Experimentally Testing Institutions And Policy Instruments To Coordinate Groundwater Recharge in the Coleambally Irrigation Area

John Ward[a*], John Tisdell[b] and Stuart Whitten[c]

[a] CSIRO Land and Water, Policy and Economic Research Unit

[b] Griffith University, Faculty of Environmental Science

[c] CSIRO Sustainable Ecosystems

*Corresponding author: Dr John Ward

CSIRO Land and Water

j.ward@csiro.au

Abstract

A rising saline aquifer in the Coleambally Irrigation Area constitutes a common pool resource, characterised by costly exclusion and rival utilisation for regional irrigators. The approach outlined in general terms in this paper is the application of formal, empirical techniques to guide the design and *a priori* testing of a proposed tradeable recharge entitlements scheme to resolve the common pool dilemma. The focus of the research is the design and quantitative evaluation of potential market impediment solutions and alternative coordinating mechanisms applying the findings of experimental economics techniques. The initial policy design process involved identifying potential impediments to the functioning of a credit trade policy which could prevent cost-effective and environmentally effective outcomes. The SWAGMAN recharge model was employed as a recharge accounting tool to determine farm specific recharge rates as a function of irrigation application, crop mix and the spatial location of the farm in the Coleambally landscape. The experimental setting relies on a context rich catchment analogue, which represents the economic decision-making and trading environment facing farmers, populated with the salient biophysical, economic and hydrological characteristics estimated for proposed land use changes. Observed behavioural responses to policy initiatives were compared according to three metrics: aggregate groundwater recharge, farm income (expressed as player payments) net of non-compliance penalties and market outcomes. The rationale and experimental design of three treatments to test the efficacy of institutional arrangements to overcome identified impediments is outlined; the provision of recharge information, the introduction of a recharge cap and market exchange of tradeable recharge credits and the face to face communication. The conclusions focus on the application of the experimental results in the specification of a potential groundwater recharge management contract and the challenges for a successful implementation with local constituency.

1. Introduction

Irrigation induced waterlogging, rising saline groundwater aquifers and subsequent increases in soil salinity is a well known problem in mature irrigation areas across Australia. The Coleambally Irrigation Area (CIA), located in the Murrumbidgee Catchment of the Murray Darling Basin is no exception. The consequences of salinity in irrigation areas include crop production losses, increased production costs and damage to environmental amenities and infrastructure assets in the region. Additionally, spatially dispersed and long term soil salinisation is increased by capillary action predicted when groundwater approaches the soil surface. Despite regulations limiting rice production and the application of irrigation water, the problem of rising saline groundwater and salinity persists (Khan *et al*. 2003).

The porous, adsorptive capacity of the soil fraction between the soil surface and the aquifer water table in the CIA can be defined as common pool resource. Common pool resources are characterised by costly exclusion of beneficiaries, a characteristic shared with public goods and rival consumption (or subtractable usage), a characteristic shared with private goods. That is, the application of additional irrigation water by an individual farmer appropriates and subtracts from the soil fractions total adsorptive capacity, reducing the opportunity of other irrigators to make use of the adsorptive resource. When joint outcomes depend on multiple actors contributing inputs or actions that are costly and difficult to quantify and there is lack of policy instruments to restrict usage, incentives exist for individuals to act opportunistically, often appropriating to a level where aggregate overuse occurs. A social dilemma occurs when individuals are tempted by short term gains to over appropriate the common pool resource, thereby imposing group shared costs on the common pool community. Additionally the opportunity exists for some individuals to free ride and benefit from the reduction in recharge by others. Individual over appropriation will eventually lead to rising water tables and lower crop productivity for all farmers (Khan *et al*. 2003).

Managing the environmental and economic consequences of rising groundwater and subsequent soil salinity loads is complex and likely to require a combination of economic instruments and community involvement in coordinating aggregate extraction strategies (Common 1995, Randall 1978). Ostrom *et al*. (1992) Poe *et al*. (2004) and Tisdell *et al.* (2004) have proposed a range of market based instruments and group crafted coalitions, facilitated by communication and reinforced by punitive and non-punitive sanctioning mechanisms as possible policy solutions to social dilemmas of a similar nature.

In a general sense environmental policy instruments are the tools available to policy makers to influence individual behaviour and societal processes such that they align with and remain compatible to defined environmental and social targets. These are made operational as policy objectives and their level of success often expressed as measures of environmental effectiveness, economic efficiency and distributional equity. As a general rule market-based policy instruments (MBI) including tradeable rights, use markets and market like mechanisms to influence the choices made by land managers. In contrast to policy approaches using explicit directives, they are designed to encourage innovative behaviour through the price signals of market exchange (Stavins 2003). Rather than rely on regulations to identify the best course of action, individuals are able to select actions that best meet the environmental target, based on typically superior individual information. The potential advantage of MBI approaches is that they can achieve environmental goals at a less and hence more affordable cost to the community. The primary motivation of MBI approaches is that if environmentally appropriate behaviour can be made more rewarding to land managers, then changing attitudes and ensuing land management behaviour will better align with more socially desirable alternatives.

To encourage the development of MBI policy approaches to manage salinity, the Commonwealth National Action Plan for Salinity and Water Quality allocated $5 million to fund eleven MBI trials in 2003. The project 'Tradeable Recharge Credits in Coleambally Irrigation Area' has explored the design, testing and implementation of potential policy initiatives, reliant on market based instruments, to manage waterlogging and salinity. The focus of this analysis has been on the potential for the use of a tradeable rights approach to offer improved economic efficiency, environmental effectiveness and the advantages of land holder flexibility over current and historical regulatory instruments deployed in the CIA.

Tradeable credits or quantity based instruments involve establishing an enforceable threshold for management, either as maximum effluent levels, prescribed resource usage or minimum environmental provision; distributing entitlements among participants or sources as specific units and allowing trade of those units among those in the scheme. The environmental objective is to ensure the total number of units does not exceed the prescribed threshold for a given accounting period (usually one year). To satisfy compliance obligations, each participant in the scheme must be able to surrender units equal to their entitlement at the end of the accounting period. Therefore, participants can choose to alter land actions in response to individual management capacity, landscape attributes and production costs. Non-compliance incurs individual penalties which are typically greater than the costs of complying.

While imposing a cost on individuals, the opportunity to trade has the potential to compensate that loss or reduce the cost burden. Some individuals will choose to use more than their quantum (and incur a debit), and others will choose to use less (being rewarded with credits). This results in a tension in the contracting process. There is a need to negotiate contracts so there is sufficient differential in the system to encourage trade but not so much that the negotiated output prevents a feasible solution. A challenge for policy is to create the opportunity for a frictionless market setting where participants could quickly learn to understand the advantages of trade with low learning and exchange costs relative to trade benefits. Information from market exchange, expressed as coherent prices signals, would reveal any differences in returns to management options that reduce environmental consequences and these would be immediately discovered and exploited.

An important advantage of quantity based instruments over other policy options is a greater level of environmental certainty as a result of the prescribed and enforceable threshold or cap. Tradeable permits, such as water trading in the River Murray or the potential for salinity trading in the Murray-Darling Basin and environmental offsets represent the two main variants of quantity based instruments.

There are a number of preconditions for a functioning and effective cap and trade scheme. They are:

- There is credible and reliable science to establish a threshold level that is clearly understood and matches the resource condition target;

- There are cost effective monitoring schemes in place that are transparent, consistent and credible to all participants. There must also be a clear link between land management actions and the subsequent environmental outcome. In cases where the environmental outcome is not readily visible (for example recharge into groundwater aquifers) a proxy indicator may be necessary (such as the type of crop mix and irrigation regime in this case);
- The nature (toxicity) of the pollutant is such that market exchange will not result in localised concentrations, which may cause excessive environmental degradation or hoarding of entitlements;
- There is sufficient differentiation in individual abatement costs across the catchment. If there are no differences there is no incentive to trade;
- There are regulatory agencies with effective regional jurisdiction to monitor and audit compliance levels and effectively enforce individual breeches;
- There are sufficient numbers of participants to ensure cost effective exchange opportunities and satisfaction of trading requirements;
- The transaction costs of monitoring, gathering information, enacting the exchange and enforcement are low in relation to the potential benefits gained;
- There are adequate and effective administrative institutions to ensure a functional market and;
- It is politically feasible to develop transferable, enforceable and tradeable private property rights, to minimise government intervention and allow flexibility of decision making.

Similarly, the analysis of competitive markets is premised by a set of articulated predicates: that exchange outcomes are highly excludable, divisible, transferable and fully internalised by those engaged in the exchange process. In an idealised market, agents acting as profit maximisers responding optimally to coherent, accurate and reliable price signals can reach collective decisions resulting in an ordered, predictable outcome which is superior to other possibilities and dispositions. The reality is that the full set of conditions necessary to ensure frictionless and efficient markets and to comply with cap and trade prerequisites are rarely if ever present. In many market settings there are numerous impediments to the satisfaction of these conditions. A number of potential impediments which potentially violate those necessary conditions were identified across an array of market structures. An overview of the practical consequences to market outcomes is specified in Ward (2004).

