Tradeable recharge credits in Coleambally Irrigation Area: Report 4

Laboratory tests of alternative institutional frameworks

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CSIRO & BDA Group

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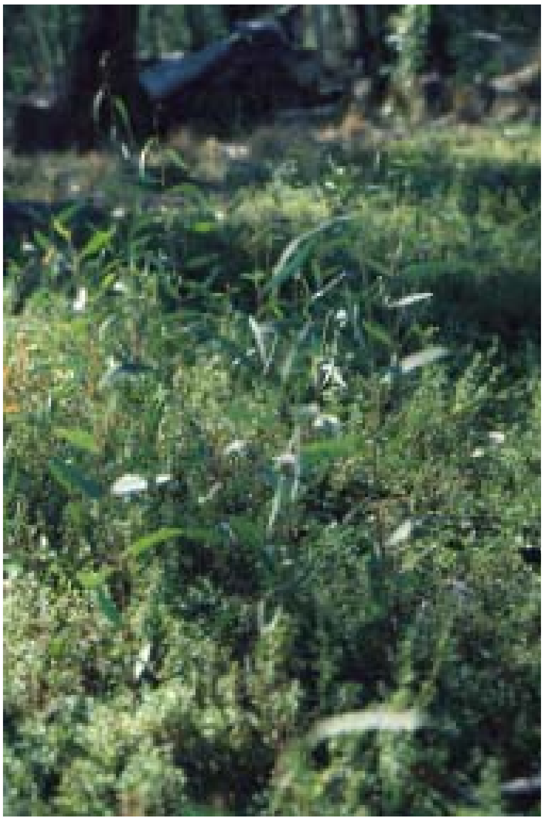

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This paper is the third in a series from a two-year research program. The focus in this paper is on laboratory tests of alternative institutional frameworks using experimental economics techniques. Papers in this series are:

- *What are the issues?*
- *Economic impact of tradeable recharge credits and other net recharge abatement policies for the Coleambally irrigation area*
- *Designing experiments to test tradeable recharge credits in the Coleambally irrigation area*
- *Laboratory tests of alternative institutional frameworks*
- *Field trial and farm case studies*
- *Biophysical modelling for linking farms with regional net recharge targets*
- *Experiences, lessons and findings*

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Executive Summary

The project 'Tradeable Recharge Credits in Coleambally Irrigation Area' is exploring the issues and practicability of implementing a 'cap and trade' instrument to improve the management of waterlogging and salinity in the Coleambally Irrigation Area (CIA). A number of issues relating to the design and implementation of 'cap and trade' approach to waterlogging and salinity management were identified in previous reports. The focus in this report is on the use and findings from the application of experimental economics techniques to aid in the design of robust and efficient institutional structures for recharge credit definition and trading.

The experimental economics approach was used because local and international 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. Additionally, the behaviour of individuals with non-market and social motivations may diverge substantially from theoretical predictions. 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.

In order to conduct laboratory tests of alternative institutional frameworks a calibrated environment where various incentives and rule combinations can be tested and evaluated was specifically designed to reflect the Coleambally Irrigation Area. In this context specific environment model farm data from the region were used to calibrate the model and provide the framework for the experimental treatments. This simulated setting was designed to:

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

Eleven market impediments were previously identified as being sufficiently important to market design that experimental testing was considered. These 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;
- Potential administrative and political feasibility; and
- Ease of designing and implementing an experimental treatment.

A number of potential experimental treatments could be considered to reduce the impact of these market impediments. Treatments were prioritised to account for limited time and resources. Solutions to a number of the most important potential impediments were embedded into the experimental design rather than tested as

treatments. This was because they were viewed as critical to any proposed outcome and therefore a necessary base for testing the effectiveness of solutions to other measures. For example, some form of property rights is essential to any market or non-market solution. Other factors were designed into the experiment via the use of a context specific parameterisation of the experiments. For example, existing farm data was used as the basis for the ensuing experiments, in part to identify the importance of thin markets in reducing market efficacy.

The prioritisation process led to a focus on testing the impact of treatments in four areas: the impact of information, communication, trading efficacy, and individual or group penalties. The treatments and anticipated outcomes are shown in the table below.

Summary of treatments and hypotheses

Treatment	Anticipated outcome
1.Baseline – no recharge information and crop loss only at end of session.	Few incentives for individuals to limit their unknown contributions, therefore excess recharge and consequent crop loss.
2.Recharge information 3.Crop loss information	Recharge will be reduced but not to levels sufficient to manage the problem.
4.Face to face communication	Face to face communication likely to increase social capital and may be effective in reducing recharge levels sufficiently to manage the problem.
5.Market to trade recharge abatement 6.Market plus communication	Market institution with communication likely to achieve recharge reduction close to levels required to manage the problem. Lack of penalty may reduce efficiency.
7.Individual penalty for non-compliance in addition to information and market.	Penalty for non-compliance will lead to lower levels of recharge than when penalty is socialised across all players.

A simulated catchment was constructed to test the hypotheses about the impact of alternative treatments. The simulated catchment comprised twelve model farms based on a representative sample of farms from the CIA, with sizes ranging from 200 to 335 hectares. The SWAGMAN Farm model was used to estimate levels of income and recharge for each model farm under alternative management options. To provide context, experimental participants were told they were playing the role of a farmer, and the nature of the recharge problem was explained. Participants were randomly assigned to a model farm, and in each period of the experiment they were asked to choose one of the five alternative management options.

The experimental simulation and recharge credit trading environment was field demonstrated at Yanco Agricultural College. The field demonstrations were intended as an extension process and to pre-test the context relevance and acceptability of the simulated catchment and proposed experimental simulations. Overall the irrigators present enthusiastically participated in the recharge trading demonstration, recognising the immediate need for remedial, shared recharge management.

Experiments were carried out using the MWATER experimental software platform developed and administered by Dr. John Tisdell. The software provides a standardised decision-making environment. Participants were drawn from a pool of approximately 200 students who had taken part in a number of previous experiments. Each session involved approximately ten periods (the exact number was randomly varied so the participants could not be sure when the experiment would end). Participants were paid based on the income earned by their model farm subject to penalties if total recharge across the 12 farm catchment exceeded the threshold level.

Overall levels of recharge were highest in the baseline and information only treatments (treatments 1-3). Among the information treatments, crop loss was significantly lower when experimental subjects were provided with crop loss information after each period rather than at the end of the session. The coordinating institutions, communication and market (treatments 4-5), were both associated with a significant decrease in overall recharge. Combining the market and communication treatments 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. In all treatments the rise in water table was below the maximum possible.

Player income was highest in the market-communication and market-individual non compliance treatments. Income in the market only treatment was significantly higher than in the communication only treatment. In the market treatments, the overall quantity traded was significantly below the levels predicted by the model. Volumes were significantly higher in the market and communication treatment than with the market only. The market and individual penalty treatment resulted in another significant increase in trade quantity. Overall gains from trade were tiny compared to overall income.

A number of conclusions can be drawn from these experiments. First, as shown in previous experiments, information may be necessary for successful management, but it is seldom sufficient. Second, providing the communication forum resulted in significant decreases in total recharge and crop loss, and increased incomes. This suggests that face to face communication is allowing the formation of social capital and informal social norms. Such institutions are attractive because they are entirely voluntary, and involve very low transaction costs. However, developing effective social norms is likely to be far more challenging among a large group of irrigators than among a dozen students. Third, the market mechanism delivered reduced crop loss and increased incomes suggesting that people can use the market mechanism to achieve voluntary abatement targets. Finally, the most dramatic reduction in recharge occurred when the crop loss penalty for non-compliance was converted to an individual rather than a group penalty. This is to be expected, as 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 predicted, reducing the already slight potential trade gains.

