An incentive-based approach to reducing the impacts of sugarcane farming on the Great Barrier Reef

Colleen James[1], Chris Dench[2], Frank Scardamaglia[3], Rachel Eberhard[4], Milena Gongora[5], Carolyn Trewin[5] & Catalina Reyes-Nivia[5]

[1]Great Barrier Reef Foundation, Suite 4, Level 3, 42 Sturt Street, Townsville, Queensland, 4810, Australia
[2]Central Resource Consulting, 3 Coryule Place, Cannonvale Queensland 4802, Australia
[3]Canegrowers Herbert River, Level 4, 11 – 13 Lannercost Street Ingham QLD 4850
[4]Eberhard Consulting, 55 Park Road West, Dutton Park Queensland 4102, Australia
[5]Great Barrier Reef Foundation, 6/88 Tribune Street, South Brisbane, QLD, 4101, Australia
Email cjames@barrierreef.org

Abstract. The Great Barrier Reef (GBR) is one of the world's most biodiverse ecosystems but is threatened by agricultural runoff which degrades water quality. Over 95% of Australia's sugarcane is grown in GBR catchments, contributing to elevated levels of dissolved inorganic nitrogen and pesticides through runoff. To address this issue, a three-year incentive-based intervention program (2021-2024) was implemented across priority Reef regions to accelerate the adoption of improved farm management practices to reduce pollutant losses. This practice-based field report outlines the program's design, impact, and lessons learned, focusing on the effectiveness of financial incentives as a tool for practice change. Modelled results show that targeted incentives fast-tracked the adoption of improved practices and delivered measurable water quality benefits, supporting the GBR's resilience to climate change. The report also reflects on key factors influencing management practice change and provides insights to inform the design of future incentive programs.

Key words: incentive-based interventions, pollutant reduction, water quality, Great Barrier Reef.

Introduction

Stretching more than 2,300km down the Queensland coast, the World Heritage listed Great Barrier Reef (GBR) is globally valued for its complex natural coral reef ecosystems. The GBR is recognised for its remarkable biodiversity with around 9000 species of marine life occurring across 3000 individual reefs (Day J 2016; Richards ZT 2018; Belwood et al. 2025). The primary threat to the GBR is human-induced climate change, and climate impacts are exacerbated by poor water quality resulting from agricultural, coastal and urban development (Waterhouse et al. 2024; Fabricius et al. 2025).

Excesses of nitrogen-based fertilisers lost through farm runoff contribute to elevated dissolved inorganic nitrogen (DIN) levels in the GBR lagoon which have been linked to increased Crown of Thorns starfish larvae survival rates resulting in outbreaks and associated significant coral loss (Waltham et al. 2021). Inorganic pesticide runoff is affecting organisms in rivers, creeks, coastal and inshore areas; ongoing low-level pesticide exposures are likely to impact coral fertility and reproduction (State of Queensland 2018). According to the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) (2018), the largest contribution of DIN (78% of anthropogenic load) and pesticides (95% of anthropogenic load) are attributed to the sugarcane growing areas of the GBR catchments.

Over 95% of Australia's sugarcane is produced in 1.2% of the 423,000km^2 GBR catchment area (Canegrowers 2024; Lewis et al. 2024). Queensland sugarcane production and processing contribute almost $2.5 billion to the economy (2023 season), generate more than 22,000 jobs throughout the sugar supply chain, and is Queensland's second biggest agricultural export (QEAS 2019; Canegrowers 2023; Furner 2023). Sugarcane is produced on around 3,000 specialty farms in Queensland (ABARES 2021). A 2021 survey of Australian sugarcane farms found that, on average, 32% of farms had a negative profit, farms had an average annual farm rate of return of 2.7% and relied on an average of $35,900 in alternative (off-farm) income sources (Topp et al. 2021). Cane production systems require large capital investment and have low profit margins. Smaller farms, in general, have higher machinery, equipment, and management costs per hectare, lower financial performance than larger farms, and often rely on off-farm income (Thompson et al. 2024).

