Full Paper

Marsh, N. et.al. – The human dimension of water quality modelling: accounting for levels of adoption.

Incorporating human dimension in water quality modelling: accounting for levels of adoption and co-benefits

Marsh, N.[1], Eberhard, R.[2], and Gordon, B.[3]

1 Truii, West End Qld, 4101 nick.marsh@truii.com

2. Eberhard Consulting, Dutton Park Qld 4101

3. Queensland Department of Environment and Science

Key Points

- The use of biophysical models to guide investment priorities in natural resource management (NRM) programs is well established for water quality. However, this approach neglects the important 'human dimensions' of NRM programs where landholder engagement is complex and variable.
- Water quality models traditionally consider the water quality outcomes of land management practices, but not the likelihood of land managers adopting those practices. Adoption curves predict peak adoption (% of population likely to adopt) and the time to reach that. Investments are also likely to generate 'co-benefits' in addition to the primary policy objective, and these are rarely accounted for in investment planning.
- We incorporated the likely rate of adoption and a co-benefits scoring system into an existing water quality cost prioritisation tool (Reefonomics) to demonstrate how these human dimensions can be presented alongside traditional water quality improvement to support NRM investment planning processes.
- The project demonstrates how investment planning can be based on more realistic assumptions about likely adoption and also consider the multiple co-benefits that could be realised from an investment portfolio. When considered in isolation, a single NRM benefit may offer marginal investment potential, but when a broader suite of co-benefits are considered, the full value of NRM investments can be explored.

Abstract

The use of biophysical models to guide investment priorities in natural resource management (NRM) is well established for water quality improvement programs. However, biophysical models neglect the important 'human dimensions' of NRM programs where landholder engagement is complex and variable. Adoption curves predict adoption over time (% of population likely to adopt and the time to reach 'peak adoption'). Investments are also likely to generate 'co-benefits' in addition to the primary objective, and these are rarely accounted for in investment planning.

Reefonomics is an existing tool that allows investors to consider the cost-effectiveness of different investment scenarios in land management practices to be explored. We have incorporated the likelihood of adoption and the potential for co-benefits in to the Reefonomics tool that already considers cost and environmental (water quality) benefit. We applied a project adoption likelihood filter (ADOPT; Kuehne et al 2017) to predict a more realistic water quality benefit that accounts for the likelihood and time lags of adoption of new practices by farmers. We also developed and applied a co-benefits scoring system to allow for the reporting of co-benefits.

We have developed interfaces to allow these human dimensions to be considered alongside traditional water quality and cost considerations for investment portfolios.

Keywords

Investment optimisation, social outcomes, adoption, co-benefits, water quality, Great Barrier Reef, human

dimensions, agricultural practices

Introduction

Modelling, either explicit numerical modelling, or implicit conceptual modelling is used to support the investment prioritisation process for Natural Resource Management (NRM) programs that seek to achieve environmental outcomes. Investment prioritisation processes generally seek to achieve the best outcomes for a given budget. Where the desired outcomes are defined in terms of water quality improvements, paddock and catchment-scale water quality models are often used to test scenarios of alternative investment portfolios. The Queensland Government's Paddock to Reef (P2R) program[1] uses this approach in order to set targets, prioritise actions and report outcomes (Carroll et al., 2012).

Water quality models allow program administrators to ask 'What water quality benefit will I get if we do these land management changes?'. In this way, water quality models are very useful for demonstrating the potential water quality benefits of alternative on-ground actions (but assume that programs will be successful in encouraging adoption of desirable land management practices).

A logical next step is to consider the cost of land use actions to optimized investment portfolios. The marginal cost abatement curve (MCAC) approach selects actions from the most cost-effective to the least cost-effective, and can be applied to a single objective function (e.g. water quality parameter) at a time. The basic MCAC portfolio of actions solution will suggest doing all of the most cost-effective actions first, then all of the second most cost-effective and so on. In practice, it would be extremely rare to achieve 100% adoption of any land management activity change within planning timeframes (or ever). The implications of this limited and lagged adoption are that firstly, water quality targets are not likely to be reached, and secondly, the investment portfolios are too constrained - budgets will not be exhausted because of slow uptake of preferred management actions.

Adoption potential

A limitation of using coupled economic and biophysical models for investment prioritisation is that there is an implicit assumption that the land management activity will be willingly adopted by landholders. Water quality improvement actions mostly occur on private land. Private landholders may not share the modellers views of the most cost-effective water quality improvement solution and their business and personal priorities may not align with the proposed land management practices.

