

Can extension programs improve grazing management in rangelands: a case study in Australia's Great Barrier Reef catchments

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Abstract. A key challenge in reducing sediment moving from grazing lands into the Great Barrier Reef in Australia is to encourage beef cattle producers to improve management practices. Excessive grazing pressures cause land degradation, leading to both increased sediment runoff and lower future profits. Although higher grazing rates may be possible (and profitable) in better seasons, slow rates of adjustment to poorer seasons can lead to overgrazing and negative impacts on land condition. For policymakers the challenge is to find mechanisms that encourage or signal producers to be more precise in their management and avoid overstocking. Some of the most common options include extension programs, grant programs that use financial incentives, and regulation.

In this paper we outline a conceptual framework that shows why extension may be a more powerful driver of management change than incentive programs, and then test this through an evaluation of a case study program conducted with beef cattle producers in catchments of the Great Barrier Reef, Australia. The pathway involving landholders to implement management change was through improved efficiency and productivity, as these are the issues that drive ongoing participation in broader environmental programs.

The results present multiple lines of evidence to infer positive outcomes of an extension program in terms of changed management practices, which may be expected to generate improved productivity and better water quality outcomes. These can be grouped into three key areas. First, outcomes show positive improvement relative to the Grazing Water Quality Risk framework for the Great Barrier Reef catchments, which is designed to assess the links between land management and water quality. This indicates that resource condition is likely to improve and sediment emissions should be reduced over time. A second outcome is increased landholder engagement and improved understanding of their business and engagement in future programs, which should underpin ongoing adoption. A third outcome is improved management of risk and developing the skills to do this through data collection and monitoring, which should improve management responses in drought years.

Keywords: economics, grazing, management, rangelands, land condition, extension program, water quality, Great Barrier Reef, sediment.

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Introduction

Overgrazing has often been identified as a cause of environmental degradation, with livestock producers typically stocking pastures at rates higher than recommended (Dunn *et al.* 2010). In Australia, sediment run-off from rangeland grazing properties draining into the Great Barrier Reef (GBR) has been identified as resulting in poor water quality outcomes, leading to a focus on improving ground cover on grazing lands (Karfs *et al.* 2009; Carroll *et al.* 2012; Bartley *et al.* 2014a, 2014b; Kroon *et al.* 2016; State of Queensland 2017a; Waterhouse *et al.* 2017). The land degradation processes that generate sediments also adversely affect grazing production and profitability, although

linkages are complex (MacLeod and McIvor 2008; Ash *et al.* 2011; Star *et al.* 2013; Thorburn *et al.* 2013).

Grazing lands account for the majority of sediment being exported to the GBR (Waterhouse *et al.* 2017). Reduced ground cover leads to water run-off with higher velocity, increasing both sediment movement from hillslopes and the risk of gullies forming, while reducing water infiltration (Scanlan *et al.* 1996; Silburn 2011; Fraser and Stone 2016). There is substantial evidence that some grazing practices, such as continuous heavy grazing without rest periods, reduces groundcover and increases susceptibility to erosion, leading to declining land condition as well as increased sediment exports (Ash *et al.* 1995;

Ash *et al.* 2000; O'Reagain *et al.* 2011). Key management factors relevant to productivity and land condition of beef cattle grazing in northern Australia are stocking rates, pasture resting, prescribed fire, and grazing distribution depending on fencing and water point development (Hunt *et al.* 2014; O'Reagain *et al.* 2014).

There has been a substantial effort by the Australian and Queensland governments to improve water quality into the GBR, with targets set for improved water quality, and widespread adoption of low-risk grazing practices under the Reef 2050 Water Quality Improvement Plan (State of Queensland 2018). Some programs aimed at achieving this are focused on improving knowledge and measurement tools to capture the impact of grazing management practices on soil erosion processes: other programs are focused on incentive mechanisms to encourage change through grant programs and other payment mechanisms, and a third approach has been regulatory mechanisms that establish minimum standards for land condition and management actions.¹ Despite these initiatives, the adoption rate of low risk grazing management practices to increase pasture cover on underpinning land condition has been low (State of Queensland 2017b). This is, in part, because of the human dimensions, where it is complex to understand how landholders make decisions to change management practices (Greiner and Gregg 2011; Rolfe and Gregg 2015).

An alternate approach to encouraging landholder management change is to use specialist extension services to help landholders become more efficient in their operations, with associated lower impacts on the underlying resource base (Pannell 1999; Marsh *et al.* 2004; Larson *et al.* 2005; Fernandez-Gimenez *et al.* 2005; Barbi *et al.* 2015). The core purpose of agricultural extension has traditionally been to improve productivity by transferring agricultural and technical knowledge to farmers, providing education and attitude change, encouraging the adoption of new farming technologies, and providing farmers and researchers with the results of research and field trials (Druce 1966; Marsh and Pannell 2000). In recent decades in Australia there have been shifts away from public provision of agricultural extension services towards more user pay models, greater focus on facilitation than the transfer of technical knowledge, and emphasis on human and environmental goals rather than just production increases (Marsh and Pannell 2000; Mullen *et al.* 2002).

A major recommendation from the 2016 GBR Water Science Taskforce in relation to farming practices was that there should be 'more effective, targeted and coordinated extension to support large-scale land management practice change' (Great Barrier Reef Water Science Taskforce 2016, p. 4). This is a very different approach to the more traditional grant and incentive schemes that have been the core focus of programs in the GBR catchments (Rolfe *et al.* 2018). Those recommended extension initiatives were essentially aimed at improving information and landholder management skills so as to address resource degradation and improve economic returns, and addressed the shortfalls in extension capacity that had been previously noted by Marsh and Pannell (2000) and Mullen *et al.* (2002). A key benefit of an extension approach is that practice change may

become more widespread and automatic than can ever be achieved with more atomised and localised grants or other positive incentives.

Some landholders may not have sufficient technical and economic information about the interaction between their production systems and their resource base, particularly when there are complex and lagged drivers between short run and long run systems (MacLeod and McIvor 2008; Ash *et al.* 2011). Gregg and Rolfe (2016, 2018) used experiments with beef producers in GBR catchments to demonstrate that there is substantial myopia about the effect of their grazing decisions on resource (land) condition. The results of Rolfe and Gregg (2015) and Gregg and Rolfe (2017) also demonstrate that risk factors are important reasons why beef producers in GBR catchments are slow to change their management practices, whereas Star *et al.* (2019) identify that risk factors may limit engagement with government schemes and agencies.