Table 1. Australian sugarcane industry performance – average per farm

Average Farm Characteristics	2020-2021	2021-2022
Number of farms	3044	Not available
Area planted to sugarcane (hectares)	136 ha	139 ha
Sugarcane irrigated (% of farm)	52%	51%
Sugarcane yield (tonnes/hectare)	84 t/ha	86 t/ha
Sugarcane price ($/tonne)	40 $/t	43 $/t
Farms with negative profit	44%	32%
Non-farm income	$35,900	Not available
Rate of return	2.0%	2.7%

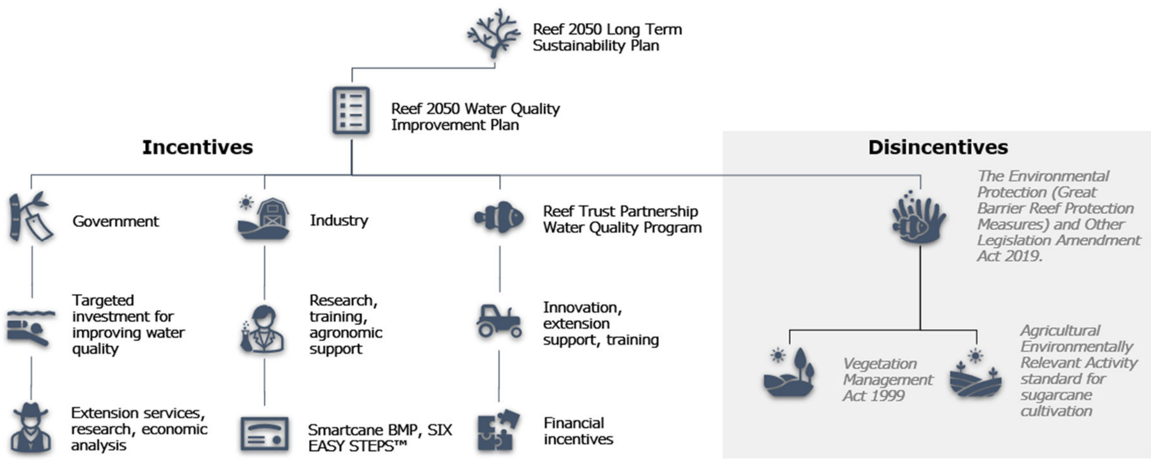
Source:(ABARES 2021)

The Herbert, Burdekin and Mackay regions, where significant sugarcane production occurs, are pollutant hotspots. As a result, these regions were identified as priority areas for the reduction of DIN and pesticides (Alluvium 2019; Topp et al. 2021). The geographical expanse of the Australian sugarcane industry increases its vulnerability to climate change (Zhao & Li 2015). According to Linnenluecke et al. (2020), increased peak temperatures and atmospheric carbon concentrations have had a significant negative impact on sugarcane output. This is compounded by fluctuating sugar cane prices, and extreme weather events resulting in poor growing conditions which impact on sugarcane productivity and profitability (Canegrowers 2024). As a result, cost is a significant barrier to growers investing in the technology and equipment required to maximise nutrient and pesticide efficiencies.

Interventions for improved water quality

There has been significant effort and strategies put in place to date to support agricultural producers to adopt management practices that will reduce pollutant losses and improve water quality (Figure 1). An overarching Australian and Queensland Government Reef 2050 Long-Term Sustainability Plan informs the management and protection of the GBR. This is supported by the Reef 2050 WQIP that guides how government, community and industry work together to achieve pollutant load reduction targets set to improve the quality of water flowing to the GBR (State of Queensland 2018). Further, the Australian and Queensland Governments together have committed more than $2 billion over 10 years (2014 to 2024) to protect the GBR (Commonwealth of Australia 2021). A mix of incentives and disincentives have been supporting incremental change.