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1. Background

Irrigation induced waterlogging and salinity is a well known problem in mature irrigation areas across Australia and the Coleambally Irrigation Area (CIA) is no exception. The consequences of salinity in irrigation areas include production losses, increased production costs and damage to environmental amenities and infrastructure assets in the region. The project ‘Tradeable Recharge Credits in Coleambally Irrigation Area’ is exploring the issues in the design and implementation of a market-based policy to manage waterlogging and salinity issues. In particular, the focus of analysis has been on the potential for the use of a tradable rights approach to offer efficiency, effectiveness and flexibility advantages over current and historical instruments.

The tradeable rights instrument investigated is a ‘cap and trade’ scheme. Under this type of policy instrument, a limit on the overall level of an activity or pollution associated with the environmental damage is established, and ‘rights’ to the agreed level of activity are allocated among users. Through the trading of these rights, greater efficiency, effectiveness and flexibility can often be achieved relative to other policy instruments. The focus in this report is on a number of outstanding issues relating to the design and implementation of a cap and trade policy approach.

A number of design and implementation issues were identified through the initial cap and trade institution exploration reported in the first report from the project titled ‘Tradeable Recharge Credits in Coleambally Irrigation Area: What are the Issues?’ An overview of the practical consequences of these issues was specified in the third report from the project sub-titled ‘Designing Experiments to test tradable recharge credits in the Coleambally Irrigation Area’. The implications for market efficiency and the relative effectiveness of alternative design options were poorly known for many of these outstanding issues. Hence, experimental economics techniques were employed to design a computer based simulation game based on modelled farms in the CIA that were used to assess the effectiveness of alternative treatments.

Experimental economics involves creating a calibrated environment where various incentives and rule combinations can be tested and evaluated. In the case of the CIA the environment is context specific, in that the environment is calibrated against model farm data from the region, as are the experimental treatments. The experimental setting is set out in some detail in the third report from the series. This setting was designed to facilitate the use of experimental economics to:

1. Test the significance of market impediments in a setting calibrated to represent important economic and biophysical features of the actual CIA;
2. Test behavioural responses to longer term policy options that may require changes to current institutional structures; and
3. 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 context 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 to test that the important aspects of context had been captured. Next, laboratory experiments to test alternative treatments of market impediments were undertaken. These experiments were used to inform a simulation trial with Coleambally landholders.

The report 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. Prioritisation of experimental tests is described in Section 3 prior to setting out the hypotheses and treatments in Section 4. Description of the context rich simulation setting is the focus in Section 5. A discussion of the pre-testing of the setting is reported in Section 6. The setting and process for the experiments that are the focus of the report is described in Section 7 and the results obtained set out and discussed in Section 8. Conclusions drawn from the experiments complete the paper in Section 9.

2. The role of experiments

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.

The expression of individual preferences is a complex psychological process where personal welfare may not be sufficient to explain the nature of choice, especially in the domain of public goods and environmental quality. The complexity of informational processing necessary to enable choice about novel environmental goods, which have remained "functionally invisible" (Vatn & Bromley 1995), and the nature of the accommodating institution (Smith 1987) may impede convergence with a theoretical equilibrium (Smith 1991, 2002). When implementing policies, agencies may need to account for behavioural and informational processing limitations which currently lie outside the domain of market analysis (Simon 1972, Sterman 1987, Smith 2002).

The proposed transitional state of the Coleambally irrigation area (CIA), the poorly defined state of information discovery and the public nature of groundwater recharge may mean that a single model is not sufficient for policy decision making. For effective recharge policy, careful instrument sequencing and accounting for the costs of complex informational processing may need to be imputed. The tendency has been to evaluate market instruments generically or in isolation. There is however a complex array of interactions between policy instruments, between the economy, environment and with societal processes.

In this MBI pilot project experimental economics has been employed to provide analytically based behavioural data and policy insights to the implementation of potential economic and community governance instruments. In a controlled setting, calibrated to represent the salient economic and biophysical features of the actual CIA, the experimental sessions have been applied to pre test feasible on-ground solutions and longer term policy options that may require changes to current institutional structures. 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 the land holder paper trial.

The construction of a laboratory based simulation or analogue of the CIA 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.

Well-designed experiments allow for the evaluation of participant willingness to exchange, the outcomes of diverse institutional structures across an array of market conditions and the efficacy of policy directives. The application of experimental results can minimise the need for trial and error in real world policy implementation, avoiding the social costs of inappropriate policies.

3. Prioritising impediments for experimental tests

In a previous report (Ward 2004), eleven market impediments were identified as being sufficiently important to market design that experimental testing was considered. These impediments are summarised in Table 1, along with a summary of likely consequences and potential solutions.

The impediments shown in Table 1 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;
- Potential administrative and political feasibility; and
- Ease of designing and implementing an experimental treatment.

A summary of these rankings is shown in Table 2, along with the impediments for which treatments are tested. A previous report (Ward 2004) identified 10 potential experimental treatments based on these market impediments. This number had to be further prioritised to account for limited time and resources. Solutions to a number of the most important potential impediments were embedded into the experimental design rather than tested as treatments. This was because they were viewed as critical to any proposed outcome and therefore a necessary base for testing the effectiveness of solutions to other measures. For example, some form of property rights is essential to any market or non-market solution. Other factors were designed into the experiment via the use of a context specific parameterisation of the experiments. For example, existing farm data was used as the basis for the ensuing experiments, in part to identify the importance of thin markets in reducing market efficacy.

Table 1: Market impediments assessed for potential experimental analysis

Market impediment	Definition	Potential solutions
Common Pool Resource	Property rights to shared aquifers are not defined leading to: • decisions confounded by a social dilemma; and • free riding behaviour.	• Allocate property rights obligations to farmers. • Social contracts formalising non-market agreements.
Property rights	The absence of defined rights makes market exchange unlikely due to • Uncertainty/unreliability in market outcomes; • low market participation; and • high transaction costs in defining and defending contractual property rights.	• Allocate property rights obligation to farmers. • Property rights assigned to beneficiaries.
Thin markets	Insufficient buyers and sellers implies a lower probability of finding trading partners thus higher transaction costs. Can lead to market power and hoarding behaviour.	• Do nothing – numbers may be sufficient to avoid issue per Smith (1982). • Centralised trading point. • Introduce external trader.
Mismatched annual supply and demand	Stochastic rainfall events can lead to systemic under or overachievement of recharge reduction, leading to most participants incurring either excess credits or debits, regardless of land management practices.	• Normalise performance leading to constant recharge credit allocations. • Allow credit banking and borrowing with specified end point for clearing.
Entitlement distribution	Irrigators hold *de facto* rights at present. Auction of rights is theoretically most efficient mechanism but procedural fairness makes grandfathering of any rights much more likely.	• Grandfather property rights obligations to farmers. • Community determined distribution of entitlements.
Risk assignment	Three risks could be faced by irrigators under a performance based system: a) stochastic events such as rainfall variability; b) effectiveness of management options in achieving recharge reduction; and c) free riding by other farmers	• Normalised performance reduces stochastic risk. • Other risk factors not proposed for experimental tests.
Performance incentive failure	Performance based approaches based on estimating recharge outcomes provide stronger ongoing incentives for recharge management than input incentives. All approaches reliant on penalty for non-compliance.	Two tiers of penalty for non-compliance: a. An individual penalty; and, b. Socialised and equally imposed penalty equivalent to production costs on all.
Insufficient variability in recharge reduction costs	Little difference in participant's costs of recharge reduction generates little incentive to trade, with a potential for thin markets.	Non market social contracts
Capital constraint	Capital constraints may limit adoption of recharge reducing management options.	Alternate finance arrangements
Information constraint	Information constraints may limit adoption of recharge management options.	Farmer participation in trials could improve information.
External market preferences	Non-market or external market preferences may limit adoption of recharge management options	No specific treatment