Unaccounted for market impediments and the common pool nature of groundwater recharge are likely to compromise *a priori* theoretical prediction reducing its capacity as an analytical tool or a reliable precursor for recharge policy decision making in the CIA. In addition the recent advances of MBI as policy tools for managing diffuse source environmental problems, has also meant limited opportunities for policy makers to gain experience and expertise in their design, testing and implementation. Appraisals of their relative importance in policy portfolios have also been informal and *ad hoc*. Although the analysis of market based instrument performance has improved, simple rules and evaluation protocols to identify *ex ante* the relative advantages over other instruments to resolve specific environmental problems have not yet emerged.

To improve *ex ante* predictions of potential policy outcomes, experimental economics was employed to provide empirically based analysis of observed behavioural responses to the implementation of possible economic and community governance instruments to reduce recharge. In a controlled decision environment, calibrated to represent the economic and biophysical features of the CIA catchment, experiments were applied to formally test and evaluate feasible on-ground market impediment solutions.

The motivation for experimental work was to help understand and compare key factors that could impede cost effective, environmentally reliable and politically feasible trial implementation by using empirically based analysis to guide policy design features.In the case of the CIA the experimental environment is context specific and calibrated against model farm data from the region. The objective of the experimental sessions was to:

- Test the significance of market impediments in a setting calibrated to represent important economic and biophysical features of the actual CIA;
- Test behavioural responses to longer term policy options that may require changes to current institutional structures; and
- Inform and pre-test on-ground solutions to support policy implementation.

The experimental research progressed through a number of stages in order to achieve these aims. First, the major market impediments identified were prioritised for inclusion in experimental treatments. Second, a simulated decision environment, based on model farms from the Coleambally region was created as a basis for experimental treatments. The simulation model was then subjected to testing via a field trial with CIA farmers to test that the important aspects of context had been captured. Next, laboratory experiments to test alternative treatments of market impediments were undertaken. The results of these experiments were used to inform a simulated recharge credit trading scheme trial with CIA landholders.

This paper describes the results of an experimental trial to assess the potential of recharge credit trading in the Coleambally Irrigation Area. The goal of the trial is to test and evaluate market based instruments that engage and coordinate the irrigation community within the CIA, in farm based strategies that substantially reduce groundwater intrusion and subsequent increases in soil salinity.

The paper is set out as follows. The role of experiments is briefly revisited in Section 2 to further explain the function of experimental economics in the institutional design process. The hypotheses and experimental treatments are described in Section 3. Description of the context rich simulation setting is the focus in Section 4. The setting and process for the experiments that are the focus of the report is described in Section 5 and the results obtained set out and discussed in Section 6. Conclusions drawn from the experiments complete the paper in Section 7.

2. The role of experiments in developing policy

Global experience indicates that many past attempts to implement tradeable permit schemes for both diffuse (e.g. ground water recharge) and point source emissions have failed because of inadequate attention to the design and timing of the market architecture deployed (Tietenburg 1998). Additionally, the behaviour of individuals with non-market and social motivations may diverge substantially from theoretical predictions (Ostrom 1998, Ostrom *et al*. 1992, Gintis 2000, Tisdell *et al*. 2004, Poe *et al*. 2004). As a corollary, variable behavioural responses to novel policy implementation, conditioned by social context, market design and institutional procedures, make *a priori* estimates of the volume and cost effectiveness of recharge reduction policies difficult and potentially unreliable. When implementing market based policies, agencies may need to account for behavioural and informational processing limitations (Braga and Starmer 2005) which currently lie outside the domain of market analysis (Simon 1972, Sterman 1987, Smith 2002). For effective recharge policy, careful instrument sequencing and accounting for the costs of complex informational processing may need to be imputed.

In many cases MBI may be advantageous, but in others the relative advantages over other instruments may be limited, poorly defined, state contingent and subject to change through time. For example a market based instrument may be cost effective, but may not perform well in the dimensions of adoption rates, administrative and transaction costs, concentration of environmental consequences and political feasibility. When these are important policy objectives, the single model terrain of economic efficiency or cost effectiveness may not be sufficient to reliably inform policy makers of instrument performance.

Experimental economics was employed to provide empirically based behavioural data and policy insights to the implementation of potential economic and community governance instruments. The experimental sessions have been applied to test feasible on-ground solutions and longer term policy options that may require changes to current institutional structures. A primary objective of the sessions was to elicit behavioural responses within institutional settings that reflect the transitional state of recharge management in the CIA, the poorly defined state of information discovery and the public nature of groundwater recharge. By evaluating behavioural responses, land-use change and the cost and level of subsequent recharge reduction, the results are intended to provide input into the design and strategic implementation of an eventual land holder trial.

The experiments were designed with field calibrated hydrological, biophysical and economic modelling relating recharge and opportunity cost to actual farm activity choices in the trial area. Experimental farms are thus heterogenous and represent the main relationships between landscape positions, farm management regimes, farm income and groundwater recharge specific to the CIA. The development of a recharge and salinity accounting tool has been detailed by Khan *et al*. (2003) in the SWAGMAN model. Experimental farm characteristics are detailed in Ward (2004) and an example is tabled in the Appendix.

The construction of a laboratory based analogue of the CIA therefore enables the formal evaluation of behaviours, economic outcomes, efficiency gains and recharge rates when participants are confronted with hypothetical decisions simulating policies and market based solutions to reduce groundwater recharge. The results provide a formal basis to examine policy options under controlled laboratory conditions and compare predicted theoretical outcomes with direct observations of economic behaviour in an analogue of the CIA.

3. Experimental treatments and hypotheses

Ward (2004) describes eleven market impediments identified as being sufficiently important to market design that experimental testing was considered. The impediments were prioritised for further investigation as resources allowed. Prioritisation was via qualitative ranking based on:

- Likely significance of the impediment in the CIA;
- Potential of the solution to improve efficiency and environmental effectiveness;
- Potential administrative and political feasibility; and
- Ease of designing and implementing an experimental treatment.

Based on the analysis of likely impediments to a successful market, as well as community and working group consultation, it was decided to focus on four areas – the impact of differential information levels, the coordination mechanisms of communication and market exchange and the effect of individual or group penalties.

The baseline treatment (treatment one) was designed to represent the status quo; farmers make decisions with little information about their impact on recharge, there are no binding recharge allocations or opportunities to trade allocations, losses due to rising water tables are shared among all farmers in the catchment and are not known in the short run. In this scenario, there is little incentive for individuals to limit their contribution to recharge, as the benefits in the form of increased income are private while the subsequent crop losses are shared. The problem of excess recharge cannot be solved by a single farmer acting alone.

3.1 Information

Provision of information from SWAGMAN effectively converts the management of groundwater recharge in the CIA from a non-point to a point source effluent problem. We define a point source as having a described marginal recharge abatement and farm production function. However in the absence of other institutions, recharge remains a common pool resource. A number of authors (e.g. Ostrom 1998) have suggested that such resources may be effectively managed if those involved can coordinate their decisions through crafted social contracts, reinforced with effective communication, using either formal or informal institutions. In contrast to game theoretic predictions (Ledyard 1995) which consign communication to non-effectual cheap talk, Ostrom argues that communication both elicits and buttresses reciprocal behaviour for the management of shared resources. The provision of information is necessary to achieve effective management, but is unlikely to be sufficient in itself (e.g. Smith 1987, 2002, Tisdell *et al.* 2004). However if it were sufficient to manage the problem, then it would avoid the need to develop more complex institutions with attendant increases in transaction costs.

Hypothesis one: Providing information on individual contributions to recharge and periodic crop damage will reduce recharge levels.

Treatments two and three provide the participants with increasing amounts of information. In treatment two they are informed how their decisions impact on total recharge, based on data from the SWAGMAN model, while in treatment three they get this information plus they learn how much income they stand to lose due to excessive recharge at the end of each period rather than at the end of the experiment.

By examining the effect of information alone, it is also possible to distinguish the effects of the institutions used in subsequent treatments from the information that must be provided with them.

3.2 Communication

Theoretical insights (eg Vatn and Bromley 1995, Ostrom *et al*. 1992, Ostrom 1998) suggest that common pool resources can be effectively managed if there are information and communication options available to those using the resource. This is supported by empirical evidence (Cardenas 2000, Poe *et al*. 2004, Ostrom *et al*. 1992, Tisdell *et al.* 2004) showing that the provision of a formal and controlled forum for discussion leads to robust and effective voluntary social contracts with high levels of contract adherence. There is considerable experimental and field data indicating that in certain cases communication can be effective in improving the outcome of resource dilemmas. Compared to impersonal communication, face to face communication has been shown to be the most effective means of promoting and reinforcing the formation of social compacts (Ostrom *et al*. 1992).