Figure 1. Interventions driving incremental change



Disincentive-based interventions

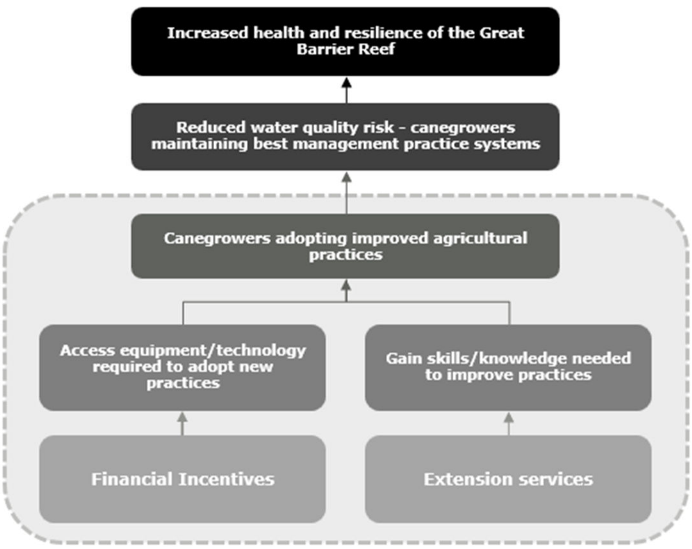
Disincentives include the strengthening of regulatory instruments to protect the GBR. The Queensland Government's Vegetation Management Protection Act 1999 and Environmental Protection (Great Barrier Reef Protection Measures) and Other Legislation Amendment Act 2019 and associated Reef protection regulations have been designed to address sources of land-based pollution to the GBR. A legislated standard provides the minimum requirements for commercial sugarcane cultivation in GBR catchments (DES 2019). Australian sugarcane growers identified the top constraint to productivity improvement as policy regulations (43%); climate (33%) and inability to afford technology (18%) were also identified (ABARES 2021).

Incentive-based interventions

Incentive-based interventions that support grower practice change for improved water quality outcomes include access to education, training, decision-making tools, agronomic support, and financial incentives through voluntary support programs (Figure 1). The Queensland Department of Primary Industries provides research, extension services and economic analysis to support sugarcane growers to adopt more sustainable and profitable farming practices throughout the GBR catchments. Industry support includes programs that record and verify practice change improvements and provide accreditation and a nutrient management training program, recognised by industry and government as nutrient best practice. However, incentive programs typically rely on growers to invest in practice change voluntarily. For those growers interested in adopting new practices, capital costs can be a significant barrier.

A partnership (RTP) between the Australian Government's Reef Trust and the Great Barrier Reef Foundation delivered an improved approach to implementing water quality incentive programs through a $200 million Water Quality program. The RTP provided strategic investment into cost-effective on ground projects across priority areas with accountable and transparent governance and reporting models to achieve enduring reduction in end-of-catchment pollutants. This included a $71 million incentive program to reduce DIN and pesticide losses from sugarcane production systems, enhance grower capability, increase motivation, and identify opportunities for practice change to achieve long-term improved management and water quality outcomes. Incentive-based interventions included financial incentives and extension services to support access to equipment/technology and skills/knowledge needed to adopt and embed improved practices into the farming system to reduce water quality risk and increase GBR health and resilience (Figure 2).

Figure 2. RTP program logic for incentive-based interventions



Financial incentives

In response to legislation and voluntary incentivised programs, sugarcane growers in GBR catchments have made positive practice changes (DETSI 2023). Despite significant industry efforts, progress has been slow, and adoption needs to accelerate if water quality targets for the long-term protection of the GBR are to be met (Waterhouse et al 2024). However, the trade-off between competing economic and environmental objectives must be considered. According to Kandulu et al. (2018), when considering the environmental costs, the socially optimum nitrogen fertiliser (N) rate is lower than the private economically optimum N rate risking productivity. Changes in productivity have potential livelihood impacts. Grower motivation for the adoption of improved management practices and technologies is influenced by consequences to farm productivity and profitability and, as a result, are less likely to be widely adopted and maintained

(Herd et al. 2022; Thompson et al. 2024). The provision of financial incentives demonstrates that government and non-government organisations (NGOs) are willing to share the financial burden with growers to achieve environmental outcomes.

