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# BEYOND ADOPTION: THE NEED FOR A BROAD UNDERSTANDING OF FACTORS THAT INFLUENCE IRRIGATORS' DECISION-MAKING

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**Abstract**

*The conventional approach to encouraging water use efficiency among irrigators has been to promote the adoption of technology and tools designed to achieve water use efficiency. However, adoption rates of such technology are low. Relatively little is known about what influences irrigators decisions in their day-to-day irrigation practices. The adoption literature focus is from the perspective of the providers of innovative technology with little information from the perspective of the intended users of the technology: growers. Adoption decisions, although important, are only one aspect of farm decision-making. There is a need for research into irrigators' decision-making that broadens the focus from adoption per se to other sorts of irrigation/farm decisions including exploring the experiential and intuitive knowledge of growers and developing an understanding of personal, socio-cultural and structural factors that may influence decisions. This will assist in the development of water saving tools and initiatives that better meet irrigators' requirements.*

**Keywords**

Water use efficiency, Adoption of irrigation technology, Irrigators' decision-making

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## Introduction

Water use is of vital importance in Australia, historically a drought affected country. In recent years much of Australia has experienced extensive periods of drought. In the twentieth century natural catchments and river systems such as the Murray-Darling underwent transformation associated with damming for use in the irrigation of agricultural products and for the generation of hydro-electric power. The current long-standing drought has led to significant water shortages resulting in severe water restrictions in most of eastern Australia including all capital cities. Many irrigators are entirely without irrigation water or are receiving substantially less water than their usual allocation. It is therefore critical that irrigators make the most effective use of the available irrigation water. Governments are under increasing pressure from citizens to strive for environmentally beneficial and sustainable outcomes associated with water use. The irrigation sector has been widely criticised (Perry, 2008) as it

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is perceived as using too much water through wasteful irrigation practices and for growing 'unsuitable' water intensive crops, in particular cotton and rice.

The conventional, or mainstream, approach to encouraging water use efficiency[1] among irrigators has been to promote the adoption, by irrigators, of technological innovations designed to assist irrigators to use their irrigation water more efficiently. Technological developments designed to achieve water use efficiencies in irrigation industries include various 'tools' aimed at optimal irrigation scheduling and application. These tools vary in complexity from simple devices such as soil moisture probes to complex integrated systems using sophisticated software to collect and interpret a variety of data including weather readings, soil moisture levels, plant development needs and evapotranspiration rates. The more complex of these tools are known as irrigation scheduling systems or decision support systems [DSSs] (see Inman-Bamber and Attard 2005 for an overview of available software tools). They are aimed at assisting irrigators to determine optimal times to water and how much water is sufficient for plant growth needs, minimising any over-watering that otherwise occurs.

Uptake of such technological innovations has been slow and is not occurring at rates that impact on the amount of water used by irrigators (Everingham et al., 2006; Montagu et al., 2006). This paper argues that the (conventional) focus on the adoption of water saving technology offers limited benefits and that there is a need for a broader approach that explores irrigator's decision-making and considers the broader social structures that irrigators face. We begin by discussing environmental concerns and the goal of improved irrigation water use efficiencies. We outline the traditional transfer of technology approach to the adoption of agricultural innovations that has been applied in the context of environmental innovations in the irrigation sector. The low levels of adoption of irrigation technology are then considered as are the influences on adoption decisions including a discussion of identified barriers and constraints to adoption. From a sociological perspective, we critique the neo-liberal philosophical underpinnings of the adoption approach and highlight the assumptions and presumptions inherent in this approach. We argue for a broader approach exploring irrigators' decision-making from the perspective of the irrigators themselves. Such an approach will take into account personal, social, cultural and structural factors that influence those decisions. This knowledge will enable modification of technological innovations to better reflect irrigator needs and the implementation of other support mechanisms designed to yield improvements in water-use efficiency. It will also provide useful information that will contribute to the development of policy initiatives aimed at addressing structural factors identified as influencing irrigators' decisions and practices (Pannell, 2008).

