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Directions for social research to underpin improved groundwater management

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Abstract

Improvements in groundwater management require strategies to change human behaviour, yet there has been limited social research in the broad arena of groundwater management. This paper provides a critical review of the small but expanding literature on that topic to identify future directions for social researchers. Comprehensive search methods identified almost three hundred potentially relevant publications, which were sorted thematically and assessed in terms of their theoretical underpinning and the evidence used to support key findings. This process enabled the authors to identify a small number of high quality publications and to identify future research opportunities. The latter includes analysing how concepts of risk and sustainable yield are constructed differently by stakeholders, especially related to divisive issues concerning coal seam gas developments and reforms that reduce irrigation allocations; how governance arrangements can be improved to achieve more effective collaborative management of groundwater, especially if managed aquifer recharge is to be more widely implemented in rural agricultural contexts; and the role that trust and social norms can play in changing groundwater use practices.

Keywords

Groundwater governance; collaborative management; stakeholder engagement; community-based NRM; capacity building; landholder decision-making

Highlights

- Results of a literature review into social dimensions of groundwater management
- Gaps are identified for how social research can improve groundwater management
- Key gaps include social construction of risk and sustainable yield
- Another gap relates to building landholder capacity and how to change behaviour
- Contemporary issues include coal seam gas developments and managed aquifer recharge
1. Introduction

Research to improve groundwater management is increasingly recognising the value of drawing on theory and methods from social research. This recognition builds from a basic assumption that all aspects of the environment have been modified by human activity, including groundwater, and that improving conditions for groundwater and dependent environments requires changing human behaviour. The social sciences offer a range of practical approaches to engaging and developing human and social agency to improve natural resource management (NRM), including a few examples where social researchers have focused on groundwater management issues. Ostrom’s groundbreaking work promoting the role of social norms in NRM governance built on her doctoral thesis examining groundwater management in California (Ostrom, 1965, 1990). In Australia, the work on justice principles by Syme and colleagues (e.g. Syme and Fenton, 1993; Syme et al., 1999) is partly based on research involving reforms in groundwater allocations. More recently, this and other groundwater-related journals have become more open to studies influenced by sociological perspectives. Agencies funding groundwater research, including Australia’s National Centre for Groundwater Research and Training (NCGRT), now expect the adoption of inter-disciplinary approaches (also see Khan, 2012; Wood, 2012). As social researchers in the NCGRT, we recognised an immediate need to review the small but expanding body of literature on the social dimensions of groundwater management. In this paper we draw upon that review to identify an agenda that would enable social researchers make an important contribution to improved groundwater management.

A traditional policy and research focus on surface water management has left major knowledge gaps involving groundwater policy and management (Burke et al., 1999; National Water Commission, 2008; Nevill, 2009), despite the world’s heavy reliance on groundwater. In Australia, for example, groundwater comprises 30% of all water consumed and people in many regions rely almost entirely on groundwater for urban water supply or irrigated agriculture. A challenge for groundwater management and research is that the resource is largely invisible and its interconnections with surface water are poorly understood or mapped. This exacerbates the difficulty faced when trying to modify human behaviour for improved groundwater outcomes as the intended outcomes are not easily or immediately identified, observed or monitored, and are thus more open to contention.

Issues in groundwater management also mirror those faced by NRM more broadly, so it is useful to identify the ways in which social research is helping to improve the wider NRM field. NRM problems are often entrenched and intractable (or “wicked” – see Rittel and Webber, 1973; Allan, 2010) and in most cases, no single actor is capable of addressing these kinds of “wicked” issues on their own. A typical social research response is to focus on strategies to engage and build human capital, i.e. the individual skills, abilities and wellbeing that contribute to our own and other’s satisfaction (Castle, 2002); and social capital, i.e. the social relations, networks, trust and norms that arise between people when they interact, and which can then lead to further benefits (Sobels et al., 2001). This focus has led to strategies to engage stakeholders more effectively both as individuals and as collectives (Curtis, 2007; Brown, 2008), and to enable more inclusive and collaborative approaches for regional NRM governance (Lockwood et al., 2010).

