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Motivators and barriers to adoption of Improved Land Management Practices. A focus on practice change for water quality improvement in Great Barrier Reef catchments

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ABSTRACT

To protect and improve water quality in the Great Barrier Reef, the Queensland Government's Reef 2050 Water Quality Improvement Plan targets that 90% of sugarcane, horticulture, cropping and grazing lands in priority areas be managed using best management practices for sediment, nutrient and pesticides by 2025. Progress towards this target is insufficient and variable across catchments and industries. The motivation to adopt improvements in management practices is heavily influenced by social, economic, cultural and institutional dimensions. In this paper we synthesise the literature on how these human dimensions influence decision making for land management practice and highlight where future investment could be focussed. We highlight that focussing on —1) investigating systems to support landholder decision making under climate uncertainty (risk); 2) generating a better understanding of the extent and drivers of landholder transaction cost; 3) understanding if there are competing 'right' ways to farm; and 4) improving understanding of the social processes, trust and power dynamics within GBR industries and what these means for practice change— could improve practice change uptake in the future.

1. Introduction

Human land use has a direct and, if unmanaged, potentially negative impact on water quality in terrestrial and marine environments. The international literature provides many examples of policies and programs implemented to influence land management for broader water quality benefits. These include programs to increase crop diversity and planting of cover crops in France (Chabe-Ferret and Subervie, 2013) and the United States (Talberth et al., 2015; Fleming et al., 2018), encourage 'set asides' in riparian areas in Finland (Laukkanen and Nauges, 2014), apply alternative pesticide regimes in Ohio, United States (King et al., 2012) and enable point to non-point source trades to achieve required reductions in nitrogen use in catchments to Lake Taupo, New Zealand (Duhon et al., 2011; Doole, 2012; Shortle, 2013; Duhon et al., 2015). Critical to the success of these programs in achieving their objectives is the recognition and understanding of the human elements that motivate or generate a barrier to improved land management and the design of policies and programs taking these into account (Floress et al., 2015).

The World Heritage listed Great Barrier Reef (GBR), located off the coast of Queensland, Australia and covering an area of 344,400 km^2, is the world's largest coral reef ecosystem (Australian Government, 2021). It is well known that the health of the GBR is in decline due to the collective impact of land run-off associated with past and ongoing catchment development, coastal development activities, extreme weather events and climate change impacts such as the 2016 and 2017 bleaching events (Schaffelke et al., 2017; Waterhouse et al., 2017; van Grieken et al., 2019; Taylor and Eberhard, 2020). The greatest water quality risks to the GBR are from diffuse source nitrogen, fine sediment and pesticide discharge generated from agricultural production in the GBR catchments (Fig. 1) (Waterhouse et al., 2017); discharge of all of these pollutants is many fold greater than under pre-European settlement (Schaffelke et al., 2017). To protect and improve water quality in the

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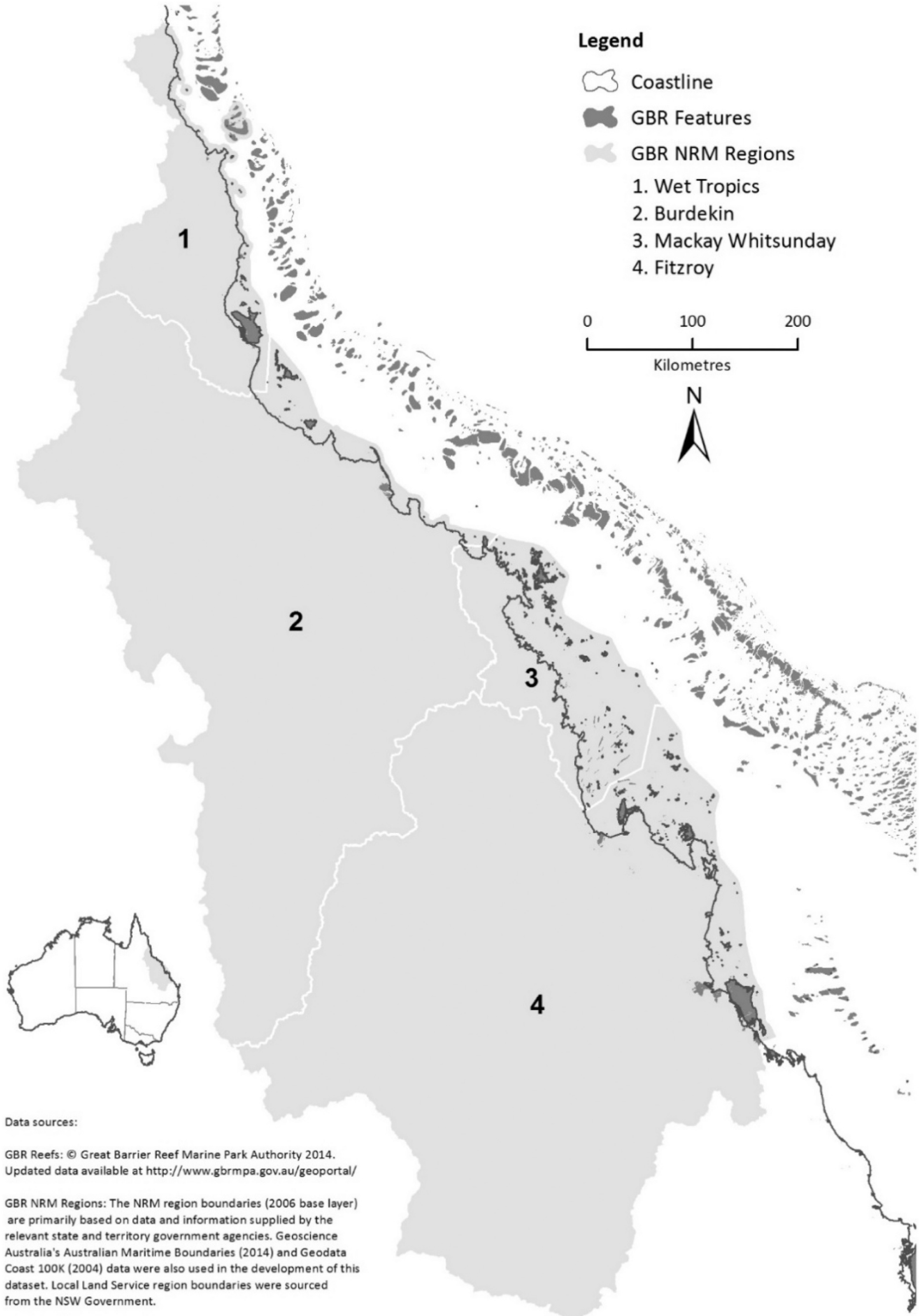

Fig. 1. The Great Barrier Reef (GBR) location and catchments.