## Public concerns and Government environmental agendas

Governments have a broad responsibility to pursue 'the common good' although how this responsibility is interpreted will vary according to the political philosophies of governments, and society. In countries such as Australia, government responsibility has been underpinned by neo-liberal, or economic rationalist, economic philosophy in which individual freedom and private enterprise are highly regarded (Gray & Lawrence, 2001; Sheil, 2000). This view holds that 'the free market' is the most efficient (and preferred) mechanism by which society can operate and, assumes primarily, private ownership of productive resources. Using these premises, governments may promote initiatives, or 'tools', that will assist the free market to become more efficient. Profitability and growth are both drivers and goals of business operators in neo-liberal economies. However, economic growth and development is now recognised as incurring substantial environmental costs[2]. As a consequence, the mainstream public worldwide are concerned about climate change that is linked to economic activity, in particular greenhouse gas and carbon emissions. In Australia, scarcity of water in many agricultural areas and years of drought has led to increasing public concerns about the sustainability of much of Australia's water supply (Connell, 2007; The Economist, 2007; Kleinman & Houston, 2007; Shepheard et al., 2006).

In addition to facilitating economic growth, governments need to respond to public opinion and scientific evidence to work towards a more sustainable use of natural resources, which includes water. Initiatives aimed at using less water are targeted at urban and rural users involving a combination of market-based strategies, such as financial incentives and non-market strategies such as regulatory approaches. These initiatives include financial subsidies for the installation of domestic rain-water tanks and promotion of grey-water and storm-water recycling systems. Water restrictions have been implemented in most capital cities, regional centres and rural towns. Reduced water consumption is also encouraged through increases in the cost of water and introduction by water supply authorities of a 'user pays' system of charging for water. Government promotion of more efficient use of irrigation water can be viewed in this context (Connell, 2007; The Economist, 2007).

Irrigation industries are major users of water (ABS, 2008; National Council of Young Farmers, 2006). Irrigated pasture (for grazing) uses 27% of irrigation water followed by cotton 16%, rice 12% and sugar cane 10% (ABS 2008) The Murray-Darling Basin accounts for almost two-thirds of Australia's irrigated land area and uses over two-thirds of Australia's irrigation water (ABS, 2008). Governments are keen to reduce water consumption in irrigation industries while endeavouring to maintain the viability of the sector. Governments also have a strong interest in maintaining Australia's ability to produce foodstuffs for the domestic population's own consumption and for the export market, in which irrigation plays a vital role.

The main goal, or objective, underpinning the discussion in this paper is improved water use efficiency. This goal is held by governments in their efforts to achieve environmental sustainability, scientists and researchers, members of the general public and often the landholder irrigators themselves. To achieve this objective, an important focus of water-saving initiatives has been directed toward individual irrigators encouraging them to be more efficient in their use of irrigation water specifically by the adoption, and use, of water saving technology[3]. The neo-liberal approach presumes the free-market remains the best way to achieve efficiency outcomes and that the adoption of this technology will occur as a result of the potential increase in profit it promises.

## The adoption approach

The adoption approach for addressing environmental issues, in this case water use, can be seen as analogous to the 'adoption' approach that has traditionally been associated with the promotion of technological innovations in the broader agricultural sector. This traditional adoption approach views 'knowledge' as developed by experts, namely scientists and engineers. The new knowledge is then imparted, or transferred, to farmers, frequently through the process of agricultural extension. This transfer of technology approach views adoption behaviour to be a result of social-psychological processes based on the model of diffusion of innovations (Rogers, 2003). These social-psychological processes are considered to influence individual decision-making in relation to adoption, viewing adoption decisions as occurring in a set of linear sequences, or stages, from awareness of an innovation to information gathering to evaluation to trial and eventually to adoption (Vanclay & Lawrence, 1995). This leads to farmers being classified into categories indicating their readiness to adopt innovations for example innovators, early adopters, late adopters and laggards (Rogers, 2003).

The traditional transfer of technology and diffusion approach to encouraging adoption has been criticised as being 'top down' and for failing to consider and value local farmer knowledge. Farmers are not viewed as active, contributing participants in knowledge development. Instead farmers are presumed to be passive recipients of new knowledge (Kloppenburg, 1991). Notwithstanding such criticism, traditional models of adoption such as transfer of technology approaches remain popular among organisations funding research projects, with such organisations requiring behavioural outcomes in terms of adoption of technology (Dunn et al., 1996).