Governance involves the interactions between social structures, processes and traditions that determine how power in society influences how decisions are made, how responsibilities are exercised and who has a say in all of this, and how (Lockwood et al., 2010). In many cases, land and
water degradation occur as a result of deficiencies in governance arrangements. That is, our societies have been unable to establish effective formal and informal arrangements to make and implement sound decisions. Indeed, in recognising that the current global water crisis is mainly a crisis in governance, Mukherji and Shah (2005) have called for a change in paradigm away from a focus on “groundwater management” towards a more inclusive and holistic focus on “groundwater governance”. “Management”, they argue, can imply expert-driven processes derived from “mathematical model-building exercises” of hydrologists and “the formulation and implementation of groundwater laws” by water managers, whereas the term “governance” takes into account concerns of hydrologists and other experts, along with policy makers, groundwater users and other stakeholders.

Groundwater issues are especially complex for science to address given that causes and effects are particularly difficult to discern with certainty. It is often difficult to link an intervention with observed changes in resource condition, and effective intervention often requires substantial effort over a considerable period of time. Social researchers engaged with similar kinds of challenges have developed processes for implementing adaptive management at regional scales (Allan et al., 2008), and improving evaluation of NRM programs (Curtis et al., 1998). Even where proposed policy and practice reforms are based on solid scientific evidence, such as reducing groundwater allocations for irrigation, they are often contested and have mixed impacts on society. Social researchers are often engaged to assist in assessing the social impacts of such reforms, with some recommending techniques that are empowering and proactive (Howitt, 1989; Vanclay and Esteves, 2011). There are also many examples in NRM where technological solutions have not been widely adopted because they were not socially acceptable (Pannell et al., 2006). Understanding the role of social norms is one strategy that can be used to influence adoption of new practices (Minato et al., 2010).

There are numerous opportunities then for social research to contribute to improved groundwater management and governance. In reviewing the existing literature on social dimensions of groundwater management, our aims were to:

1. Provide an overview of the current literature related to social dimensions of groundwater management.
2. Identify areas where social researchers can contribute to knowledge.
3. Provide a sound foundation for social research within NCGRT’s work, including the identification of worthwhile topics for doctoral and post-doctoral research.

The paper begins with an overview of the search and analytical methods used for the review and an introduction to the five themes subsequently identified. The literature is then briefly reviewed according to those themes to identify knowledge contributions and gaps. We conclude by summarising recommended future directions for social research related to groundwater management.

2. Literature search and analysis methods

Three steps were used in an iterative, reflective way to identify relevant literature: a literature search; identifying and prioritising the most relevant literature; and organising the literature into themes.
2.1. Literature search

Identifying literature on social dimensions of groundwater management requires ingenious search methods. The terms “groundwater”, “ground water” and “aquifer” are a straightforward way to identify groundwater-related publications, but there are no useful terms we could have adopted to narrow the results to focus on social dimensions of groundwater management. Our first trial search was of the Informaworld database, and we used the keywords “groundwater” in title/abstract AND “social” AND “sustainability” in all fields. Only five results were deemed to be relevant, but we were able to use these publications to identify others. To further build our initial database, we also searched an existing EndNote database on social dimensions of NRM more broadly that had been developed by one of the authors over nearly a decade of research. We then expanded on that initial database using a combination of snowball searches from the papers and authors identified, and keyword searches of specific journals and journal databases. The snowball searches included reading papers to identify other relevant papers the author had cited; using journal database facilities to identify other papers that had cited the paper; and undertaking searches for literature by specific authors and/or examining selected authors’ web pages. EndNote’s group facility was used to organise the publications identified according to perceived relevance to social dimensions of groundwater management from an initial reading of the abstract (i.e. (1) most relevant; (2) moderately relevant; and (3) peripherally or not relevant). Additional searches using groundwater related terms were also undertaken of specific social science journals (e.g. Society and Natural Resources, Geoforum, World Development and Local Environment) and of the Australian Public Affairs – Full Text (APA-FT) to address perceived gaps in our database. While we had a practical interest in research that would be relevant to the agricultural context in Australia, we monitored the results to ensure that we had a geographical spread of studies from across the world. Our review focused on peer-reviewed publications but included some technical reports.

