Paddock to reef: Measuring the effectiveness of large scale investments in farm management change

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Abstract. The Great Barrier Reef (GBR) is the largest coral reef in the world, spanning over 2,300km along the Queensland coast. Agricultural land uses dominate the catchments directly adjacent to the GBR, with approximately 3,800 sugarcane farms, 8,500 cattle grazing properties, 940 horticultural farms, and 600 grain growing farms. Concern over levels of water borne pollutants from these farms having a detrimental effect on GBR health has led to the development of the Great Barrier Reef Water Quality Protection Plan (Reef Plan) a $375M 5 year joint Australian and Queensland Government program. The effectiveness of Reef Plan is measured through a monitoring, evaluation and modelling program called Paddock to Reef (P2R). P2R monitors the degree of adoption of best management practices, the pollutant loads in streams and marine waters, and a range of biophysical indicators of resource condition. P2R also estimates the potential future pollutant load reductions resulting from the adoption of best management practice. This paper focuses on the challenge of actually quantifying the degree of adoption over time of best management practice across a large and diverse agricultural landscape.

Keywords: Reef, Practice change, Water quality, adoption

Introduction

The Reef Water Quality Protection Plan 2013 (Queensland Department of Premier and Cabinet 2013) aims to improve the quality of waters entering the Great Barrier Reef (GBR) lagoon. The Reef Water Quality Protection Plan (Reef Plan) addresses diffuse source pollution, originating from broadscale land use. The main pollutants are sediments, nutrients, and pesticides leaving farming and grazing systems in the terrestrial catchments adjacent to the GBR.

Reef Plan is a joint commitment of the Australian and Queensland Governments. It coordinates investments across several Federal and State agencies and partners with many community based NRM organisations, industry peak bodies, and private service providers. The long term goal of Reef Plan is: 'To ensure that by 2020 the quality of water entering the reef from broadscale land use has no detrimental impact on the health and resilience of the Great Barrier Reef.'

To this end there are a range of time-bound water quality targets. The main thrust of Reef Plan is that these targets, the required improvements in water quality, can be achieved through the adoption of best management practice on grazing and farming lands. So, the target for these industries is: '90 per cent of sugarcane, horticulture, cropping and grazing lands are managed using best management practice systems (for soil, nutrients, and pesticides) in priority areas.'

There are a range of programs delivered under Reef Plan that aim to foster the adoption of these best management practice systems (farming systems dominated by best practice for specific management issues). They include provision of financial incentives for infrastructure and equipment, projects offering programmed learning and training, industry Best Management Practice (BMP) programs, specific action learning extension projects, reef protection legislation through the *Queensland Environmental Protection Act 1994*, and market based incentive projects for specific priority issues in priority areas.

Reef Plan includes a dedicated monitoring and evaluation (M&E) program, the Paddock to Reef (P2R) program. P2R monitors the degree of adoption of land management practices, the pollutant loads in streams and marine waters, and a range of biophysical indicators of resource condition (e.g. terrestrial groundcover, wetland extent, seagrass health, coral cover). P2R also estimates the potential future pollutant load reductions resulting from the adoption of best management practice on farming and grazing lands, through agricultural systems models integrated with catchment scale hydrological models.

This paper focuses on the challenge of actually quantifying the degree of adoption over time of best management practice across a large and diverse agricultural landscape.

Management Practice Frameworks

Best management practice means different things to different people and stakeholders. In the Reef Plan context best management practice is defined through the use of management practice frameworks.

Management practice frameworks have been utilised by agricultural NRM investors for some time (for example Drewry, Higham & Mitchell 2008). Management practice frameworks in this context provide a practical description of the range of ways that particular issues are managed on farms. The example in Table 1 below articulates the manner in which wheel traffic is managed on Central Queensland grain farms.