Hypothesis two: Providing a forum for discussion, allowing the formation of a voluntary social contract to coordinate management decisions, will reduce recharge levels.

In treatment four, participants were provided with the same information as in treatment three. Additionally, before each experimental period they were brought together and allowed to discuss coordinating their decisions.

3.3 Trading

With the provision of information, communication can reinforce the crafted social contract stipulating collective resource usage. It may however be less effective where those involved face different costs and benefits from cooperation. A recharge trading mechanism can provide an alternative means of coordinating individual decisions to ensure that overall recharge targets are not exceeded. If there is sufficient heterogeneity among farms in their marginal costs of reducing recharge, as estimated in the CIA, then there are potentially gains from trade among farms to determine who should contribute to reducing recharge. Under a market institution, farmers have an increased incentive to reveal their true costs of avoiding recharge, which they do not have under communication and voluntary social contracts.

In reality, gains from trade are often considerably less than would be expected under efficient market conditions. The extent of trade and cost savings depends on behavioural responses that vary according to the market design and contextual factors. Participation rates and market outcomes are likely to be conditional on the cost of informational processing, in turn a function of the complexity of the decision environment and the potential gains from trade relative to aggregate farm income. Simulating trade with realistic Coleambally supply and demand characteristics provides an opportunity to measure behavioural responses to proposed market constructs and conditions and assess the potential cost effectiveness of the policy.

Hypothesis three: Providing a market mechanism to trade voluntary recharge entitlements will reduce recharge levels.

Treatment five consisted of information plus a closed call market for trading recharge allocations. In a closed call market potential buyers submit sealed bids to buy and potential sellers submit sealed offers to sell. The market is called, bids ranked and trades executed by a clearing-house, in this case the experimental recharge management authority. The authority computes a single equilibrium price at which all trade takes place based on the aggregate supply of and demand for credits. When the price has been computed, the authority notifies successful traders and announces the market price and informs successful traders of the individual volume traded only.

An important characteristic of the closed call auction is the limited disclosure of bidding information. The only information disclosed is market price and volumes traded, no information on specific transactions is reported. There is no public disclosure of individual bidding information or the individual volumes traded. In contrast, an open call market publicly declares all individual bidding and volume offers.

The closed call market is characterised by simpler information – each period provides a single piece of high quality information (the market clearing price) rather than many pieces of low quality information (individual bids). Experimental studies in the Bet Bet salinity credit trading MBI demonstrated that closed call markets performed better than open call markets (Connor *et al*. 2004, Tisdell *et al*. 2004). Treatment six combined the market with the communication treatments, providing a discussion forum before each period.

3.4 Individual penalties

Constrained by the institutional rules described in the previous section, any costs resulting from non-compliance are shared among all farms. Therefore individual farmers may still be tempted to free ride. An alternative would be to create an individual incentive for compliance with recharge targets with an attendant individual non-compliance penalty. Such an institution would resolve the common pool resource impediment and is likely to lead to more efficient farm management decisions.

Hypothesis four: Imposing recharge target non-compliance penalties on individuals will lead to lower levels of recharge than when the excess recharge penalty is imposed equally on all players.

Treatment seven combined the information and market treatments, but in contrast to the socialised crop loss imposed for all other treatments, the inability of individual players to surrender sufficient recharge units at the end of each decision period incurs an individual crop loss penalty. The design of the experiments and the details of provided information, institutional rules, market exchange and associated penalties are summarised in Table 1. An experimental session is comprised of 10 independent, repeated periods of annual management decisions, market trading or a forum for discussion. Each session was replicated twice.

Table 1: Experimental design to test levels of information and coordination in the CIA

Treatment		Individual recharge information	Institution		Penalty			Replicates
			Communication	Market	Socialised	Individual	Timing	
1	**Control**	×	×	×	✓	×	End of session	2
2	**Recharge information**	✓	×	×	✓	×	End of session	2
3	**Recharge + crop loss**	✓	×	×	✓	×	Each	2

	information						round	
4	**Communication**	✓	✓	×	✓	×	Each round	2
5	**Market**	✓	×	✓	✓	×	Each round	2
6	**Market + communication**	✓	✓	✓	✓	×	Each round	2
7	**Market + individual penalty**	✓	×	✓	×	✓	Each round	2

4. Development of the experimental CIA catchment

Experimentally testing the management of salinity reduction requires simplified yet realistic simulations of farm decision making, that include the most important aspects of the system and yet are simple enough to be implemented as an experimental treatment. The objective of the simulation was to represent the economic decision-making and trading environment with the salient biophysical, economic and hydrological characteristics estimated for the Central sub-catchment of the CIA.

Previous research employing the SWAGMAN model has established and enumerated the relationship between an established and proposed crop mix, water application, groundwater depth, soil type and subsequent management with farm income and recharge volumes spatially located to specific landscape positions in the CIA (Khan *et al*. 2003). A simulated catchment was constructed comprising twelve model farms based on a representative sample of farms from the CIA, with sizes ranging from 200 to 335 hectares. The SWAGMAN model was used to estimate levels of income and recharge under alternative crop mix and management options. For each model farm there were five alternative management options, representing different mixes of crops. Each of the five crop mix decisions are characterised by a specific farm income associated with a recharge level. Higher incomes are associated with higher recharge levels. SWAGMAN was used to estimate the threshold level of recharge below which the water table would not rise – this was the policy target in this simulation. The set of selected farm enterprises represent the main relationships between landscape positions, farm management regimes, farm income and groundwater recharge.

Additional context was iteratively introduced into the experimental domain, where participants are informed they are hypothetically farmers, are located in a closed catchment and produce recharge which in turn potentially affects other farmers. Using the experimental setting, we sought to elicit and measure behavioural responses to hypothetical decision environments simulating policies and diverse institutional structures across an array of market conditions in an analogue specific to the CIA.

Contextualisation is not usual experimental protocol, however this research follows the practical and theoretical lead of Cardenas (2000), Krause *et al*. (2003), Poe *et al*. (2004) and Tisdell *et al*. (2004). As an important insight from cognitive psychology, Lowenstein (1999) and Loomes (1999) advocate that decision making is highly context dependent. This has lead some experimentalists to conclude that to inform policy meaningfully, experiments may need to be designed to include salient features of the policy setting of interest (Lowenstein, 1999; Loomes 1999; Krause *et al*. 2003, Tisdell *et al*. 2004). Adherents conclude that while experiments designed to eliminate any confounding effects are useful for isolating influence of single treatment factors, they may not tell us much about how people are likely to react in real world contexts where confounding factors exist. There is now a growing body of experiments conducted in context rich environments. Results demonstrate that differences in context lead to differences in bargaining behaviour, risk-taking and sharing (see Camerer and Lowenstein 2004, Gintis 2000; Krause *et al*. 2003).

While experiments from context rich settings may allow only limited inference about behaviour in other contexts, according to proponents they represent the most appropriate way to draw inferences about behaviour that are valid for specific contexts where policy design is being investigated (Lowenstein, 1999; Plott and Porter, 1996). Context also makes the simulation more readily transferable from the laboratory to field trials, and can provide a tool to facilitate learning and engagement by the catchment community. Figure 1 illustrates the predicted outcome of trade in recharge units, assuming traders were profit maximisers who completely understood and acted upon optimal trade strategies. The values are derived by computing the demand and supply relationships underlying the range of management decisions that subjects faced in the experiments. The predicted equilibrium is 407 ML traded at a price of $43 per ML and aggregate gain from trade in the recharge market is $17,501. The estimated aggregate gain from trade, relative to the estimated maximum income ($1,272,484), is 1.38%.

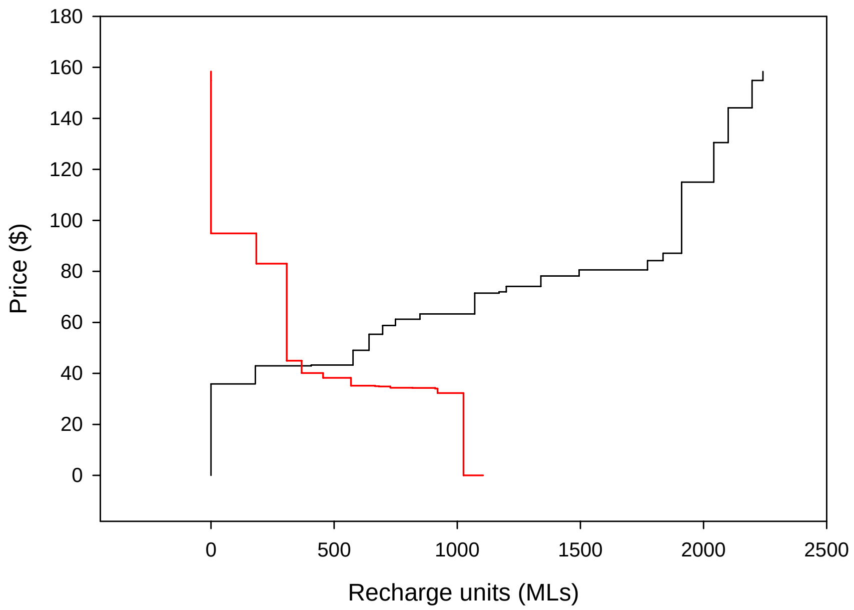

Figure 1: Estimated supply and demand for recharge in the experimental simulation of CIA

Player payments and penalties

Experimental economics tests and measures real rather than hypothetical economic behaviour by paying participants based upon the outcomes of their decisions. The comparison and analysis of experimental treatments is statistically more robust when participant decisions are responses to equivalent payment options. Therefore in these experiments, payments for each period were relative to the optimal decision responses for each farm. It was also necessary to ensure that payment functions are equivalent *between* experimental treatments. Player payments were therefore calculated as a function of actual and optimum aggregate farm management and trading outcomes, specific to each experimental treatment.