2.2. Evaluating and prioritising the most relevant literature

As the body of literature under consideration expanded, we recognised the need to develop a more coherent approach to prioritise publications to be reviewed in-depth, especially given that by the end of 2011 we had identified nearly 300 most relevant publications. We therefore further assessed the most relevant publications against two criteria:

1. Evidence of empirical social research: About two-thirds of the groundwater publications most relevant to social dimensions were descriptive analyses or policy reviews. Most of these were written by groundwater specialists seeking to address social dimensions of groundwater management. We therefore examined publications for evidence of original empirical research, prioritising those that used social research methods. From a pool of almost 100 publications that were based on empirical research, we identified about a quarter that appeared to draw on established social research methods for in-depth review. We found deficiencies in many of these publications, including a failure to draw on established theoretical frameworks and inadequate definition of social constructs as basis for survey instruments, as detailed in the themed sections below.

2. Underpinned by social theory: We also examined the publications to identify whether the research was underpinned by social theory and could therefore make a more useful contribution to the scientific literature.
These two criteria were particularly helpful when selecting a set of publications for in-depth review. An Excel spreadsheet was created to assist in this process, allowing the most relevant publications to be organised in multiple ways: topic, geographical location or methods used.

2.3. Organising the literature into themes

Key themes emerging from the literature matched many of the typical themes pursued by social researchers of NRM. The process that led to the identification of these themes involved a number of steps, including the creation of a mind map where we identified 17 key themes and 37 sub-topics. We reduced these themes to five overarching topics, and selected at least one publication per theme for in-depth review. A more detailed report based on this review is available (Mitchell et al., 2011).

3. Thematic analysis of groundwater literature

As depicted in Figure 1, there is a trend from more general themes towards themes more specific to groundwater management in rural agricultural contexts. Theme 1 explores the effect of power and influence on groundwater management, and conflict over the perceived unsustainable use of groundwater. This broad theme provides a strong rationale for social research in groundwater management and thus underpins much of the discussion of the remaining themes. Theme 2 relates to social impact assessment. We highlight the application of a justice-based theoretical framework to assessing impacts of reforms to reduce groundwater allocations for irrigation (Syme et al., 1999).

Agricultural groundwater contexts have also been used to explore opportunities for community self-regulation of resource use, and this is identified as Theme 3. Under this topic we identify what we think is important literature about the role of social capital, social norms and collective action (López-Gunn and Cortina, 2006; Mustafa and Qazi, 2007; van Steenbergen, 2006; López-Gunn, 2003). Social research expertise is often called upon when researchers or planners seek to develop improved stakeholder engagement strategies (Theme 4), including in groundwater research,
management and policy implementation (e.g. Zellner, 2008). Under this topic we highlight the modified use of decision support modelling techniques to enhance collaboration, participation and social learning (Henriksen and Barlebo, 2008). The final theme is about understanding farmer decision-making (e.g. Bekkar et al., 2009), an important topic given that NRM outcomes continue to be shaped by the actions of a relatively small number of rural landholders.

3.1. Theme 1: Power, influence and conflict over “sustainable yield”

Most of the papers reviewed that explored how power and influence are exerted did so in the context of conflict over groundwater access, especially where there were conflicting interpretations of how that resource could be used sustainably (e.g. Shriver and Peaden, 2009). Many of the papers in this theme were based on sound research methods and were underpinned by social theory (e.g. Birkenholtz, 2008; Bolin et al., 2008; Budds, 2009 – all using political ecology to frame their investigations), setting them apart from the bulk of the literature we identified during our review. The investigation by Budds (2009) provides a particularly forceful case to explain why it is crucial to incorporate a social dimension to groundwater research.

Budds (2009) critically examined a hydrological assessment undertaken by a contractor for a government agency seeking to limit groundwater extractions in La Ligua basin, a groundwater dependent agricultural region north of Santiago in central Chile. In this case, the social context should have been critical to assessing current and future impacts of groundwater use, but was effectively ignored by the contracting agency. Their modelling failed to incorporate data on the widespread illegal use of groundwater, an amount that was estimated to be almost twice that of actual legal extractions. The illegal groundwater use was predominantly by peasant farmers. The wealthier and better educated farmers upstream were more able to secure groundwater allocation rights, including substantial additional amounts of water they had sought prior to the hydrological assessment, and which was secured as a result of the assessment. The effect of the assessment was to maintain privileged access to groundwater by agribusiness estate plantations upstream at the expense of most groundwater users who were peasants located downstream. Budds’ (2009) investigation illustrates how efforts to produce purely technical and neutral assessments can do the opposite, effectively using science to reinforce prevailing and intractable injustices in natural resource use.