There is currently limited information about how effective extension programs can be for improving resource management. This paper addresses this research gap by showing conceptually the linkages between extension and resource management in an economic framework, and then provides some evidence and analysis of an extension case study program conducted in GBR catchments. In this paper, the first section covers the economic tradeoffs between grazing management, profitability and land condition are presented in conceptual terms. We then present a case study followed by conclusions in the final section.

The economics of grazing management

Economic analysis of grazing operations has shown that there are long-term financial benefits for graziers to adopt better management practices (Ash *et al.* 1995; O'Reagain *et al.* 2011, 2014; Star *et al.* 2013). More conservative stocking rates tend to avoid major land-degradation events that occur during drought periods, and underpin economic benefits in maintaining lower stocking rates or reducing forage utilisation rates (Landsberg *et al.* 2002; O'Reagain *et al.* 2011). Bio-economic modelling (Star *et al.* 2013, 2015, 2017) and long-term grazing trials (e.g. O'Reagain *et al.* 2011; O'Reagain *et al.* 2014; Koci *et al.* 2020) have shown that profitability can be maximised and land condition maintained or improved by using a conservative stocking rate which is adjusted as seasons change.

Decisions about stocking rates in rangeland enterprises are complex because of the variety of internal and external factors and heterogeneity in resources and production functions (MacLeod and McIvor 2008), and because it is very difficult to identify if equilibrium resource conditions can be reached in grazing management (Westoby *et al.* 1989). Some complexity is externally imposed because climate and ecological processes are stochastic and external markets for beef vary, and some complexity is internal to operations, or mixed because of lag effects between external forces such as drought and animal performance, and the flow through effects on herd dynamics and cattle markets (Star *et al.* 2015). Beef producers manage these complex choices about production and stocking rates through a

¹The Reef Regulations amendment Bill was passed by the Queensland Government on 19 September 2019 – see <https://www.qld.gov.au/environment/agriculture/sustainable-farming/reef/reef-regulations>.

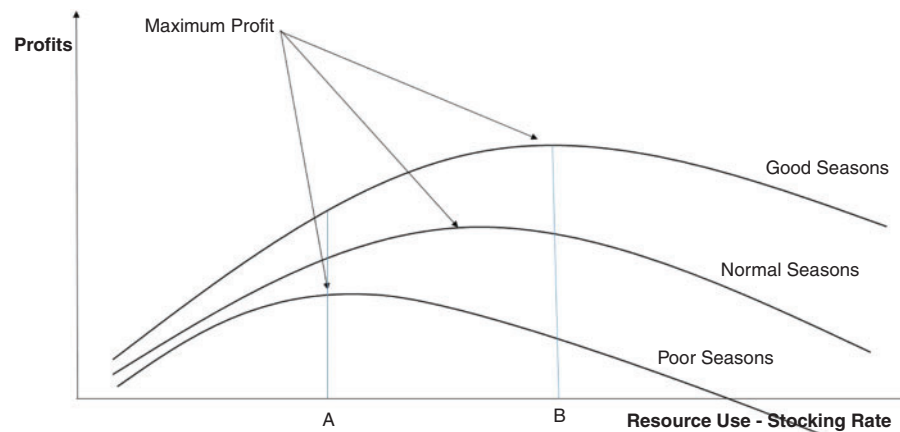


Fig. 1. Tradeoffs between increasing stocking rates and profitability over season type.

combination of factors such as experience, management and business skills, and constant appraisal of herd and pasture conditions.

Short- and long-term profitability

Decisions about herd management and stocking pressures, particularly in drought years, have long-run resource condition implications (Ash *et al.* 1995; O'Reagain *et al.* 2011). Overgrazing, in different formats, can degrade pastures and land condition and cause other effects such as erosion. Although overgrazing can be simply the effect of higher stocking rates, it can also occur in more subtle ways, such as on localised areas of fragile vegetation or soils, in waterways and frontage areas in wet seasons, or through failure to destock appropriately in drought years (Orr *et al.* 2010; Orr and O'Reagain 2011; O'Reagain *et al.* 2011). It may also relate to management styles, where techniques such as pasture resting, wet season spelling for frontage areas or more varied access to water can limit impacts of stock on soils (McKeon *et al.* 2004; Orr and Phelps 2013; Moravek and Hall 2014)

The challenge in any production enterprise is to identify the optimal point of production where profit is maximised. In a beef grazing enterprise, this challenge can be summarised to the choice regarding the amount of grazing pressure that is applied to the available pasture resources.² If the stocking rate is too low then beef production is not maximised, although if the stocking rate is too high, then per animal performance falls with detrimental effects on beef production (Scanlan *et al.* 1994; MacLeod and McIvor 2008; Orr and Phelps 2013; Scanlan, *et al.* 2013). Between these extremes, producers have to tradeoff production to optimise performance, where variations in intensity often have only marginal impacts on productivity and profit in agricultural systems (Pannell 2006).

Beef producers also have to consider impacts on the resource base in decisions about stocking rates (Gregg and Rolfe 2016, 2017). Higher stocking rates can lead to more profits in the short-term, particularly if seasons are favourable, but increase risks of lower future returns if land degrades. Lower stocking rates are

associated with more conservative management operations that limit opportunities for extra short-term profits but may better maintain the resource base and longer term profits (O'Reagain *et al.* 2014). Overlaid with this are substantial variations in weather and market prices, making it difficult for landholders to predict both short- and long-term tradeoffs.