The targeted RTP Financial Incentives Program (FIP) aimed to motivate lasting change by removing barriers to the adoption of best management nutrient and pesticide practices that will deliver long-term water quality improvements. The FIP (2021-2024) addressed the following assumptions:

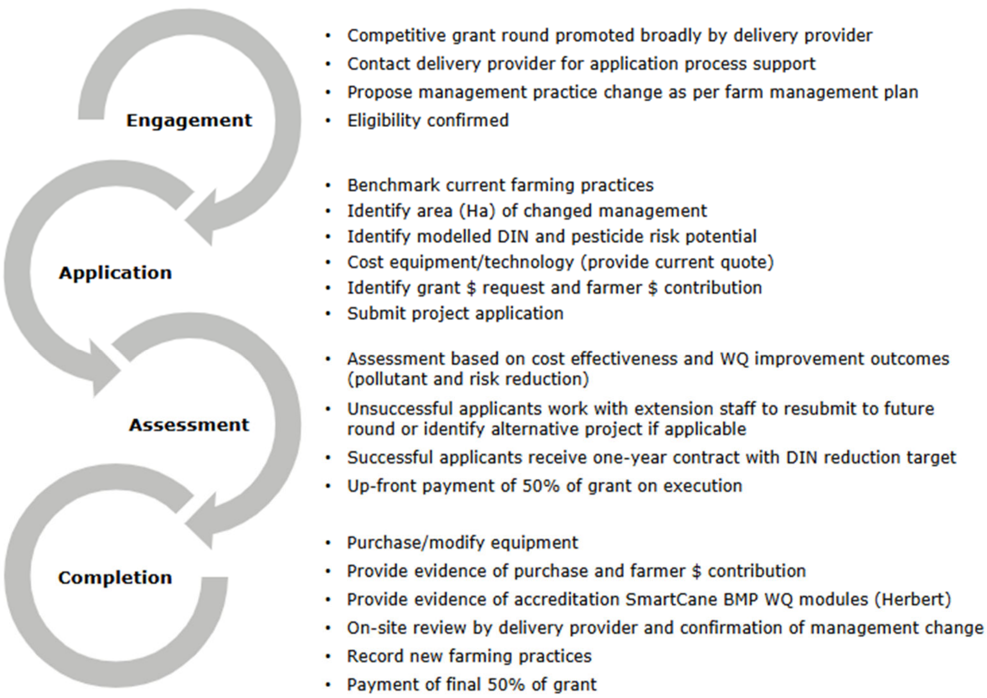
3. Limited capital is a barrier to adoption: Canegrowers lack the funds to invest in the technology/equipment required for best practices.
4. Financial incentives reduce financial risk: Offering financial support to reduce upfront costs helps to overcome this barrier, encouraging willing growers to adopt best management practices.
5. Cost-sharing and extension services support sustained adoption: Sharing costs will increase the likelihood of growers investing in new technologies, and extension support helps to embed management practices into the farming system long-term.

The FIP supported practices that require equipment or technology for the adoption of improved on-farm nitrogen/pesticide management, such as matching inputs to crop variability, improving irrigation efficiency through automation, and optimal timing of fertiliser/pesticide application and/or application method. The FIP was designed around four core elements: flexibility, environmental impact, collaboration, and cost sharing.

Flexibility

The FIP was delivered across the three geographically dispersed priority GBR catchments (Herbert, Burdekin and Mackay) which have unique production systems. A flexible delivery model allowed for adaptation to suit regional needs (Figure 3). The Herbert program was industry-led, while the regional Natural Resource Management (NRM) NGO led the Burdekin and Mackay programs. Delivery providers, including agronomic and environmental organisations, engaged growers, developed regional project guidelines and rolled out discrete grant funding rounds.