Other researchers have analysed contexts where there are conflicting interpretations of how groundwater resources can be used sustainably (e.g. Shriver and Peaden, 2009; Weber et al., 2011), and where the impacts of groundwater use are spatially dislocated from those who benefit (e.g. Bolin et al., 2008). Such investigations reinforce the need to move away from expert-driven management approaches towards more inclusive governance approaches that encourage co-management among a wider range of stakeholders at different geographical scales (Mukherji and Shah, 2005; Taylor et al., 2009), especially where groundwater resources traverse boundaries (e.g. Feitelson and Fischhendler, 2009; Morris et al., 2006).

The literature cited above also connects with debates over the terms used to describe the situation where intensive groundwater use exceeds sustainable, safe or acceptable levels (Sophocleous, 2000; Custodio, 2002; Alley and Leake, 2004), and suggestions for how to improve groundwater management in these contexts. These suggestions include adopting processes that draw on adaptive management principles (Maimone, 2004; Seward et al., 2006) and/or stakeholder engagement.
Underpinning these suggestions is an appreciation that the conflicting interpretations of sustainable groundwater yield reflect different ideas about how knowledge is constructed (Seward et al., 2006). We therefore recommend research that examines how key experts and other stakeholders socially construct the concept of sustainable yield, and the impact this has on the allocation of groundwater resources for environmental and social benefit. This research would build on studies examining social construction of other NRM concepts and issues (e.g. Greider and Garkovich, 1994; Kalof, 1998).

Risk perception can also be expected to vary across stakeholders (Slovic, 1999), especially given that “lay” people usually assess risk differently to “experts” (Douglas, 1994). In the groundwater context, risk management is an important consideration for rural landholders, public land managers and those responsible for the management of infrastructure such as surface dams. The conjunctive use of groundwater and surface water is increasingly being highlighted as a way of managing risks associated with a highly variable Australian climate. In Australia, as in the United States, the rights of coal seam gas (CSG) miners to employ “fracking” are being challenged by farmers and conservationists because of perceived risks of damage to water quality in aquifers, streams and lakes. While there is an established body of research into the social acceptability of carbon capture and storage (e.g. van Alphen et al., 2007), research into stakeholder perceptions of risks associated with coal seam gas is in its infancy (Shackley et al., 2006; Jacquet, 2009). Given the scale of public controversy over CSG mining, we believe there is considerable scope to inform those policy debates by investigating how CSG risks are perceived and communicated.

3.2. Theme 2: Social impacts of changes in resource access

Changes in resource access have been a key element of government responses to environmental degradation and water scarcity. Such reforms have included reductions in groundwater entitlements and the introduction of water trading to groundwater (e.g. Thompson et al., 2009) and conjunctive use contexts, such as where seasonally excess water is “banked” in aquifers for future use (Schlager, 2006; Contor, 2009). Irrigators, as the most affected stakeholders, have recounted to social researchers how frustrating, unfair, uncertain and confusing water sharing planning and the water reforms process have been (e.g. Kuehne and Bjornlund, 2006). A review of social impact assessment processes in Australia concluded that they have been underutilised, undertaken too late in the decision-making process, lack quality, and focus on economic impacts while ignoring social impacts (Baldwin et al., 2009). Yet some Australian researchers have been at the forefront of developing solid theoretical foundations for social impact assessment (Howitt, 1989; Syme et al., 1999; Syme and Nancarrow, 2006; Vanclay and Esteves, 2011). Given the existence of strong social impact analysis theory and methods, there is considerable scope for these to be integrated into future research efforts involving proposed groundwater reforms, including reforms that develop groundwater markets.