The short-run tradeoffs can be presented in a conceptual format (Fig. 1). Drawing on the empirical summaries reported by Jones and Sandland (1974), production per hectare (Y_h) can be related to stocking rate (x) by a quadratic expression: $Y_h = ax - bx^2$ (where a and b are constants). The overall production function for a beef cattle operation can then be represented as the relationship between profits and the number of stock on the grazing enterprise. That relationship is subject to the underlying resource condition, where grazing lands in poorer condition have lower levels of livestock production and profitability (Ash *et al.* 1995; MacLeod *et al.* 2004; Orr and O'Reagain 2011). Profitability is small with low stocking because production per area is limited, and also small with very high stocking because per animal performance is limited, and there are 'crashes' in drought years. Between these extremes, the production function domes upwards, but not sharply, implying that producers can change stocking rates without having major impacts on production and profits, at least in the short term. Maximum profits and optimal stocking rates are lower in poorer seasons. Higher stocking rates create payoffs if seasons and prices are good, but lower returns if seasons are bad and droughts occur. This is shown in Fig. 1 where a landholder who stocks conservatively (Stocking rate A) will maximise profits in a poor season but miss out on windfall profits in a good season. Conversely, a landholder who stocks aggressively (Stocking rate B) will maximise profits in a good season but have much lower returns in a poor season.

Impacts of land condition on profits

Profit rates are also dependent on land condition. Land in better condition generally responds more quickly and produces more grass per rainfall event than land in poorer condition, thus

²The available pasture resource is the amount available for domestic animals after consumption by wildlife, white ants or decomposition is accounted for.

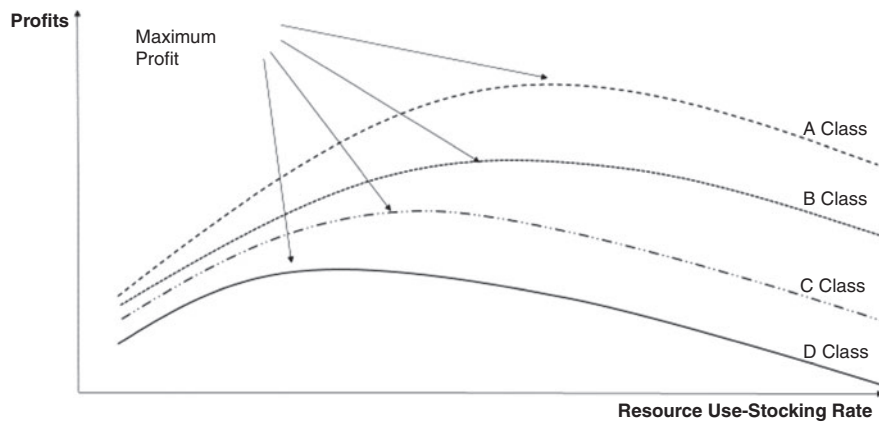


Fig. 2. Tradeoffs between increasing stocking rates and profitability by land condition class.

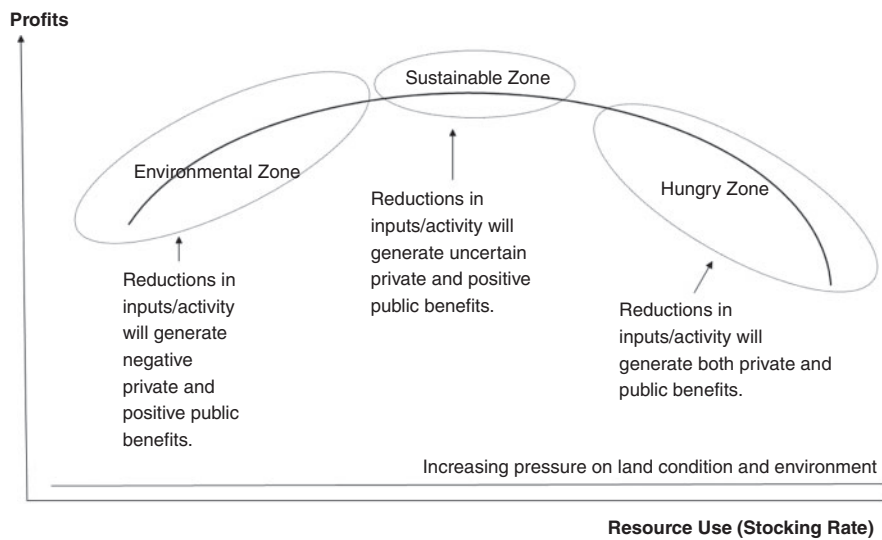


Fig. 3. Tradeoffs between grazing pressures, production and profitability.

leading to greater production and higher profits (Orr and O’Reagan 2011; Orr and Phelps 2013; Koci *et al.* 2020). This can be shown conceptually in Fig. 2, where land condition can be classified into four classes from A (best) to D (degraded) under the ABCD land condition framework (Chilcott *et al.* 2003, 2005). Better land condition is characterised by higher profit rates and higher stocking at optimal profit levels, as demonstrated by Star *et al.* (2011). Yet stocking rates influence land condition, particularly in more extreme seasons (Ash *et al.* 1995). This means that producers making decisions about grazing intensity have to generally tradeoff opportunities for higher profits in the short-term, particularly if seasons are favourable, against the risks of negative impacts on land condition, particularly if seasons are unfavourable.

Negative impacts on land condition reduce future profits (Fig. 2). They also generate public losses through effects such as impacts on biodiversity, land degradation and increased erosion and sediment pollution. There are similar effects in reverse, where improvements in land condition generate both private and public benefits. However, changes in land condition are difficult

to predict precisely because weather conditions and ecological conditions are stochastic, the relationship between grazing pressure and land condition is complex, and there can be lag effects between impacts and changes in condition.

The complexity of long-term stocking rates is summarised into three broad zones of influence for a land manager (Fig. 3). Low levels of stocking generate less-than-optimal levels of profit, but have limited impact and pressure on resources. Stocking within this zone may be deliberately chosen as a strategy to repair pastures and improve land condition, hence this production area is termed the ‘environmental zone’.