Table 1. Management practice framework describing how machinery wheel traffic is typically managed on grain farms in Central Queensland

Management Issue	Outdated	Minimum Standard	Best Practice	Innovative, may not be economic in all situations
Water Quality Risk	**High Risk**	**Moderate Risk**	**Moderate - Low Risk**	**Lowest Risk**
Wheel Traffic	Farming equipment has different widths and wheel spacing.	All farm equipment except headers and mobile grain bins operates on the same wheel spacing and consistent implement width.	A controlled traffic system is in place with all tractors and implements, headers and mobile grain bins operating on the same set of wheel tracks. Spraying and planting occurs under machine guidance of at least 10cm pass-to-pass accuracy.	A controlled traffic system is in place with all tractors and implements, headers and mobile grain bins operating on the same set of wheel tracks. All machines operate under RTK guidance of at least 4cm pass-to-pass accuracy.

Source: extract from Grains industry P2R Water Quality Risk Framework 2015, www.reefplan.qld.gov.au

Management practice frameworks can be developed for any issue or any suite of issues. P2R has developed Water Quality Risk frameworks to articulate best practice in relation to the Reef Plan adoption targets. Features of the P2R water quality risk frameworks are:

- The suite of practices relevant to each pollutant is described in the frameworks. This does not mean all of the practices in the farming system, only those farming practices that pose the greatest potential water quality risk through movement of sediments, nutrients, or pesticides off-farm.
- Not all practices are equal. The P2R frameworks allocate a percentage weighting to each practice depending upon its relative potential influence on off-farm water quality. The example in Table 2 shows the practices most influential in terms of potential loss of applied nitrogen from sugarcane farms.
- The 'best practice' level is that targeted by Reef Plan investments.

Table 2. Management practices relating to nitrogen management on sugarcane farms in coastal Queensland (actual practice level descriptions not presented)

Water Quality Risk weighting	Management Issue
60%	Matching nitrogen supply to crop nitrogen requirements
30%	Timing of fertiliser application with respect to rainfall
10%	Method of application (surface or subsurface)

Source: extract from Grains industry P2R Water Quality Risk Framework 2015, www.reefplan.qld.gov.au

How are these frameworks used?

Water quality risk frameworks are simple tools that are extremely important to Reef Plan. They are the basis for evaluating the effectiveness of a range of investments in farm management change.

Establishing baselines

At the commencement of Reef Plan 2013, P2R has estimated the degree of adoption of each key management practice as described in the water quality risk frameworks, for each agricultural industry and in each river basin within each major catchment area of the GBR lagoon (spanning roughly from Maryborough in the south through to Cooktown in the north). Evidence used in developing these baseline estimates includes direct landholder surveying, anonymous data from

industry BMP programs, data collected from discrete projects and programs, and focus groups of local experts (ref report card methods).

For example, Table 3 contains 2013 baseline estimates for the adoption of practices related to sediment loss from sugarcane farms in a single river basin of the Wet Tropics in far north Queensland. Data can also be aggregated to provide baselines at region and/or entire GBR catchment levels. These baselines represent the management state at the commencement of the investment period

Table 3. 2013 management practice baselines (per cent of area farmed) for practices related to runoff and soil loss (sediment) for sugarcane farms in the Herbert River basin (practice descriptions not included)

Management Issue (% weighting)		Outdated	Minimum Standard	Best Practice	Innovative
		High Risk	Moderate Risk	Moderate - Low Risk	Lowest Risk
30%	Crop Residue Cover	0%	2%	98%	N/A
25%	Wheel Traffic	1%	53%	44%	2%
25%	Land management during cane fallow	25%	11%	63%	1%
20%	Tillage in plant cane	3%	57%	39%	1%

Measuring impact and progress

Impact: Organisations receiving funding through Reef Plan are required to report the impacts of their work as per the relevant Water Quality Risk frameworks. In practice the ideal situation is that when an intervention results in a farm management change, P2R (and the funder) receives a GIS polygon of the area impacted, with a description of the overall farm management both *before and after* the intervention.