State government departments and agencies have historically provided agricultural extension services with the aim of increasing farm profitability through increasing production outputs via the adoption of new technology (Vanclay & Lawrence, 1995). This approach reflects a neo-liberal philosophy that a key role of government is to facilitate the aim of profitability for private industry by providing suitable infrastructure and support for business. Economic growth in terms of increased production outputs, often measured in such economic terms as GDP (Gross Domestic Product), is a significant, if not overriding, goal of the neo-liberal position (Sheil, 2000). In an agricultural context this position has historically been reflected in the goal of increased agricultural production (Gray & Lawrence, 2001).

Agriculture, as a primary industry, is an important export earner for Australia and many other economies. The current approach assumes that production increases (increases in output) have been necessary to enable profitability that maintains viability of the sector, while earning export income. Addressing environmental water issues from a framework of neo-liberalism therefore leads to a focus on producing more from the same water or using less water to produce the same output. The role of government[4] has been to facilitate and promote tools, knowledge and techniques that can be optionally adopted by irrigators where the irrigator believes these will be of benefit to the irrigation enterprise. In some instances incentives such as rebates and subsidies are provided to encourage irrigators to invest in the new tools and technologies, particularly when the benefits of such technologies accrue more broadly (than to the individual enterprise).

As a consequence of the long-term drought and damage to riverine ecological systems, the aims of government-provided agricultural extension have broadened from facilitating economic development to include the pursuit of more environmentally oriented goals (Vanclay & Lawrence, 1995). This is reflected in a change from the promotion of commercial innovations to promotion of environmental innovations. In the irrigation sector, extension officers now promote the 'adoption' of technologies and practices aimed at achieving desired environmental outcomes, often expressed in terms of water efficiency, thereby retaining the 'productivist' discourse that is associated with commercially oriented innovations (Gray and Lawrence 2001). Such technologies include decision support systems, irrigation scheduling systems or similar 'tools' designed to provide information to irrigators about irrigation scheduling and application rates. There is an assumption that in addition to environmental benefits, such technology results in increased profitability, although this assumption is questionable as water savings may not lead to increased profits (Kaine et al., 2005). In summary, the adoption approach is focussed on changing the behaviour of individual irrigators and specifically seeks to influence irrigators to adopt innovative irrigation technology and practices as an important means of achieving water-use 'efficiencies' in the irrigation sector.

## Developments in the agricultural sector

The farming and agricultural sector in Australia has changed significantly since the mid-twentieth century. There have been substantial changes in how farms and farm families operate with massive reductions in employed labour and commensurate increases in the use of labour saving technology and agricultural machinery (Lawrence, 1987; Lawrence & Gray, 2000; Vanclay & Lawrence, 1995). Farm productivity has increased exponentially (Gray & Lawrence, 2001). Small family holdings have given way to larger holdings, many still family operated, and an increasing 'corporate' presence in Australian agriculture. Rural demographics have changed markedly with small towns and hamlets shrinking and disappearing as demand for rural labourers has ceased (Salt, 2001).

Historically, there has been a major decline in farm incomes associated with declining terms of trade for Australian agricultural products as Australia participates in global agricultural trade that has been increasingly controlled by multi-national agribusiness corporations (Lawrence & Gray, 2000) and is impacted by protectionist agricultural policies of the United States and European Union. To be successful, or even to just remain viable, farmers have needed to adapt to these changes (Gray & Lawrence, 2001). Australian farmers are now highly sophisticated business operators who must take a myriad of factors, including international markets and local climatic conditions, into consideration when planning and conducting their business operations. Farmers are price takers; they cannot pass costs on via price increases so they need to reduce other input costs and/or increase production. To this end, farmers have taken-up new technology with alacrity, particularly when it has resulted in economic benefit. Farming is now highly mechanised with farmers using sophisticated machinery as necessary equipment in the production process. In short, farmers have adopted innovative technology at significant levels (Gray & Lawrence, 2001). Reflecting the neo-liberal approach, this adoption has largely been underpinned by a commercial rationale that is focused on increasing production leading to increased economic profitability.

