: the model not being evaluated against empirical data or at an early stage of development (6) and potential conflicts of interest (2). For the latter, this was not perceived to be a major problem as their findings tended to be consistent with findings from other studies addressing similar issues.

Confidence

Despite the diversity of questions addressed by the papers relevant to the primary question and the diversity of methods used there is Moderate confidence in the body of evidence used to make statements in the synthesis key findings for Question 7.2. This is due to the High relevance of studies but the Moderate consistency of the conclusions arising from multiple study types (Table 10).

Table 10. Summary of results for the evidence appraisal of the whole body of evidence used in addressing Questions 7.2 and 7.2.1. The overall measure of Confidence (i.e., Limited, Moderate and High) is represented by a matrix encompassing overall relevance and consistency. The final row summarises the additional quality assurance step.

Indicator	Rating	Overall measure of Confidence
Relevance (overall)	High	
-To the Question	High	
-Spatial	Moderate	
-Temporal	Moderate	
Consistency	Moderate	
Quantity	High (106 studies in total, of which 102 from the GBR)	
Diversity	High (29% mixed, 12% secondary data analysis, 17.5% quantitative, 15% qualitative, 9% review, 17.5% conceptual model)	
Additional QA (Reliability)	High	• Most studies (85%) had no concerns relating to reliability, with none excluded for this reason. • A rating of minor concern was given to 7%, with the common cause being qualitative data with a small, non-random sample size, but these had rich data. • A further 8% were rated as having some concern, mainly due to a theoretical unvalidated model (6%), with concerns about a conflict of interest being the cause for 2%.

4.4 Indigenous engagement/participation within the body of evidence

Given the target audience for Question 7.2 was farmers and councils, very little research was conducted that engaged or involved the participation of the Indigenous community. However, some planning processes involved participation by representatives of the local Indigenous communities.

However, the organisations and numbers or people involved in these activities were not normally clearly articulated.

4.5 Knowledge gaps

Knowledge gaps for questions 7.2 and 7.2.1 and the potential benefits from addressing them are given in Table 11.

Table 11. Summary of knowledge gaps for Questions 7.2 and 7.2.1.

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
Approaches for collaborative design of innovation processes in different contexts.	What are the principles underlying successful collaborative innovation processes for the meso to the macro level?	Better design, implementation and evaluation of all aspects of the innovation process.
Principles for the design of systematic M&E processes that include social, economic, governance, programmatic, adoption stages and time dimensions.	What are the principles required to undertake successful collaborative M&E processes within and across projects that incorporate social, economic, governance, program, adoption stages and time dimensions?	Improved M&E process and consequently better design and implementation of all programs from macro governance to meso-micro innovation processes.
Innovation processes that develop triple bottom line management practices that reduce the gaps between those developed by environmental and production science actors, institutions and policy.	What are the triple bottom line implications (for relevant actors) of all management practices proposed to improve GBR water quality? What changes are required to the current innovation and governance processes to deliver triple bottom line management practices that are relevant to the actors who will implement them?	Improved innovation processes developing management practices that incorporate triple bottom line considerations and consequently lead to increased adoption & better water quality outcomes.
How to link scaling processes to the innovation process so that they overcome relevant factors hindering uptake and lead to improved uptake of management practices?	What principles are required to integrate collaborative scaling practices into innovation processes? What principles are required to integrate a mix of instruments into the innovation processes?	Better scaling processes with improved M&E leading to increased adoption and better water quality. Better processes for scaling that involves a mix of instruments.
Strategies for GBR scientists, extensionists, governance and policy professionals to communicate in the current media environment.	What current strategies for media communication are currently being used, how might they be improved and what processes should be put in place to improve outcomes?	Improved media communication outcomes that reduce conflict and improve community understanding of issues relevant to improving GBR water quality.

5. Evidence Statement

The synthesis of the evidence for **Question 7.2** was based on 106 studies published after 2000, including 102 undertaken in the Great Barrier Reef. The synthesis includes a *High* diversity of study types (29% mixed, 12% secondary data analysis, 17.5% quantitative, 15% qualitative, 9% review, 17.5% conceptual model) and has a *Moderate* confidence rating (based on *Moderate* consistency and *High* overall relevance of studies). Only four studies were found in Australia since 2000 that discussed disadoption of management practices in agriculture. None of these discussed the Great Barrier Reef and none measured the levels of disadoption or the factors that hinder or enable disadoption of management practices.