For example, the sugarcane water quality risk framework is easily converted into a suite of short multi-choice questions (example in Table 4). When a sugarcane grower changes the way they manage crop residues, changing from pre-harvest burning to leaving the cane trash in the paddock, P2R receives data accompanying a GIS polygon. This data includes a 'before' management state of 1.1, and an 'after' state of 1.3, as well as analogous coded responses for all of the other practices represented in the framework. In this way there is a definitive measure of impact of the intervention, the exact nature of that impact on the *farming system* is understood, and the exact area affected by the change is known.

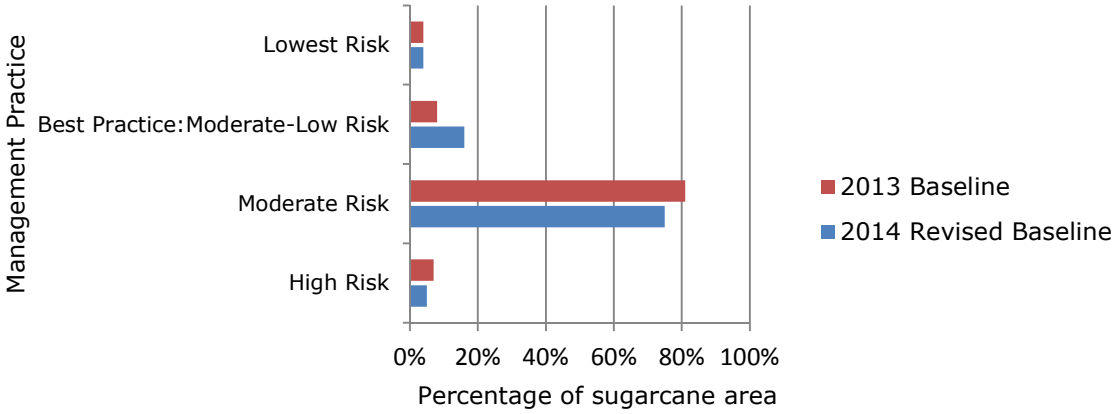
Table 4. Simple coded responses (practice levels) to a management issue described in the sugarcane water quality risk framework.

1.	**Crop Residue Cover: Do you normally use a green cane trash blanket?**
1.1	No
1.2	Often burn or bale replant and/or fallow blocks but maintain trash on ratoons.
1.3	Yes, standard practice in all crop stages.

Source: after Reef Plan 2013 Sugarcane Water Quality Risk framework. www.reefplan.qld.gov.au

Measuring progress: For each river basin in the GBR lagoon catchment there is a management baseline for each agricultural sector, i.e. for each management issue, there is an estimate of the area managed in each practice level. Recipients of Reef Plan funding report the impact of their activities against exactly the same parameters used to establish these baselines. This provides a reasonably accurate measure of the actual hectares of change and enables an annual revision of these baselines as a means of describing the nature and rate of adoption.

Figure 1. Targeting application of residual herbicides in sugarcane in the Wet Tropics – estimated management changes during the 2013-14 year



For example, Figure 1 above contains data on the adoption during 2013-14 of practices related to targeting the application of residual herbicides in sugarcane. The progress toward adoption targets can be monitored in this way, for any practice and at a range of scales.

Advantages of the approach

Frameworks help clarify program investment goals Farming systems are complex and there are usually many issues with scope for management improvement, all of which may have some kind of link to broader program outcomes. The water quality risk frameworks used by P2R make it clear from the outset which specific issues need to be focused on (through inclusion of only the highest weighted practices), and what specific aspect of management practice needs to be addressed.