Table 2: Summary of the experiment selection process

Market impediment	**Solutions**	*Significance of impediment*	*Administrative alignment*	*Political feasibility*	*Efficiency gain*	*Field test and simulated trial*	*Experimental treatment*
Common Pool Resource	Develop coordination mechanism: Allocate recharge property rights to enable market exchange	High	High	High	Low to medium	✓ FT, D	✓ D
	Develop non-market social contracts		Medium	High	High	✓ ST	✓
Property rights	Allocate temporary recharge property rights	High	High	High	High	✓ FT, D	✓ D
Thin markets	Rely on existing farm data	High	High	High	Medium	✓ D	✓ D
	Introduce agency trader		Medium	Medium	High		
Mismatched supply and demand	Normalised performance	High	High	High	High	✓ D	✓ D
	Credit banking / borrowing		Medium	High	Low to medium		
Entitlement distribution	Allocate property rights to farmers	Medium	High	High	Low	✓ FT, D	✓ D
	Community determined		Medium	Medium	High		
Risk assignment	Normalised performance	High	High	High	Low	✓ D	✓ D
Performance incentive failure	Rely on improved recharge information (via SWAGMAN)	Medium	Low	High	Low		✓
	Socialised production based penalty		Medium	Medium	High	✓ D	✓
	Individual non-compliance penalty		Medium	Medium to high	High	✓ FT	✓
Insufficient gains from trade	Develop non-market social contracts	High	Low to medium	Medium to high	High	✓ ST	✓
Capital constraint	Alternate finance arrangements	Uncertain	High	Low	Low to medium		
Information constraint	Field trial participation	Uncertain	High	High	Medium to high		
External preferences	No specific treatment	Uncertain	Uncertain				

(FT = Field trial, ST = Simulated trial, D = embedded in design)

4. Treatments and hypotheses

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 information, communication, trading and 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.

4.1 Information

Provision of information from SWAGMAN effectively converts the management of groundwater recharge in the Coleambally irrigation area from a non-point to a point source effluent problem. However in the absence of other institutions, it remains a common pool resource. [1]A number of authors (eg 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. The provision of information is necessary to achieve effective management, but is unlikely to be sufficient in itself (eg 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.

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.

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When joint outcomes depend on multiple actors contributing inputs or actions that are costly and difficult to quantify and there is lack of institutional protocols to restrict usage, incentives exist for individuals to act opportunistically, often appropriating to a level where overuse occurs. A social dilemma occurs when individuals, tempted by short term gains, over appropriate the common pool resource, thereby imposing group shared costs on the common pool community. Individual over appropriation in the Coleambally irrigation area will eventually lead to rising water tables, spatially dispersed increases in soil salinity and lower crop productivity for all farmers (Khan *et al.* 2003). In accordance with common pool resource characteristics, the difficulty in excluding beneficiaries is a characteristic shared with public goods, the rival or subtractable nature is a characteristic shared with private goods.

4.2 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 very effective in improving the outcome of resource dilemmas. Face to face communication has been shown to be the most effective means of promoting the formation of social capital.

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, and before each period they were brought together and allowed to discuss coordinating their decisions.

4.3 Trading

Communication is sometimes very effective in such situations, but other times not. It tends to 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[2] among farms in their costs of reducing recharge, as 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 incentive to reveal theirtrue 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.

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[2] If rights to recharge were both capped and tradeable, landholders could be allowed to meet their cap either through land management actions that reduce recharge or by purchasing "recharge credits". Each recharge credit would represent a right to a certain quantum of recharge in excess of a landholders cap and could only be purchased from landholders who reduce recharge below their cap. 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 has no resolution.
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 would 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.

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 the closed call market all buy and sell offers are ordered by price, with trades occurring at a single price where the buy and sell functions intercept. Information is disseminated in the form of a single market clearing price. Under alternative institutions such as open call and double auction markets all bids are revealed. The closed call market is informationally simpler – 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). Treatment six combined the market with the communication treatments, providing a discussion forum before each period.

4.4 Individual penalties

Under all these institutions, any costs resulting from non-compliance are still 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. 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.

Table 3: Experimental design

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 information**	✓	✗	✗	✓	✗	Each round	2
4	**Communication**	✓	✓	✗	✓	✗	Each round	2
5	**Market**	✓	✗	✓	✓	✗	Each round	2
6	**Market + communication**	✓	✓	✓	✓	✗	Each round	2
7	**Market + individual non-compliance penalty**	✓	✗	✓	✗	✓	Each round	2

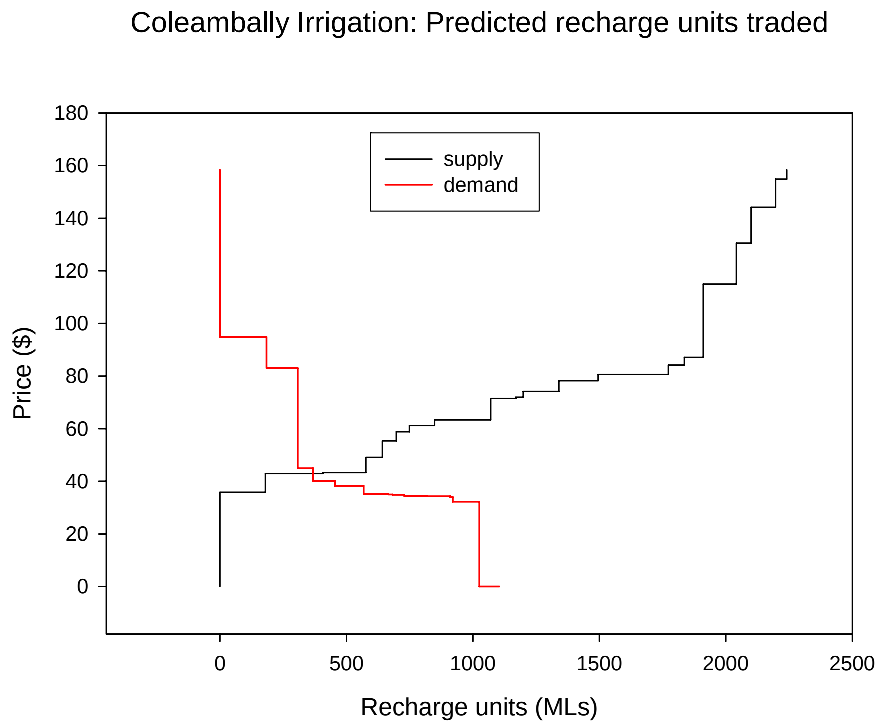
5. Simulated catchment

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 a gaming session. 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 Coleambally irrigation district.