Summary of findings relevant to policy and management action

The factors that influence the uptake of management practices to improve water quality operate at various systems levels. These levels can be described as macro (governance, culture, media, economics, policy and legislation), meso (industry, research and development agencies and community), micro (individuals and relationships to people) and practice or behaviour characteristics. The macro context, including the enabling environment and governance systems, directs and moulds what occurs at each of these levels and hence influences efficiency and effectiveness. Landholder distrust and suspicion of certain groups including government and scientists involved in Great Barrier Reef research, program delivery organisations, program managers and delivery staff is a key factor hindering uptake of management practices. To overcome this distrust, management practices and programs for agricultural and urban land managers would be more efficacious if they were developed, tested, scaled, monitored and evaluated using collaborative processes that actively involve key actors in the relevant communities, value chains and innovation systems. Context and the processes used to engage with the land managers are critical to consider but factors identified that may be associated with improved uptake include levels of human and social capital, economies of size, presence of trusted advisors and bottom-up development of practices.

Supporting points:

- Recent literature has identified several principles that can be used to help address the lack of trust, particularly active engagement of key actors from the planning stages onwards which can improve the design, implementation and scaling of management practices to improve water quality outcomes for the Great Barrier Reef.
- There has been extensive investigation of factors hindering and enabling the uptake of management practices at the practice, landholder and micro-level. Perceptions of these factors vary between researchers and farmers and within farming communities, creating a diversity of evidence about drivers of management practices. Options to address these factors need to be incorporated within the innovation processes (research, development & extension).
- While real and perceived economic factors are important to landholder decision making, even profitable practices can take time to be adopted because of the interactions within and between economic factors and landholders, research, extension, industry and community attitudes and systems. Less profitable practices are likely to take even longer and will require further development of approaches, supporting policies and instruments. Additionally, for all land uses, demonstrating links between practice change and improved water quality outcomes was identified as an important factor that could enable and hinder practice adoption. Other factors for major land uses include:
    - For sugarcane, social norms, costs of adoption, compatibility with farming systems, economies of size effects, and the interaction of technology characteristics and context were identified as factors that hinder and enable uptake.

- For grazing, the interaction of weather and climate with property and decision-maker context, financial and other support over time, transaction costs and skills required.
- For urban, social resilience, and innovative and adaptive capacity may be important but there were few studies to support this.

- Mixes of instruments (e.g., regulation, incentives) could be collaboratively designed, implemented and evaluated alongside or in coordination with extension approaches to improve their efficiency and effectiveness.
- Government policies and the introduction of regulations were mentioned by multiple authors as resulting in mistrust that hindered the uptake of recommended management practices to improve water quality outcomes beyond minimum standards. When these decisions didn’t have the support of the target audiences (e.g., landholders or councils), they generated resistance and conflict that was supported and intensified by industry, media and politicians.
- Program evaluation from the micro to the macro levels is still weak and requires guidelines and funding that puts a greater focus on outcomes and impacts beyond the life of programs or projects. Ideally, evaluation would be part of the planning process, extend beyond the lifespan of the program, and include changes in behaviour, and human and social capital that may have ongoing benefits.
- Disadoption has not been studied in the Great Barrier Reef catchment area. However, there are two factors that need to be quantified to improve this understanding: 1) the number of landholders (as a portion of the landholder population) that adopt management practices which improve water quality and 2) those that then disadopt, noting that there may be very few that disadopt when compared with those that don’t shift land use practices in the first instance. The factors influencing disadoption are also likely to vary in the same way that factors influencing initial uptake vary. Understanding disadoption does not require extra studies, rather it should be part of ongoing evaluations.

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.

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Appendix 1: 2022 Scientific Consensus Statement author contributions to Question 7.2

Theme 7: Human dimensions of water quality improvement

Primary Question 7.2 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?

Secondary Question 7.2.1 What factors influence disadoption of management practice in agricultural industries and are there examples from elsewhere on how to address it?