For example, using the appropriate nozzles on a spray rig is important and it's also a relatively easy issue to address for extension and incentive programs. However, it doesn't make much of a difference to the amount of pesticide that may end up in a receiving waterway. We can make some kind of a link between nozzles, inefficient application and offsite water quality, but there are far more influential things to get right first, such as the timing of applications with respect to rainfall and reducing overall volume applied through good weed management and targeting applications within the paddock. Hence it's not an explicit target for Reef Plan effort and it's not in any water quality risk framework.

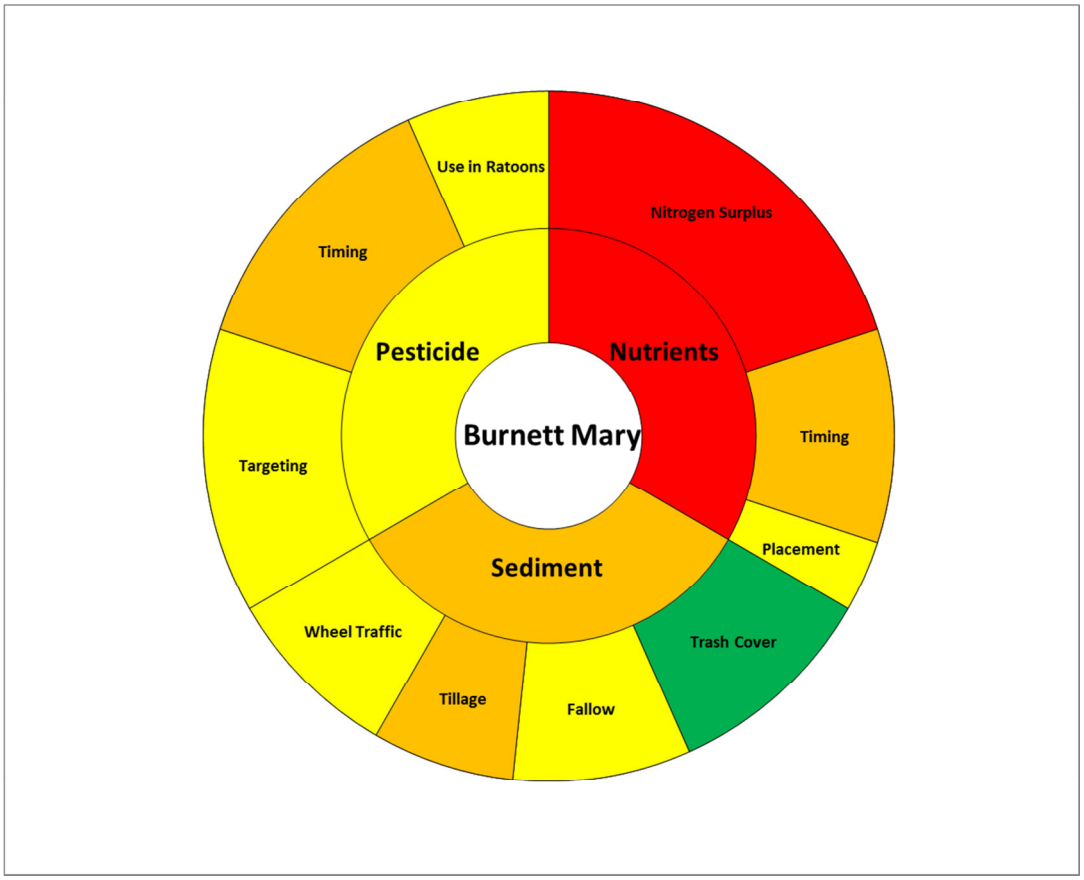
Communicating adoption needs The frameworks by themselves make it apparent what the priority adoption needs are. The management baselines provide more focus. For example Figure 2 is a simple graphic that represents how the sugarcane industry in the Burnett Mary NRM region is progressing toward best practice with regard to the main water quality issues.

At a glance it is apparent that there is good adoption of some practices and low adoption of a practice that has a very large influence on water quality (nitrogen surplus). There is no urgent need for extension agents or their investors to focus on the placement of fertiliser, improving crop residue cover, managing fallows, or use of residual herbicides in ratoon crops.