GBR, the Australian and Queensland Government, through the Reef 2050 Water Quality Improvement Plan (WQIP), has established water quality improvement targets. These targets include a reduction in anthropogenic end of catchment loads of dissolved inorganic nitrogen (60% reduction by 2025); fine sediment (25% reduction by 2025); and particulate nutrient (20% reduction by 2025). To achieve these water quality targets, desirable land management practices have been articulated for the management of sediments, nutrients, and pesticides across grazing, sugar cane, horticulture, bananas and broadacre cropping industries in GBR catchments (see Australian and Queensland Government (2020b, 2020a) for more detail on water quality risk frameworks and the development of desirable improved land management practice change). The WQIP also includes a target of 90% of land being managed following best management practices by 2025 (Thorburn and Wilkinson, 2013; Queensland Government, 2018). Given that the overall objective of the WQIP and associated programs is to improve land management practices, we refer to Improved Land Management Practices (ILMPs) in this paper rather than 'best practice'.

The latest report card for the GBR (https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card/2017-2018) shows that landholder adoption of improved practices is insufficient, and variable across catchments and industries. Poor adoption by GBR landholders is detrimental to achieving end of catchment water quality improvement targets and long-term health of the GBR. But what motivates or creates a barrier for a landholder to improve their land management practices, especially when the benefits are often external to the property, such as the case with water quality? The focus of this paper is to begin to unpack this question. We do this through a review of the literature on the economic, social, cultural and institutional processes (human dimensions)[1] behind adoption and especially as these relate to sugarcane growers and graziers within the GBR catchments. This paper consolidates literature on factors that influence land management decision making in the GBR Basin, which are often only discussed in isolation to one another.

The paper is set out as follows. The method of literature review is outlined in Section 2. In Section 3 the concept of adoption as it relates to ILMPs for externally beneficial outcomes such as water quality is introduced. This is followed by the synthesis of current knowledge on how economic, social, cultural and institutional processes impact on practice change decision making broadly and specifically for sugarcane producers and graziers in GBR catchments. The convergence of the human dimensions and how they influence adoption of ILMPs is synthesised in Section 4. Identification of current knowledge gaps occurs in Section 5 with conclusions in Section 6.

2. Method

The method used in this analysis can be best described as a systematic literature review, utilising a narrative synthesis and tabular accompaniment. According to Grant and Booth (2009), there are fourteen types of literature review and associated methodologies. The appropriate literature review approach depends on many factors including the role of the review in the broader research, audience and timeframes for analysis (Knopf, 2006). We systematically searched for, appraised and synthesised research evidence with an analysis focussed on what is known, what is unknown, uncertainties and recommendations for future research (Grant and Booth, 2009). The primary databases searched were *Web of Science*, *Scopus* and *Google Scholar*. Priority for inclusion was given to studies focusing on motivations and barriers to adoption of practices with water quality enhancing outcomes, with a further focus on studies that included direct references to economic, social, cultural and institutional factors. A secondary focus was given to empirical analysis in GBR catchments and then to the industries of focus. Other review type papers were included as part of this literature review. Empirical papers were restricted to be those published in the 10 years prior to the time of writing (2010−2020). Review and theoretical papers were still included if outside of these time bounds.

3. Adoption of Improved Land Management Practices (ILMPs) and the human dimensions of influence

Pannell and Classen (2020) highlight that historically, adoption has been treated as a binary concept —there is adoption or there is no adoption. As a result, in many studies assessing adoption, the difference between complete, long term adoption and partial adoption (some of the property, some of the time), as well as the permanence of adoption (adoption whilst support continues) is not distinguished. Marra et al. (2003), Pannell and Classen (2020); Pannell et al. (2006); Tey and Brindal (2012), Weersink and Fulton (2020) and Montes de Oca Mungia et al. (2021) all highlight that adoption is non-binary and continuous. For example, a practice may be applied on some parts of the property only some of the time due to factors such as crop rotations, trialling, transaction costs to transition to full adoption, heterogeneity in land suitability, weather conditions. As a result, it is suggested in the literature that adoption, as it relates to ILMPs, is best understood as a dynamic learning process which proceeds via the following steps: 1) awareness of a problem or opportunity; 2) non-trial evaluation (looking over the fence, consultation or collaboration with neighbouring farms); 3) trial evaluation; 4) adoption; 5) review and modification; and 6) adaptation and expansion or non- or dis-adoption.

Understanding landholder adoption of practice change has been the focus of production and institutional economists and social scientists for many years. Interest in adoption initially focussed on understanding low farm returns in an effort to improve agricultural productivity through the adoption of new practices. The focus of adoption study now includes a focus on supporting landholders in the adoption of land management practices that are deemed environmentally sustainable, either because they conserve resources that underpin agricultural productivity (such as maintaining soil quality) or generate external benefits (such as those that reduce pollution of waterways or enhance habitat for wildlife) (Pannell and Classen, 2020; Weersink and Fulton, 2020). With this shift comes the need to understand motivations or barriers to change beyond economics. Whilst still including economic motivations, the study of adoption has expanded to also value the broader human dimensions of social processes, culture and institutions. Each of these dimensions is introduced and discussed in the context of adoption of ILMPs for GBR sugarcane producers and graziers in the remainder of this section. The interaction of all the elements of human dimensions to influence the learning process of adoption is consolidated visually at the end of this section as Fig. 2.