In this paper we note that irrigation scheduling systems and decision support systems (DSSs) have been promoted with an environmental rationale, which differs substantially from the commercial rationale that underpinned the development and promotion of many of the innovations hitherto adopted by farmers (Vanclay & Lawrence, 1995). The immediate costs of both types of innovations are largely borne by the farm enterprise yet the benefits accrue differently. In the case of commercial innovations, the benefits of adoption accrue to the growers and the cost of non-adoption only affects the non-adopting farm enterprise – in terms of reduced profit.[5] The benefits of farmers adopting technology designed to yield environmental benefits accrue collectively in terms of more widespread social and environmental benefits (Pannell, 2008). Similarly, the costs of non-adoption of environmental innovations are borne more broadly than by the non-adopting grower (Gray & Lawrence, 2001). This difference in accrued benefits may partly explain why adoption rates of environmental initiatives remain low as the requisite investment is not reflected in a direct benefit to the investing grower.

## Adoption of irrigation technology

In contrast to adoption of broader (commercially focused) agricultural tools, the uptake of irrigation scheduling tools has been slow (Montagu et al., 2006), with levels of adoption 'extremely low' (Everingham et al., 2006, p. 2). This suggests that change in irrigator practices is not occurring on a significant enough scale to meet environmental goals. Voluntary approaches to adoption were usually satisfactory for commercial innovations, however, different policy initiatives such as regulatory and subsidy approaches may be necessary for the promotion of environmental innovations. See Vanclay and Lawrence (1995, Chapter 6) for further discussion of this topic. It is also important to note that adoption involves a process and that irrigators may be in various stages of transition in the acquisition of new technology.

The most common type of irrigation scheduling tool monitors the amount of moisture in the soil using soil moisture probes (Montagu et al., 2006). Such tools vary in capability, sophistication, effectiveness and cost. These tools are marketed under various brand names but essentially provide feedback to irrigators about soil moisture levels (see Charlesworth, 2000 for an overview of soil moisture monitoring technologies and products). Soil moisture monitoring is particularly important when drip irrigation is used as the surface soil may appear quite dry yet may be moist at the root level. Irrigators using drip irrigation systems who are accustomed to visually inspecting the soil to determine moisture levels may presume the soil is dry and consequently over irrigate. Other tools used by irrigators to assist in their scheduling decisions are external scheduling services, evaporation figures, calendar/rotational systems (Montagu et al., 2006) and computer-based decision support systems (Inman-Bamber and Attard 2005; Jakku et al., 2007).

According to Montagu et al. (2006), in 2003 of the irrigation scheduling methods used by Australian irrigators only 15% involved objective methods for measuring soil moisture levels, defined as soil probes (9%) and tensiometers (6%) as opposed to visual and intuitive methods. Expressed conversely, 85% of irrigation scheduling decisions did not involve specific measurement of soil moisture levels, despite widespread availability of soil moisture monitoring technology. In the cotton and grape growing sectors, which are recognised as the most likely sectors to adopt innovative irrigation technology, two thirds of growers are not using the available soil moisture monitoring technologies (Montagu et al., 2006). It would seem that the available soil-water monitoring technologies do not meet irrigators' needs or are not deemed necessary by the majority of irrigators. High costs, in terms of both financial investment and labour requirements, may act as a disincentive for growers to adopt available soil moisture monitoring technology. Similarly, in the sugar cane sector, Everingham et al. (2006) discuss the very low adoption levels of both decision support systems and climate forecasting technologies designed to assist irrigators in making scheduling decisions.

Low levels of adoption does not necessarily mean that irrigators are not endeavouring to use their irrigation water more efficiently; it simply means that irrigators are not using (adopting) the available products. It is possible for irrigators to increase water use effectiveness without continued use of technological products (Jakku et al., 2007). Agricultural Census data reveals that 70 percent of irrigators made changes to improve irrigation practices in the five years to 2003 (ABS, 2003). These changes included increasing the efficiency of the application system (46%) and more efficient scheduling (37%) (Montagu et al., 2006). Further research into irrigators' scheduling decisions is needed in order to gain a broader understanding of how irrigators decide when to irrigate their plants and therefore, what tools and support structures they see as useful in improving water-use efficiency.