Author team

Name	Organisation	Expertise	Role in addressing the Question	Sections/Topics involved
1. Roy Murray-Prior	Agribiz RD&E Services	Agricultural science, extension & economics & agribusiness systems	Lead Author	All Sections
2. Tracy Schultz	The University of Queensland	Social & behavioural sciences, Environmental psychology	Contributor	Searches & data extraction Urban sections Review all sections
3. Peter Long	Peter Long Consulting	Agricultural science, extension, evaluation, natural resource management, & agribusiness systems	Expert advice & review	Review all sections

Appendix 2: An agricultural innovation system for GBR value chains

This agricultural innovation system (AIS) model (Figure 4) was developed from the agribusiness systems model outlined by Murray-Prior et al. (2004) and incorporates insights from other sources (de Boon et al., 2022; Murray-Prior, 2020; Murray-Prior et al., 2004; Paschen et al., 2021; Rajalahti, 2012). It is built around the value chains for the main industries that affect Reef water quality, sugar and beef, but can also include other horticultural industries such as bananas. Because the main industries have largely separate chains, there is limited overlap between the farmers, farmer organisations and upstream and downstream actors in the chains. However, many of the agencies, systems and institutions associated with the GBR for these value chains (e.g., GBR RD&E funding agencies, GBR specific policies and regulations) have responsibilities across all the chains. At the macro level, the GBR AIS is influenced by the broader national and international governance systems.

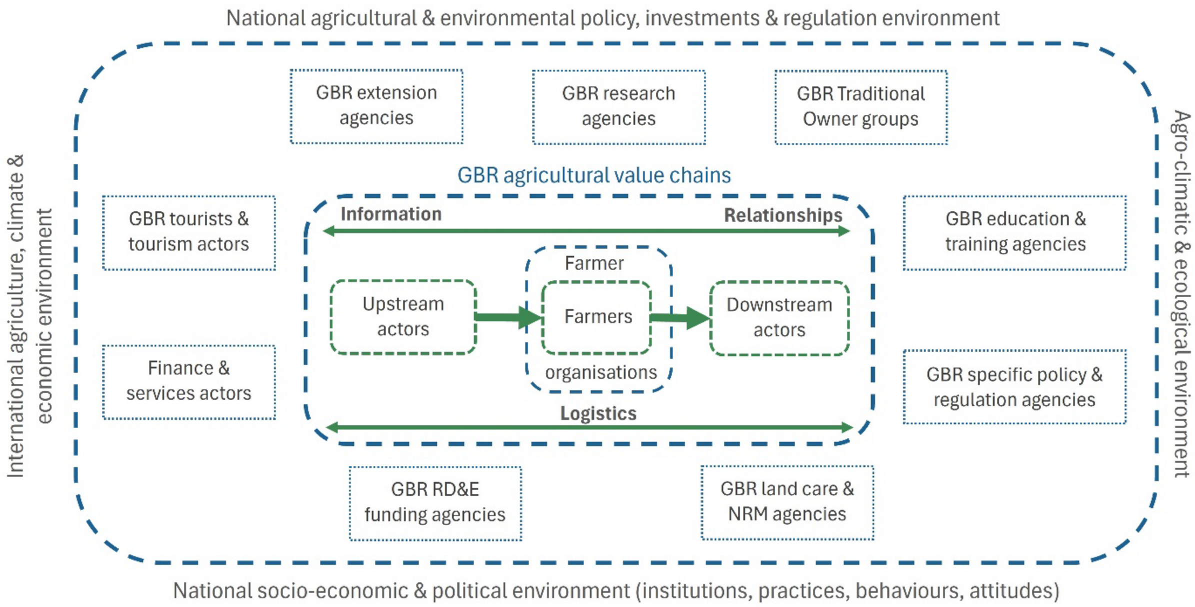


Figure 4. A simple AIS model of key actors and institutions involved in GBR agricultural value chains. Sources: Adapted from: Bennett et al. (2018); Birner et al. (2009); de Boon et al. (2022); Murray-Prior (2020); Murray-Prior et al. (2004); Paschen et al. (2021); Rajalahti (2012).