3.1. Human dimensions and understanding adoption of ILMPs

3.1.1. Economic processes and ILMP adoption

Weersink and Fulton (2020), following on from Pannell et al. (2006), suggest that the economic factors that impact on decisions about land management practice change relate to the extent of the establishment, opportunity and transaction cost relative to the short and long term benefit from the change. This is impacted on by the time lags to realise the benefit; the perceptions of uncertainty and risk; complexity; spill over impacts to other parts of the business; and other factors that generate utility such as environmental stewardship, work life balance (Weersink and Fulton, 2020) and farming system compatibility (Pannell et al., 2006).

The economic factors can be grouped into those that influence the capacity to change (cost of change) and the motivation to change

[1] 'Human dimensions' is a term that emerged from the ecological sciences literature in reference to the human side of land management. Human dimensions are regularly referred to in the multi-disciplinary social sciences policy discussion related to GBR water quality. Human dimensions encapsulate the economics, social, cultural and institutional influences to human behaviour.

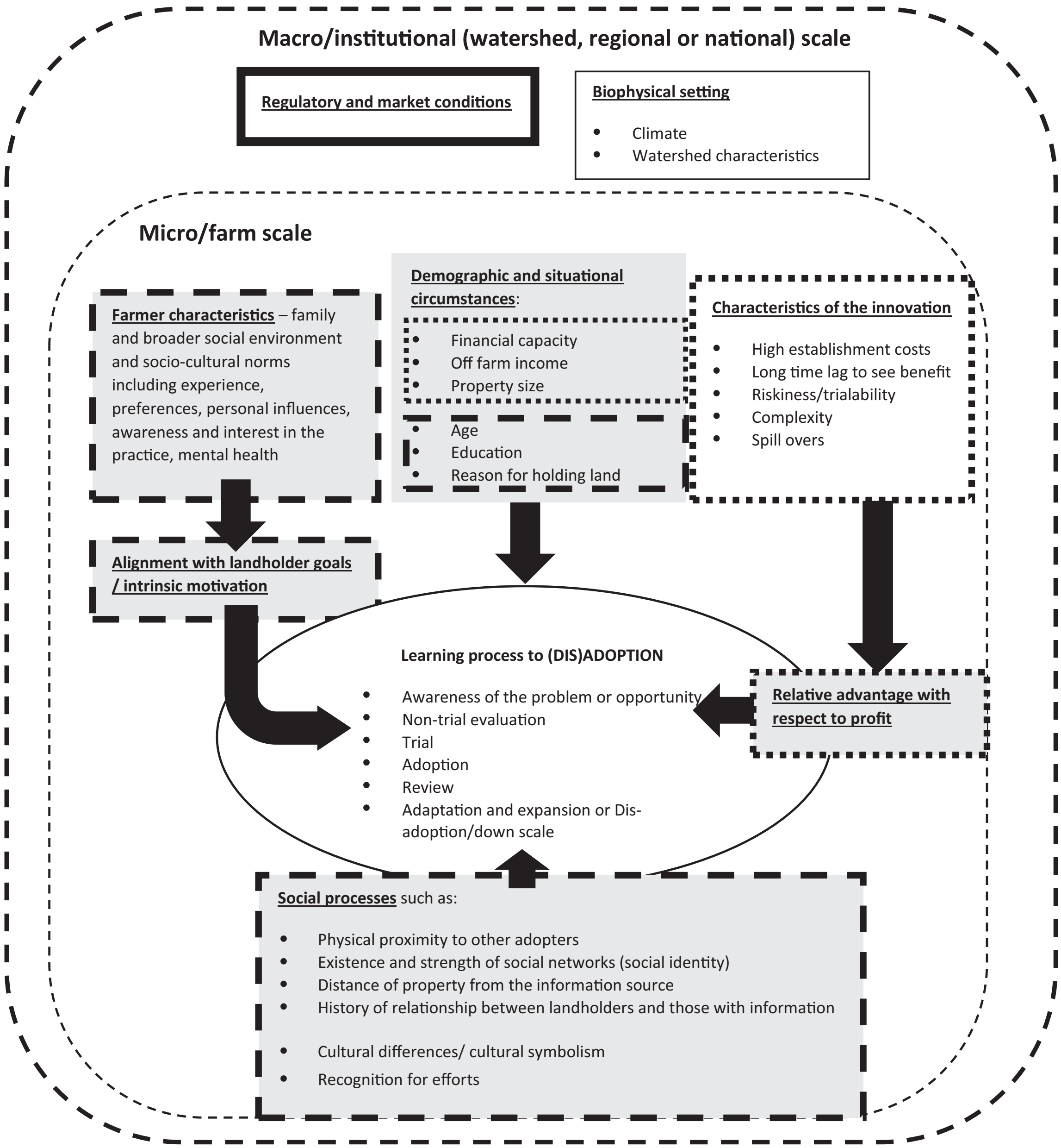

Fig. 2. Framework for understanding the interactions of the human dimensions on adoption.

(relative advantage of changing – profit, alignment with broader goals). These are discussed as such below.

3.1.1.1. Cost of change and ILMP adoption. The cost of changing to an ILMP includes the upfront capital cost, cost of missed opportunities (opportunity cost), transaction and transition costs. Capital costs are the costs of purchasing infrastructure such as fencing, watering points or machinery to implement the ILMP (Rolfe and Gregg, 2015) as well as the start-up capital and labour costs (Greiner and Gregg, 2011). Rolfe and Gregg (2015) and Greiner and Gregg (2011) both highlight that start-up capital costs are key barriers to the adoption of ILMPs such as pasture spelling, rotational grazing, sustainable stocking rates and river frontage management for graziers in GBR catchments. This is particularly the case for the management of river frontage and rotational grazing due to the cost of fencing and providing off-stream watering points. Rolfe and Gregg (2015) highlight that grazier perceptions of high start-up capital costs could be overcome through the use of one-off and upfront grants or tenders more so than incentive schemes that make payments based on outcomes over the long term.