A challenge for implementing on-ground NRM actions is engaging landholders to implement the preferred solution. The water quality models may show the *potential* water quality improvement (assuming 100% adoption) but they do not show the *likely* water quality improvement because the human elements of capacity and motivation for implementing on-ground actions is not considered. Considering adoption potential at the time of portfolio planning presents an opportunity to iterate on project actions by considering the further support mechanisms (and associated costs) required to increase adoption and optimise outcomes for a given investment.

There are social, financial and regulatory instruments that can be used to encourage higher levels of adoption. However, these all have an associated cost, which in turn influence the cost-benefit of the land management action. To create a more realistic cost benefit analysis requires the consideration of activities as the combination of both the biophysical activity (land management practice change) and the support program associated with that activity. For example, adoption of a land management practice which is encouraged by, for example, direct grant funding to landholders, an industry education and awareness program and regulation of undesirable practices, will achieve higher levels and rates of adoption rate (at higher total cost) than the same activity without the additional support mechanisms. We suggest that a cost

[1] https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef

benefit analysis should consider each action as a combination of the on-ground activity and the support programs that influence the adoption potential of the action.

Kuehne et al (2017) develop a method to predict the adoption curve based on the characteristics of a land management practice and the target population (ADOPT). Key outputs are the likely maximum adoption ('peak' adoption) and the rate of adoption (time to peak adoption). This is based on an understanding of the factors that influence adoption decisions, such as the economic and environmental benefits, ease and convenience, risk and fit with farmer and farm characteristics. The ability to learn about a new practice is also important, and that is influenced, again, by the characteristics of the practice and the population. The influence of programs that encourage voluntary adoption of land management practices through financial incentives or agricultural extension services can be represented in ADOPT. ADOPT thus provides a useful approach to predicting adoption responses.

Co-benefits

The motivation for NRM investment is multi-faceted. In the case of investing in water quality for the Great Barrier Reef, the primary motivation is to reduce sediment and nutrient loads entering the GBR lagoon, that is, downstream water quality benefits. However, there are other co-benefits (and potentially dis-benefits) that can occur through implementing alternative actions. Those co-benefits may be felt locally by the land holder or ecosystems, or by the regional community through employment or the industry through productivity improvements, or even internationally, such as through carbon sequestration. Increasingly, NRM investments seek to consider these co-benefits in developing investment portfolios. An excellent example is The Queensland Government's Land Restoration Fund (LRF) which invests in projects that produce carbon credits and additional co-benefits. The LRF explicitly considers environmental, social and first nations people's co-benefits in selecting carbon credit projects for investment (see Queensland Government, 2020).

The concept of co-benefits is straightforward. However, the challenge is to develop a robust and generalised approach to quantitatively capture and report co-benefits that allow the relative co-benefits of alternative portfolios of GBR water quality improvement actions to be compared.

The concept of quantifying social co-benefits is not new. However, our experience, and observations through review is that there is no agreed and standard approach. The problem of defining social co-benefits is often perceived as locally unique, so, custom, unique and hyperlocal solutions are created for quantification. The result is that there are a large number of locally relevant but non-generalisable solutions.

Traditional social impact assessment is associated with the development approval process where environmental impact assessment processes are complemented by social impact assessments. Social impact assessments in this context are very site and project specific, and the trend has been towards adopting participatory social impact assessment methods to facilitate negotiation of development outcomes that mitigate social impacts (Esteves et al., 2014).

More recently, social impact reporting has developed as organisations become interested in demonstrating social outcomes (initially not-for profit organisations, but now also corporate bodies and government investors). Social impact reporting in this context is concerned with providing metrics and reporting systems to compare the social co-benefits of alternative financial investment programs. The concept is to standardise the way we measure a business's social credentials so that we can compare and rate them. The approach is not completely mature, and the current leading approach appears to be the Social Return on Investment (SROI) method (Lingane & Olsen, 2004).

SROI is a form of stakeholder-driven evaluation blended with cost-benefit analysis tailored to social purpose. It was developed to enable social enterprises to quantify and monetize social impact in a consistent and defensible way. The SROI approach converts all social and environmental outcomes into a dollar value to then give a ratio of invested dollars to equivalent dollar value of social outcome. This is a compelling approach, but relies on firstly being able to quantify the social and environmental outcomes and then in being able to define the dollar value of those social and environmental outcomes. This method is highly sensitive to assumptions of monetary value of social outcome.

The Global Impact Investment Ratings System (GIIRS) has a more compelling approach than the SROI because there is no attempt to convert the result into a dollar value. The GIIRS approach simply generates a score based on a rating across a businesses' governance, community engagement, employee rights, environmental score and business model. The method is simple to understand and implement. GIIRS has been developed to support impact investing markets with a product that provides transparent and consistent reporting of social and environmental benefits through a ratings and analytics platform (Mendell & Barbosa, 2013). The approach is not directly applicable here because the focus is on commercial investment programs, but the principles of scoring are applicable.