## Influences on adoption decisions

Researchers have explored the influences on adoption in an effort to increase adoption rates of environmentally focussed technologies and practices and have identified a number of factors that influence adoption (Cary, Webb & Barr, 2001; Mendham et al., 2007; Pannell et al., 2006). These factors may facilitate or constrain adoption. Personal, family and social, or cultural, factors are among those identified as influencing adoption decisions (Montagu et al., 2006; Pannell, 2006). Personal and family factors include:

- financial position including attitude to borrowing
- age
- attitude to risk
- capacity to understand and learn new information
- availability of labour
- lifestyle goals (work/leisure)
- family needs – current and future
- succession considerations (Montagu et al., 2006; Pannell, 2006)

Social/cultural factors include:

- local farming/irrigation practices
- social norms and expectations (Montagu et al., 2006; Pannell, 2006)

The irrigation-specific adoption literature has a rather narrow focus on decision-making relating mainly to the up-take of technology or practice change (for example Carey & Zilberman, 2002; Inman-Bamber, Webb & Verrall, 2006; Everingham et al., 2006; Kaine et al., 2005; Montagu et al., 2006; Pannell et al., 2006; Webb, Inman-Bamber & Mock., 2006). As mentioned above, such technology includes irrigation scheduling systems, decision support systems and soil moisture monitoring technology. Innovative practices are designed to yield environmentally favourable outcomes, which in the irrigation context, is equated with water use efficiencies. While the adoption or take-up of innovative technology and practices is important, it is only one aspect of farm decision-making and only one aspect of irrigation decision-making. It is possible that environmental objectives including more efficient use of available irrigation water can be met without adoption and continued use of new technology (Everingham et al., 2006; Jakku & Thorburn, 2008). To understand irrigators' decisions about their use of irrigation water it is necessary to explore all types of irrigation related decisions and not simply focus narrowly on adoption of scientific technologies.

There are other more macro, or what sociologists refer to as structural, factors that are broader and more pervasive than the more individual influences on irrigator decision-making mentioned above. Structural factors exist above and beyond individual enterprises and 'set the scene' in which enterprises operate. Examples of structural factors include financial systems, legal and regulatory requirements, product marketing and selling relationships and water markets. The political context and changes in government priorities also influence growers as individuals and the industry more broadly. Other structural influences that affect growers include such factors as frequent fluctuations in commodity prices, costs of inputs such as fuel for machinery and electricity for pumping and costs of finance, in particular changes in interest rates. Some such structural factors have been identified as 'barriers' to adoption. For instance, Mendham et al. (2007) found the availability, or otherwise, of one-to-one extension services to be an important consideration in whether or not landholders' decided to adopt an innovative conservation practice.

Institutional organisations form part of the structural arrangements that underpin irrigation activities. Such organisations include catchment management authorities, irrigation companies, government departments and industry bodies such as marketing boards. Organisations may influence growers through regulatory requirements and or pricing mechanisms. For instance, the availability of 'off-peak' low-priced electricity from the relevant electricity supply company encourages irrigators who use electric pumps to irrigate at specific times to avail themselves of the lower electricity prices (Whittenbury and Davidson – research in progress). The personal relationships that develop between local employees of institutional organisations and local growers may also influence growers' attitudes and behaviour toward adoption.

Socio-cultural factors such as local community norms and values, expectations of being a 'good' farmer (Barlett, 2006; Phillips, 1998) and gender identity (Brandth & Haugen, 2006) also influence growers, although this influence may be somewhat indirect (Whittenbury, 2003). A broader exploration of the ways structural and cultural factors influence irrigators' decision-making, not merely in the context of adoption, is necessary to develop a greater understanding of how irrigation decisions are made.

In their exploration of irrigation decisions, Montagu et al. (2006) found that 'local knowledge/ observation' accounted for 64%, almost two-thirds, of irrigation scheduling methods used by irrigators. A broad exploration of irrigators' decision-making would include developing an understanding of the intuitive and subjective knowledge, or heuristics, irrigators draw on to guide their irrigation practices in addition to developing an understanding of personal, socio-cultural and structural factors that influence irrigators' decisions.