Capital costs have been recognised as a barrier to adoption of ILMPs by sugarcane growers in GBR catchments (van Grieken et al., 2019). The Australian Government's Reef Rescue (2008–2013) Program was designed to overcome this by paying a portion of the cost of capital invested to improve practices. However, the requirement to match the up-front capital program funds invested was found to be a barrier to adoption for many (van Grieken et al., 2013).

Transaction costs are the indirect costs associated with the transfer of a good from one agent to another (Niehans, 1971). Transaction costs are incurred by landholders in the time and effort expended collecting information about practice change options and implications on their farm business (time to meet with consultants or do research on their own, consultant fees, fuel cost to travel to meetings or workshops) and in the time, effort and expenses incurred when conducting activities required by funding agencies (monitoring and reporting). Where assessed, land manager's private transaction costs when implementing agricultural or agri-environmental practices have been shown to be between 7% and

37% of any payment received to support the practice change (Falconer, 2000; Falconer and Saunders, 2002; Vatn et al., 2002; Rorstad et al., 2007; Mettepenningen et al., 2009; Coggan et al., 2013a). The variability in cost is most affected by the observability of the change (Rorstad et al., 2007). Coggan et al. (2014) demonstrated that, on average, the private and uncompensated transaction costs borne by sugarcane producers in Mackay Whitsunday catchments were equivalent to 38% of the funding received under Reef Rescue. In a study of graziers in GBR catchments by Rolfe and Star (2019), more than three quarters of participants identified the largest perceived risk of entering a grant or tender scheme to improve water quality into the GBR was related to the paperwork associated with contractual arrangements (transaction cost). The impact of perceived and actual transaction costs on adoption of ILMPs by GBR landholders is not well known. This is particularly the case for grazing.

3.1.1.2. Relative advantage and ILMP adoption. Relative advantage is influenced by the profit, complexity and risks associated with the change (and how these are managed), and any spill over impacts to other parts of the farm business. Standard economic models historically used to assess adoption typically assumed that a farmer's motivation is to maximise profit, expected profit or expected utility (Weersink and Fulton, 2020). Lankester et al. (2009) suggest that this is particularly the case when agricultural production is the main land use and the sole income source of landholders.

Studies that explore economic processes as an influencing factor on adoption also tend to be geographically and/or practice specific. For the GBR, Roebeling et al. (2009) assessed the cost to sugarcane growers and graziers of adopting practices to improve water quality. They showed that significant water quality improvements can be obtained by sugar producers at negative cost (i.e., for a profit) to a point (35% reduction in total suspended solids and 50% reduction in dissolved inorganic nitrogen). This is the case for practices that involve reduced or zero tillage, economically efficient rates of fertiliser application, nitrogen replacement and split nitrogen application. However, modelling sugarcane farms in the Wet Tropics, Kandulu et al. (2018) find that switching nitrogen application from maximizing private to maximizing public benefit (including impacts on carbon emissions) could reduce expected private net returns by $99/ha but yield additional external environmental benefits of $191/ha. Further switching nitrogen application from maximizing private return in years of highest profit potential to maximizing mean social net returns could reduce expected private profits in good years by $277/ha but yield additional external environmental benefits equal to $287/ha.

Roebeling et al. (2009) found that all ILMPs for grazing came at a cost to the grazier. However, Star et al. (2015) reports that landholder optimism related to future weather patterns impacts on perceptions of the potential of practice change to generate net private returns. Star et al. (2015) suggest that grazier adoption of improved management practices could be enhanced by reducing weather uncertainty in decision making through improvements in spatially specific forecasting of future weather patterns and their production implications.

3.1.1.3. Other factors that impact on perception of relative advantage of ILMPs. A landholder's perception about the relative advantage of an ILMP is also affected by their perception of risk and uncertainty. This is well covered for grazing by Greiner et al. (2009); Greiner and Gregg (2011); Moon et al. (2012); Greiner (2015) and Rolfe and Gregg (2015) and for sugarcane by Benn et al. (2010); Kandulu et al. (2018); Rust (Pending) and Thorburn et al. (2020). For graziers in the Burdekin and other northern Australian catchments, pasture levels and growth, market prices for beef and annual rainfall were the aspects of risk that had a high impact on decision making (Rolfe and Gregg, 2015). Grazier perception of risk surrounding ILMPs and climate could be further ameliorated by investing in demonstration sites that allow landholders to see the impacts of dry season management (Star et al., 2019). Star et al. (2019) also assess the impact of input (cost to conduct works are higher than expected) and outcome risk (works fail to achieve the outcome) in grazier decision making surrounding gully remediation. Star et al. (2019) found that outcome risk (which did not include production risk) had a greater bearing on participation than input risk. It is thought that this may be because landholders are intrinsically motivated to protect the environmental values of their land (corresponding to the findings of Greiner et al. (2009); Greiner and Gregg (2011); and Rolfe and Gregg (2015)). Other driving factors may be that landholders are reluctant to see a project fail (reputational risk); they do not want to risk having a long term legacy of a gully in a worse state, particularly if they intend to pass the property on to younger members of the family. Landholders are also concerned about the management of the gully remediation in years of lower than average summer rainfall; and/or the risk of more regulation as a result of project failure.