At the other extreme, high stocking rates generate private losses in both the short-term (from ‘crashes’ in drought years) and the long-term (through declines in land condition), with corresponding public losses. Once land is over-stocked and pasture condition and biomass declines, animal performance is reduced, hence this production area is termed the ‘hungry zone’. However, reductions in grazing pressure should generate improvements in profitability, particularly over the longer term. Between those ranges is the ‘sustainability zone’ where there is

Table 1. Evaluating the participants' changes to management against the Paddock to Reef grazing management practices

Study responses	Paddock to Reef water quality risk categories			
	Low risk (A)	Low to moderate risk (B)	Moderate risk (C)	High risk (D)
Expectations of seasonal and/or annual stocking rates that each paddock will carry, are realistic and tactical	Stocking rates do not exceed 10–30% pasture utilisation and >2000 kg/ha pasture biomass	Stocking rates do not exceed at least 30% pasture utilisation at least 2000 kg/ha pasture biomass	Stocking rates achieve pasture utilisation levels of 30–50% and at 1000–1500 kg/ha pasture biomass	Stocking rates achieve pasture utilisation levels of <50% and at 1000 kg/ha pasture biomass
Question categories	A lot more (proportion of participants selected)	A bit more (proportion of participants selected)	About the same (proportion of participants selected)	Much less or somewhat less (proportion of participants selected)
Number of times stock handled each year	30.43%	39.13%	21.74%	8.7%
Adjusting stock for feed availability	43.48%	43.48%	13.04%	0
Paddock Spelling/rotation	69.57%	30.43%	0	0
Expectations of long-term carrying capacities (LTCC) (> 10 years) for the whole property are strategic and realistic.	LTCC estimates are equivalent to or less than district benchmarks. LTCC is developed using: <ul style="list-style-type: none"> land condition monitoring data, district benchmarks, historical data, paddock records. LTCC is reviewed each year and if changes in land condition occur	LTCC estimates are equivalent to district benchmarks. LTCC is developed using a combination of the following: <ul style="list-style-type: none"> land condition monitoring data, district benchmarks, historical data, paddock records. LTCC is not reviewed on an annual basis	LTCC estimates are greater than district benchmarks. LTCC is developed using at least one of the following: <ul style="list-style-type: none"> land condition monitoring data, district benchmarks, historical data, paddock records. LTCC is not reviewed on an annual basis	LTCC estimates are greater than district benchmarks. LTCC is developed based on personal experience and limited additional data sources. LTCC Never reviewed
Average stocking rate	17.39%	21.74%	43.48%	17.39%
Data recorded for pasture (e.g. feed budgets)	56.52%	30.43%	0	0

more limited effect of changes in stocking rates on profits, but a greater capacity to manage in poor seasons.

Grazing management practices that are low risk and maintain pastures and soils in good condition (A class and B class condition – (Chilcott *et al.* (2005)) can maintain higher levels of production and profitability into the longer term than high risk practices that degrade pastures and soil to C Class or D class condition. Continued high grazing pressure will tend to place excessive pressure on pastures and soils, noting that there may be long time lags between pressure and negative effects, and that major sediment movements or gully formation tend to be triggered at critical times by events such as droughts or floods. The effects vary across land types and regions, with larger impacts on those that have fragile soils or higher slopes, or experience more extreme weather events. The resilience of pastures and soils to grazing pressure varies, making it difficult to predict exactly when damage and recovery will occur or, in the case of recovery, if it will occur (Westoby *et al.* 1989).

In Queensland, the grazing management practices framework classifies practices into risk categories that align to the ABCD land condition framework, where low risk management aligns to A land condition through to high risk management practices which align to D land condition (Table 1) (Chilcott *et al.* 2003, 2005). A similar classification is adopted in the GBR report cards. The 2016 GBR report card identified that 4% of grazing lands are managed at very low risk (A), 25% at low risk

(B), 52% at moderate risk (C), and 19% at moderate-high risk (D) (Australian Government and Queensland Government 2018). This implies that more than two-thirds of grazing lands are associated with high grazing pressures and subsequent risks of land degradation. Using this dual classification framework, the broad relationships between classes of grazing management/land condition (A, B, C, D) and both profits and sediment generated is shown in Fig. 4. This framework demonstrates that:

- sediment generation increases as grazing pressure increases/land condition declines,
- profits are higher for A Class and B class practices/land condition,
- profit change between A Class and B Class can be uncertain, and
- the largest win-wins are likely to be from moving from D to C and C to B Class.

Encouraging adoption of better management practices

An important policy challenge is to find mechanisms that will encourage beef producers to improve land management practices. Although improvements in land condition could be simply generated by reducing grazing pressure, landholders are generally very reluctant to reduce their herd size because of concerns about debt servicing abilities and potential opportunities if seasons or prices are better. An alternative is to consider changes in management systems, such as fencing to country type or more

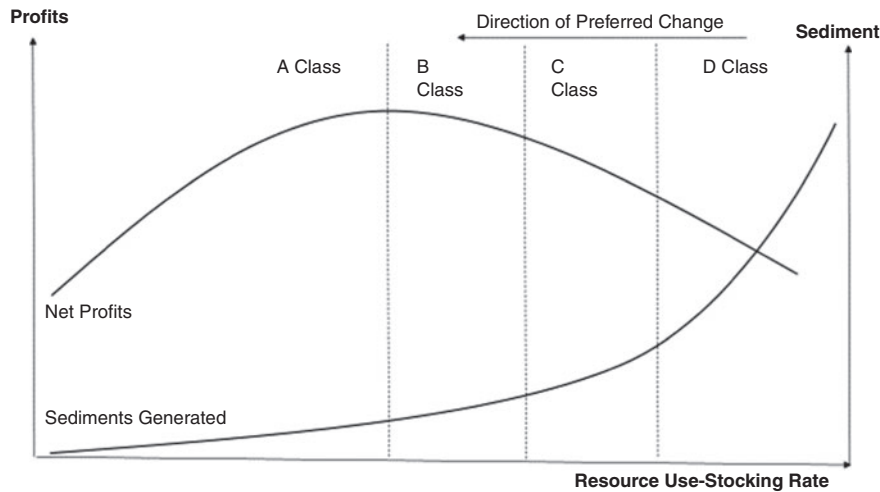


Fig. 4. Tradeoffs between increasing stocking rates, profitability and pollution by land condition class.