Another, more generalised approach, the Global Reporting Initiative (GRI) (Hussey et al., 2001) has developed a set of sustainability reporting standards and guidelines for organisations to report their impacts. There are 36 GRI standards across environmental, social and economic impacts and organisations can use relevant standards to prepare sustainability reports. The emphasis is on providing methodological detail for the quantification of impacts that can be applied in a wide range of global contexts. GRI illustrates how standards for social impact can be developed and applied, but the standards are too broad for consideration here.

A similar approach to GIIRS has been applied to land remediation projects (Reddy *et al.* (2014). The approach by Reddy *et. al* is similar to the ADOPT method in that there are key dimensions (socio-individual, socio-institutional, socio-economic, and socio-environmental) with multiple sub-scores (up to 20 for each dimension). Each sub-score is rated on a five point scale (-2 to 2). The sub-scores are summed to give a score for each dimension which are then compared between scenarios. In our view, the summing of scores is problematic because there are different numbers of sub-scores for each dimension, hence the relative dimension score is heavily influenced by the number of sub-scores. A better approach would be to apply a weighted average of the sub-scores. Whereby the weighting is an explicit consideration of the importance of the sub-scores. Monitoring, Evaluation and Reporting (MER) frameworks commonly applied in natural resource management, often use a similar nested reporting approach of sub-scores being weighted and aggregated to create scores across different areas of interest (see Reef Report Card https://reportcard.reefplan.qld.gov.au/).

The approach applied by Reddy et al. (2014) provides a useful scoring system that is relatively easy to implement and also maintains flexibility in that it can be applied to a range of co-benefit metrics across social, environmental, economic and cultural measures. It allows, for example, environmental co-benefits such as beneficial impacts on freshwater systems, to be considered alongside downstream marine water quality benefits, and expands the concept from social co-benefits to co-benefits more generally.

Methods

To implement the adoption and co-benefits approach we have used the case study of investment portfolio planning for water quality improvement in the Great Barrier Reef (GBR) catchments. We have incorporated the approach into the Reefonomics tool.

Adoption potential approach

A method to quantify the likely level of adoption of an action (combination of on-ground activity and associated support mechanisms) is well presented by Kuehne et al (2017) in the Adoption and Diffusion Outcome Prediction Tool (ADOPT). ADOPT is based on a 22 question survey related to the biophysical activity, the industry, and the support mechanisms and networks for the industry and action. By using the ADOPT approach, a realistic likely adoption level and the time to achieve that peak adoption can be estimated.

We have applied the ADOPT method computational approach (presented in Kuehne et al (2017)) directly, incorporating some rewording of the survey questions to better reflect the terminology used in GBR land management projects.

ADOPT Method summary

The adopt method has a series of 22 survey questions that relate to four domains:

1. Population (industry related networks and support)
2. Relative advantage for the population (profit and environmental orientation of the population)
3. Learnability of the action (complexity, ease of trialling)
4. Relative advantage of the action (reversibility, ease and convenience, risk, cost)

The survey questions have a five point scale, and the answers to the questions are used to calculate a likely peak level of adoption (% of population) and time to achieve that peak level of adoption (years)

Co-benefits approach

As described earlier, a co-benefits approach seeks to provide a robust and adaptable method to assess and investment portfolios with multiple benefits. In order to capture a quantitative representation of co-benefits we have adopted a three level, nested approach based on weighted averaging of sub-scores (equations 1 and 2). This approach will allow for an expansion of the areas of interest, and still allow for the generation of scores that are in the same numerical domain (-1 to 1).

$$CB = \frac{\sum_1^d CB_d CB_{dw}}{d} \qquad (1)$$

$$CB_d = \frac{\sum_1^{sd} CB_{sd} CB_{sdw}}{2sd} \qquad (2)$$

Where:

- CB = Co-benefits score (-1 to 1)
- d= Co-benefit dimension
- CB_d=Co-benefit dimension score (-1 to 1)
- CB_{dw}=Co-benefit dimension weighting
- Sd = sub-dimensions
- CB_{sd}=Co-benefit sub-dimension score (-2 to 2)
- CB_{sdw}=Co-benefit sub-dimension weighting

The nested scoring approach adopted for the co-benefits scoring framework has been developed to allow for review and refinement. In order to test the framework we have developed an initial set of domains and sub-domain survey topics. This approach is being tested in Great Barrier Reef catchment land management projects. We anticipate changes in the overall domains and sub-domains as our data matures.