Focussing on sugarcane production, Rust (Pending) highlights that financial risk associated with new production technologies is an important factor in decision making surrounding adoption. Rust (Pending) highlights that Australian sugarcane growers are price takers on the international market which means they face substantial risk to the value of farm production if there are adverse commodity price movements. Risk exposure due to being price takers is reported to impact on decisions about trialling new technologies or land management techniques, especially if they require substantial capital investment. Thorburn et al. (2020) highlight that sugarcane farmers manage production risk through the application of nitrogen. This is supported by Kandulu et al. (2018) who calculated that the long-term economically optimal rate of nitrogen fertiliser (N) application on sugarcane in the Tully subcatchment of the Wet Tropics was 120 kg/ha. This is significantly lower than the optimal rate of N application when inter-year variations in profits are taken into account and risk exposure to expected returns in good years is optimised (150 kg/ha). Given low fertiliser cost as a percentage of expected returns, and tending to be averse to missing out on a high yielding crop, applying high N rates presents a low risk proposition in the face of high profit potential (Kandulu et al., 2018). Kandulu et al. (2018) also note that sugarcane growers make decisions at the beginning of the season with little knowledge of future economic or seasonal conditions. Accordingly, selecting appropriate N fertiliser application rates could be enhanced with improvements in seasonal climate forecasting coupled with risk-based assessment of expected returns although the practical application of this concept is complex and not readily accepted by sugarcane farmers (Thorburn et al., 2011b).

Given that many sugarcane growers apply nitrogen fertiliser in excess of crop needs to minimise the risk that crop yield is limited by the availability of nitrogen in the soil, Thorburn et al. (2020) asked whether insurance, rather than overapplication of N fertiliser might be an effective risk management tool. They showed that this was possible, although they had to develop an original insurance product concept for the problem as there were no relevant existing insurance products. The risks of yield loss, and hence the price of insurance were highly heterogeneous. However, there were situations where the cost of insurance was less than the cost savings from reduced fertiliser and thus purchasing insurance was an economically rational risk management approach. There also might be situations where insurance is attractive, even if economically irrational, such as where farmers have to reduce N fertiliser applications to meet government regulations where they believe above-regulated applications are needed to maintain production.

Despite the focus on profit and cost, Greiner and Gregg (2011) suggest that intrinsic motivation, that is motivation to do an action because it makes you feel good, is a strong motivator for grazier investment in ILMPs in GBR catchments. This is particularly the case for low cost ILMPs. Greiner and Gregg (2011) note that care should be taken when engaging financial incentives for land management practices such that they do not 'crowd out' intrinsic motivation. There is some evidence that some landholders may feel insulted if they are paid to do something that they consider of social value (Greiner and Gregg, 2011). Financial incentives could also create a situation where landholders delay conducting activities in case they might be paid for these in the future.

3.1.2. Social processes

Social processes primarily influence adoption through their impact on landholders' motivation to change (Weersink and Fulton, 2020). Social processes are described as: the existence and strength of social networks (family through to community); the physical proximity of other adopters (due to observability and trialability) and information sources; the history of relationships between landholders and those with the information; and ethnic and cultural associations (Pannell et al., 2006; Weersink and Fulton, 2020).

3.1.2.1. Social networks and social learning. Social networks, the interactions and personal relationships between people, have the greatest bearing on the learning process regarding the adoption of an ILMP at the problem identification and non-trial of solutions phase. This is because social networks influence landholder perception of the existence of a problem to begin with and then allow landholders to learn socially by 'looking over the fence' and observing others conducting small scale solution trials (Streletskaya et al., 2020; Weersink and Fulton, 2020). However, the role of the social network in social learning is weaker when the profitability of the technology depends on characteristics that vary across the population of potential adopters (Chavas and Nauges, 2020). Heterogeneity in agriculture amongst family farmers and farms tends to be high which impedes the potential for social learning (Benyishay and Mobarak, 2019).

Based on their study into drivers of adoption of riparian management by graziers in the Burdekin, Lankester et al. (2009) suggest that knowing what works well and why through more thorough and collaborative monitoring and evaluation of implemented practices would help the cycle of social learning with the potential for greater adoption. Star et al. (2019) also suggest that to capitalise on social learning of graziers, trials need to be designed with a focus on management practice techniques that are most relevant to common perceptions of risk.

Social learning with regard to ILMP is challenging in situations where problems that ILMPs are addressing are not perceived to be overly important to the landholders that need to adopt the ILMPs or there is a perception they will negatively influence the profitability of their farm businesses. For example, in the sugarcane industry the application of nitrogen fertiliser to increase crop vigour and greenness is commonplace and reductions in rates of application can be perceived to be extremely detrimental to industry and farm productivity. As such, work to co-develop decision support tools with sugarcane farmers and collaborative water quality monitoring programs are two forms of activity that have been conducted to help maintain productivity, at the same time increasing awareness of the environmental consequences of over-application of nitrogen fertiliser (Thorburn et al., 2011b). In this manner, the social group norms within leading farmers and their peers are beginning to shift so that conversations about how to experiment with ILMP that reduce nitrogen fertiliser use are seen as important to the future of their farms and the broader industry (Vilas et al., 2020).

Social norms and social identity involve membership in emotionally significant groups. Where landholders are acutely aware of social norms and identity they will judge their own behaviour referenced to the behaviour of their peer group (Ferraro et al., 2019). In lab-based experiments, non-point source pollution management programs could reduce (theoretical) pollution, drawing on social identity and presenting information to potential participants about decisions made by others like them in a similar situation. There is also evidence of policies that draw on social identity operating on the ground. For example, Minnesota's Agricultural Water Quality Certification Program allow farmers to display a sign to recognise their farm as water quality friendly once they have adopted a core set of practices (Ferraro et al., 2019). There are also examples of this for the sugar growing community of the GBR through Cane Changer– a program which set out to generate a positive social identity for sugarcane farmers through record keeping and stem negativity directed towards sugarcane farmers through the signing of a behaviour contract which recognised farmers for their environmental stewardship. Sugarcane farmers were then comfortable to sign their own behaviour contracts to improve farming practices (Pickering et al., 2018). It is important to note that the effectiveness of any approach to learning about ILMPs will be influenced by the nature of the people to be influenced. Taylor and Van Grieken (2015) found that production orientated sugarcane growers did not like the articulation of farming practices linked to GBR water quality issues.