## Barriers and constraints to adoption

The adoption approach is premised on a belief that farmers will adopt environmentally beneficial practices and technology if identified barriers and constraints to adoption are addressed (Montagu et al., 2006; Pannell et al., 2006; Stanley et al., 2006). Stanley, Clouston and Baker (2006) suggest that constraints tend to fall into two distinct categories: characteristics of the innovation or the practice itself and characteristics of the individuals or communities expected to implement the innovation or practice. Constraints of the latter type include financial capacity, grower lifecycle/ lifestage, attitude to risk, succession/future plans, confidence in the technology, social and community norms and expectations and past experience with government agencies/proponents of change (Mendham et al., 2007).

In the irrigation context, in addition to the above mentioned barriers to adoption, there are also structural constraints, in particular, uncertainty of water allocation and inadequate water availability (Carey & Zilberman, 2002). Timing is also important as irrigators may be less likely to invest in new technology in times of drought and low commodity prices. Furthermore, there are other pressures on irrigators resulting in lack of time to consider and/or implement potential innovations (Montagu et al., 2006).

Interventions aimed at addressing identified barriers to adoption have tended to be focussed on single issues such as financial incentives. Financial incentives involve payments of grants or subsidies to growers who invest in a particular technology or who undertake a specific conservation activity or practice. The up-take of financial incentives for adopting technologies and practices designed to yield environmental benefits is often low, which could indicate that it is necessary for interventions to address a number of barriers in addition to financial constraints (Stanley et al., 2006). The value to growers of financial incentives is an important consideration but in some instances, financial incentives are themselves not sufficient for growers to co-invest in the initiative being promoted. Uncertainty on the part of growers is a powerful disincentive for grower investment.

Such uncertainty might relate to water availability (Carey & Zilberman, 2002), marketing produce (McClintock, 2007), or more general uncertainty about the future viability of the growers' enterprise in addition to scepticism about the value of the technology or practice being promoted.

As yet there has been little exploration beyond identification of these barriers to adoption. While barriers may have been identified, there is need to develop an understanding of the complexities and interplay among the identified barriers. These barriers have been identified from the perspective of the suppliers and promoters of the technology or innovative practice – the supply side (see below). Adoption involves complex processes. Barriers to adoption are also complex and multi-faceted. There is a need to explore these perceived barriers from the perspective of the intended users of the initiatives: growers and grower communities – the demand side (see below). In this context it is important to understand the goals, motivations and behaviour of growers and their families.

## Irrigator motivation for adoption

It is presumed that irrigators will be motivated to invest in water saving technology because it reduces the amount of water used and hence the cost of irrigation water (Carey & Zilberman, 2002; Glyde & Dunn, 2007). In usual circumstances, water is not the greatest input cost so financial gains from water saving may be of little significance in the overall operation of the irrigation enterprise (Kaine et al., 2005). That is, water savings are unlikely to mean much in terms of overall profit[6]. Growers may be more motivated to save labour and time (Bjornlund et al., 2009; Kaine et al., 2005; Keeble et al., 2004). However, scarcity of water and the very high cost of buying water in times of drought may lead to adoption of water saving irrigation practices that are then continued in more 'normal', that is, non-drought, times (Montagu et al., 2006; Carey & Zilberman, 2002). Similarly, during times of water scarcity, irrigators who have water entitlements may be motivated to reduce their consumption of irrigation water in order to sell surplus water on the market to take advantage of high water prices (McClintock, 2007). To gain a clearer understanding of irrigator decision-making, it is important to explore how changing circumstances influence decisions.

The push for grower adoption of innovative irrigation technology comes from the providers, or suppliers, of the technology (researchers, developers, agencies) and from governments pursuing environmental goals. Research and Development corporations are influential in this context as are the relevant Cooperative Research Centres. Similarly, the adoption literature focus stems from the perspective of these providers, promoters and suppliers of the technology. While there have been studies that look at grower motivation, behaviour, characteristics and so forth in relation to potential adoption (eg Shrapnel & Davie, 2001; Stanley et al., 2006; Vanclay et al., 1998; Vanclay et al., 2006), there is a dearth of information that addresses the needs and wants of growers from the growers' perspective. There is a need to understand what drives demand from grower-irrigators for innovative irrigation technology.