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 management options. For each model farm there were five alternative management options, representing different mixes of crops. SWAGMAN was used to calculate 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. Appendix 1 details the data for each model farm, as obtained from SWAGMAN.

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 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[3]



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 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. The optimum farm income is calculated according to theoretical predictions if players were to behave as profit maximisers acting optimally in response to provided information and treatment constraints. 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 Coleambally irrigation area. To ensure the integrity of future experimental sessions, the payment functions have not been reported here. They are available upon request from the authors.

If aggregate recharge exceeds the threshold for a zero water table rise, farms incur crop loss, resulting in a reduced income. Nett player income is calculated by

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[3] The predicted equilibrium is 407 ML traded at a price of $43 per ML

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. 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.

To provide context, experimental participants were told they were playing the role of a farmer, and the nature of the recharge problem was set out. Contextualisation is not standard experimental economic protocol, but is being increasingly applied (eg Cardenas 2000, Poe *et al*. 2004, Tisdell *et al*. 2004). Context allows a greater range of behavioural responses to an analogue of the proposed institutional and market initiatives specific to the catchment in question. It is 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.

6. Pre-tests – Yanco field trial

The experimental simulation and recharge credit trading environment was field demonstrated at Yanco Agricultural College. Seventeen irrigators and seven CIA staff participated. The demonstration was relatively informal, precluding use of the data for subsequent analysis. Rather the field demonstrations were intended as an extension process, to familiarise irrigators with the inter-dependent nature of excess groundwater recharge, to promote acceptance of the SWAGMAN model and enable irrigators to explore and experiment with recharge market structures. It also provided an opportunity for participants to provide feedback on the proposed experimental simulations.

Overall the irrigators present enthusiastically participated in the recharge trading demonstration, recognising the immediate need for remedial, shared recharge management. Importantly the cohort of irrigators represented those affected by increasing catchment recharge and rising groundwater, and those from high recharge areas of the catchment. The demonstration provided a forum for constructive and vigorous discussion of the shared nature of catchment recharge and highlighted the social dilemma facing constituents.

In the experimental simulations, market prices generally reflected modelled outcomes, although the level of trade was limited. 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. 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 are also deducted from farm income.

There was widespread consensus for a combined two day SWAGMAN/ market trading workshop. The reliability of the SWAGMAN model was generally not perceived nor recognised by participating irrigators. Improved recognition and adoption of the model would be enhanced by the combined workshop. In order to coordinate with farm management schedules, the majority of participants agreed the best time for the workshop was early 2005.

7. 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. 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). Tisdell and Ward (2003) found no statistical difference between farmers and students when participating in similarly complex and heterogenous resource natural trading environments.

At the beginning of each session, participants accessed a set of 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. On 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; it is visible throughout the experiment. All information is derived from the SWAGAMN model.

At the beginning of each period, participants are asked to select one of the five 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 see their 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.

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, after which a trade macro is run to match the buyers and sellers and calculate the market clearing price. 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). 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).

Figure 2: Information provided to experimental participants in the market treatments.

Recharge allocation 3 units	Total traders income $10	
Recharge value #1 $5	Recharge units #1 3	Income #1 10
Recharge value #2 $4	Recharge units #2 5	Income #2 12
Recharge value #3 $3	Recharge units #3 7	Income #3 14
Recharge value #4 $2	Recharge units #4 9	Income #4 16
Recharge value #5 $1	Recharge units #5 11	Income #5 18

Note: #1-#5 refers to the alternative management options. In the baseline (treatment 1) they are only provided with the income associated with each option, while in the non-market treatments they are provided with the recharge units and income associated with each option. Each model farm is associated with a different set of data, derived from SWAGMAN.

Figure 3: After each period, participants can see their decisions, and the outcomes of those decisions, in a table on their screen.

Trade period	Farm income	Market price	Cost of recharge bought	Revenue from recharge sales	Nett farm income	Traders Income

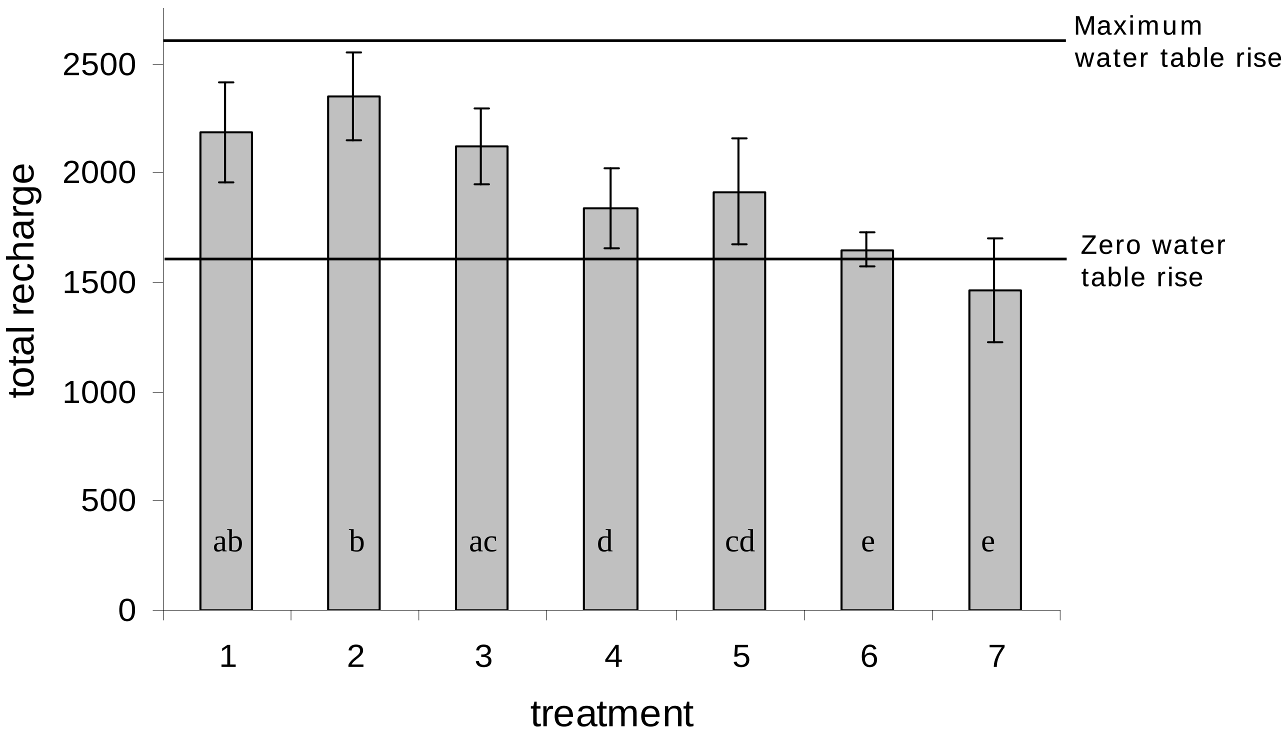
Note: Only the relevant columns are displayed in each treatment. 'Traders Income' shows the amount of money earned by a participant in a period. This table is displayed below the one shown in figure one. Both are visible throughout the experiment.