Fielding et al. (2008) demonstrate the importance of norms on behaviour when assessing landholder adoption of riparian zone management. They found that graziers who perceived that other landholders in their community were more approving of (injunctive norms) and more likely to engage in (descriptive norms) riparian zone management, were more likely to intend to engage in riparian zone management themselves. However, this was only significant for landholders who strongly identified with their landholder community group. That is, the behaviour and expectations of a behaviourally relevant reference group were more motivating than global perceptions of support from important others. Getting visible and respected in-group members who have similar farming practices (see Benyishay and Mobarak (2019)) to promote practices may therefore be one way to influence in-group members. Communicating information about the behaviour and practices of in-group members is another possible strategy. Emtage and Herbohn (2012) and Pickering et al. (2018) highlight that the credibility of the information source and the trust in who delivers the information will impact on the uptake of the information in adoption decision making. Benyishay and Mobarak (2019) suggest that communication of results could be enhanced through the use of a performance bonus based on knowledge change and adoption.

3.1.3. Culture

Culture is broadly defined as a set of basic assumptions and values, orientations to life, beliefs, policies, procedures and behavioural conventions that are shared by a group of people, and that influence (but do not determine) each member's behaviour and his/her interpretations of the 'meaning' of other people's behaviour (Spencer-Oatey, 2008).

Cultural capital is the resources in the form of knowledge, skills, dispositions and possession of culturally significant artefacts (Burton and Paragahawewa, 2011). Cultural capital is important because it generates symbolic capital which then strengthens social relations (Burton and Paragahawewa, 2011), generating status and peer esteem. Cultural capital may be institutionalised (qualifications or standardised recognition – for example, industry sanctioned young farmer of the year), objectified (new farm equipment or a well-tended 'tidy' field) or embodied (learned skill and knowledge – he/she knows how to manage farm dogs).

Blackstock et al. (2010) note that farmers attach symbolic meaning to the choices that they make and the behaviours they exhibit. Further, farmer decision making is a complex process involving multiple criteria which is strongly influenced by peers. If the interpretation of 'good farming' is associated with high productivity and high yields, then persuading farmers to conduct activities that are counter to this position will be very difficult. Farmers allocate each other 'symbolic capital' for visible demonstration of values. Schemes that undermine these visible symbols of 'good farming' (buffer strips for habitat which may be seen as overgrown and untidy) may be less effective than those that contribute to signs of good farming (new fences). Different sub-cultural groups in agricultural communities have a different perception of good, best and proper farming (Blackstock et al., 2010). The impact of this is magnified due to the fact that farming decisions can often be publicly viewed by a peer group that is highly judgemental and critical, particularly of practices that fall outside standard production orientated farming (Burton and Paragahawewa, 2011). Conventional farmers around the world are known to dislike untidy farming (perceived as a lack of straight crop lines or hedge rows with undergrowth etc.) (Burton and Paragahawewa, 2011). Untidy farming is seen as inefficient with production wasted due to the inability to apply the correct fertilisers and pesticides at the right time, plough straight etc. (Burton and Paragahawewa, 2011). Roadside farming means that farmers can judge each other from a distance; however, complex landscapes which support biodiversity cannot be easily read from the roadside.

In the GBR catchments, Taylor and Eberhard (2020) note that beef producers in the Burdekin rangelands report a 'loss of pride related to receiving handouts' whilst Lankester et al. (2009) note that landholder 'concern about how others see riparian management' is important in participation decisions. Taylor and Van Grieken (2015) highlight that when sugarcane growers feel that incentive programs reward poor growers rather than recognising those that are more progressive, participation will remain low. Greiner and Gregg (2011) argue that a financial focus to conservation programs has crowded out stewardship focussed motivation, and, combined with a landholder cynicism towards government, has reduced participation in programs in high priority regions such as the Burdekin.

Understanding culture may provide insight into whether a policy or program will be successful in the short or long term. If adoption of ILMPs requires a shift in culture, it may take a long time for large scale adoption to occur, if it ever does. At the same time, adoption by lead farmers can begin to shift the conversation with others which may help increase the scale of adoption. Initiatives that publicly recognise land management practice change are seeking to modify the culture around visible symbols of 'good' farming.

3.1.4. Macro/institutional influences

Stuart and Gillon (2013), Liu et al. (2018), Baur (2020), Bennett et al. (2018) and Taylor and Eberhard (2020) add further context to the work of Pannell and others by highlighting that in addition to social and cultural processes and economic drivers, a number of factors external to the farmer and the farm operation impact on adoption. These are referred to as macro-scale or institutional influences and include changes in factors such as agricultural policies, standards (such as food quality standards), market conditions and the biophysical setting.

Institutions are the humanly devised rules designed, developed and enforced by society which structure economic, social and political behaviour and thereby shape interaction (Bromley, 1989; North, 1990; Bromley, 1991). Regulatory institutions tend to be coercive and are the highly visible social processes of making rules, monitoring behaviour and implementing incentives to encourage compliance. Transgressing regulatory institutions results in punishment or loss of reward. Normative institutions are softer and exert pressure for behaviour through social obligation, peer expectation or standards of appropriate behaviour rather than enforcement. Transgressing normative institutions results in shame, loss of standing or social exclusion. Cultural-cognitive institutions are the patterns of thinking, feeling and acting that operate at a 'taken for granted' level and shape shared understanding of how the world works and how collective meaning is produced. Transgressing cultural-cognitive constraints results in confusion or disorientation (Scott, 2013).

Baur (2020) categorises five types of institutional carrier that constrain or drive landholder decision making around land management (Table 1). Baur (2020) also notes that biophysical aspects of land and climate, soil fertility and health, pest pressure, cropping decisions and pathogen loading, property rights, land values and farm loan conditions impact on farmer land management decision making. Baur (2020) notes the complexities brought to land management decision making about the 'right' way to farm by conflicting institutions around food safety and environmental outcomes in the United States. Taylor and Eberhard (2020), specifically related to the GBR, highlight the conflicting signals given to land managers from production versus environmental institutions. For example, in the sugarcane industry, awards are given for record high yields (Walker, 2019). Yet meeting GBR water quality targets may require farmers to management their crops in such a way that small reductions in yield is more common (Thorburn et al., 2011a).