We identified Syme et al. (1999) as a key paper in this theme because of the paper’s solid theoretical foundation in the concepts of fairness and justice, and the rigorous empirical research used to explore these in the context of changes in resource access. Their paper summarises several case studies used to develop theories of justice, equity and fairness in response to reforms implemented by the Australian government. After discovering that existing equity and procedural justice theories were inadequate to explain public evaluation of water allocation decision-making, Syme et al. (1999)
developed a set of fairness principles and a fairness heuristic that could be used to assess the justice of such decisions. These fairness principles were tested and further developed in subsequent studies using consistent survey items into how respondents perceived these universal fairness principles. Their research demonstrates the value of multiple studies enabling researchers to build their understanding of theory and methods over time. With consistency in some of the Syme et al. (1999) survey items across all studies, direct comparison across time and locations was possible, enhancing the credibility and impact of findings. Syme et al. (1999) found that the public considered both distributional and procedural justice when deciding whether water allocation processes were fair. Additionally, they concluded that most of the community assessed fairness as both situational – relating to specific water allocation decisions and each community’s unique context; and universal – relating to overarching principles, such as a community’s rights to have a say in allocation decisions, adherence to principles of procedural justice in the decision-making process, and rights of the environment.

3.3. Theme 3: Community self-regulation: role of social capital, trust and norms

There is increased interest in exploring the potential for community self-regulation of groundwater given the trend to devolve responsibilities away from centralised authorities (e.g. Wilder and Lankao, 2006), problems associated with increased privatisation (Bluemling et al., 2010), and the difficulties government agencies face in regulating groundwater use and preventing over extraction. Defined as the “collective management of groundwater by water users” (Wester et al., 2011; López-Gunn, 2003), the concept is also referred to as local, community-based and/or participatory management (van Steenbergen, 2006; Yamamoto, 2008; Sandoval, 2004). In Gujarat, India, for example, government agencies in partnership with local non-governmental organisations have nurtured the development of farmer cooperatives and other credible local institutions (Tewari and Khanna, 2005). Drawing on this and other South Asian, Middle Eastern and North African examples, van Steenbergen (2006) examined the role of “informal” norms where local management of groundwater has been promoted. With the proliferation of privately constructed wells across South Asia, van Steenbergen concluded that informal norms based on moral imperatives (or “injunctive” social norms – see Minato et al., 2010) have been the most effective means to control the consequences of excessive private development of groundwater use. Referring to a case study in Mexico, Wester et al. (2011) also describe difficulties faced by external authorities attempting to promote self-regulation of groundwater. Ross and Martinez-Santos (2010) confirmed Ostrom’s (1990) suggestion that self-regulation is more likely to work for smaller scale groundwater systems than larger ones.

From these papers we conclude that community self-regulation is most effective when it evolves through collective action, building on the strength of existing social capital, including trust and norms. Yet most of the literature identified for this theme explored constraints on community self-regulation, government actions that undermined social capital, and cases where external efforts to promote self-regulation were ineffective (e.g. López-Gunn and Cortina, 2006; Mustafa and Qazi, 2007; and the papers cited above). Existing literature had little to say about how to build and engage community capacity for self-organisation. We identified one paper (Diwakara, 2006) that explored the role of social capital but the analysis was based on vaguely defined constructs and there was little interpretation of results. Yet there is a body of research exploring attributes of social capital
that could provide researchers examining groundwater management with a rich pool of theory and research tools to draw upon. For example, de Vos and van Tatenhove (2011) described the evolution of trust relationships between fishers and government through the development of co-management arrangements in the Netherlands. They concluded that development of co-management arrangements was inevitable and necessary in building trust between fishers and government. By applying these well-conceptualised notions of collective action, trust and norms, there is considerable potential to use research to support community self-regulation of groundwater in Australia and other industrialised world contexts – both as a means to improve community regulation but also as an influence on landholder decision-making more broadly, as further discussed in the sections below.