In addition to a $10 attendance payment, player payments are calibrated using a single variable OLS regression, relating a $2.00 per period for achieving the derived optimum farm income and $0.40 for decisions predicted to produce minimum farm incomes. Theoretical optima assume players are profit maximises acting optimally to available levels of information and strategies. To ensure salience of player behaviour and response to income variance in the simulated catchment, the player payments are therefore a scaled representation of the income decisions confronting farmers in the CIA. To ensure the integrity of future experimental sessions, the payment functions have not been reported here. They are available upon request from the corresponding author.

If aggregate recharge exceeds the threshold for a zero water table rise (1610 MLs), farms incur crop loss, resulting in a reduced income. Nett player income is calculated by subtracting the crop loss penalty from the gross player payment for each period. The crop loss penalty represents a socialised cost (except in the individual penalty treatment), equally imposed on all players, as rising groundwater increases salinity for the whole of the Coleambally catchment. The maximum crop loss penalty is $1.50 or 75% of the optimum player payment, corresponding to estimates of actual crop loss due to maximum water table rise and subsequent soil salinity (Khan pers. comm. 2004). The crop loss penalty is calculated as a linear function of the rise in water table. Khan (2004, pers comm.) proposes the function is likely to be non-linear function, but an accurate estimation was not available at the time. In the individual penalty treatment, participants who exceeded their recharge allocation had their income reduced to that of the nearest option which did meet their allocation.

The experimental simulation and recharge credit trading environment was field demonstrated at Yanco Agricultural College with CIA based irrigators. In the experimental field simulations, observed market prices for recharge units generally reflected modelled outcomes, although the level of trade was limited and the incentive to trade was small, i.e. the proportion of trading income relative to farm income was very low. The data for the simulated catchment were refined and re-framed for the laboratory sessions in accord with irrigator comments. Suggestions were made for a larger penalty for non-compliance with recharge targets. In accord with farmer consultation, current experimental penalties reflect a reduction in farm income corresponding to an income level associated with a complied recharge target. The market cost of recharge purchases that partially fulfil targets were also deducted from farm income.

5. Characteristics of the experimental setting

Experiments were carried out at the Griffith University experimental economics laboratory in Brisbane, using the MWATER experimental software platform developed and administered by Dr. John Tisdell. The software provides a standardised decision-making environment and allows for the inclusion of complex biophysical data in the experimental decision set. Participants were drawn from a pool of approximately 200 Griffith students who had taken part in a number of previous experiments. The use of students as experimental participants is in accord with standard experimental economics practice (Friedman & Sunder 1994, Kagel & Roth 1995, Smith 2002).

At the beginning of each session, participants accessed a set of power point instructions through their computer terminal. The instructions explain the rules, protocols of the experimental setting and the characteristics of the experimental farm. They are specific to the treatment being tested in that session. Staff supervising the experimental sessions do not verbally present the instruction sets to avoid personality or behavioural biases and delivery nuances. Talking, unless in a formal treatment, is forbidden throughout the sessions, except to clarify questions regarding the experimental setting. To ensure consistent understanding participants were asked to complete a quiz comprising 10-12 questions specific to the experimental treatment. All questions must be completed successfully before participants can access the experimental software.

Participants are randomly assigned to the 12 model farms. Upon accessing the experimental software they are presented with a table listing the farm income associated with each of the five management options available to them. They are also told their farm's initial recharge allocation (R_a), nominally set as the crop mix option corresponding to a zero water table rise. In treatments two onwards they are also told how much each decision would contribute to total recharge. Recharge information is provided to participants as the number of recharge units, rather than as ML. Participants only have access to their own farm information, updated throughout the experiment. All information is derived from the SWAGMAN model.

At the beginning of each period, participants are asked to select one of the five discrete farm management options by entering a number into a box, which appears on screen for 90 seconds. After entering the chosen management option, screens are updated with the option-specific income. In treatments one and two subjects are provided gross income for each round, and are told that there is likely to be a crop loss penalty, which will not be known until the end of the session. In subsequent treatments, subjects learn their income nett of any crop loss in each period. If all experimental players choose the crop mix that maximises income, recharge is also maximised to a level of 2683 MLs. A crop mix decision set that corresponds to a zero water table rise represents a recharge value of 1610 MLs.

In the market treatments participants are also told the required recharge balance for the selected option and the marginal value of recharge units. The recharge balance (R_b) is calculated as the initial recharge allocation less the amount needed for the farm management option the participant selects. R_b can represent a surplus or deficit of recharge units depending on the farm allocation and management option selected. For example if R_a =100, $R_{option\ 1}$ = 200; R_b = -100. If R_a =100, $R_{option5}$= 0, R_b =100. Option one has a 100 recharge unit shortfall, requiring purchase in a recharge market; option five has a surplus of 100 units, allowing a sale in the market. The marginal value of a recharge unit is calculated as the difference in income between that of the target recharge option and the selected management option, divided by the cumulative difference in recharge between the target recharge and the selected management options.

Players voluntarily enter the market to meet recharge shortfalls and sell surplus recharge units. Market trading options are contingent on player behaviour and conditioned by farm characteristics. Participants can either buy or sell (subject to having surplus recharge units), but may only enter a single bid in each period. Market entrants enter bid quantities (based on R_b) and their price (based on the marginal value of recharge). Players are prevented from offering surplus recharge units for sale in excess of their calculated R_b. A closed call market institution is used in the trading session. Bids are accepted over a 90 second period, and the market clearing price calculated. The market price is announced (in the event that there are no matching buy and sell offers, it is announced that no trades occurred), but individual bids are not revealed. Participants' screens are then updated to reveal the outcome of their bids, the market price and their total income from the period.

In the communication treatments, participants are asked to move into a separate room and encouraged to discuss coordinating their recharge decisions. The initial forum, lasting five minutes, is prior to selecting management options in the first experimental period. Before each subsequent round participants are again asked to move into a side room for a further three minute discussion forum. Players cannot reveal their farm characteristics, intended or historical market strategies or the value of their recharge units. Making threats, or arranging side payments outside the laboratory, are forbidden. Players who contravene these experimental protocols are excluded from future sessions. Consensus is achieved by majority vote if required. Communication between players is not permitted between the discussion forums. Supervising staff are able to facilitate the discussion forum by answering technical questions and calculating aggregate recharge reduction and social payment estimates only. They cannot engage in any strategic discourse with the players. Participation in the treatment is voluntary, subsequent decisions remain anonymous, and there is no individual penalty for non-adherence to the group consensus.

Each session involved approximately ten periods (the exact number was randomly varied so the participants could not be sure when the experiment would end) and varied from 1.5 to 2 hours depending on treatment design. Participants were paid their total earnings for all periods in cash at the end of each session. All decisions and payments were anonymous. A complete set of the experimental instructions can be obtained from the author (j.ward@csiro.au).

The experimental rules and player information in the treatments are summarised as:

- ***Treatment $_1$ (control):*** farm income (converted to gross player income) only associated with 5 crop mix decisions, no recharge information. The total crop loss penalty (equally shared amongst all players) is announced at the end of the 10 period experimental *session* (i.e. the penalty is announced once).
- ***Treatment $_2$:*** farm income corresponding to 5 crop mix decisions plus associated recharge rate and the farm income/crop mix associated with zero water table rise (called SWAGMAN information). The crop mix decision associated with the zero water table rise specific to each farm corresponds to the recharge entitlement. The total crop loss penalty is announced at the end of the 10 period *session*.
- ***Treatment $_3$:*** SWAGMAN information, zero recharge rate and player income net of crop loss penalty plus crop loss penalty is publicly announced at the end of each *period* (i.e. the penalty is announced 10 times).
- ***Treatment $_4$:*** SWAGMAN information, zero recharge rate, period announcement of crop loss penalty plus communication forum.
- ***Treatment $_5$:*** SWAGMAN information, zero recharge rate, period announcement of crop loss penalty plus cap and trade market.
- ***Treatment $_6$:*** SWAGMAN information, zero recharge rate, period announcement of crop loss penalty plus market and communication.