8. Results

Data were analysed using ANOVA. If the homogeneity of variance is significantly different, as measured by the Levine statistic, then Dunnett's T3 post hoc test is used, which accounts for heterogenous variance. The raw data from the experiments are plotted in Appendix two.

Overall levels of recharge were highest in the baseline and information only treatments (Figure 4, treatments 1-3). The coordinating institutions, communication and market (treatments 4-5), were both associated with a significant decrease in overall recharge. Combining the market and communication treatments 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. In all treatments the rise in water table was below the maximum possible.

Figure 4: Total recharge by treatment[4].



Mean +/- 5%: 95% CI

[4] Mean +/- 5%: 95% CI – bars with the same letter are not significantly different at the 5% level

Table 4: Corresponding table for Figure 4

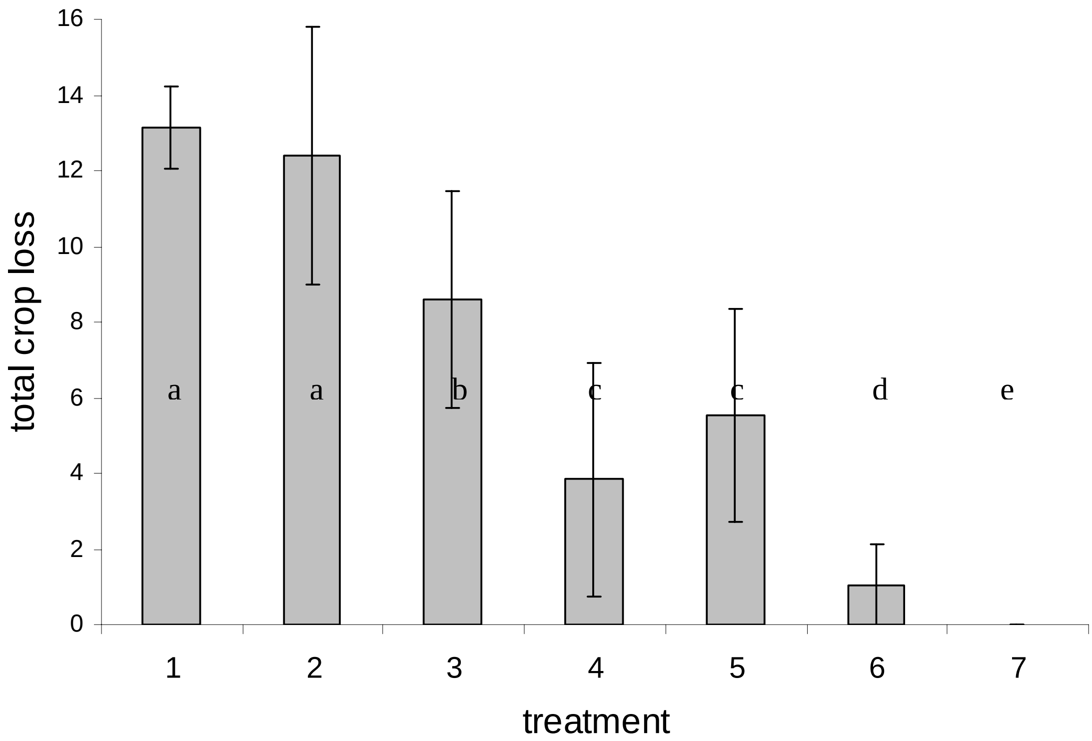
DESCRIPTIVES Total Recharge								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
control	20	2189.15	229.93	51.41	2081.54	2296.75	1742	2440
swagman	20	2349.20	202.11	45.19	2254.61	2443.79	1887	2658
Swagman+crop loss	20	2122.15	170.51	38.13	2042.35	2201.95	1891	2492
communication	20	1839.15	183.21	40.97	1753.41	1924.89	1610	2302
market	20	1914.30	244.40	54.65	1799.92	2028.68	1091	2335
market+communication	20	1650.30	81.04	18.12	1612.37	1688.23	1480	1769
Market+non-compliance	20	1464.55	235.79	52.72	1354.19	1574.90	988	1928
model	10	1610	0.00	0.00	1610	1610	1610	1610
Total	150	1911.17	346.81	28.32	1855.22	1967.13	988	2658

	Treatment							**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 $\alpha=0.05$.)

Crop loss was zero with the individual non-compliance penalty, and was very low in the market-communication treatment (Figure 5). Crop loss was significantly higher in the market only and communication only treatments, and higher still in the information only treatments. 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 rather than at the end of the session.

Figure 5: Total crop loss by treatment[5]



Mean +/- 5%: 95% CI

[5] Mean +/- 5%: 95% CI -bars with different letters are significantly different at the 5% level

Table 5: Corresponding table for Figure 5

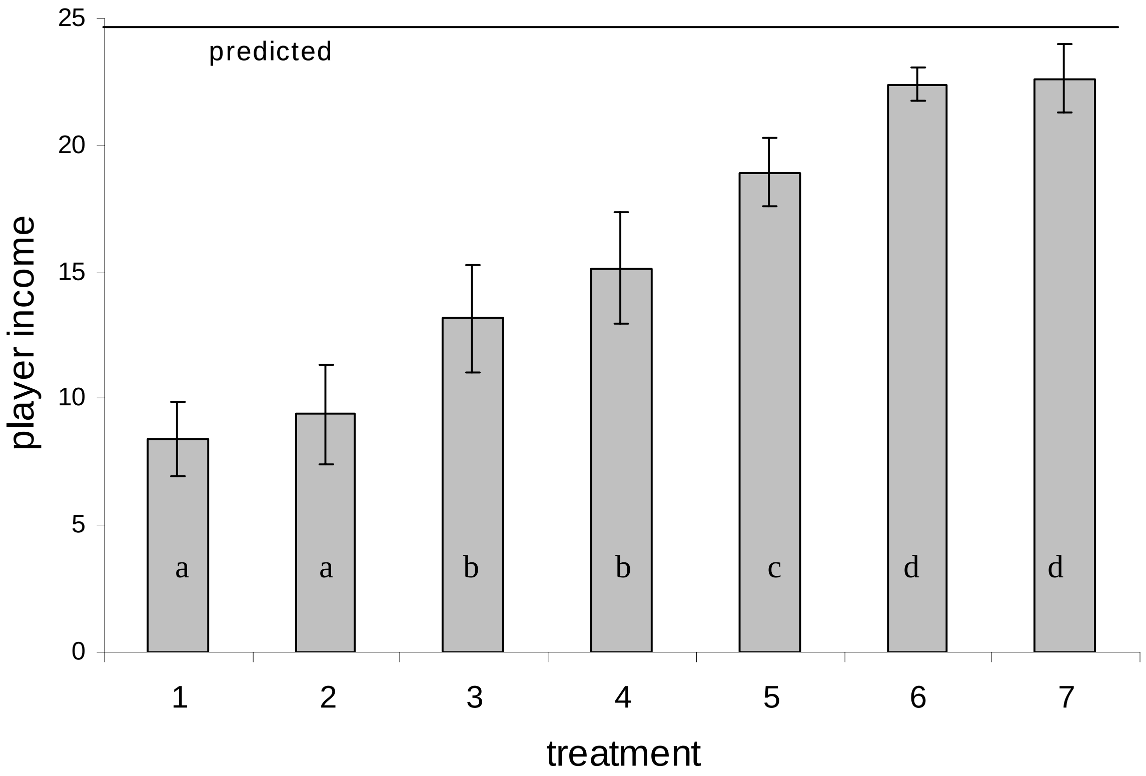
DESCRIPTIVES Total crop loss								
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
control	20	13.15	1.11	0.25	12.63	13.66	11.16	15.36
swagman	20	12.41	3.39	0.76	10.82	13.99	4.68	17.64
Swagman+crop loss	20	8.59	2.86	0.64	7.25	9.93	4.68	14.76
communication	20	3.84	3.08	0.69	2.39	5.28	0.00	11.64
market	20	5.53	2.81	0.63	4.22	6.85	0.00	12.12
market+communication	20	1.02	1.10	0.25	0.50	1.54	0.00	3.48
market+non-compliance	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
model	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	150	5.94	5.43	0.44	5.06	6.82	0.00	17.64