3.4. Theme 4: Stakeholder engagement

Stakeholder engagement is a broad topic that overlaps with other themes in this review. We adopt the term “stakeholder” to indicate the range of people who might participate, encompassing both those who are influenced by a particular action, organisation or phenomenon, and those who influence that action, organisation or phenomenon (Freeman, 1984). In the groundwater context, stakeholders can include experts, policy makers and users (Zellner, 2008). The implication is that decision-making is not just done by experts and policy makers, but that users are also engaged as key stakeholders. Community self-regulation of groundwater exemplifies the “citizen control” end of Arnstein’s (1969) ladder of citizen participation. However, Arnstein’s typology has been criticised for idealising “citizen control”, potentially disparaging a wider range of participation approaches that might be appropriate in different contexts (Collins and Ison, 2009; Ross et al., 2002).

Baldwin (2008), for example, investigated an irrigation community’s effort to initiate a system of co-management of groundwater with government through a water planning process in the Lockyer Valley of southern Queensland, Australia. She concluded that groundwater management should draw on values-based rules developed by stakeholders to reflect Ostrom’s principles for improving self-governance of common pool resources, but that these should be enforced by government. Taylor et al. (2009) also concluded that government authorities should maintain a role in groundwater management. Sparked by the notorious 2000 case of lethal contamination of groundwater supplied for domestic use in Ontario, Canada, they analysed the challenges involved in efforts to prevent future cases of groundwater contamination. They concluded that a nested governance approach (Margerum, 2007; Neef, 2009) would facilitate a more flexible approach to groundwater system investigations. Drawing on this idea, they proposed a range of strategies aiming to strike a balance between local needs and perspectives, and the requirement that groundwater data be collected consistently for compatibility with data collected elsewhere. Ross and Martinez-Santos (2010) argued that adaptive management strategies adopted by locally autonomous forms of governance may be quicker to adapt to changing needs and conditions than traditional forms of regulation.

Henriksen and Barlebo (2008) provide an example of how stakeholder engagement can be integrated into decision support systems using adaptive management principles, in this case through the development of a Bayesian Network model. The paper is one of many where stakeholders have been engaged in planning through participatory modelling (Martínez-Santos et al., 2008), agent-based modelling (Zellner, 2008), integrated assessment modelling (Letcher and Jakeman, 2003) or
cooperative modelling (Tidwell and van den Brink, 2008). Henriksen and Barlebo (2008) analyse the use of Bayesian Networks (BNs) as a tool to enable stakeholder engagement in policy implementation and evaluation. BNs are a type of decision-making tool with a graphical structure that maps out and quantifies causal links between variables. According to Henriksen and Barlebo (2008), the advantages of BNs include: (1) they can be updated as new information becomes available; (2) they can integrate data from multiple sources and disciplines; (3) they are good at modelling complex problems where there is uncertainty in the data; and (4) they can be used to easily communicate relationships between variables to stakeholders because the graphical model presents a visual picture. BNs are thus particularly suited to participatory processes because stakeholders are engaged in defining variables, providing opportunities to identify all relevant information and clarify gaps, and thus incorporating multiple forms of knowledge. In turn, the participatory process has the potential to strengthen relationships among stakeholders and build commitment to management decisions before being implemented. Use of BNs also enables the engagement of stakeholders to be adaptive to change, and accommodate the uncertainty and complexity associated with environmental and social systems. In this sense they promote stakeholder engagement as a process of social learning (Schusler et al., 2003; Reed et al., 2010).

Henriksen and Barlebo (2008) conclude that there is scope for further research to address questions relating to which stakeholders should be involved in the model building processes, and in what capacity. There is also scope within integrated modelling, including using BNs, to improve the way social variables are measured and integrated, such as those related to stakeholder values, beliefs, norms and attitudes. We also recognise the need to compare approaches for their effectiveness in assisting stakeholders to reconsider their positions, and/or propose alternative management approaches. The hidden and complex nature of groundwater provides an ideal context for social learning, including within an adaptive management framework, to address the uncertainties and multiple interpretations of risk. A contemporary context for such an investigation could be the proposed use of managed aquifer recharge in Australia to capture surface water from large flood events for later supply for irrigated agriculture. It would be timely to engage stakeholders early to provide input into the governance arrangements needed to ensure the practice effectively meets the needs of stakeholders and the environment.