Figure 3. RTP financial incentive process



Environmental impact

The expected environmental impact was quantified through modelling. Pollutant targets across all regions were based on kilograms of DIN reduced through improved management practices, and the Mackay region also targeted pesticide toxicity. Management practices were ranked based on relative water quality risk using a framework to identify and report nutrient management practice improvements (Queensland Government, 2024). In the irrigated Burdekin region, an Irrigation

Rapid Assessment tool rapidly assessed the economic and environmental impacts from sugarcane irrigation practices (Collins et al. 2023). A pesticide decision support tool was used in the Mackay region to estimate potential water quality improvement measured in risk units (RU). Reductions in DIN as a result of practice changes were determined using the Paddock to Reef Projector tool that uses monitoring and modelling data to "estimate the water quality benefits of farm-scale agricultural improvement projects in Great Barrier Reef catchments" (McCosker & Northey 2015; p2rprojector.net.au 2023). As a result, a pollutant reduction associated with a proposed management change on a specific farm was identified. The cost effectiveness of the proposed pollutant reduction was determined and considered in a competitive grant round. For example, a reduction of 366 kilograms of DIN across a 168-ha farm (2.18 kg/ha) for a grant investment of $16,000 would result in an RTP investment cost effectiveness $44 kg/yr. The modelled pollutant reduction was contracted as part of the grant agreement and 50% of the grant was paid up front. Prior to the final payment, an on-site review allowed growers to discuss and demonstrate the management change was in place with extension staff on the farm.

Collaboration

Collaboration was key to achieving water quality outcomes. The financial incentives project was one of a suite of projects within an RTP regional water quality program where industry and environmental organisations (delivery providers), worked together towards the collective goal of improving regional water quality. Acknowledging that financial incentives alone may not be sufficient to drive change, the RTP program allowed growers to combine increased capability (knowledge and skills) gained from extension support with financial incentives (grant) to invest in the equipment/technology required for management changes.

Extension officers from a diverse range of RTP funded delivery organisations provided support for the identification of management practices aligned with the goals of the water quality program and development of grower grant applications. Locally established relationships with growers were maintained throughout the process to identify and mitigate risks. This model was critical to the recruitment of growers and the successful completion of on-ground project activities.

Cost sharing

Recognising that financial incentives as a motivation for practice change may not result in sustainable behaviours (Lee 2022). The RTP's cost-sharing approach aimed to both reduce the financial barriers to adoption while ensuring that growers had a long-term commitment to the management practice change. Further, stimulating private investment extended the reach of the limited funding source and introducing regional grants caps mitigated equity issues while maximising opportunities to participate. Growers were required to contribute at least 50% cash for the total on farm project cost; where the total cost of the practice exceeded the cap, the grower contribution would increase. For example, a $70,000 practice change project with a capped $25,000 grant component would require a $45,000 grower cash contribution, whereas a $50,000 project would have an even 50/50 grant/grower cash split.

Outcomes

Overall, the RTP delivered over $4.5 million in financial incentives through 198 grants across the three regions (refer to Table 2). Growers invested over $6.6 million equating to $1.47 invested by growers for every grant dollar received. Contracted pollutant reduction targets (14 t/yr of DIN and 732,500 RU/yr) were exceeded with an estimated reduction of over 21 tonnes of DIN and 1.7 million RUs of pesticide per year achieved through the FIP.