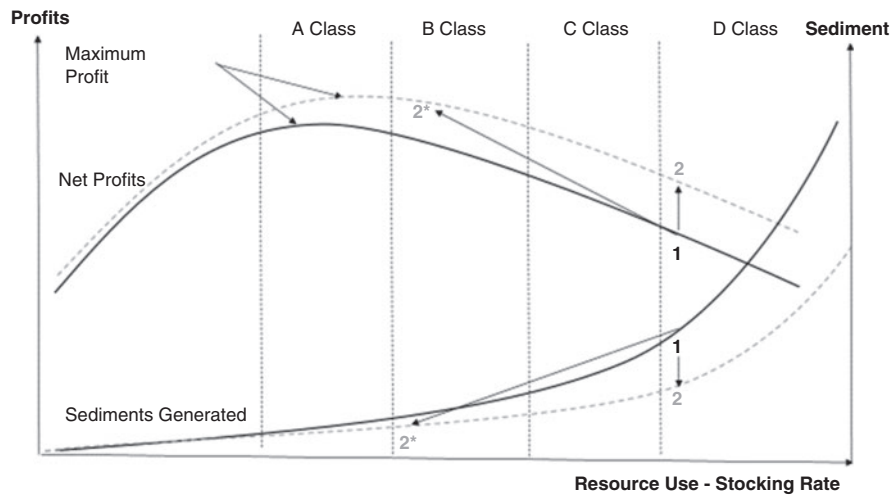


Fig. 5. Effects of improvements in management systems from B Class Condition to A Class condition.

intensive matching of stock to pasture availability. Such improvements typically require investment in infrastructure (e.g. fences, waters, yards) as well as improvements in systems (e.g. pasture monitoring, feed budgeting, livestock recording). Most proposals to improve resource management, including those funded through incentive and grant schemes, involve changes to management systems where infrastructure changes can be funded through grant processes.

Improvements in management systems are typically more appealing to landholders than simply reducing grazing intensity because there are tangible increases in production and profit available. This is represented in Fig. 5 by a shift from system 1 to system 2, where even an operation in D class condition can generate increases in production and land condition through improved management. However, improvements in management systems typically involve greater technical skills in pasture, herd and financial management, which may lead to better optimisation of resource use. This is represented in Fig. 5 by the additional shift from 2 to 2*.

The role of expert extension can be summarised from Fig. 5 as providing producers with the skills and encouragement to move from point 1 to point 2*, with corresponding reductions in sediment emissions. Incentive and grant schemes may only achieve the improvements from point 1 to point 2 from specific case study applications, whereas an extension process that involves the transfer of better and more technical information can potentially achieve more systematic changes. Extension processes often work best with a component of direct funding for systems change, because this provides the producers with the incentive to be involved. However it is the flow-on effects of the skills improvement that extension provides that can generate the largest returns.

Case study analysis

Project Pioneer was a dedicated extension and incentive program funded by the Australian Government from 2016–2019 to 50 targeted grazing businesses in the Cape York, Burdekin, Fitzroy and Burnett Mary catchments in eastern Queensland to

adopt practices and information gathering tools tailored to each grazing business. The aim of the program was to improve property management capacity and profitability and to reduce sediment entering the GBR. The program was delivered by an agricultural business consultant (Resource Consulting Services) in conjunction with an environmental group (WWF-Australia), technology providers (Maia Technology and Farm Map Analytics) and a university (CQUniversity).

The extension program was focused around six key areas:

- new digital tools and technology for precision livestock management;
- automated monitoring of livestock performance;
- spatial farm mapping to assess long-term sustainable carrying capacity;
- monitoring and decision support tools to track livestock, rainfall and grazing activities;
- business analytics and enterprise support; and
- specialist communication of farmer case studies.

These map closely to the traditional roles of agricultural extension of transferring technical knowledge, providing education and attitude change, encouraging the adoption of new farming technologies, and providing information back to researchers and farmers (Marsh and Pannell 2000).

The program involved a variety of activities and training over a three year period, including field days, workshops and training on new precision technologies, information databases and management tools, the establishment of producer demonstration sites, training in business and management analytics, and development of better communication, planning and strategic skills. As well as targeting management practices, the enterprises involved were supported to treat areas of active erosion on grazing lands (16 046 ha), install erosion structures (130), install additional livestock water points to remove cattle off riparian waters (232), and to construct fences to protect riparian and sensitive areas (408 km).

The conceptual framework developed in Section 2 identifies that Project Pioneer can be framed as a test of whether a broader extension approach can be more effective in generating management changes than more focused grant approaches. Key differences from simpler grant approaches are that extension has a whole-of-enterprise focus, works in partnership with landholders to help plan for change and identify training needs, focuses closely on improving financial monitoring and management skills, and has a longer time frame to establish relationships and achieve outcomes. This aligns with the recommendations of the Water Quality Taskforce to invest in more targeted extension activities (Great Barrier Reef Water Science Taskforce 2016).

Evaluating effectiveness over short time frames can be challenging because extension is focused on a whole-of-enterprise level, improvements in management systems are often complex, there are typically long lag times between changes in operations and outcomes, and there are confounding effects with other factors such as seasonal conditions. In recognition of these

difficulties, the evaluation of the effects of extension on the landholders in Project Pioneer have focused more on evaluating their self-perceptions about the effects of the program on their operations. Project Pioneer involved a mix of different extension activities and some direct funding opportunities, and respondents were asked to evaluate the effects of the program as a whole on their operation.

Information was collected from participants through an online survey assessing landholder management and attitudes in 2017 and then at the final stages of the project in 2019.³ A total of 18 and 23 respondents completed the 2017 and 2019 surveys respectively, which represented 38% and 55% of the samples at the time of survey (there were 48 participating enterprises in 2017 and 42 in 2019, with six withdrawing because of drought or other reasons). Approximately 90% of respondents had children, of which 85% expect their children will stay in the pastoral industry. This provides insight into the intergenerational impacts that such extension programs have on long-term outcomes. It may also result in management changes that have long time frames (potentially up to 20 years) to achieve the outcomes being implemented.

Questions relating to grazing management practices were asked across all data collection points to provide a basis for predicting future reductions in sediment emissions. It is very challenging at the site level to measure changes in pollutant loads from management adjustments because of the complexity of geographical and climate variations. Because of this, the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program⁴ (P2R) that measures progress towards the Reef 2050 Water Quality Improvement Plan⁵ evaluates management practice adoption to generate estimates of changes in pollutant runoff. To evaluate Project Pioneer, the same Grazing Water Quality Risk framework⁶ that is used in the P2R assessments was employed to group changes and actions that are most likely to translate to land condition changes and subsequent outcomes for sediment exports. These categories were used to assess the responses from questions that were asked of respondents. The grazing management practices changes were captured 12 months into the project in 2017 and again at the end of the program in 2019 where participants were asked about their management changes compared with 5 years ago.