A marketing perspective may offer useful insights into exploring irrigator demand. Marketing concepts such as buyer segmentation and consumer behaviour theory may be utilised to better understand grower/irrigators and their requirements (Kaine et al., 2005). However, conventional marketing approaches are premised on notions that the products and services promoted will benefit the buyer, usually by increasing profitability. As previously mentioned, the promotion of irrigation decision support technology is premised on environmental benefits as the main outcome. While not necessarily directly contributing to increases in profitability, savings in water can open up alternative possibilities to growers for use of saved water such as expansion of irrigated area or selling surplus water on the market (Carey & Zilberman, 2002; McClintock, 2007).

It is important to note that water efficiency gains due to modern irrigation technology are not uniform and vary according to individual farm characteristics such as crop type, soil type and land slope (Carey & Zilberman, 2002). However, there may be considerable differences of opinion in what different stakeholders would see as 'efficiency gains'. Drip irrigation is designed to use less water than flood irrigation yet drip irrigation requires energy for pumping whereas flood irrigation usually relies on gravity. So a simple comparison of water use may lead to the conclusion that drip irrigation is more water efficient than flood irrigation but the extra energy requirements of drip irrigation is not factored in to the comparison.

## Inherent desirability of adoption (a presumption)

The adoption approach is based on a neo-liberal, or economic rationalist, view that accords primacy to economic factors in farm decision-making (Gray & Lawrence, 2001). This view maintains that potential alternatives are evaluated on the basis of economic cost and benefit and presumes that growers, or grower enterprises, act in isolation as 'economic units'. Indeed growers themselves attest to the importance of economic considerations when making decisions (Glyde & Dunn, 2007; Whittenbury & Davidson, in progres). However, this view ignores, or at best significantly minimises, other factors that influence decisions made on farms. It also presumes decision-making to be a formal process, although it is likely that many on-farm decisions are made informally. Irrigators make some types of decisions infrequently while other decisions are made more often, yet the neo-liberal view presumes all decisions to be evaluated in the same way. Teasing out economic costs and benefits from complex activities encompassing domestic family living arrangements and lifestyle pursuits is not a simple task and is likely to rely on a considerable number of assumptions and estimates.

Underlying the adoption approach is a presumption that adoption is a good thing and that outcomes associated with adoption will be beneficial to growers and the environment. The discussion around adoption is premised on a belief that growers will adopt if the identified barriers and constraints can be overcome. The starting point appears to be normative in that it is presumed that growers ought to adopt. From the growers' perspective the starting point may be very different. The implicit presumption (by proponents of irrigation scheduling technology), that using irrigation water efficiently requires the adoption of scientific technology, is simply that: an assumption. Research undertaken in the Australian sugar industry has found that it is not necessary to adopt and continue to use technological irrigation scheduling systems in order for irrigators to become more efficient in their use of irrigation water (Jakku et al., 2007). An alternative perspective is that a decision support system can be considered to be successful if it leads to desirable practice change resulting in environmentally beneficial outcomes, even if the decision support system is not used on an ongoing basis. As such, a decision support system, or similar tool, may be used in order to facilitate learning, which may lead to a change in practice without the necessity of continued use of the system or tool. Jakku and Thorburn (2008) describe a participatory process whereby grower participation in the development of a decision support tool in the irrigated sugar industry led to practice change resulting in improved outcomes without the need for continued use of the decision support system.

## Conclusion

The mainstream approach to improving water use efficiency among irrigators has been to promote the adoption of technologically based innovations to individual grower-irrigator enterprises. There is an implied assumption that water use efficiency can only be achieved by grower adoption of the available technology. The approach overlooks changes in practices that may occur without the adoption of technological tools. It is as though adoption has become a goal in itself rather than simply a mechanism that can assist in the overriding aim of improved water use efficiency. This approach is led from the supply-side (of the technology) and largely ignores the perspectives of the irrigators themselves. It is premised on a belief in the inherent desirability of adoption and views non-adoption as the result of 'barriers and constraints' that need to be overcome.