	Treatment						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 α=0.05)

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

Figure 6: Player income by treatment[6]



Mean +/- 5%: 95% CI

[6] Mean +/- 5%: 95% CI - bars with different letters are significantly different at the 5% level

Table 6: Corresponding table for Figure 6

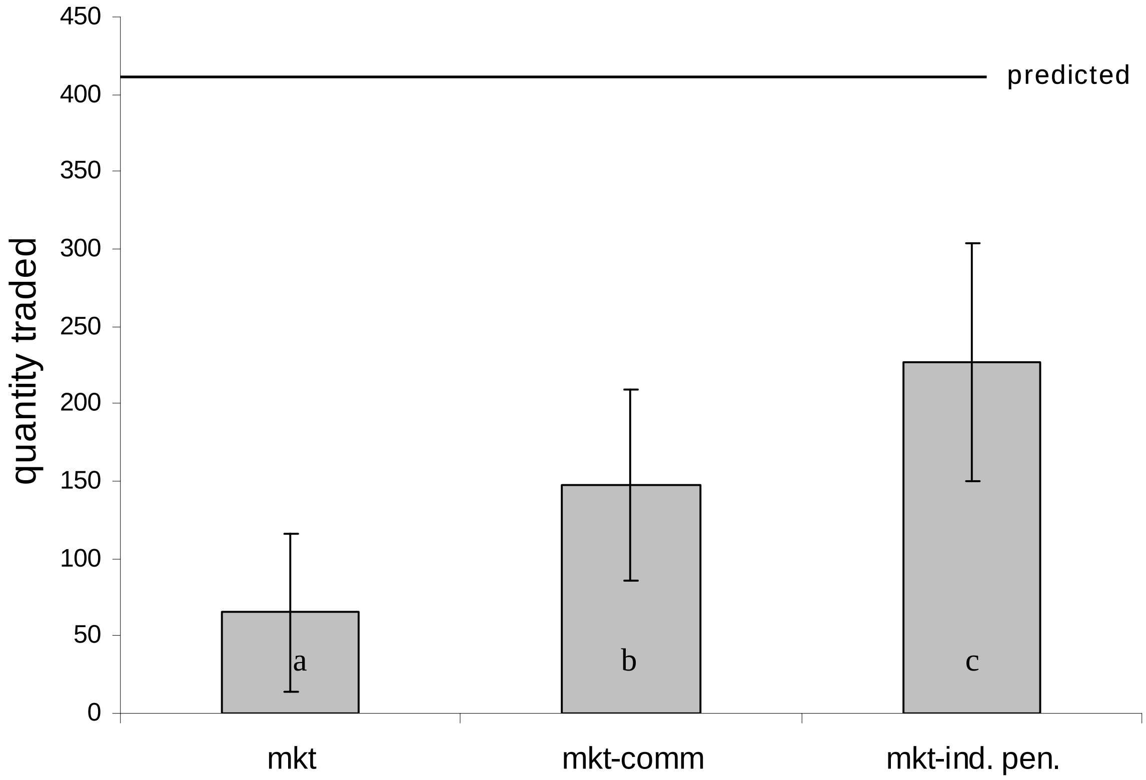
DESCRIPTIVES								
Player Income								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
control	20	8.39	1.47	0.33	7.70	9.08	6.63	10.92
swagman	20	9.38	2.01	0.45	8.45	10.32	6.38	13.87
Swagman+crop loss	20	13.17	2.13	0.48	12.17	14.17	8.24	16.29
communication	20	15.15	2.19	0.49	14.12	16.17	9.67	17.98
market	20	18.93	1.36	0.30	18.29	19.56	15.48	20.91
market+communication	20	22.39	.67	0.15	22.08	22.70	21.22	23.43
Market+non-compliance	20	22.64	1.35	0.30	22.01	23.27	19.32	24.59
model	10	24.00	.00	0.00	24.00	24.00	24.00	24.00
Total	150	16.27	5.84	0.48	15.33	17.21	6.38	24.59

	Treatment							**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)

In the market treatments, overall quantity traded was significantly below the levels predicted by the model (Figure 7). Volumes were significantly higher in the market and communication treatment than with the market only. The market and individual penalty treatment resulted in another significant increase in trade quantity. Gains from trade followed the same pattern, increasing from treatment five to six to seven, but still falling well short of the level predicted by the model. Overall gains from trade were tiny compared to overall income. Even in the treatment with the most active market (treatment 7), gains from trade still made up only around 1% of total farm income.

Figure 7: Quantity of recharge units traded by treatment[7]



Mean +/- 5%: 95% CI

[7] *Mean +/- 5%:95% CI - bars with different letters are significantly different at the 5% level*

Table 7: Corresponding table for Figure 7

DESCRIPTIVES Quantity traded								
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
market	20	65.20	50.96	11.39	41.3491	89.05	0.00	174.00
market+communication	20	147.5	61.84	13.83	118.5561	176.44	0.00	254.00
Market+non-compliance	20	226.45	77.06	17.23	190.3832	262.51	116.00	409.00
model	10	407.00	0.00	0.00	407.0000	407.00	407.00	407.00
Total	70	183.61	124.94	14.93	153.8235	213.40	0.00	409.00

	Treatment			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 $\alpha=0.05$.)

The market price for recharge allocation credits in the market and the market plus communication 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 and the predicted level (Figure 8).

Figure 8: Market price in each experimental period, by treatment.