For our testing regime, the overall co-benefit score is achieved through a weighted average of five *domain* scores with subdomains noted. The domains and subdomains are:

1. Environmental - to capture local environmental benefits such as wetland conservation.
    a. Wetland conservation protection
2. Economic – to capture farm profitability and regional and/or industry economic impact
    a. Farm benefit
    b. Regional and or industry economic benefit
3. Social – to capture social learning and network value.
    a. Social learning benefit

4. First Nations – to capture indigenous peoples' involvement in actions.
    a. First Nations people benefit through project
5. Climate – to capture carbon sequestration potential of actions.
    a. Carbon capture benefit
    b. Land resilience benefit
    c. Nitrous oxide benefit.

Each of the sub-domains are scored using a five point survey from:

- Significant decline (-2)
- Slight decline (-1)
- No change (0)
- Slight improvement (1)
- Significant improvement (2).

The subdomain element scores are combined with a weighted average. To achieve the domain score, the domain scores (equation 2) are combined with a weighted average to achieve the overall co-benefits score (equation 1). For the example demonstrated we use an equal weighting at all levels, and we report at the domain level score (not an overall co-benefit).

Results

Consider an example management practice change in grazing lands where riparian frontage management practice is improved from poor to good condition through decreased stocking pressure and spelling during the wet season.

Adoption

Through a workshop of land management support practitioners to apply the ADOPT method, we stepped through the 22 ADOPT questions. The predicted adoption level with no direct financial investment but moderate extension support was 30% of available lands would adopt the practice over a predicted adoption period of 13 years.

Co-benefits

If we apply the same practice considered in the adoption example to the co-benefits survey assessment we achieve an overall co-benefit score of 0.4 (Table 1), with the dominant co-benefits being environmental (wetland conservation) and social benefits (learning benefits as a demonstration site).

Implementing the approach

We have redesigned the Reefonomics tool to include the adoption and co-benefits approaches described here. The Reefonomics tool applies a marginal cost abatement curve approach to create portfolios of 75 alternative land management actions across Great Barrier Reef catchments. The actions are applied across several agricultural industries (Sugarcane, Grazing, Banana, Grain) and land management processes (soil management, nutrient management, pasture management, riparian zone management and gully remediation).

The implications of the adoption potential in the Reefonomics tool are that the temporal response of water quality benefit is better represented by considering the overall adoption rate and the level of adoption through time. The co-benefits scored are scaled by the amount of the action implemented to provide overall scores to allow comparison between portfolio scenarios.

We have developed an interface to allow these human dimensions of NRM investment prioritisation to be considered alongside the more traditional cost and water improvement benefits (Figure 1). We are in the process of applying the approach to 75 alternative land management practices designed for water quality improvement in the Great Barrier Reef region. We anticipate further refinement of the approach through this process.

Table 1. Co-benefits example survey results

Domain Sub-domain	Survey score (-2 to 2)	Co-benefit score (-1 to 1)	Notes
Overall co-benefit score		0.4	
Environmental benefit		1	
Wetland conservation protection	2		
Economic benefit		0.5	
Farm Benefit	1		Slight benefit through controlled stocking rates
Regional or industry benefit	1		Slight benefit through controlled stocking rates
Social benefit		1	
Social learning benefit	2		Grazing community engaged through practice learning
First Nations benefit		0	
First Nations inclusion	0		No explicit first nations people involvement
Climate Benefit		0.5	
Carbon Capture benefit	1		Increased soil carbon
Land resilience benefit	1		Riparian zones under less pressure
Nitrous oxide benefit	1		Reduced stocking rates reduces methane production