Table 1
Baur's five types of institutional carrier which constrain or drive landholder decision making.

Institutional carrier	Description
Rules and standards:	Preventative intent.
Markets and supply chain forces:	Land uses may be promoted or limited by production costs, prices, market access and exclusion. Some examples of this include organic production, non-GMO seed, labels and certifications, production contracts between growers and buyers which specify production method.
Legal liability:	Reactive regulatory institution that discourage socially undesirable behaviour by punishing after the fact
Social networks and norms:	Norms emerge, persist and adapt through webs of interpersonal relationships. Social networks regulate information and resource flows to farmers, circumscribing a farmer's opportunity space. Norms shape farmer interpretation and response to other institutions. Policies that NUDGE farmers in a way that respects existing information networks are more effective than policies that BUDGE farmers out of familiar relationships of trust and realms of experience Baur (2020).[a]
Scientific knowledge and available technologies:	Frame what is possible. Farmers are more receptive when expert or knowledge making institutions speak to both the societal importance and feasibility of adoption. Farmers tend to have a negative view of practices that complicate operations or challenge technical beliefs

[a] A nudge is a concept in behavioural economics, political theory and behavioural sciences which proposes positive reinforcement and indirect suggestion as a way to influence behaviour. To be considered a nudge, the intervention must be cheap and easy to avoid. Fruit placed at eye level is a nudge whilst banning junk food is not (and probably could be considered a budge). Source: Baur (2020).

Whilst considered critical to understanding adoption, there is very little analysis of how institutional factors impact on adoption and how these can be best utilised to support increased adoption. Drawing on Liu et al. (2018), Baur (2020) highlights this, noting that out of 121 papers on adoption of agricultural and agri-environmental best management practices, only 7 addressed macro factors and out of these, only 2 assessed the role of over-arching policies, markets, businesses or agencies on land management decision making.

4. A framework for thinking about the human dimensions influencing on adoption

In Section 3, we describe the numerous human dimensions that influence adoption of ILMPs. However, we need to understand how they interact to develop better programs to facilitate adoption of ILMP. Fig. 2 synthesises existing literature and provides a visual framework describing the relationships between the direct and indirect human dimension influences on the non-binary and continuous learning process of adoption. In summary, the interest/ability of a landholder to move along the learning process to some level of adoption is influenced by the social and cultural characteristics, demographic and situational characteristics of the landholders, and the economic characteristics of the innovation which generate relative advantage (Pannell et al. (2006); Montes de Oca Mungia et al. (2021)). Dis-adoption can also be explained through relative advantage where the same influences can negatively affect the adoption process, for example decisions to adopt rely both on the credibility of the product but also on cognitive and normative influences (Moore, 2002; Hay, 2018). In Fig. 2, shaded boxes indicate a direct link to the learning process supporting adoption whilst unshaded boxes indicate an indirect link. For example, the cost, benefit, risk, spill over impacts to other parts of the farm business and uncertainties of a practice all influence the relative advantage of the ILMP which will then in turn influence practice adoption (or extent). In Fig. 2, heavy dashed outlines on boxes indicate categorisation as relevant 'social' human dimensions (cultural dimensions are inlcuded within this category) and heavy dotted outlines indicate categorisation as relevant 'economic' human dimensions. The heavy solid lined boxes in Fig. 2 indicate the 'institutional' human dimension.

5. Where should future research in this area focus?

Based on the review of the literature focussed on human dimensions and adoption of ILMPs broadly and with specific focus on sugarcane and grazing landholders in GBR catchments there are three key areas for future research to support ILMP adoption. These areas include barriers to adoption (specifically landholder perception and actions associated with risk) and two areas where better understanding of the current human environment could enhance motivation for ILMP adoption. These relate to social connectedness and the role of institutions in framing opportunities for landholders. A summary of key findings and current gaps in knowledge is provided in Table 2.

5.1. Overcoming the barrier of risk

A common theme throughout the general and GBR focussed literature was landholder reluctance to adopt ILMPs or even become involved in programs promoting ILMPs due to perceived risks. Perceived risks relate to climate, on-ground outcome, social and reputational domains.

5.1.1. Climate risk

It is well articulated in the literature that landholders are accustomed to, and influenced by, their perception of climate risk. A number of studies highlight areas where better information about climate could influence landholder decision making around ILMPs. Star et al. (2015) suggest that grazier adoption of ILMPs could be enhanced through improvements in spatially specific forecasting of future weather patterns. Better forecasting could further influence adoption if this was easily understood in terms of production implications. Seasonal climate forecasting related to production and expected returns has also been recognised as influential to decision making around nitrogen application rates for sugarcane producers.

5.1.2. Outcome, social and reputation risk

Outcome risk refers to the risk that on-ground actions made by farmers (such as filling in gullies or implementing an improved fertiliser regime) fail to achieve the expected outcome. In some circumstances, outcome risk (which did not include production risk) had a greater bearing on participation than input risk. Greater understanding of the type of outcome risk perceived by landholders matched to landholder type and ILMP could assist in managing outcome risk and improving uptake.

Transaction costs can also be a form of outcome risk. Particularly when landholders are reluctant to become involved in programs supporting ILMP adoption due to a perception of high levels of paperwork which could come their way once they are engaged (Rolfe and Star, 2019). There is some understanding of the extent of transaction costs incurred by sugarcane farmers in ILMP engagement (see Coggan et al. (2013b)) but no literature reporting the drivers of perceived transaction costs nor the actual transaction costs incurred by graziers as they adopt ILMP with or without government support. Understanding what generates the perception of high transaction costs and determining how this aligns with reality is valuable when designing programs that seek to engage with landholders to enhance ILMP adoption.