Table 2. RTP financial incentives summary of achievements

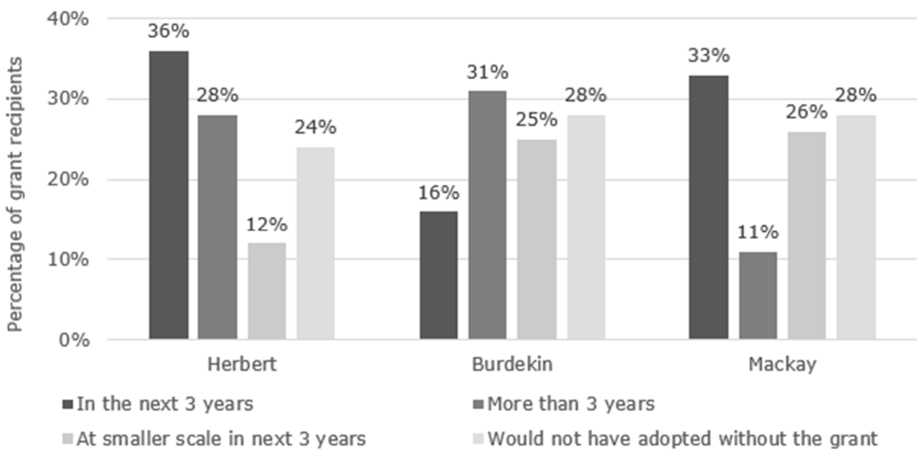
Aspects	Herbert	Burdekin	Mackay
Number of grants awarded	93	33	72
Total RTP grant $ awarded	1,700,000	1,019,809	1,838,805
Grower cash contribution	1,983,076	1,292,727	3,511,655
DIN reduction achieved kg/yr (all DIN associated with grants)	11,975	5,882	3,480
Pesticide toxicity reduction (Risk Unit)	-	-	1,768,219

The FIP assumptions were tested and assessed through an independent evaluation. Some key results are reported below, and they support the assumptions behind the program design highlighted earlier - namely that: capital costs are a barrier to adoption, financial incentives can help willing growers to overcome this barrier, and cost-sharing and extension can support long-term adoption.

Did incentives help to overcome financial barriers to management practice change?

While there were differences between regions, across all regions ~30% of growers said they would not have adopted the management practice without the grant. A further ~30% of growers believed it would have taken up to three years to adopt the practice without the grant; while others reported longer, or that the grant enabled them to adopt at a larger scale. Therefore, the speed and extent of change were influenced by the grant, with new practices adopted earlier and at larger scale than would have occurred otherwise (Figure 4).

Figure 4. Practice change implementation timescale without financial assistance

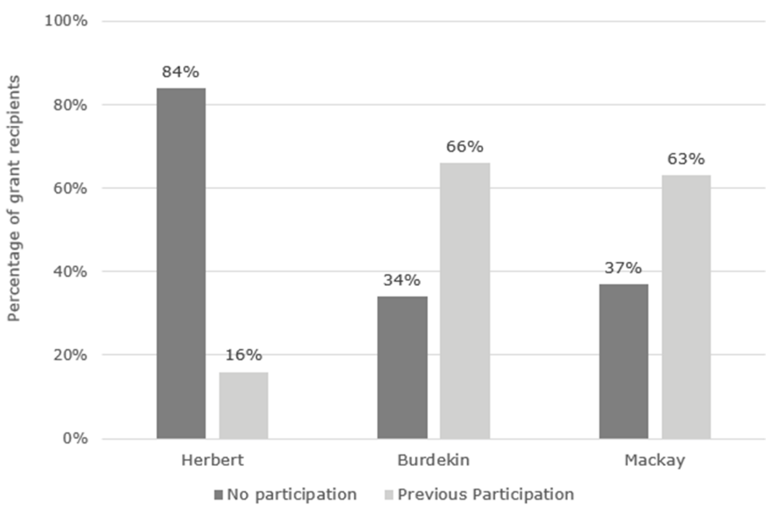


Note. There were a few 'other' answers in each region (Eberhard 2024).

Did the delivery model attract growers who had not engaged with previous programs?

Despite sustained government efforts since 2008 to improve agricultural practices in GBR catchments, some growers had never previously participated. For example, in the industry-led Herbert program, 84% of growers had not engaged in any previous water quality programs. Conversely, in the NRM NGO-led Mackay and Burdekin regions, around 30-40% of growers were first time participants. The model of coupled extension services and financial incentives, delivered by diverse local service providers, supported growers to adopt practices earlier and at scale.