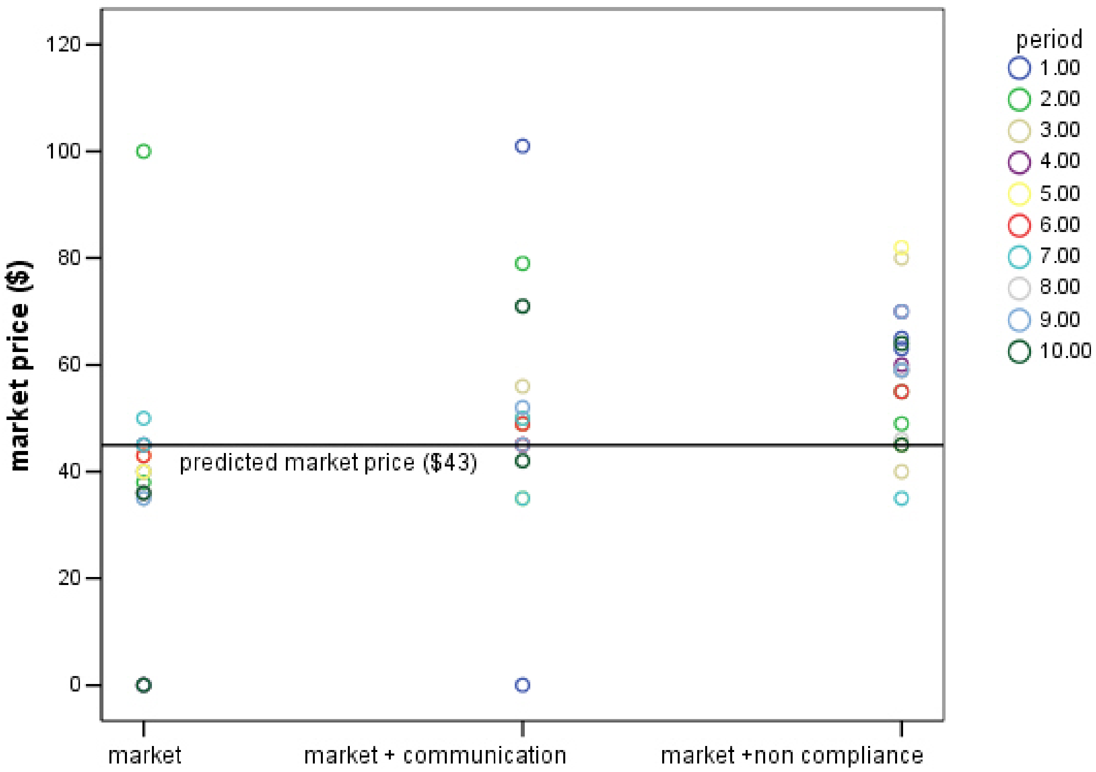


Table 8: Corresponding table for Figure 8

DESCRIPTIVES								
Market price								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
market	20	34.90	22.67	5.07	24.29	45.51	0.00	100.00
market+communication	20	50.75	19.88	4.45	41.45	60.05	0.00	101.00
Market+non-compliance	20	58.00	12.35	2.76	52.29	63.78	35.00	82.00
model	10	43.00	0.00	0.00	43.00	43.00	43.00	43.00
Total	70	47.19	19.39	2.32	42.56	51.81	0.00	101.00

	Treatment			**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 $\alpha=0.05$.)

9. Conclusions

In the baseline treatment, in which experimental subjects were provided with no information about recharge, overall recharge levels were high, resulting in significant crop loss. However it should be noted that recharge levels were still some way below the maximum, suggesting that some participants may be voluntarily limiting their income in order to keep recharge down. Introducing additional information about individual contributions to recharge did not result in a reduction in total recharge when crop loss was not known until the end of the experiment. Crop loss remained high in both these treatments. However, providing crop loss data at the end of each period did result in an overall decrease in crop loss and a corresponding increase in 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 successful management, but it is seldom sufficient (eg Tisdell *et al.* 2004).

Providing the communication forum resulted in significant decreases in total recharge and crop loss, and increased incomes. Hypothesis two is therefore supported by the experimental data. This suggests that face to face communication allows the formation of social capital and informal but robust social contracts. 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. 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 students.

The market mechanism also delivered reduced crop loss and increased incomes. Even in the absence of an enforceable cap on individual contributions to recharge, the ability to trade appeared to provide a reasonably effective coordination mechanism. Combining the market with a communication forum further improved performance. This suggests that people can use the market mechanism to achieve voluntary abatement targets. 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 was converted to an individual rather than a group penalty, supporting hypothesis four. This is to be expected, as 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 allocation 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 thetransaction 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 accruedfrom trade.

These experiments have demonstrated that communication, trading 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. These field trials are reported in the next report from this project titled 'Tradable Recharge Credits in Coleambally Irrigation Area: Field Trial and Farm Case Studies'.

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Appendix

Appendix one: Dataset underlying the model farms in the simulated catchment

Table A1: Gross margins and water use of crops grown in the CIA, sourced from the SWAGMAN model.

Crop	Price	Yield	Variable costs (LESS water costs)	Water use	Water costs	Total variable costs	Gross Margin (GM)	GM (less water cost)	GM/ML
	($/tonne)	(tonnes/ha)	($/ha)	(Mls/ha)	($/tonne)	($/tonne)	($/tonne)	($/tonne)	($/Ml)
rice	207	9.5	730	12	202	932	1034	1237	86
maize	180	10	838	8.5	143	981	819	962	96
soybean	389	2.8	427	8	135	562	527	662	66
sorghum	135	6.5	521	7	118	639	238	357	34
lucerne hay	150	15	1259	12	202	1461	789	991	66
wheat	130	5	379	2.5	42	421	229	271	92
barley - malt	140	4	335	2.2	37	372	188	225	85
barley - feed	105	4.5	333	2.2	37	370	102	140	47
canola	318	2.7	555	3	51	606	253	304	84
fababean	220	4	625	3.5	59	684	196	255	56
lucerne pasture	30	26	191	10	169	360	420	589	42
summer pasture	30	30	223	12	202	425	475	677	40
winter pasture	30	12	89	3	51	140	220	271	73
dryland pasture	30	2	0	0	0	0	60	60	0
dryland wheat	130	2.5	240	0	0	240	85	85	0