Table 2
Key findings about influences on ILMP adoption and future research focus.

	Key finding about influence on ILMP adoption	Potential future focus
Climate uncertainty (risk generally)		
Grazing	Climate uncertainty impacts on understanding of future profitability of practices	Could (and how could) climate forecasting reduce risk related to ILMPs? How might this be designed and integrated into ILMPs? Are demonstration sites best designed to ameliorate risk perceptions related to climate and production?
Sugarcane	Sensitive to yield variability which is more related to climate than nitrogen application	What is the potential (supply and demand) for technology (e.g. climate forecasting) to help farmers better understand and manage climate risk?
Transaction costs (economic)		
Grazing	Perception of high transaction costs associated with engaging in grants and tenders for land management change.	What is driving this perception? Does this perception match reality? If yes, what can be done to reduce risk? What support can be established to reduce actual and/or perceived costs?
Perceived and actual outcome/output risk (economic)		
Grazing	High perceived risk related to outcomes from ILMP implementation	What is driving this perception (eg fear of regulation if voluntary actions fail)? What is the impact of reputational risk on landholder decision making? What program design initiatives can be incorporated to manage output and reputational risk?
Sugarcane	Growers tend to value a few bumper crops more than avoiding many smaller losses and manage the risk of climate on this through nitrogen application often in excess of crop need. An insurance product is being considered as an alternative for how farmers manage upside risk.	Would and how would a regional champion for an insurance product create product trust and product viability? What are the implications for upstream and downstream industries, and how might these be managed?
Social networks/social norms and learning (social processes)		
Sugarcane and grazing	**Social networks and learning** are most important in the awareness and learning phases to adoption.	Do positive (for good environmental outcomes) social networks exist in key industries in GRB catchments? What group dynamics, trust and power relationships exist between landholders? Is learning transferable (what is the impact of heterogeneity on learning and what are the implications for scheme design?)
	Emotional ties to a behaviourally relevant reference group influence action	What is the potential benefit of getting visible and respected in-group members with relatable farming practices to promote practices? How will this be achieved? What is the potential for a performance bonus for knowledge transfer and adoption improve adoption (or alternative strategies)? What is the impact on effectiveness of starting with a bonus and losing it versus the

(continued on next page)

Table 2 (*continued*)

	Key finding about influence on ILMP adoption	Potential future focus
		potential to gain a bonus (as per Streletskaya et al. (2020))
Culture		
Sugarcane and grazing	If the culture of 'good' farming conflicts with ILMPs, then adoption will be negatively impacted	What is the symbolic capital of good farming in GBR catchments? Will this support or conflict with ILMPs? How will multiple decision makers and inter-generational farms impact on culture and ILMP adoption? Are there alternative measures of symbolic capital which support ILMPs and how can these be supported?
Institutional		
Sugarcane and grazing	Little is formally (as opposed to anecdotally) known about the macro influences in sugarcane and grazing and if these create an environment of conflicting 'rights' for landholders	What are the institutional carriers (rules and standards, markets and supply chain forces, legal liabilities, social networks and norms, scientific knowledge and available technologies) for land management behaviour for sugarcane and graziers in GBR catchments? How do these facilitate or constrain landholder ILMP choices Are there cases where landholders face conflicts in terms of the right way to farm? If so, how can these be dismantled?

5.2. *Capitalising on social connection*

Social processes are highlighted in the literature as having a significant bearing on the adoption of ILMPs by landholders. Social networks and interactions are particularly important during the early phases of learning about ILMPs, especially when ILMPs are difficult to trial and lessons from trials are transferable. More knowledge regarding the intricacies of the social networks of sugarcane growers and graziers in GBR catchments could facilitate better design and targeting of ILMP adoption support structures. Specific gaps remain around understanding the interaction between social capital and trust and how these interactions impact on perceived power dynamics, social learning and the process of (non) adoption. How these interactions inform policy design and how this might be trialled in the future are also recognised as current information gaps.

5.3. *Institutions creating competition over the 'right' way to farm*

Whilst there is good understanding of the role of institutions generally, and how these govern the way landholders behave in catchments such as the GBR, little investigation has been conducted to assess if and how institutions create conflicts for landholders surrounding the 'right' or 'best' way to farm. As institutions encompass all interactions and are constantly in flux, this understanding is critical to the design of policies and programs for supporting adoption of ILMPs.

6. Conclusion

The adoption of ILMPs by landholders is critical to the achievement of any level of water quality improvement targets that counter terrestrial runoff. Further, when the benefits generated by the behaviour change are external to the landholders who change behaviour, understanding motivations and barriers to adoption including and beyond economics is critical to supporting ILMP adoption. In this paper we highlight how the human dimensions of economic, social, cultural and institutional processes interact and influence the learning process to adoption of ILPMs. Further, we highlight what is known about the role these dimensions have at different parts of the learning process to adoption of ILMPs especially related to sugarcane and grazing in GBR catchments. With significant investment still occurring to support landholders adopt ILMPs in GBR catchments we highlight the need to invest in: 1) systems to support landholder decision making under climate uncertainty (risk); 2) better understanding of the extent and drivers of landholders transaction cost and processes to reduce these; 3) improved understanding of competing 'right' ways to farm, the impact this is having on land management decisions and ways to seamlessly dismantle these; and 4) improved understanding of the social processes, trust and power dynamics and what these means for ILMP adoption and support towards this. Broader understanding of human dimensions and adoption in other contexts and other countries would also be beneficial.

CRediT authorship contribution statement

Anthea Coggan: Conceptualization, Funding acquisition, Formal analysis, Writing – original draft. **Peter Thorburn:** Funding acquisition, Formal analysis, Writing – original draft, Writing – review & editing. **Simon Fielke:** Formal analysis, Writing – original draft, Writing – review & editing. **Rachel Hay:** Formal analysis, Writing – review & editing. **James C.R. Smart:** Funding acquisition, Formal analysis, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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