This concentration on adoption of new technology as a means of attaining improved water use efficiency among irrigators, while of some value, is too limited given that the vast majority of irrigators are not adopting such technology. A focus on encouraging individual irrigators to adopt technology intended to achieve broader environmental benefits presumes that individual behaviour change is desirable and achievable and that behaviour change will not occur without adoption of technology. This focus also presumes that individual behaviour change (by irrigators) will substantially reduce the overall consumption of irrigation water. This individual focus places the responsibility for water saving on individual irrigators and does little to address the more macro, or structural, influences that are also relevant to irrigators and to water usage.

Improvements in water use efficiency leading to real environmental benefits require a multi-faceted approach including macro initiatives addressing structural factors as well as a focus on encouraging individual irrigators to be more efficient in their use of irrigation water. Efforts to achieve behaviour change among irrigators need to be viewed as *part* of a broad-based strategy that includes macro initiatives. Further exploration of the factors that influence irrigators will develop an understanding of the influence of structural factors in addition to providing a broader, more nuanced, understanding of irrigator decision-making that can assist researchers and program developers to develop and pursue initiatives with the needs and goals of irrigators in mind.

Irrigators, like other farmers, have a vast amount of experience and knowledge, which traditionally has not been recognised by researchers and extension providers (Kloppenburg 1991). Action research methodologies and other forms of participatory research in which growers are partners in the research process seek to understand, validate and value this experiential knowledge (Spriggs et al., 2002; Jakku et al., 2007). Farmer knowledge can provide an important base for 'bottom-up' research and initiatives that can be embraced and 'owned' by the stakeholder community (Glyde & Dunn, 2007; Spriggs et al., 2002). To develop a better understanding of irrigators' decision-making it is important to explore irrigators' intuitive and experiential knowledge and the ways that this knowledge is incorporated into the decision-making process.

Decision support systems and irrigation scheduling systems have been developed to assist irrigators in making their irrigation decisions yet little is known about how irrigators go about making irrigation related decisions. An understanding of how irrigators make decisions including the influences on decision-making would enable decision support systems and irrigation scheduling systems to be developed so that they better meet irrigators' needs.

To further understand how irrigators make their irrigation decisions, a broad-based approach exploring irrigators' decision-making from the perspective of the irrigators themselves is required. A research study addressing this topic is currently being conducted (Whittenbury & Davidson in progress). The project takes an in-depth, ethnographic approach aiming to understand irrigators' goals, motivations and concerns as well as exploring irrigators' intuitive and experiential knowledge. This broader exploration of irrigators' decision-making and heuristic devices will enable an understanding of the varied factors, including personal, social and structural that impact on irrigators and their enterprises. Such understanding will assist in the development of broad-based strategies aimed at improved efficiencies in water usage in irrigation industries. In particular, it will contribute the development of policy initiatives aimed at addressing the influence of structural factors. It will also provide valuable information for scientists and researchers working on technological developments as it will provide information about irrigators' decision-making that may be taken into consideration in the development of decision support systems so that they can be better targeted to meet irrigators' perceived needs.

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## Endnotes

1 The term 'water use efficiency' has been criticised as being nebulous because contradiction in the literature about the definition of the term 'water use' (Perry, 2007).

2 Such growth also results in substantial social costs associated with high levels of social and economic inequality inherent in the pursuit of growth in free-market economies.

3 Other water-saving initiatives are being applied to irrigation infrastructure, with existing aged and leaking channels being upgraded and/or piped. For instance, Murrumbidgee Irrigation is implementing pressurised irrigation water through a network of pipes and the Victorian Food Bowl Modernisation Project aims to invest $1 billion to upgrade aging irrigation infrastructure.

4 Through funding criteria applied to such bodies as Research and Development corporations and the CRC for Irrigation Futures.

5 Unprofitable operators may be encouraged to leave the industry as part of an industry rationalisation process, or 'restructure', to be replaced by more profitable operators. There may be some costs to the community in terms of income support and other services associated with families leaving the land.

6 This has historically been the case but is changing as scarcity of water is likely to be a perennial issue facing irrigators.

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