In the previous section, we referred to the value of investigating trust as an attribute of social capital to improve community capacity for self-regulation. Trust is also a key ingredient shaping the success of collaboration between government agencies and groundwater users, and an outcome of effective engagement that can be drawn upon by agencies and their staff in the future. Future research could assess the level of trust and identify key factors affecting irrigator trust in agencies and their staff in the groundwater context. Such research could provide an opportunity to explore the efficacy of important contemporary theory (e.g. Values–Beliefs–Norms theory – see Stern et al., 1999) that focuses on a small range of personal factors to predict behaviour.

3.5. Theme 5: Rural landholder decision-making

Concern for stakeholder engagement logically leads to the final theme which relates to rural landholder decision-making. Rural landholders have a major role in groundwater management because they have entitlements to groundwater, their land use and management can impact on groundwater quantity and quality, and most groundwater is located under land they manage.
However, our review found only a few papers relevant to this theme. Groundwater research has focused mostly on the resource, rather than the actors who use and manage the resource, and there is very little research that integrates social and biophysical aspects (groundwater users’ behaviour with aquifer dynamics) (Hammani et al., 2009). Only a limited set of factors that might influence landholder decision-making in the groundwater context has been explored. We highlight Bekkar et al. (2009) as one of the few studies that attempt to explain landholder behaviour. Two earlier papers by Albrecht (1990, 1995) explored the links between landholder behaviour and potential influences on adoption.

Bekkar et al.’s (2009) study examined three contrasting situations in Morocco: the Tadla (a large area where farmers rely heavily on groundwater); Taroudant in Souss Valley (a small public irrigation scheme where severe drought has seen large areas converted to drip irrigation); and the Berrchid Plain (a private irrigation scheme under urban pressure). The authors used a survey and interviews to explore landholder attitudes to the management and ownership of groundwater, including knowledge regarding physical representation of the aquifer, perspectives of the reasons for overdrawing, ideas for solutions to overdraining, and attitudes regarding potential for aquifer renewal. They were able to classify their case studies according to the nature of access (individual vs. collective; public vs. private); use of water saving irrigation equipment; and whether landholders adopted offensive or defensive groundwater use strategies. Offensive strategies included installing additional individual tubewells, planting new crops of high water use and high value, and installing new water-saving irrigation techniques (e.g. drip irrigation). Defensive strategies included maintaining current levels of water use through existing tubewells, planting less water intensive crops, and reducing areas used for cropping. The authors explained that strategies adopted seemed to relate to ownership patterns and the nature of access (those with individual access tended to use offensive strategies, and those with collective access utilised defensive strategies).

Albrecht (1990) explored a range of adaptations that farmers in the Texas High Plains made in response to the depletion of their primary source of irrigation water, the Ogallala Aquifer. The author tested relationships between changes in the aquifer and four variables: farmers’ positions in relation to the saturated zone, financial condition, farm structure, and social and demographic aspects. He found that farmers adopting more expensive irrigation technologies (e.g. centre-pivots) had larger farms with a more extensive groundwater supply, and were in a better position to justify a major irrigation investment. Albrecht (1995) provided an empirical comparison of the views of farmers and the non-farm public on three critical Edwards Aquifer water issues. He found the non-farm population was more likely than farmers to believe that the water problems associated with the Edwards Aquifer were severe. Farmer respondents placed a higher priority on agricultural water uses and were more likely to oppose government involvement in management decisions.

In Australia, Kuehne et al. (2008) examined the influence of irrigator values toward family, land, water, community and lifestyle on their management. Based on research in the Namoi Valley with a substantial cohort of groundwater dependent irrigators, the authors classified irrigators into three types: (i) investors (i.e. profit oriented, 25%); (ii) lifestylers (lifestyle oriented, 25%); and (iii) providers (family-succession oriented, 50%). They found differences between each of these types in their decision-making behaviour. Family and other non-commercial considerations were identified as highly influential, but the extent of this influence differs between irrigator types. A trend among investors, for example, is to adopt decisions motivated by profit maximisation early in life, but then
become providers after getting married and having children, when their decisions are more heavily influenced by family considerations.