Macro context of the AIS for the GBR value chains

The system boundary for the AIS model for the GBR value chains incorporates the actors and agencies associated with the value chains for the main agricultural industries in the GBR area. In this context the suprasystem (or macro context) outside this boundary comprises the international and national environments. The agro-climatic and ecological environment for the GBR system encompasses the natural capital, which interacts with and changes due to human activities. This is shown at the macro level but is relevant to the meso and micro levels of the system. Another component of the suprasystem is the international agricultural, climate and economic environment, which includes the listing of the GBR as a World Heritage Area by UNESCO with the concurrent responsibilities for its management (Dale et al., 2016a).

The enabling environment is another key component of the suprasystem, in this diagram referred to as the national agricultural and environmental policy, investments and regulation environment. Broadly, an enabling environment has been defined by Konig et al. (2013, p. 5) as “sets of policies, institutions, support services and other conditions that collectively improve or create a general business setting where enterprises and business activities can start, develop and thrive”. For agriculture Diaz-Bonilla et al. (2014, p. 6) suggest it comprises “(i) a multifaceted setting for the sector and economy wide of non-distorting and stable policies; (ii) adequate provision of public goods, good governance through laws and regulations that address market failures; and (iii) strong and effective institutions through which government measures and activities are operationalised”.

This is similar to the categories or enabling factors outlined by Roseboom (2012, p. 449) as: ”(1) innovation policy and corresponding governance structures to strengthen the broader framework for agricultural innovation policies; (2) regulatory frameworks that stimulate innovation directly … or indirectly … or steer innovation towards preferred outcomes …; and (3) accompanying agricultural investments in rural credit, infrastructure, and markets”. The latter definition is particularly relevant to this study because it includes innovation policies and governance structures and associated regulatory frameworks. In the case of the GBR system we would need to include the innovations, regulations and investments relevant to international and national programs aimed at protecting the Reef and its associated tourist activities.

While most of the discussion about the enabling environment for agriculture and agricultural innovation occurs at the macro or national/international level (e.g., de Boon et al., 2022; Diaz-Bonilla et al., 2014; Roseboom, 2012), practically and conceptually, enabling factors that will influence the development and adoption of innovations can occur at the local, farm or micro level, at the regional, value chain or meso level, and at the broader state, national, international or macro level (Bryant, 1989; Teng & Oliveros, 2016). In the context of the development and adoption of innovations to enhance water quality for the Great Barrier Reef, the elements of the enabling environment that will constrain and enhance this process can be evaluated at the local farm and community level, at the broader agribusiness level for the main value chains and at the state, and at the national and international level.

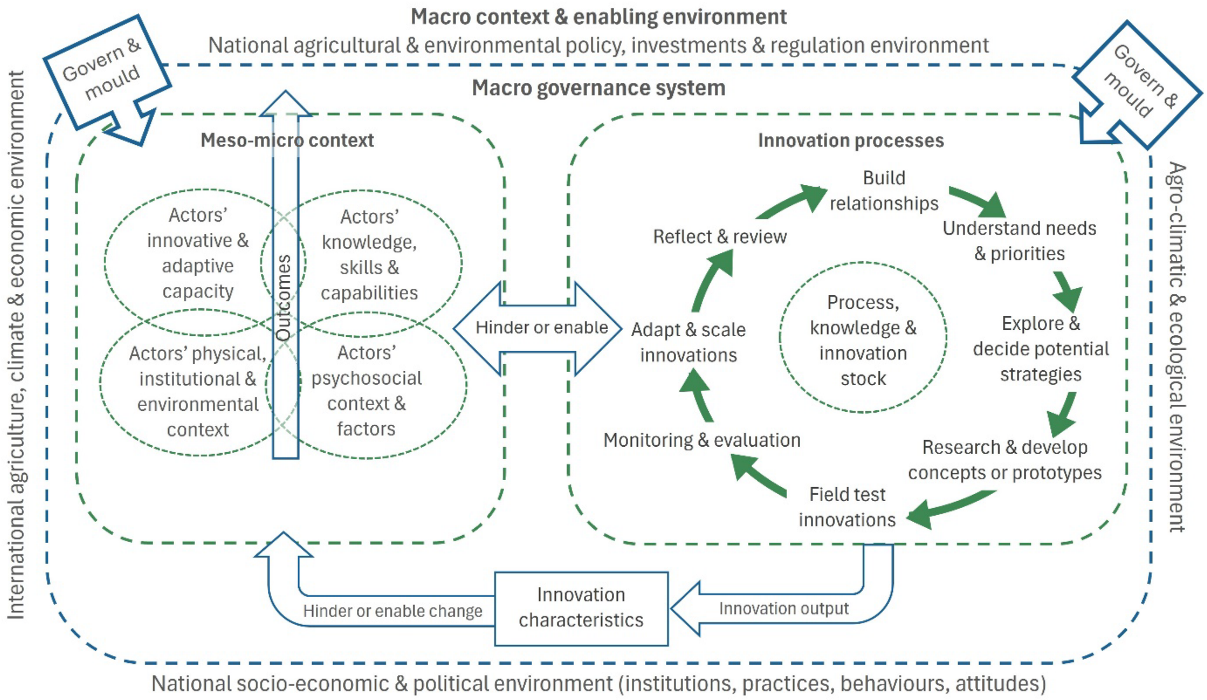
The socioeconomic and political environment includes the other capitals of produced economic, human, financial and social and other elements such as the formal and informal institutions, practices, behaviours and attitudes of the surrounding society. To a degree this overlaps with the enabling environment, however, these are treated separately here because the literature for the enabling environment tends to focus on functional elements that create favourable business conditions (Christy et al., 2009; Konig et al., 2013), while the processes that drive changes to the enabling environment are constrained and influenced by the socioeconomic and political environment.