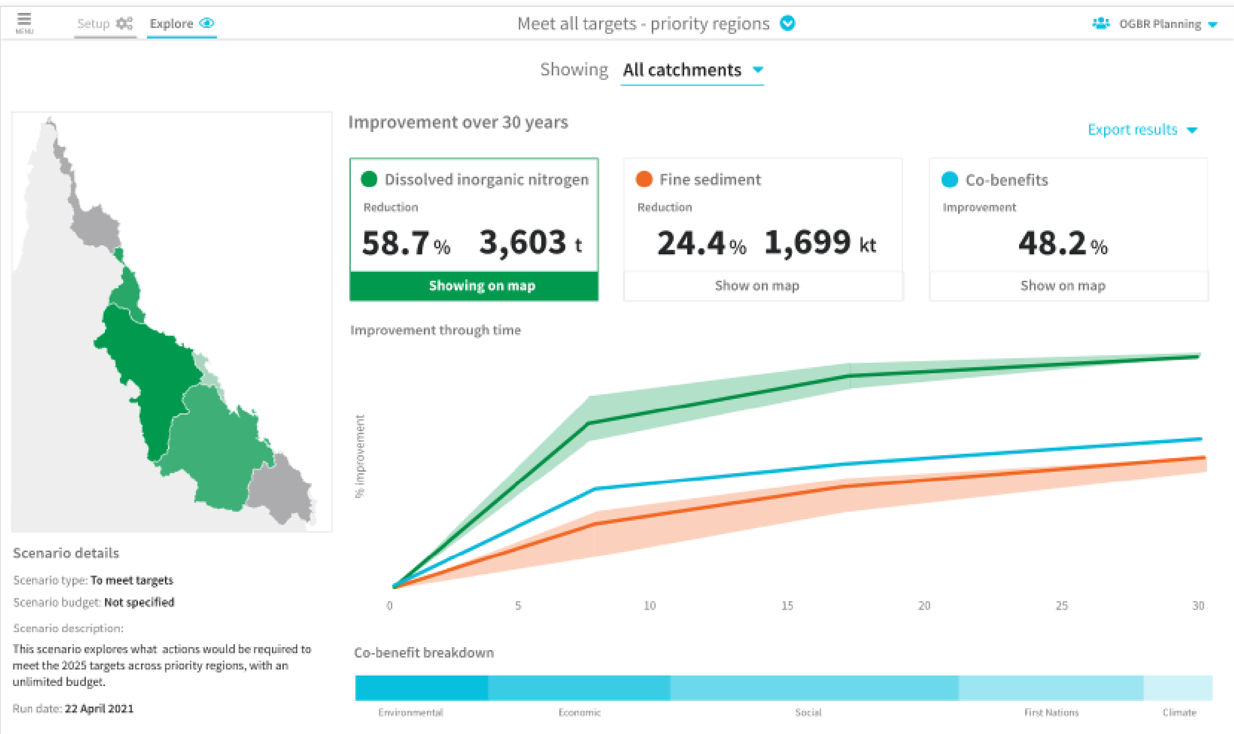

Figure 1. Mock-up of Reefonomics explore page showing temporal water quality improvement and co-

benefit breakdown of the portfolio

Conclusions

Traditional biophysical models and economic modelling have been useful in developing NRM investment portfolios. We suggest an extension of this approach to also include quantitative representations of the human dimensions and co-benefits to provide a more holistic view of the benefits of NRM investment.

We anticipate growth in this collective reporting of impacts and an increase in the sophistication with which co-benefits are modelled and reported.

Acknowledgments

This project has been financially supported by the Queensland government via the Office of the Great Barrier Reef and the Queensland Water Modelling Network. We would like to thank members of the Human Dimensions Working Group for their invaluable input into the project.

References

Carroll, C., Waters, D., Vardy, S., Silburn, D. M., Attard, S., Thorburn, P. J., Wilson, B. (2012). A monitoring and modelling framework for the Great Barrier: paddock and catchment component. *Marine Pollution Bulletin, 65*(4-9), 136-149. doi: 10.1016/j.marpolbul.2011.11.022

Esteves, A. M., Franks, D., & Vanclay, F. (2012). Social impact assessment: the state of the art. *Impact Assessment and Project Appraisal, 30*(1), 34-42.

Hussey, D. M., Kirsop, P. L., & Meissen, R. E. (2001). Global reporting initiative guidelines: an evaluation of sustainable development metrics for industry. *Environmental Quality Management, 11*(1), 1-20.

Kuehne, G. Llewellyn, R. Pannell, D. Wilkinson, R. Dolling, P. Ouzman, J. and Ewing, M (2017) Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. Agricultural systems 156 pp115-125

Lingane, A., & Olsen, S. (2004). Guidelines for Social return on Investment. *California Management Review, 46*(3), 116-135.

Mendell, M., & Barbosa, E. (2013). Impact investing: a preliminary analysis of emergent primary and secondary exchange platforms. *Journal of Sustainable Finance & Investment, 3*(2), 111-123.

Queensland Government (2020) Land Restoration Fund Co-benefits standard. Available at https://www.qld.gov.au/__data/assets/pdf_file/0025/116548/lrf-co-benefits-standard-exposure.pdf

The State of Queensland and Commonwealth of Australia. (2019). Results. Reef Water Quality 2017 and 2018. Reef 2050 Water Quality Improvement Plan. Brisbane: Queensland Government.

Reddy, K., Sadasivam, B. and Adams, J. (2014) Social Sustainability Evaluation Matrix (SSEM) to quantify social aspects of sustainable remediation. American Society of Civil engineers https://doi.org/10.1061/9780784478745.078