Several papers explored farmer adaptation strategies and groundwater use without analysing factors influencing decisions. Mudrakartha (2007) identified a great variety in how farmers adapted to drought conditions, reinforcing the need for policies that can complement people’s existing efforts and adaptive strategies at local levels. Birkenholtz (2008) identified examples where conflicting environmental knowledge between farmers and government “experts” exacerbates mismanagement of over-exploited groundwater resources (also see Clarke and Brake, 2009). Several papers showed how water and/or electricity pricing can be used as a surrogate means to limit groundwater use (e.g. Shah et al., 2008; Zhang et al., 2010).

Our review failed to identify research using established social theory to examine landholder behaviour in the groundwater context. Clearly, this is an important gap. While some of the research examining decision-making by surface water irrigators will be useful, we argue that groundwater contexts are different, and established theory suggests that context is critical in explaining rural landholder decision-making (Pannell et al., 2006). As noted in the previous section, there is a trend in social research focussed on environmental behaviour drawing on Values–Beliefs–Norms theory (Stern et al., 1999). Our view is that this and related theories arising from the theory of planned behaviour (Ajzen, 1991) are adequate for explaining the conservation behaviours of the general public, but is currently not capable of taking into account the larger set of factors influencing decisions by rural landholders. These additional factors include attributes of specific practices; government interventions to influence landholder decisions; global commodity prices; and the existence/development of social norms through local organisations. An additional layer of complexity is emerging as a result of the trend to non-farmer (by occupation) rural landholders, and a substantial cohort of absentee owners (Mendham and Curtis, 2010).

4. Conclusions

Our review of the international literature exploring social dimensions of groundwater management was conducted over 2010–2011, revealing almost 300 peer-reviewed publications deemed as being relevant. These publications were assessed according to the extent they were based on relevant social theory and on original empirical research using established social research methods. Using an iterative process we categorised the literature into five themes: power and influence; social impact assessment; self-regulation; stakeholder engagement; and farmer decision-making. Our review identified some important publications that demonstrate the potential contribution of social research to efforts to improve the efficacy of groundwater management (e.g. Budds, 2009; Birkenholtz, 2008; Weber et al., 2011). We also identified a larger body of research where groundwater specialists had sought to incorporate approaches and learnings from the social sciences (e.g. Mukeherji and Shah, 2005; Henriksen and Berlebo, 2008), especially to improve stakeholder engagement (Morris et al., 2006; Wester et al., 2011). Upon critical analysis, we concluded that much of the literature identified during our research lacked an adequate foundation in social theory or was not based on sound research methods.

Drawing on our review, our knowledge of the more expansive social research contributions to NRM, and our understanding of the groundwater context, we have identified a number of research topics
that could be pursued by social researchers. Sustainable yield remains a problematic concept for groundwater managers and scientists. Social researchers could make an important contribution here by describing, explaining, and perhaps assisting in reconciling the different ways stakeholders define or interpret “sustainable yield” and how those different interpretations affect their attitudes and behaviours, and in turn, policy and management. The contemporary proliferation of CSG developments in Australia, Canada and the United States that have the potential to impact negatively on aquifer integrity and water quality also provides a context to examine stakeholder perceptions of risk, and the nature and the role of trust between stakeholders. Theoretical constructs and frameworks associated with justice, collective action, trust and social norms can be explored further as researchers contribute to efforts to undertake social impact assessment processes, develop improved collaborative management and community self-regulation, and identify interventions designed to influence landholder behaviour.

A potentially significant groundwater-related development relates to managed aquifer recharge (MAR) in agricultural landscapes where surface and groundwater are managed conjunctively to reduce evaporation losses from surface storages, recharge depleted aquifers and provide for the “banking” of surplus water during higher rainfall periods for later use during lower rainfall periods. As with CSG, MAR is likely to provide opportunities for cutting-edge social research that contributes to contemporary public discourse and policy development.

Some of the suggested future research directions have become part of the social research contribution to the NCGRT, including through the research of PhD students and post-doctoral research fellows. This research includes studies exploring the relationship between trust and trustworthiness in the context of landholder and agency relationships; risk perception amongst groundwater stakeholders; the potential for resilience thinking to underpin efforts by resource-dependent communities to identify alternate futures; the social acceptability of MAR in farming landscapes; and groundwater stakeholder perceptions of resource condition targets for the application of environmental water. The NCGRT social researchers are also contributing to integrated projects examining the environmental, economic and social impacts of water reform and climate change.

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