Meso-micro context for relevant actors of the GBR agricultural systems

Within the outer boundary of AIS for the GBR are the meso-level actors involved with the main agricultural value chains of sugar, beef and horticulture. These include the main research, extension, education, regulation, funding and NRM agencies that are involved with these industries. While the agencies are shown as separate, there is considerable overlap, with some agencies involving elements of research, development, education, extension and funding (e.g., Universities, NRMs and the Queensland Department of Agriculture, Fisheries and Forestry). While the value chains are quite different (for example, sugar has its own research, extension and farmer organisations), each has similar elements, particularly in the upstream components. Other considerations in the model include the relationships and information flows between the various actors and to a lesser extent logistics for the chains. In all industries, most farms are family owned, although in the beef industry and the horticultural industry there are some large companies involved. Sugar and horticultural farmers live near each other and know many of the other farmers in their mill area. On the other hand, cattle graziers have much larger properties and consequently are more isolated from their peers, although they too will know many of them.

Appendix 3: Explanations of the five dimensions of a governance and innovation processes framework

This appendix discusses the five dimensions of governance and innovation processes framework presented in Figure 2.



Macro context and the enabling environment

In this model, the system boundary is similar to that for the ecological systems framework, although in the context of this review, the focus will be more on the policies, investments, regulations, and socio-economic and political factors that govern and mould the macro governance system, the meso-micro context and the innovation processes relevant to changing management practices affecting Reef water quality. Farm managers and community members have little to no influence over the macro context and enabling environment, although innovations may influence these structures over time (de Boon et al., 2022). However, the macro context and the enabling environment are key drivers of change and can work as enablers and barriers to improving practices affecting Reef water quality.

Governance system

The governance system refers to the structures and processes used by public and private actors to interact, exercise power, make and implement decisions that aim to steer the AIS and the agricultural value chains in the GBR towards improving Reef water quality (de Boon et al., 2022). The governance system operates and influences across the macro, meso and micro levels of the system. Perceptions of legitimacy of the governance system and the level of participation of those affected by the innovation processes and their outcomes influence it effectiveness. Uncertainty about context, drivers and outcomes leads to contested goals, pathways and responses, so the governance system should allow for diversity and be flexible and adaptable. Because of these factors de Boon et al. (2022, p. 411) argue:

> "Actors involved in the governing process should deliberately reflect on the potential (unintended) consequences of their decisions and on how the way that decisions are made, and the values that underly these decisions, reproduce the structures that can undermine sustainability and erode the foundation on which they are built."

Consequently, we need to develop an understanding of the components of the governance process that affect the efficiency and effectiveness of an AIS for the GBR.