- ***Treatment $_7$:*** SWAGMAN information, zero recharge rate, plus market plus individualised penalty for non-compliance with the specific individual recharge entitlement.

6. Experimental Results

Observed data measuring behavioural responses to treatments were analysed using One Way Analysis of Variance (ANOVA). For both ANOVA (F) and pairwise t-tests, * indicates significantly different values at α=0.05. Homogeneity of variance between treatments was tested by Levene's statistic and found to be significantly different (p<0.05) for all treatments. Therefore, Dunnett's T3 *post hoc* test was used for pair wise comparison and described by subscript letters across the ***mean value*** row. Differences in subscripted letters across rows indicate the ***post hoc*** comparison is significantly different at α=0.05. Data are tabled for the seven treatments as: Total recharge (MLs), total crop loss ($); Nett player income ($):and for the market treatments: Market price ($); Quantity traded (MLs) and Gains from trade ($). The model prediction of total farm recharge represents the policy objective of a zero water table rise (1610 MLs) and corresponds to players acting as profit maximisers, responding optimally to available information.

Observed Total Recharge was highest in the baseline and information only treatments (Figure 2, treatments 1-3). The coordinating institutions, communication and market treatments (4-5), were both associated with a significant decrease in overall recharge compared to the information only treatments and the control. Combining the market and communication treatments significantly reduced recharge still further (treatment 6), and introducing individual penalties for non-compliance treatment (7) was associated with the lowest level of recharge, in this case below the target threshold of zero water table rise. Treatments 6 and 7 are not statistically different from both the modelled prediction of a zero water table rise and each other. In all treatments the rise in water table was statistically less than the predicted maximum.

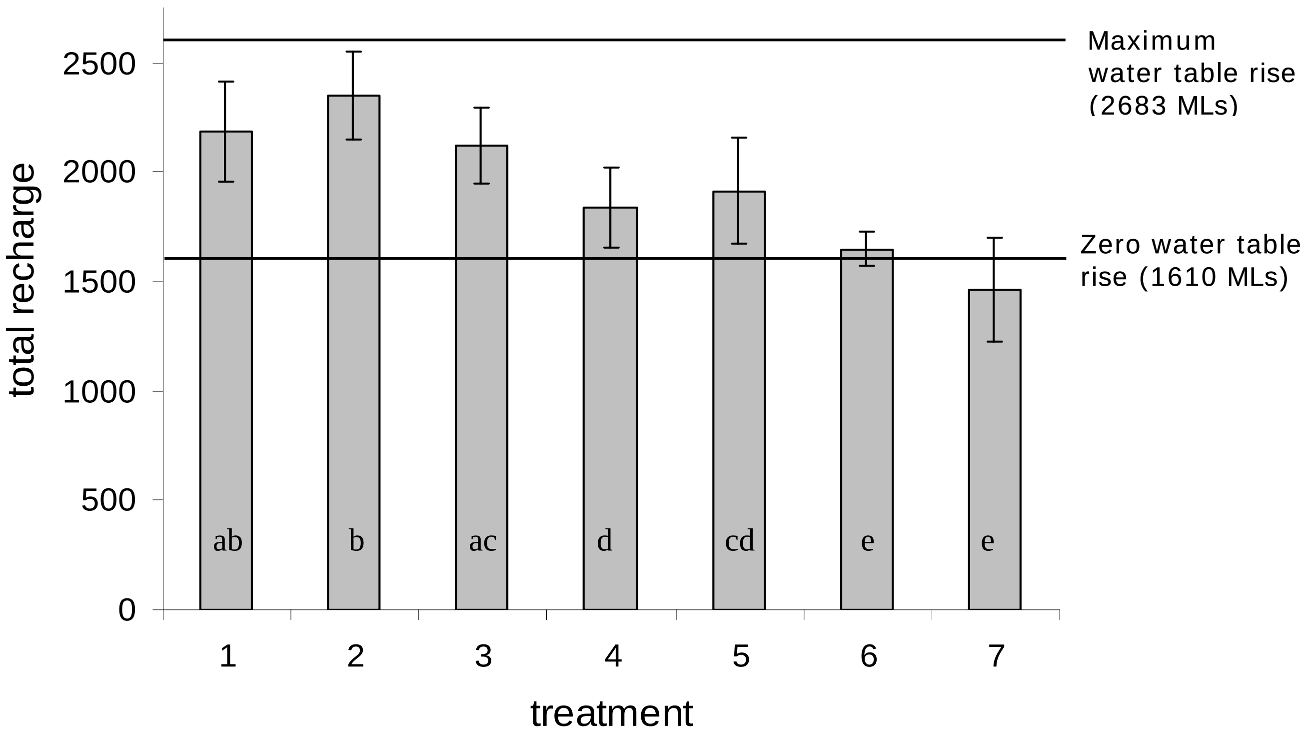

Figure 2: Total recharge (mean +/- 5%: 95% CI) by treatment[1].

[1] Bars with the same letter are not significantly different at the 5% level

Table 2: Table of descriptive statistics and ANOVA Total recharge

DESCRIPTIVES								
Total Recharge								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Min**	**Max**
control	20	2189.15	229.927	51.41335	2081.5406	2296.7594	1742.00	2440.00
swagman	20	2349.20	202.105	45.19214	2254.6118	2443.7882	1887.00	2658.00
Swagman+crop loss	20	2122.15	170.505	38.12626	2042.3508	2201.9492	1891.00	2492.00
communication	20	1839.15	183.209	40.96688	1753.4053	1924.8947	1610.00	2302.00
market	20	1914.30	244.400	54.64951	1799.9173	2028.6827	1091.00	2335.00
market+commun-ication	20	1650.30	81.0367	18.12037	1612.3736	1688.2264	1480.00	1769.00
Market+non-compliance	20	1464.55	235.791	52.72448	1354.1964	1574.9036	988.00	1928.00
model	10	1610.00	.00000	.00000	1610.0000	1610.0000	1610.00	1610.00
Total	150	1911.17	346.809	28.31686	1855.2188	1967.1278	988.00	2658.00

	T'ment t_1	**T'ment t_2**	**T'ment t_3**	**T'ment t_4**	**T'ment t_5**	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	2189 ^{ab}	2349 ^{b}	2122 ^{ac}	1839 ^{d}	1914 ^{cd}	1650 ^{e}	1464 ^{e}	1610^{e}
T'ment t_1								
T'ment t_2	0.455							
T'ment t_3	1.000	0.000 *						
T'ment t_4	0.000*	0.000*	0.000*					
T'ment t_5	0.020*	0.000*	0.091	0.999				
T'ment t_6	0.000*	0.000*	0.000*	0.007*	0.003*			
T'ment t_7	0.000*	0.000*	0.000*	0.000*	0.000*	0.069		
model	0.000*	0.000*	0.000*	0.001*	0.001*	0.555	0.244	

(*p* value, Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(7, 142)} = 48.480$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at α=0.05.)

The results indicate that observed Crop Loss was zero with the individual non-compliance penalty, and significantly less in the in the market-communication treatment (T_6) compared to treatments 1-5, (see Figure 5). Crop loss was significantly higher in the market only (T_4) and communication only (T_5) treatments compared to T_6, and significantly higher still in the information only treatments (T_{1-3}). The market only and communication only treatments were not significantly different. Among the information treatments, crop loss was significantly lower when experimental subjects were provided with crop loss data from the SWAGMAN model after each period (T_3) rather than at the end of the session (T_{1-2}).