The variation in respondents between the 2017 and 2019 surveys and the small sample sizes (<30 respondents) mean that it is not appropriate to analyse the results with parametric tests. Small sample sizes are common in tailored extension programs, so there is an ongoing challenge to analyse results. In this paper we apply descriptive statistics to describe and compare results to demonstrate that behavioural change is occurring.

In the first 12 months, there were clear changes to management practices such as stocking rate, monitoring, spelling and data management which are considered highly weighted management practices under the framework (Fig. 6). Although participants may have considered them only to be 'A bit more'

³The survey was conducted through CQU under standard ethical guidelines.

⁴See <https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef>.

⁵See <https://www.reefplan.qld.gov.au/water-quality-and-the-reef/the-plan>.

⁶See https://www.reefplan.qld.gov.au/_data/assets/pdf_file/0034/78865/grazing-water-quality-risk-framework-2017-22.pdf.

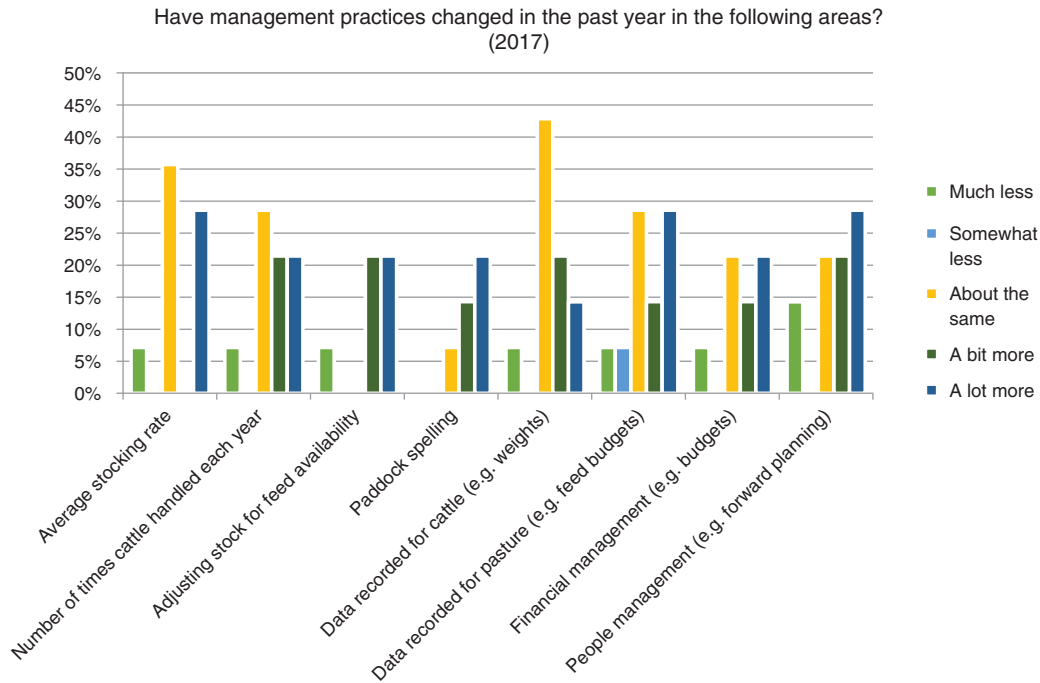


Fig. 6. Changes to management areas in the first 12 months of Project Pioneer.

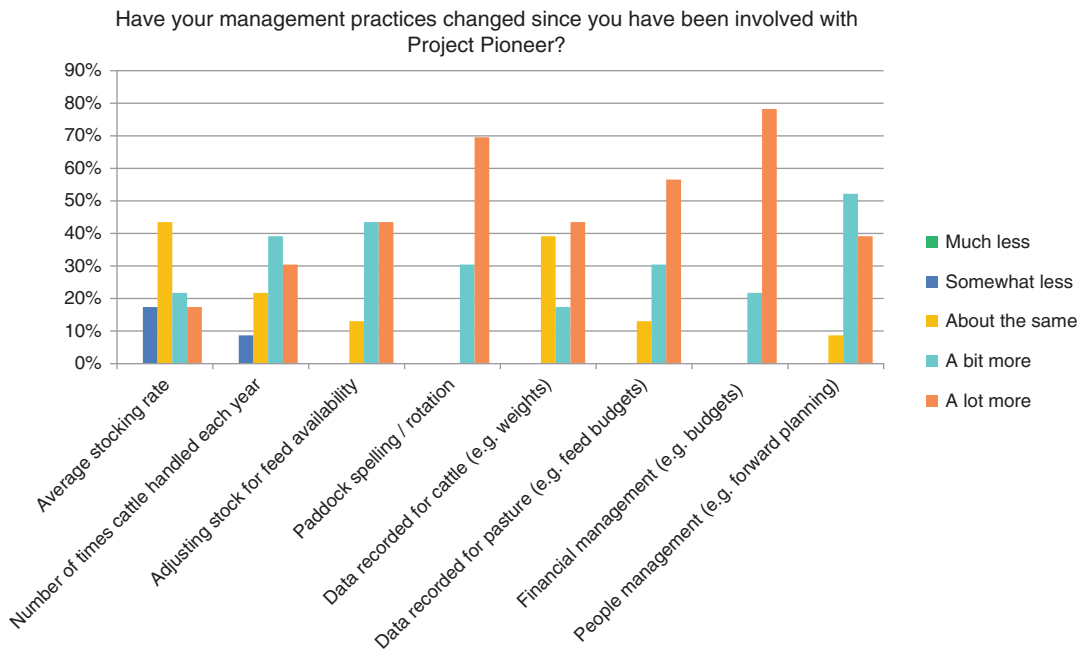


Fig. 7. Participants changes to management since involvement with Project Pioneer.

across the majority of areas, participants had made changes and improvements were already being implemented.

In 2019 participants were asked the same questions regarding management as in 2017, and there were clear changes in paddock spelling, monitoring, and data management which are considered highly weighted management practices under the framework (Fig. 7). Participants, however, did note that their

average stocking rate was still the same as before 2017, even although they also noted that they were selling cattle a bit more or a lot more frequently and they were adjusting stock for feed ‘a bit more’ or ‘a lot more’. This can be interpreted that overall the average stocking rate was still the same even though they were potentially matching the higher feed availability when available and selling stock when the ground cover was declining.