Meso-micro context for relevant actors of the GBR agricultural systems

The meso-micro context includes the main actors for the agricultural value chains (sugar, beef & horticulture), but also the relevant actors in the enabling environment for the value chains (e.g., RD&E). This is essentially the meso and micro equivalents of the macro context and enabling environment that can enhance, constrain and influence the operations of the innovation processes and the ability of actors in the system to change their practices in line with the innovations that are developed (de Boon et al., 2022).

The governance framework developed by de Boon et al. (2022) incorporates three main components for the micro-meso context (actors' innovative capacity, actors' adaptive capacity, actors' psychosocial factors) which they refer to as the foundation. In the GBR framework, four components are discussed using insights from the Extension Model of Practice proposed by Williams et al. (2021), the Behaviour Change Wheel proposed by Michie et al. (2011) and the implications of the educational process outlined by Tully (1966). These components are: actors' innovative and adaptive capacity; actors' knowledge, skills and capabilities; actors' personal psychological context and factors; and actors' physical, institutional and environmental context.

While there is considerable overlap and interaction between the underlying causes, influences, determinants and drivers of these components, together they help describe the elements that will constrain and influence the innovation processes and changes to improve water quality. The actors can be thought of as individuals, groups of individuals or agencies that are part of the GBR system. Different communities and industries will have varying levels of these components, which will in turn influence the ability of the system to undertake particular innovations and also influence the operations of the innovation processes and the innovations that are developed (de Boon et al., 2022). When there is an incompatibility between one or more of the components (e.g., infrastructure, market incentives) and the innovation, this will constrain adoption.

Actors' innovative & adaptive capacity

Innovative and adaptive capacity are shown separately in the de Boon et al. (2022) framework but are combined in this discussion because together they determine the ability of individuals and agencies to react to or generate change. They define innovative capacity as the "ability to create or generate innovations" (p. 413) but not the actual implementation. Adaptive capacity is defined as "the capacity to adapt to (anticipated) change through the implementation of innovative or old practices" (p. 413). In the GBR framework innovative and adaptive capacity are combined since they are determined by many of the same elements (see de Boon et al. 2022, Table 2, p. 412) and interact and influence each other. However conceptually, innovative and adaptive capacity is at a more generic or abstract level in the GBR framework than for the governance framework, since the latter incorporates innovation specific knowledge, skills and resources under innovative and adaptive capacity. In this sense innovative and adaptive capacity in the GBR framework are akin to the dispositional factors that are characterised by Dessart et al. (2019, p. 5) as being "higher order, general "macro" principles, relative remote from specific decision-making situations". In the GBR framework these capacities are regarded as stable, difficult to change and include factors such as personality, risk tolerance, resistance to change, farming vision and objectives, and moral concerns.

Actors' knowledge, skills & capabilities

In the GBR framework, an actors' knowledge, skills and capabilities are defined as their awareness, knowledge, skills, and physical and psychological capacity to change their practices in certain ways (Michie et al., 2011). Hence they are treated separately, as they are at a more proximal or concrete level to particular decisions (Dessart et al., 2019) than in the governance framework. This component includes the knowledge, skills and capabilities of all actors in the AIS for the GBR. It includes:

- The knowledge, skills and capacity of farmers to adopt a particular innovation (e.g., technical, managerial).
- The knowledge, skills and capacity of extensionists to scale out the practice.
- The knowledge, skills and capacity of those involved in developing the innovations to identify, develop and evaluate innovations that improve water quality, but most importantly innovations that are perceived by farmers as consistent with their goals and relevant to their situation and resources.

Actors' psychosocial context and factors

While actors' psychosocial context and factors are related to a similar concept in the governance framework, in the GBR framework they are defined at the more concrete level and include the combination of psychological factors (which occur mostly at an individual level) and the social factors that influence individuals (but which occur mostly at the family, community and agency level). Social context also includes the levels of social capital in the farming community or more broadly in the AIS. In the Australian context, this is defined by the Australian Bureau of Statistics as "networks, together with shared norms, values and understandings which facilitate cooperation within or among groups" (Edwards, 2004, p. 5). The World Bank defines social capital as "institutions, relationships, attitudes, and values that govern interactions among people and contribute to economic and social development" (Grootaert & van Bastelaer, 2002, p. 2). In the context of the GBR framework, social capital will follow the ABS definition and be understood as the networks, together with shared norms, values and understandings which facilitate cooperation within or among groups in the AIS for the GBR. The ABS subdivides social capital networks into three types that are relevant to this framework: bonding, bridging and linking. Their definitions of these are used here: bonding social capital refers to "relationships between similar kinds of people or groups"; bridging social capital "to connections where members have less in common, or even differences"; and linking social capital "vertical relationships with sources of influence or authority which assist with access to financial and other resources" (Edwards, 2004, p. 5). More generally in the context of the GBR framework, social capital should be considered as both an enhancer and barrier to change and reflected broadly across the main actors and agencies in the AIS of the GBR.