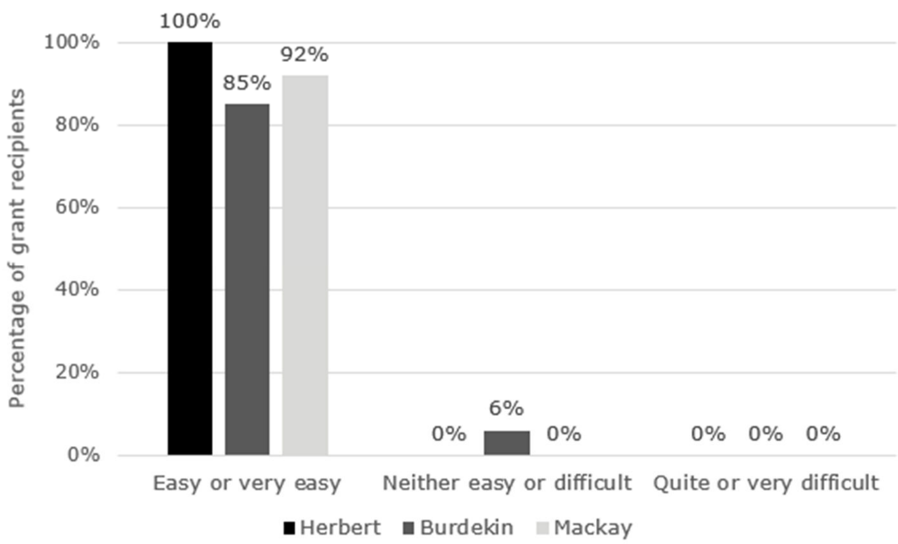
Figure 5. Grower participation in previous water quality programs



Did sharing costs and providing extension support increase the likelihood of management practices being embedded into the farming system long-term?

Only long-term monitoring can determine if practices have been embedded into the farming system. As the financial incentives-based program concluded in 2024, the evaluation focused on the grower expectations around their ability to maintain the practice supported by the grant. The evaluation found that across all regions, no growers expected it to be difficult to maintain the practice. 92% of Mackay, 100% of Herbert and 85% of Burdekin growers said they expect it will be easy or very easy to maintain the practice suggesting that dis-adoption should be low. Further, delivery providers were also very confident that adoption will be enduring because of the co-investment by growers and extension support services.

Figure 6. Grower expectations around ability to maintain practice supported by grant



Conclusion

The Financial Incentives Program (FIP) was designed to overcome barriers to the adoption of improved farming practices in the Herbert, Burdekin, and Mackay sugarcane regions, priority catchments for water quality in the Great Barrier Reef. While improved practices are adopted on larger-scale farms with sufficient cash flow, or prior experience with similar techniques, others delay adoption due to higher perceived risks, limited resources, or uncertainty about maintaining new practices. Capital costs for new technology or machinery can be a major barrier for smaller farms with limited cash flow. By providing financial incentives, the FIP enabled and accelerated the adoption of sustainable practices that may have otherwise been delayed or not implemented. A lack of grower confidence in taking on or maintaining new practices was mitigated through extension support which built grower confidence, provided reassurance, and tailored advice to individual farm contexts. Coupling financial incentives with extension services delivered by a diverse local network of providers proved effective, with the FIP exceeding its targets by preventing over 21 tonnes of dissolved inorganic nitrogen and 1.7 million pesticide risk units annually from entering the Reef lagoon. These outcomes reduce water quality risks and strengthen the Reef's resilience to climate change. The FIP demonstrates that well-structured incentives, combined with practical support, can promote environmental stewardship. Understanding the factors that influence adoption will help program designers more effectively and anticipate where additional targeted support or incentives are needed to accelerate adoption.

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