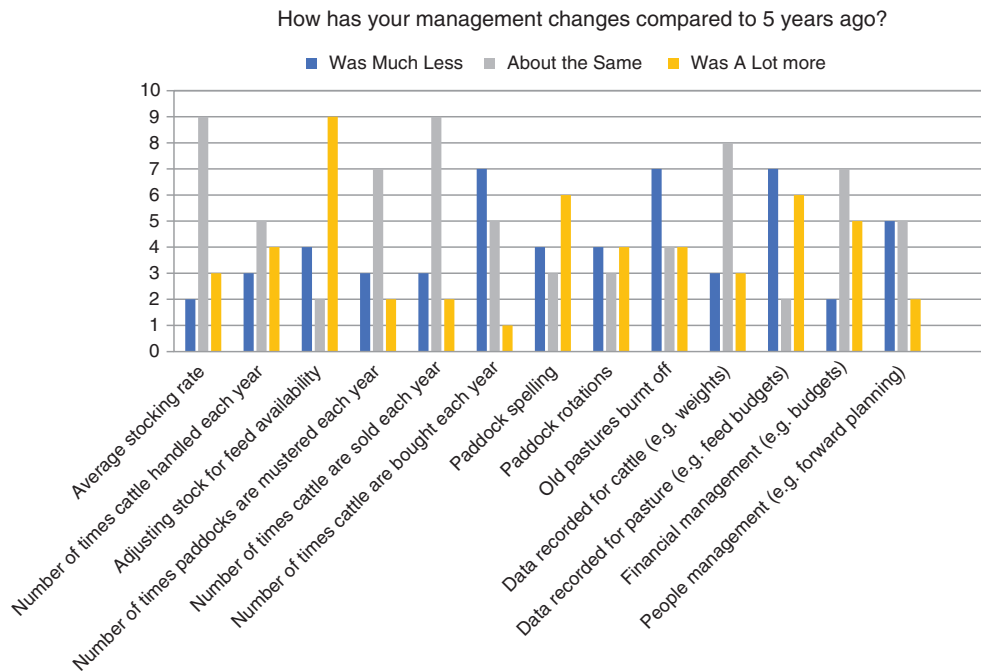


Fig. 8. Changes to participants' management compared to 5 years ago.

The response to the same question at the two different time points highlights that enterprise management shifts happened relatively early in the project and then either improved further and or expanded to other management areas in the enterprise.

To align the changes in grazing management practices to water quality improvements, the selection of 'A lot more' was aligned to the P2R management categories (Table 1). It was assumed that landholders started at a lower level of management given the question then asked: 'how have they changed since being involved in Project Pioneer'. It was assumed that landholders answering 'about the same' were staying at a 'moderate risk' level. From the results, it can be noted that the majority of landholders have increased from potentially 'moderate risk' to 'low to moderate risk' or 'low risk' management practices. A key area that landholders noted in the first 12 months of the project was the changes that they had made to financial management. This was self-assessed as the largest change, with participants noting that they were doing it 'a lot more'.

At the end of the project in 2019, the participants were again asked the same question but framed in the context of changes in management over the last 5 years (Fig. 8). It is important to note that the surveys were anonymous and that different landholders may have responded to each survey. On this occasion, a larger portion of graziers selected that the management was about the same as in the initial sample, although there was a greater emphasis on adjusting stock to match feed requirements along with an increase in data recording for pasture monitoring. This again links directly to the management practices framework, with 30% of the weighting being on managing stocking rate and ground cover.

After 12 months in the program, a majority (42%) of participants noted that they adjusted stocking numbers on their property about quarterly, with 31% noting that they adjust monthly by feed

availability (Fig. 9). At the end of the project, participants were then asked to rank in importance how they made the decision regarding stocking rates (Fig. 10). Adjustments by land condition and pasture budgeting were considered most important by participants, with decisions based on historic patterns and prices being considered less important. We note that adjusting stocking rates based on historic patterns is one of the key factors in assessing the long-term carrying capacity, along with land condition and pasture records. The fact that land condition and pasture budgeting were identified as the most important ways of setting stocking rates indicates that participants were moving towards more technical and best practice approaches.

Discussion and conclusions

Although overstocking from pastoral activities is widely recognised as a source of sediments into the GBR, finding mechanisms to encourage better management has been challenging (McIvor 2012; Orr and Phelps 2013). This is because of the heterogeneity in sources and property management (erosion rates differ between and within grazing properties), the complexity of grazing management systems (because of multiple factors, interrelationships and long time lags between causes and effects), and heterogeneity between landholders (affecting both management styles and varying levels of interest in improvements) (Sangha *et al.* 2005; Orr *et al.* 2006; Moravek and Hall 2014; Rolfe and Gregg 2015).

Extension programs are mechanisms that can be used to encourage landholders to adopt more sustainable management practices. These tend to be integrated programs providing technical advice and support, together with information and incentives to encourage change. The benefits of extension approaches are that they may stimulate higher levels of adoption

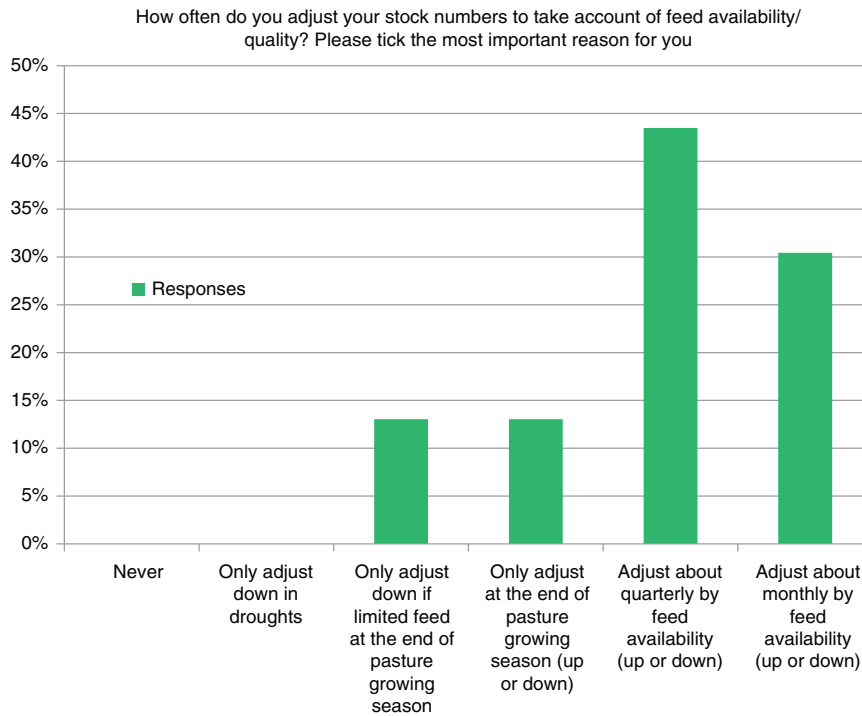


Fig. 9. Participants adjustment of stocking numbers based on feed requirements.