Actors' physical, institutional & environmental context

In the GBR framework, the actors' physical, institutional and environmental context is considered at the meso and micro levels and includes: farm soils, climate, infrastructure, equipment, resources, local environment, and remoteness; public infrastructure (e.g., roads, communications, transportation, irrigation, education, energy); private infrastructure particularly related to the industries of the Reef regions (sugar, beef, horticulture); formal and informal organisations; and formal and informal institutions.

Innovation processes used to develop and spread the innovations

A key component of an AIS is the innovations processes that develop and shape the direction and outcomes of innovations aimed at achieving sustainable impacts, in this case improved water quality for the reef. For the GBR system these are the processes implemented at the meso and micro level by the key actors and agencies in the AIS to develop, refine and spread a suite of innovations. While there are many variations on the structure and stages of the innovation processes, most contain similar stages. The stages in the framework for assessing governance, meso-micro context and innovation processes are based on de Boon et al. (2022), but since the processes need to incorporate the research, development and extension elements, they include insights from Coutts et al. (2005), Michie et al. (2011), Murray-Prior (2020), Tully (1964) and Williams et al. (2021). Therefore, the stages of building relationships, scaling out, and reflecting and reviewing are added. This model needs to consider the innovation processes that occur on-farm, with little if any input from outside actors, as well as those that occur in the wider RD&E community.

Following the framework of de Boon et al. (2022), at the core of the innovation processes is the existing explicit and implicit stock of technical knowledge, research and innovations at various stages of development and adoption, along with the explicit and implicit stock of processes used to develop and extend innovations. The technical knowledge, research and innovation stock will be more or less relevant to the various actors in the GBR system depending on the processes used to develop them. In turn these processes depend on the stock of process knowledge, skills and attitudes of the main actors directing and implementing the innovation processes.

The paradigms underpinning the innovation processes, from funding model and research priority design through to scaling out of innovations, can be critical enhancers and barriers to the type and speed of change and consequent outcomes for water quality in the reef. Most models start with identifying the problem or need to be addressed, but this ignores the very important stage of developing relationships, which are the core of any change (Pannell et al., 2006; Williams et al., 2021). Building relationships is the first stage in the innovation processes for the GBR framework. This builds on levels of social capital already in the system and can lead to improvements in the levels of social capital if the relationships are based on mutual trust and understanding. Next comes understanding needs and priorities at various levels of the innovation system, but critically this part of the process must allow for participation and influence by those who will be involved in implementing the innovation; in the case of the GBR this is often farmers. How a need, problem or goal is framed is often decided by those with power in the innovation process and consequently will have significant influence on the solutions developed and consequently whether the end users or farmers will adopt these solutions. As de Boon et al. (2022) recognise, the early stages of the innovation processes are highly politicised, set the strategic direction for the innovation processes and consequently should be explicitly understood and considered for their role in acting as enhancers and barriers to behaviour change.

The fourth stage is to research and develop concepts or prototypes of innovations. This can range from a farmer using his welder to add an improvement to a piece of machinery, to a group of researchers working on a blue-sky solution to reducing pesticide residues. Once again who is involved in these activities and who controls them can influence their potential to be relevant innovations for the end user. This is followed by a stage of field testing the innovation under the relevant conditions, which may initially in a laboratory and research station and then on-farm. The stages up to and including this stage should be participatory, involve multiple approaches and involve all relevant stakeholders whether at the meso or micro level. As asserted by Coutts et al. (2005, p. 52): "technologies or practices that can be effectively developed in isolation and handed down to a waiting industry or community are rare". Ideally innovations are tested in multiple locations, with actors of different capacities, and then adapted as required to context. Alongside this stage, and the preceding and following stages, there should be a monitoring and evaluation stage, preferably using participatory processes with relevant actors at all levels, with the aim of increasing relevance and learning about and assessing changes and outcomes. Unfortunately, this stage is often poorly designed, implemented and funded. As implied by de Boon et al. (2022), monitoring and evaluation can also be a political process. Whoever has the power over this process can determine who is evaluated, what lessons are emphasised, and who is held accountable if they are not satisfied with the outcomes. Because of the dominance of the transfer of technology paradigm, farmers and extension have been the focus of much of the evaluation of adoption. Consequently, they have often been blamed for slow adoption rates for innovations, with little evaluation occurring of governance, the meso level environment, and the innovation processes that underpinned the development of the innovations (Rickards et al., 2019).