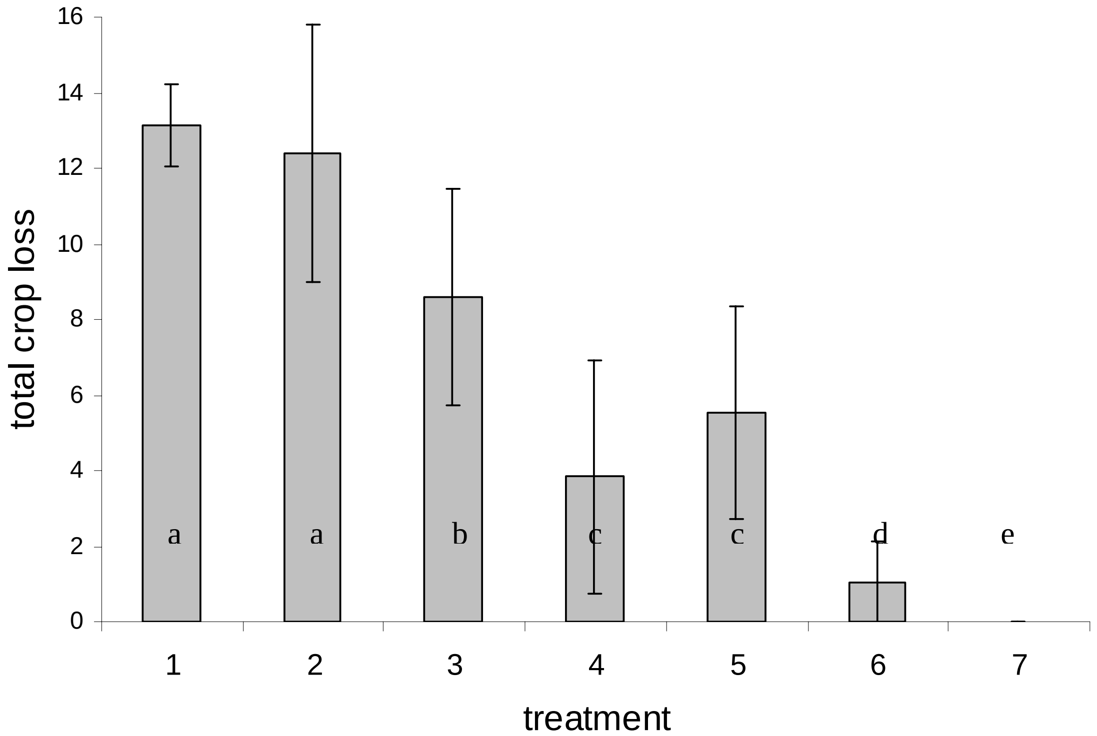

Figure 3: Total crop loss (mean +/- 5%: 95% CI) by treatment[2].

[2] Bars with different letters are significantly different at the 5% level

Table 3: Table of descriptive statistics and ANOVA Total crop loss

DESCRIPTIVES

Total crop loss

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
control	20	13.1460	1.10427	.24692	12.6292	13.6628	11.16	15.36
swagman	20	12.4080	3.39018	.75807	10.8213	13.9947	4.68	17.64
Swagman+crop loss	20	8.5920	2.86136	.63982	7.2528	9.9312	4.68	14.76
communication	20	3.8400	3.08138	.68902	2.3979	5.2821	.00	11.64
market	20	5.5320	2.81368	.62916	4.2152	6.8488	.00	12.12
market+commun-ication	20	1.0200	1.10085	.24616	.5048	1.5352	.00	3.48
market+non-compliance	20	.0000	.00000	.00000	.0000	.0000	.00	.00
model	10	.0000	.00000	.00000	.0000	.0000	.00	.00
Total	150	5.9384	5.43479	.44375	5.0615	6.8153	.00	17.64

	T'ment t_1	**T'ment t_2**	**T'ment t_3**	**T'ment t_4**	**T'ment t_5**	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	13.15 [a]	12.41 [a]	8.59 [b]	3.84 [c]	5.53 [c]	1.02 [d]		0.00[e]
T'ment t_1								
T'ment t_2	1.000[1]							
T'ment t_3	0.000*	0.012 *						
T'ment t_4	0.000*	0.000*	0.00*					
T'ment t_5	0.000*	0.000*	0.041*	0.845				
T'ment t_6	0.000*	0.000*	0.000*	0.020*	0.000*			
T'ment t_7								
model	0.000*	0.000*	0.000*	0.001*	0.000*	0.014*		

(*p* value: Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(7, 142)} = 98.600$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at $\alpha=0.05$)

Player income was highest in the market-communication and market-individual non compliance treatments (*$T_{6,7}$*) (see Figure 4). Income in the market only treatment was significantly higher than in the communication only treatment. The lowest incomes were in the information only treatments (*$T_{1,2}$*), but treatment three, which provided the most SWAGMAN information to participants, had significantly higher incomes than treatments one and two.

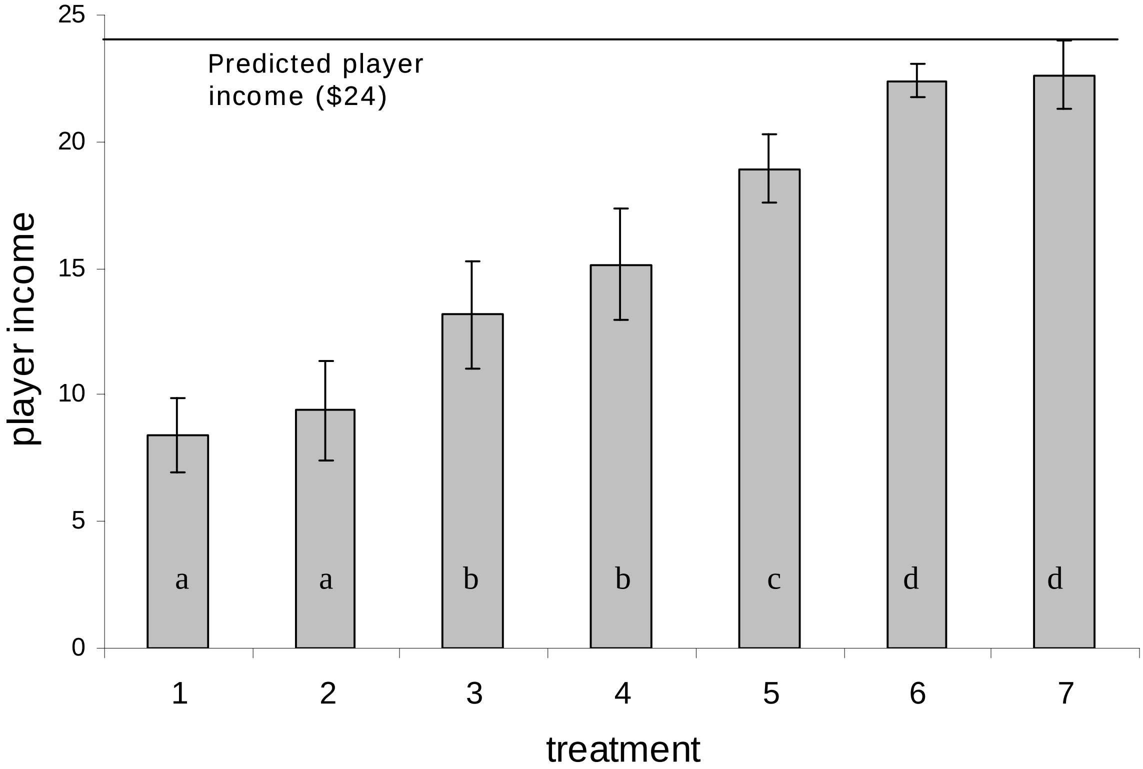

Figure 4: Player income (mean +/- 5%: 95% CI) by treatment[3].

[3] Bars with different letters are significantly different at the 5% level

Table 4: Table of descriptive statistics and ANOVA for player income

DESCRIPTIVES Player Income								
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
control	20	8.3910	1.46815	.32829	7.7039	9.0781	6.63	10.92
swagman	20	9.3845	2.00641	.44865	8.4455	10.3235	6.38	13.87
Swagman+crop loss	20	13.1710	2.13244	.47683	12.1730	14.1690	8.24	16.29
communication	20	15.1475	2.18506	.48860	14.1249	16.1701	9.67	17.98
market	20	18.9265	1.36004	.30411	18.2900	19.5630	15.48	20.91
market+communication	20	22.3895	.66705	.14916	22.0773	22.7017	21.22	23.43
Market+non-compliance	20	22.6370	1.34919	.30169	22.0056	23.2684	19.32	24.59
model	10	24.0000	.00000	.00000	24.0000	24.0000	24.00	24.00
Total	150	16.2729	5.83797	.47667	15.3310	17.2148	6.38	24.59

	T'ment t_1	T'ment t_2	T'ment t_3	T'ment t_4	T'ment t_5	T'ment t_6	T'ment t_7	model
Mean value								
T'ment t_1								
T'ment t_2	0.859[1]							
T'ment t_3	0.000*	0.000 *						
T'ment t_4	0.000*	0.000*	0.148					
T'ment t_5	0.000*	0.000*	0.000*	0.000*				
T'ment t_6	0.000*	0.000*	0.000*	0.000*	0.000*			
T'ment t_7	0.000*	0.000*	0.000*	0.001*	0.000*	1.000		
model	0.000*	0.000*	0.000*	0.001*	0.000*	0.000*	0.006*	

(*p* value: Dunnett's T3 post hoc test; Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(7, 142)} = 256.086$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at α=0.0)

The market outcomes of quantity traded, market price and the gains from trade are illustrated in Figures 5-7 and the results of statistical testing summarised in Tables 5-7. In the market treatments ($T_{5\text{-}7}$), the overall quantity traded was significantly below the 407 Mls level predicted by the model (Figure 5). Volumes were significantly higher in the market and communication treatment (T_6) than with the market only (T_5). The market plus individual penalty treatment resulted in a significant increase in trade quantity compared to the other market treatments.