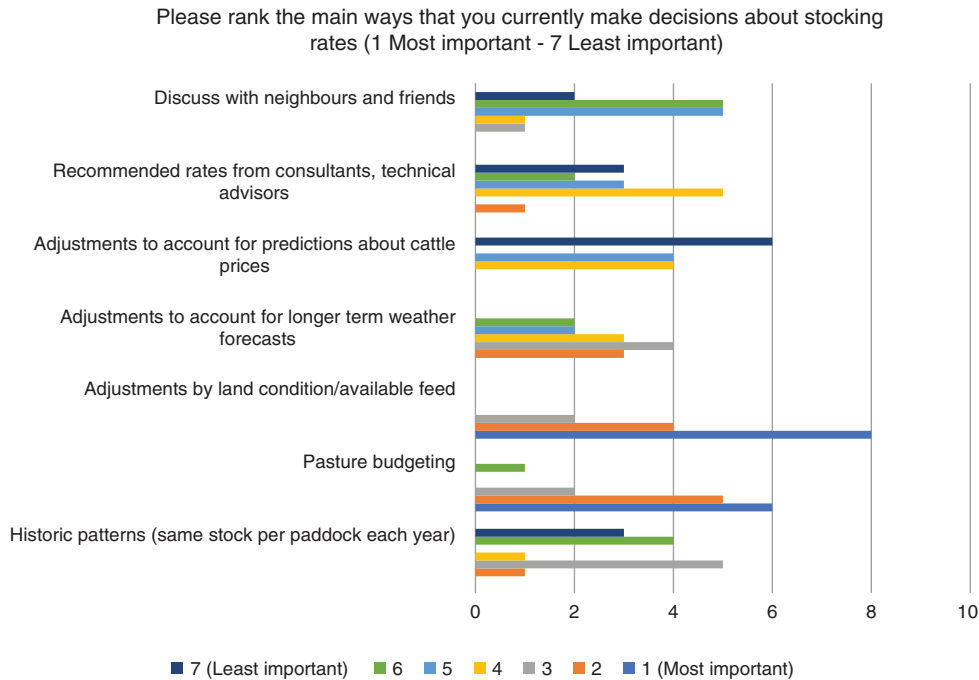


Fig. 10. Importance of factors used to make decisions regarding stocking rates.

and create a larger footprint across the catchment than other mechanisms because of the links to productivity gains, and that changes from field trials that are successful are likely to scale up to property level adoption without outside help. These advantages have to be balanced against the longer time scales involved

to change whole-of-management systems, and the risk that landholders will focus on production improvements that do not have environmental benefits.

The evaluation of the Project Pioneer case study presents multiple lines of evidence to infer positive outcomes of an

extension program for both graziers and water quality outcomes in catchments of the GBR. These can be grouped into three key areas. First, outcomes show positive improvement relative to the Paddock to Reef, Grazing Water Quality Risk frameworks. Given the links between management and resource condition (Silburn 2011; Silburn *et al.* 2011; Bartley *et al.* 2014b) it is likely that that resource condition has improved and sediment emissions should be reduced over time. A second outcome is increased landholder engagement and improved understanding of their business and engagement in future programs, which should underpin ongoing adoption. A third outcome is improved management of risk and developing the skills to do this through data collection and monitoring, which should improve management responses in drought years.

The pathway involving landholders to implement management change was through improved efficiency and productivity, as these are the issues that drive ongoing participation in broader environmental programs. The technical enterprise management assessments proved to be challenging for new producers to generate the data and complete the evaluations. Yet despite these challenges, there is substantial evidence that producers have upgraded their financial management skills, with increases in different forms of monitoring and data collection, more focus on profit and managing business conditions (compared with simply maximising production), and increased willingness to look for external advice.

There was a strong theme of innovation coming from landholders in the programs. The programs appeared to give producers a framework in which they could take some risks of innovation and trial different approaches. Changes in management are largely at the whole-of-enterprise level, as distinct from the atomised approach of project funds. As well, changes appear to be sustainable because they are driven by improved understanding of productivity and profitability tradeoffs.

We do note some important caveats to these results. A key one is that the analysis does not include a technical assessment of changes in ground cover and land condition achieved, or a model to predict the reductions in pollutant emissions that would be generated by those management changes. Although it is expected that more systematic management will lead to improved land condition and reduced rates of degradation (O'Reagain *et al.* 2014), further research is required that compares management changes to subsequent impacts on land condition across grazing enterprises. That would also allow a cost-benefit analysis of the extension program where the projected reductions in pollutants can be compared to the costs involved. A second caveat is that the effectiveness of extension programs may depend on combinations with other mechanisms (e.g. incentive payments) and background conditions (e.g. trust in agencies), which we have not considered in this analysis. This is another important topic for further research. A third caveat is that the sample size is small and potentially non-random, as it is likely that more interested landholders have engaged in these programs, so care needs to be taken in extrapolating results to all landholders.

Noting these caveats, these results do identify that extension programs, particularly those that develop financial and business analysis skills for producers, are likely to generate beneficial, longer-term management changes in rangeland grazing. However, there is still much that we do not understand. For example,

two issues identified from our research to date are that financial analysis and training must be tailored to enterprise and participant needs, and that backgrounding engagement is important. Further work on these types of issues will help to identify how extension activities can be tailored in ways that will generate greater involvement with landholders.

Conflicts of interest

The authors declare no conflicts of interest.

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