A consistent basis for impact evaluation Reef Plan investments are delivered by a highly diverse suite of partners including government agencies, industry peak bodies, universities, community based NRM organisations, and private sector consultants. Synthesising what is achieved through their efforts is a major challenge. Water quality risk frameworks provide a consistent and repeatable means of describing impact regardless of the delivery partner or the nature of the investment. For example a commercial consultant working with a grazier on forage budgeting can report to P2R in exactly the same way as an NRM organisation facilitating financial grants, i.e. provide P2R with a defined before and after management state.

A consistent evaluation framework makes it possible (or at least simpler) to compare different types of interventions and their effectiveness in addressing a specific adoption issue. An example in the Reef Plan context might be 'has reducing the nitrogen surplus in sugarcane farming systems been most efficiently achieved through extension or provision of financial incentives? Or a combination of both?'

Figure 2. Degree of adoption of best management practice on sugarcane farms in the Burnett Mary NRM region.



*Specific management issues occupy the outer ring of the graphic. The size of the wedge occupied by each issue represents its influence on water quality. For example, nitrogen surplus represents 60% of the total risk associated with nutrient loss.

Customising to suit different regional production systems The principles underpinning the relative water quality risk of different practices are reasonably consistent, but often the local or regional way of articulating the issue is quite different. There is sometimes also significant agro-ecosystem differences which the content of a management practice framework needs to capture. For example, Reef Plan has water quality risk frameworks for grazing systems in wet coastal environments, as well as rangeland environments. The same management issues are described, but the articulation of relevant practices is quite different. Another example is the difference between sugarcane grown under supplementary overhead irrigation in one region, and under flood irrigation in another region.

Being able to quantify impact The water quality impact of a change in farm management can only be described if the management before the change, and as a result of the change is known, i.e. the before and after. Much evaluation considers only the 'after' state.

For example '50 farmers adopted controlled traffic as a result of involvement in the project'. Estimating the impact of that adoption means that knowledge of the before state is also required and yet this is often unknown. Table 1 describes three levels of controlled traffic – which level have the 50 farmers attained? Where did they start from? The impact of a farmer changing from 'outdated' to 'best practice' management of wheel traffic is going to be greater than for a farmer who already has most machinery operating on the same wheelbase. Describing the range of practices in a framework allows for a more detailed examination of actual impact.

Critical success factors

Buy-in from investors getting impact evaluation to happen at all can be challenging, especially with those that have not previously had an evaluation culture. The P2R experience has been that consistent impact evaluation starts with being mandated by the provider of funds.

Realistic assessments P2R has independently driven the development of management practice baselines. The reporting from service deliverers is to provide evidence to change these baselines. While the water quality risk frameworks do provide a consistent basis for this impact reporting, there is a need for technical review of reported impacts for two main reasons:

- To check that the degree of reported impact is sensible. For example, it's not reasonable to describe the provision of a single off-stream watering point as having a large impact on 10km of stream frontage. It should be noted however that this is not always about overstating the impact; there are instances where impact is understated or negated.
- All impact reporting includes a 'before' and 'after' management state. The 'before' management state is often overstated. Many extension officers positively identify with landholders and this sometimes seems to result in optimistic assessments of how the farming system is managed in relation to best practice. Added to this is the reasonable view from people that they are aware of an issue and an improved practice to alleviate it, and they occasionally or partly implement that practice. For example, a landholder may manage a paddock with zero tillage once every ten years, and now identifies as a zero tillage farmer. The net result for P2R is the same – there is very limited scope to demonstrate improvement on farms that are already genuinely at best practice. Investments in these situations are hard to justify.

User capability and feedback most of the problems encountered with unrealistic assessments arise from situations where people do not understand exactly how the evaluation data is used and how important it is in describing the impact of their work, to the investor/s and to the broader community. There have also been problems with people not understanding why certain practices are more important than others.