The observed market price for recharge allocation credits in the market (T_5) and the market plus communication (T_6) treatments was not significantly different from the price predicted by the model. Introducing individual penalties for non-compliance significantly increased the market price over the market only (T_5) and the predicted level (Figure 6).

Gains from trade followed the same pattern, significantly increasing from treatment five to six to seven, but significantly less than the level predicted by the model (Figure 7). Overall gains from trade were small compared to overall income. Even in the treatment with the most active market (T_7), gains from trade still comprise approximately 1% of total farm income.

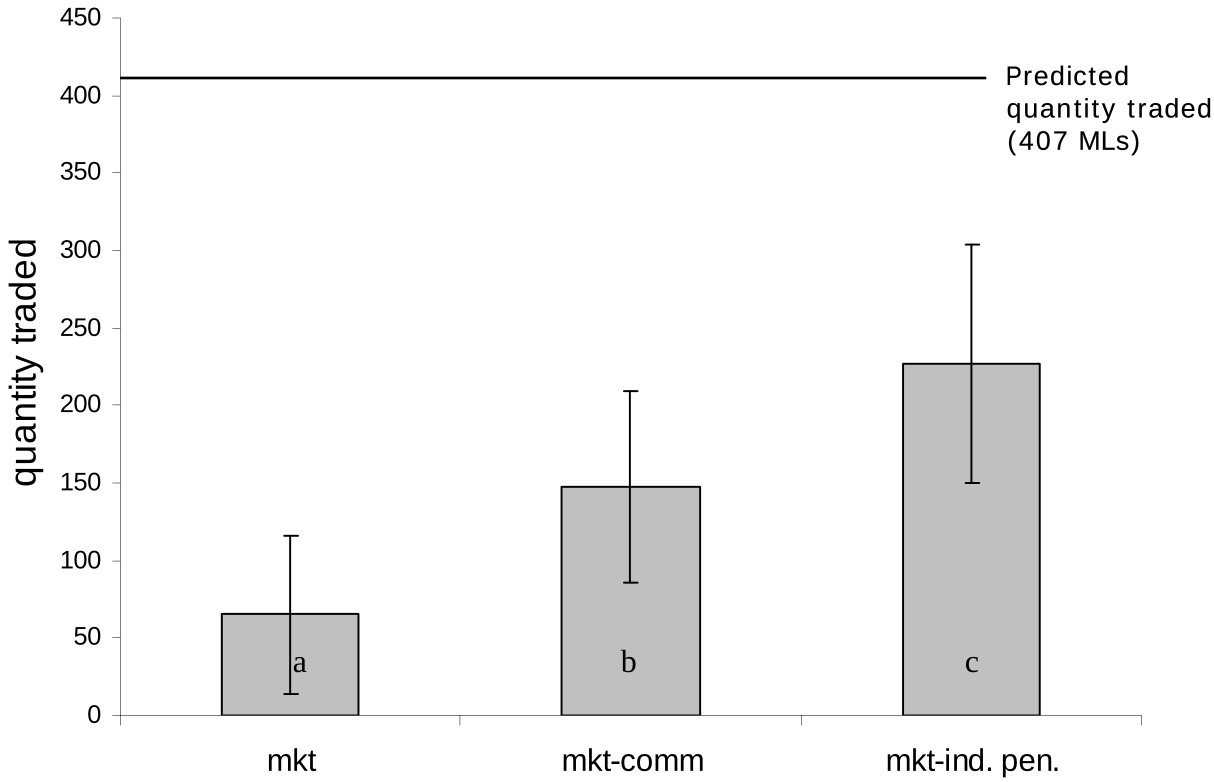

Figure 5: Quantity of recharge units traded (mean +/- 5%:95% CI) by treatment4.

[4] Bars with different letters are significantly different at the 5% level

Table 5: Table of descriptive statistics and ANOVA of quantity traded

DESCRIPTIVES								
Quantity traded								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
market	20	65.2000	50.96191	11.39543	41.3491	89.0509	.00	174.00
market+commun-ication	20	147.5000	61.84403	13.82875	118.5561	176.4439	.00	254.00
Market+non-compliance	20	226.4500	77.06352	17.23193	190.3832	262.5168	116.00	409.00
model	10	407.0000	.00000	.00000	407.0000	407.0000	407.00	407.00
Total	70	183.6143	124.93967	14.93315	153.8235	213.4051	.00	409.00

	T'ment t_5	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	65.20 ^{a}	147.50 ^{b}	226.45 ^{c}	407.00^{d}
T'ment t_5				
T'ment t_6	0.000*[1]			
T'ment t_7	0.000*	0.006*		
model	0.000*	0.000*	0.000*	

(*p* value: Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(3, 66)} = 78.897$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; treatment means with the same letter were not statistically different at α=0.05.)

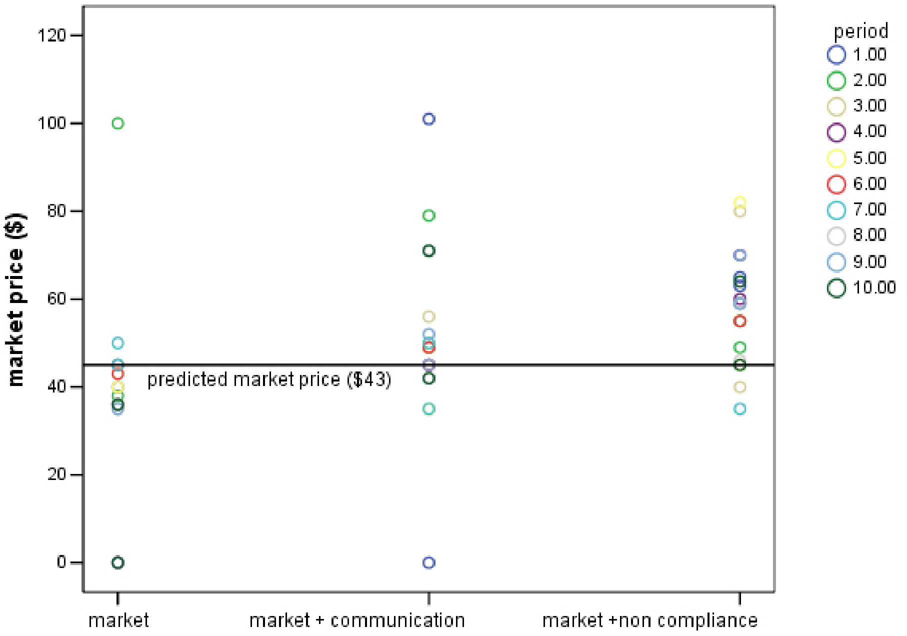

Figure 6: Market price in each experimental period, by treatment

Table 6: Table of descriptive statistics and ANOVA for market price

DESCRIPTIVES								
Market price								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
market	20	34.9000	22.67134	5.06946	24.2895	45.5105	.00	100.00
market+communication	20	50.7500	19.88090	4.44550	41.4455	60.0545	.00	101.00
Market+non-compliance	20	58.0000	12.35442	2.76253	52.2180	63.7820	35.00	82.00
model	10	43.0000	.00000	.00000	43.0000	43.0000	43.00	43.00
Total	70	47.1857	19.39766	2.31846	42.5605	51.8109	.00	101.00

	T'ment t_5	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	34.90 ^{a}	50.75 ^{ab}	58.00 ^{b}	43.00 ^{a}
T'ment t_5				
T'ment t_6	0.132[1]			
T'ment t_7	0.002*	0.666		
model	0.525	0.431	0.000*	

(*p* value: Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(3, 66)} = 6.310$; $p< 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at α=0.05.)