The governance framework (de Boon et al., 2022, Figure 1, p. 410) has a stage called implementation, which they view as the efforts taken to spread the innovation more widely to its intended audience. However, in the agricultural extension and development literature this is often referred to as scaling (out and up) to achieve transformational change (Douthwaite et al., 2003; Murray-Prior, 2020; The World Bank, 2012). In this approach, a distinction is made between: scaling out (spreading within the same stakeholder groups); scaling up (institutional scaling to involve other stakeholders and improve the enabling environment – from micro to macro); and spatial scaling up (from research plot, to field, and then outward to catchment and region) (Douthwaite et al., 2003). Perhaps just as important from the AIS perspective, is the concept of scaling deep or scaling down, which focuses on the need to move from single-loop learning (improving the existing system - How can we improve how we do it?), to double-loop learning (questioning the underlying assumptions, policies and ways of working – Are we doing the right thing?), to triple-loop learning (questioning our underlying values, beliefs and paradigms – Is our theory of change correct?) (Maru et al., 2018; Rickards et al., 2019; Tropical Agriculture Platform, 2016).

The scaling deep or scaling down concept is appropriate also to the last stage in the model of reflection and review, which is about undertaking an in-depth analysis of not just the innovation processes, but also assumptions and understanding about the meso-micro context, the governance system, and the macro context and enabling environment. This latter reflection and review stage incorporating double and triple-loop learning is rarely undertaken, particularly for the whole innovation process including research, development and extension and the interactions with the meso-micro context and the governance system.

While the stages are shown as separate, they overlap, interact and for some innovations, won't get past the conceptual or prototype stage. An additional complication is that the innovation processes interact, influence and are influenced by the meso-micro context as this includes the actors who are to a greater or lesser degree involved in the innovation processes and in adopting or not adopting the innovation outputs. In-turn, the process itself and the adoption of innovation outputs lead to outcomes and impacts, which in the case of the GBR are hopefully improved water quality.

Characteristics of the technologies

In this context, a step is included that incorporates the characteristics of the innovations or practices as this is included in the ecological systems model and have been widely discussed in the literature as factors that enable or hinder the adoption of innovations (e.g., Guerin & Guerin, 1994; Guerin, 1999; Pannell et al., 2006; Rogers & Shoemaker, 1971). Rogers (1995) defined five key characteristics or attributes of innovations that determine the rate and level of adoption: relative advantage, compatibility, complexity, trialability, and observability. However, these are not always useful for predicting adoption behaviour (Tully, 1968). Pannell et al. (2006) recognise these attributes but combine them into two broad categories: relative advantage (which includes relative advantage, compatibility and complexity plus others) and trialability (which includes trialability and observability). Farmer perceptions of these are the key to their adoption, but the characteristics of innovations are also influenced by the processes used to develop the innovations and scale them out. As indicated earlier, from the perspective of farmers, inappropriate framing of the problem and lack of farmer involvement in the RD&E process by policy makers, scientists and extensionists can lead to the wrong solutions to the wrong problems.

An important distinction, that is relevant to the GBR, is made by Guerin & Guerin (1994) when they distinguish between commercial innovations, which increase productivity quickly and are visible, and environmental innovations, which are mostly focussed on protecting or improving the environment, but whose productivity or other effects may not be immediately apparent and are more likely to take years to appear. An additional issue with the latter type of innovation is that farmers may not be aware or agree there is an environmental problem, and even if they do, may not perceive the solution being promoted to be relevant.

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