In the Reef Plan context it has become clear that there is a need to step through the content of water quality risk frameworks with operational staff at all levels to ensure that they grasp the intent of the frameworks. The other critical element of this is that people come to understand that *the evaluation data actually goes somewhere and influences things*, which can improve the overall rigour and quality of reporting. The best way to convey this is to provide very specific feedback on projects they are working on.

Settled frameworks Because these management practice frameworks have such a profound influence on the targets for projects/programs and the way they are ultimately judged, they *need to be developed prior to the on-ground implementation* of programs. Similarly the content of frameworks should ideally remain constant for the life of programs. There will be instances where it's not sensible to do this, such as when new science results in a better understanding of the impact of practices, or when that new science alters the investment priorities.

One example is the role of alluvial gullies in exporting sediments from grazing lands to the GBR (Wilkinson et al. 2013, Wilkinson et al. 2015). As the prominence of the gully erosion process (relative to hillslope and streambank erosion processes) has become better understood, it has been necessary for P2R to amend water quality risk frameworks for the grazing industry to include more emphasis on gully prevention and remediation.

Get the frameworks right Because of the potential influence of management practice frameworks on program design and impact evaluation, there is some pressure to make sure the content is sound. This is exacerbated in instances where there stakeholders have varying views on what actually constitutes best practice, or what is reasonable to expect of farmers and graziers.

The starting point is deciding what the most critical issues are. It is ok to start with all or many issues but it's important to distil down to *only* those that make the greatest difference to the sought outcome. P2R convened workshops with scientists and agronomists to capture and prioritise all of the management issues with a bearing on offsite water quality. From there the process allocated a percentage weighting to each issue. Any issue that was believed to have under 15-20% influence on the outcome was heavily scrutinised with regard to whether it was important enough to be in the framework. The lowest weighted issue in any P2R framework now is 10%. In practice these actually make little difference to an outcome as all-encompassing as offsite water quality.

When the issues captured in the framework are clear, the best practice level needs to be described. This is where judgement needs to be applied as it often won't be possible to achieve wide consensus. Some of these issues may be contentious. There are a number of examples where the P2R description of best management practice could be regarded as significantly more progressive than an accepted industry norm. In these instances it's important for frameworks to be independent. What does the science and contemporary knowledge tell us is a reasonable goal to have for best practice?

Once the goal, best practice, is described the rest of the framework can be developed. These need to be good practical descriptions of the levels of practice typically encountered in the real world, and logical 'stepping stones' to a best practice state. P2R generally has settled on four practice levels. There are no rules. Some issues will have two sensible levels (you either do something or you don't) and some may have five or six. It's important to get these right too as these levels are the basis for accurately describing progress.

Conclusions

Reef Plan is a very large and complex program covering multiple catchments, multiple industries, a number of different funding sources and a number of different approaches to foster the uptake of best practice. Paddock to Reef has evolved over time to meet the need for a consistent practical method to describe and measure change over such a large and diverse program.

Water Quality Risk Frameworks have been developed for each industry. The frameworks describe the management practices which have the largest impact on water quality. The frameworks describe what best practices is in terms of water quality risk and also describe the steps below (and above) best practice. The frameworks also identify which practices are the most important to water quality. All change recorded as a result of Reef Plan activities is described in terms of a movement through the steps identified for each practice in the frameworks. When the reported change is added to the established management baselines, progress toward the Reef plan target of '90 per cent of sugarcane, horticulture, cropping and grazing lands are managed using best management practice systems (for soil, nutrients, and pesticides) in priority areas' can be tracked.

Having a consistent and practical method of describing and measuring change across all regions makes it possible to:

- identify region-specific issues for targeting adoption investments
- quantify impact and the progress over time
- compare different types of interventions and their effectiveness in addressing a specific adoption issue

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