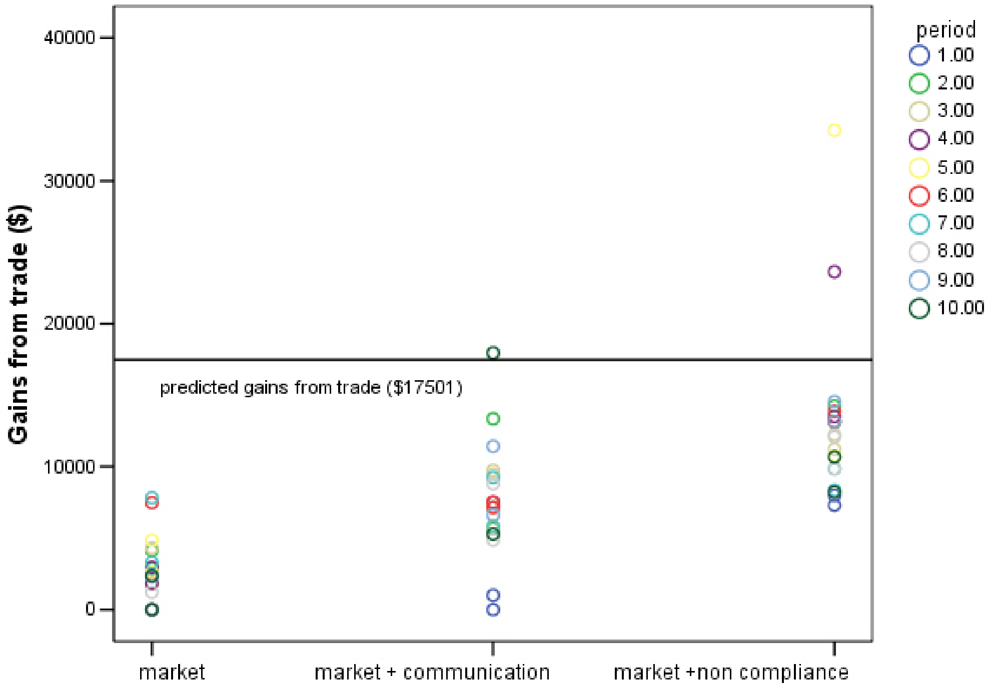

Figure 7: gains from trade in each experimental period, by treatment

Table 7: Table of descriptive statistics and ANOVA for gains from trade

DESCRIPTIVES tradegains Gains from trade								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
market	20	2748.1000	2202.74907	492.54967	1717.1817	3779.0183	.00	7830.00
market+communication	20	7582.8000	3925.55147	877.77999	5745.5854	9420.0146	.00	17963.00
Market+non-compliance	20	13072.4500	5966.24937	1334.09392	10280.1593	15864.7407	7308.00	33538.00
model	10	17501.0000	.00000	.00000	17501.0000	17501.0000	17501.00	17501.00
Total	70	9186.8143	6522.11823	779.54223	7631.6701	10741.9585	.00	33538.00

	T'ment t_5	**T'ment t_6**	**T'ment t_7**	**model**
Mean value	2748 [a]	7582 [b]	13072 [c]	17501[d]
T'ment t_5				
T'ment t_6	0.000*[1]			
T'ment t_7	0.000*	0.010*		
model	0.000*	0.000*	0.021*	

(*p* value: Dunnett's T3 post hoc test: Homogeneity of variance (Levine statistic) $p < 0.05$; ANOVA coefficients: $F_{(3, 66)} = 38.843$; $p < 0.05$; * indicates significantly different at $\alpha = 0.05$; Treatment means with the same letter were not statistically different at α=0.05.)

7. Conclusions

In the baseline control treatment, in which experimental subjects were provided with no information about recharge or the aggregate penalty for incurred crop loss, overall recharge levels were high, resulting in significant crop loss. However it should be noted that recharge levels were still below the predicted maximum of 2683 MLs, suggesting that some participants may be voluntarily limiting their individual income in order to keep recharge down. Introducing additional information about individual contributions to recharge did not result in a significant reduction in total recharge when crop loss was not known until the end of the experiment. Crop loss also remained high in both these treatments. However, providing the monetary value of crop loss at the end of each period did result in a significant decrease in crop loss and a corresponding increase in player income. Therefore these experiments provide only limited support for hypothesis one, that providing information about recharge and crop loss will reduce recharge levels. As previous studies have found, information may be necessary for co-ordination and successful management, but it is seldom sufficient (eg Tisdell *et al.* 2004). Coordination of individual behaviour in this research refers to the total recharge resulting from land management decisions of individual players complying with the specified zero water table threshold for the yearly accounting period.

Providing the communication forum resulted in significant decreases in total recharge, crop loss and increased incomes. Hypothesis two is therefore supported by the experimental data. This suggests that face to face communication allows and reinforces the formation of an informal but robust social compact. The results are in accord with Ostrom *et al*. (1992), Tisdell *et al*. (2004) and Poe *et al*. (2004). Additionally, levels of observed voluntary adherence to the crafted contract were high and in contrast to game theoretic predictions (Ledyard 1995) did not decay through the experimental periods. Such institutions are attractive because they are entirely voluntary, and involve low transaction costs. This form of institution should be investigated further in the field trial to test whether the result holds among groups of irrigators characterised by potentially diverse social norms and competing demands. As a cautionary note, developing effective social norms is likely to be far more challenging among a large and diverse group of irrigators than among a dozen experimental participants.

While capping recharge clearly imposes a cost on landholders, allowing trade should compensate or reduce this burden. In a “frictionless” market setting where participants could quickly learn to understand the advantages of trade with “zero learning” cost, savings to landholders through market exchange between individuals with surplus recharge rights and those in deficit may be considerable. Information from frictionless market exchange would reveal any differences in returns to farm management options that reduce recharge and these would be immediately discovered and exploited.

The evaluation of the treatment testing behavioural responses to a clearance market mechanism indicated reduced crop loss and increased player incomes. In the presence of a cap, distributed according to a specified allocation limiting individual contributions to recharge, and enforced by a socialised penalty for breeching the cap, the ability to trade appeared to provide a statistically effective coordination mechanism. Combining the market with a communication forum significantly improved performance compared to the individual market and communication treatments. This suggests that people can use the market mechanism to achieve voluntary abatement targets, and sufficiently compensate the loss of farm income with trade generated income. Hypothesis three, that markets can facilitate a reduction in recharge, is therefore also supported.

The most dramatic reduction in recharge occurred when the crop loss penalty for non-compliance with the cap was converted to an individual rather than a group penalty, supporting hypothesis four. This is to be expected, as the imposed individual penalty represents the elimination of the common pool dilemma and there is no longer any incentive to free ride. Combined with the market institution, this treatment delivered the highest gains from trade. However, as in all the market treatments, gains from trade were still significantly lower than predicted by the economic model. Participants traded less than expected, reducing the already relatively small potential trade gains. In the market and the market plus communication treatments, the price of recharge credits was not significantly different from the equilibrium price predicted by the model. However with the individual penalty for non-compliance, the price was significantly higher. Risk adverse buyers may be paying more than the equilibrium price in order to avoid incurring the penalty. Trading occurred after participants had made their management decision; participants who had selected an option which required them to purchase additional recharge credits will therefore have been under strong pressure to succeed in buying the necessary credits.

An overall assessment of the net gains from trade will need to account for the transaction costs of administering an effective market in concert with establishing and monitoring individual compliance levels. The implementation of an individualised, point source institution for recharge management is likely to be associated with high transaction costs, which potentially may outweigh the benefits accrued from trade. Policies considering the development of a market in tradeable recharge credits will need to balance likely participation rates when the gains from trade (1.38% in this simulation) are very low relative to farm incomes.

These experiments have demonstrated that communication, market exchange and individual non-compliance penalties are all effective institutions for reducing recharge in the simulated catchment when combined with information from the SWAGMAN model. Subsequent field trials should aim to investigate these institutions further in experiments with stakeholders from the CIA.

Acknowledgements:

This report was produced for the Commonwealth National Action Plan for Salinity and Water Quality Market-based instruments pilot program. The National Action Plan for Salinity and Water Quality is a joint initiative between the State and Commonwealth Governments. Coleambally Irrigation Cooperative provided information input and coordinated irrigator responses. All errors remain the responsibility of the authors.

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APPENDIX Typical experimental farm data

Table 7a Table showing relationship of water table (WT) rise, gross magin (GM), recharge and crop mix

Max WT rise (m)	Surplus water (MLs)	GM ($)[1]	Recharge(MLs)	Crop type (Ha)								TOTAL (ha)	Irrigation MLs
				rice	maize	lucerne hay	wheat	canola	dryland wheat	dryland pasture	fallow		
max		103965	228	69	20	3	48		40		20	200	1154
0.6		103548	211	69	20	8	23	0	40	20	20	200	1152
0.5	0	102737	191	66	20	13	14	0	40	27	20	200	1153
0.4	0	101180	160	56	20	13	66	0	25		20	200	1163
0.3	0	98790	132	57	9	12	100	2			20	200	1161
0.2	33	95333	104	57		11	52	60			20	200	1126
0.1	128	90687	74	48		11	61	60			20	200	1041
0[2]	223	86041	44	39		10	71	60			20	200	946
-0.1	318	81395	14	30		10	80	60			20	200	860
-0.15	366	79071	0	25		10	85	60			20	200	813

Table 7b Table showing relationship of water table rise, experimental decision set, farm income and recharge

Max WT rise (m)	Experimental decision	GM ($)	Recharge (MLs)	Marginal change[3] in GM ($)	Marginal change in recharge (MLs)
max	1	$103,965	228	17924	184
0.4	2	$101,180	160	15139	116
0.2	3	$95,333	104	9292	60
0	4	$86,041	44	0	0
-0.15	5	$79,071	0	6970	44

[1] Gross margins include the sale of surplus water a$30/ML

[2] zero water table rise: recharge allocation for experimental farm is set at 44 MLs

[3] marginal change is calculated as the difference in decision value ($ or MLs) and zero water table rise (viz. $86,041 or 44 MLs)