Table A2: Income, crop mix and recharge of 12 farms in the simulated catchment

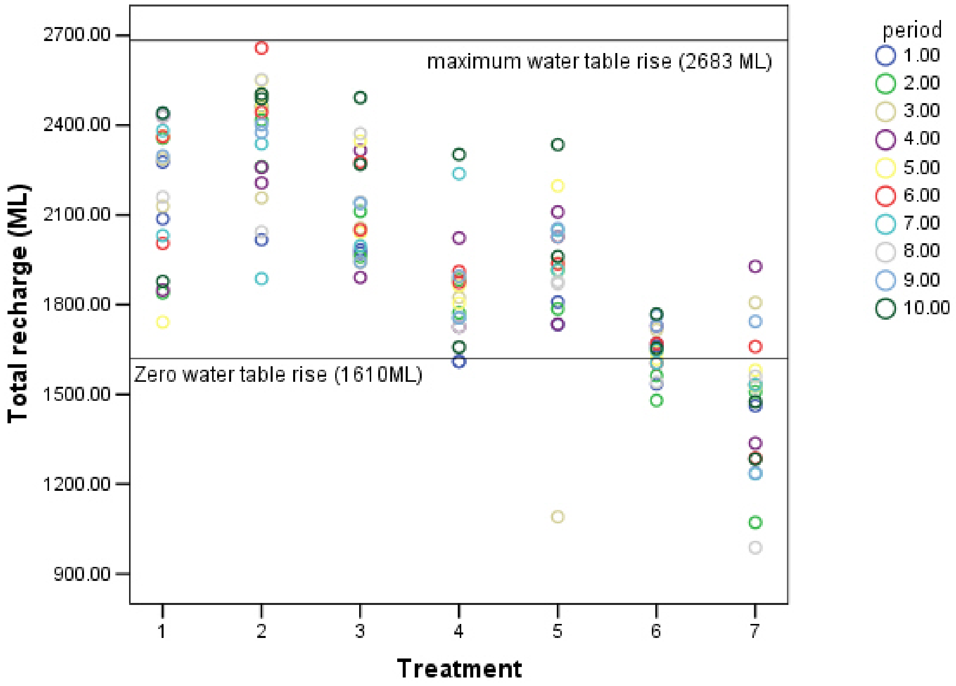
						Crop Type (ha)										
Farm	Farm Crop Mix	Water Table rise (m)	Surplus water (Mls)	GM ($)	recharge (Mls)	rice	maize	lucerne hay	lucerne	wheat	canola	dryland wheat	dryland pasture	fallow	TOTAL (ha)	Total water use (MLs)
1	1	max		106417	200	69	22			56		45	9	22	224	1158
	2	0.3		104442	150	64	22	17				45	53	22	224	1162
	3	0		100532	63	40	22	22		93		24		22	224	1172
	4	-0.1		98382	34	33	22	22		112	12			22	224	1171
	5	-0.25		95041	0	26	22	22	10	112	9			22	224	1078
2	1	max		103965	228	69	20	3		48		40		20	200	1154
	2	0.4	0	101180	160	56	20	13		66	0	25		20	200	1163
	3	0.2	33	95333	104	57		11		52	60			20	200	1126
	4	0	223	86041	44	39		10		71	60			20	200	946
	5	-0.15	366	79071	0	25		10		85	60			20	200	813
3	1	max		106706	180	69	22			59		45	6	22	223	1163
	2	0		106363	170	69	22	4		39		45	22	22	223	1161
	3	-0.3		104321	111.5	62	22	19				45	52	22	222	1159
	4	-0.5		102584	62	50	22	22		46		45	15	22	222	1166
	5	-0.758		98751	0	46	8	22		112		12		23	223	1164
4	1	max		105687	246	69	22			57		44	5	22	219	1158
	2	0.2		104165	201	66	22	15				44	49	22	218	1159
	3	0		102562	155	58	22	22		7		44	43	22	218	1165
	4	-0.325		96292	56	35	16	22	2	56	66			22	219	1158
	5	-0.472	101	90073	0	57	22	21		20		44	32	22	218	1173
5	1	0		119547	227	69	34			46		67	87	33	336	1232
	2	-0.2		117472	166	63	34	16				67	122	33	335	1237
	3	-0.3		116206	132	57	34	22				67	122	33	335	1237
	4	-0.5		112048	31	25	34	19		167	7	50	0	33	335	1256
	5	-0.571		109714	0	15	34	18		167	53	15		33	335	1262
6	1	max		105396	220	69	22	9		15		44	37	22	218	1161
	2	0.2		100901	148	61	11	13		67		44		22	218	1149
	3	0		95038	97	56		11		99	26	4		22	218	1130
	4	-0.2	152	86605	38.5	39		9		82	66			22	218	979
	5	-0.4	274	80811	0	28		9		94	66			22	219	877

						Crop Type (ha)										
Farm	Farm Crop Mix	Water Table rise (m)	Surplus water (Mls)	GM ($)	recharge (Mls)	rice	maize	lucerne hay	lucerne	wheat	canola	dryland wheat	dryland pasture	fallow	TOTAL (ha)	Total water use (MLs)
7	1	max		106619	221	69	22			58		45	8	22	225	1163
	2	0		103107	123	55	22	22		19		45	38	22	224	1162
	3	-0.2		99874	68	42	22	22	5	65		45		22	224	1121
	4	-0.4		95983	24	43	12	22	12	69		45		22	225	1055
	5	-0.495		92897	0	46		22	15	35	40	44		22	224	1024
8	1	max		105619	229	69	22			56		44	5	22	218	1155
	2	0.2		104059	177	66	22	15				44	50	22	219	1159
	3	0		102116	124	55	22	22		22		44	31	22	218	1166
	4	-0.2		98931	72	43	22	22	5	60		44		22	218	1117
	5	-0.491		93251	0	35	12	22	12	109		7		22	219	1059
9	1	0.5		105332	221	69	21	2		54		42		21	209	1166
	2	0.15		103852	172.8	66	21	16				42	43	21	209	1163
	3	0		102753	141	61	21	21		2		42	41	21	209	1168
	4	-0.3		99129	75.5	46	21	21	6	52		42		21	209	1113
	5	-0.649	25	91729	0	25	21	21	12	46	63			21	209	1035
10	1	max		103751	244	69	21			49		43	11	21	214	1129
	2	0.2		102212	192	66	21	14				43	49	21	214	1139
	3	0		99218	131	47	21	14		92		19		21	214	1141
	4	-0.2	67	92102	56	48		11		69	64			21	213	1073
	5	-0.381	251	83143	0	30		11		88	64			21	214	904
11	1	max		97758	196	57	32					64	134	32	319	956
	2	0		97198	180	54	32	3				64	134	32	319	956
	3	-0.2		94881	113.5	43	32	15				64	133	32	319	968
	4	-0.4		92564	46.5	32	32	26				64	133	32	319	968
	5	-0.532		90740	0	21	32	32		28		64	110	32	319	978
12	1	max		105687	246	69	22			57		44	5	22	219	1158
	2	0.2		104165	201	66	22	15				44	49	22	218	1159
	3	0		102562	155	58	22	22		7		44	43	22	218	1165
	4	-0.325		96292	56	35	16	22	2	56	66			22	219	1158
	5	-0.472	101	90073	0	57	22	21		20		44	32	22	218	1173

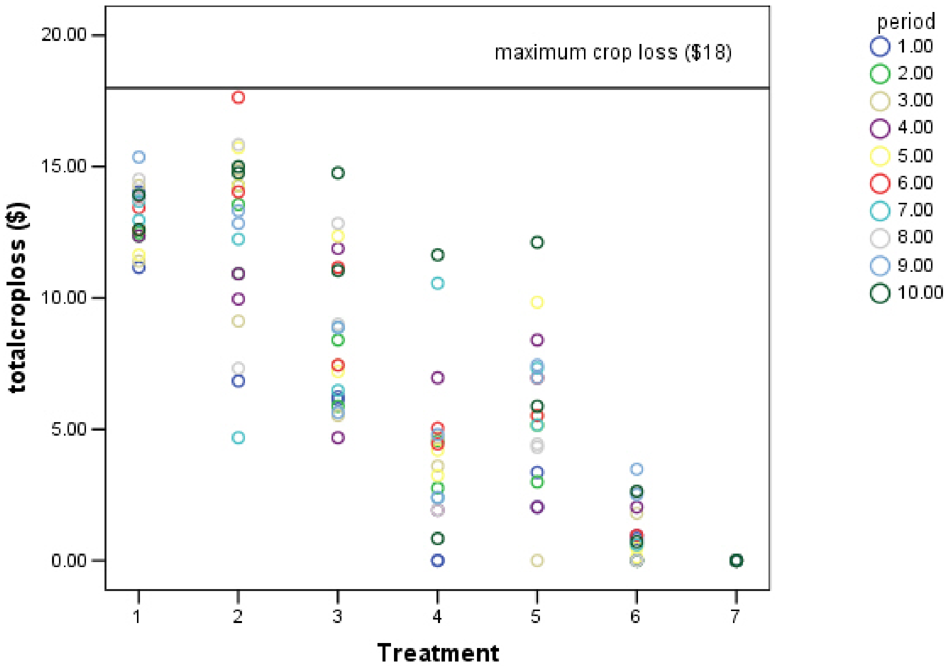
Appendix two: Experimental data

Below are plots of the data, descriptive statistics and significance test for each of the outputs analysed from the experimental sessions.

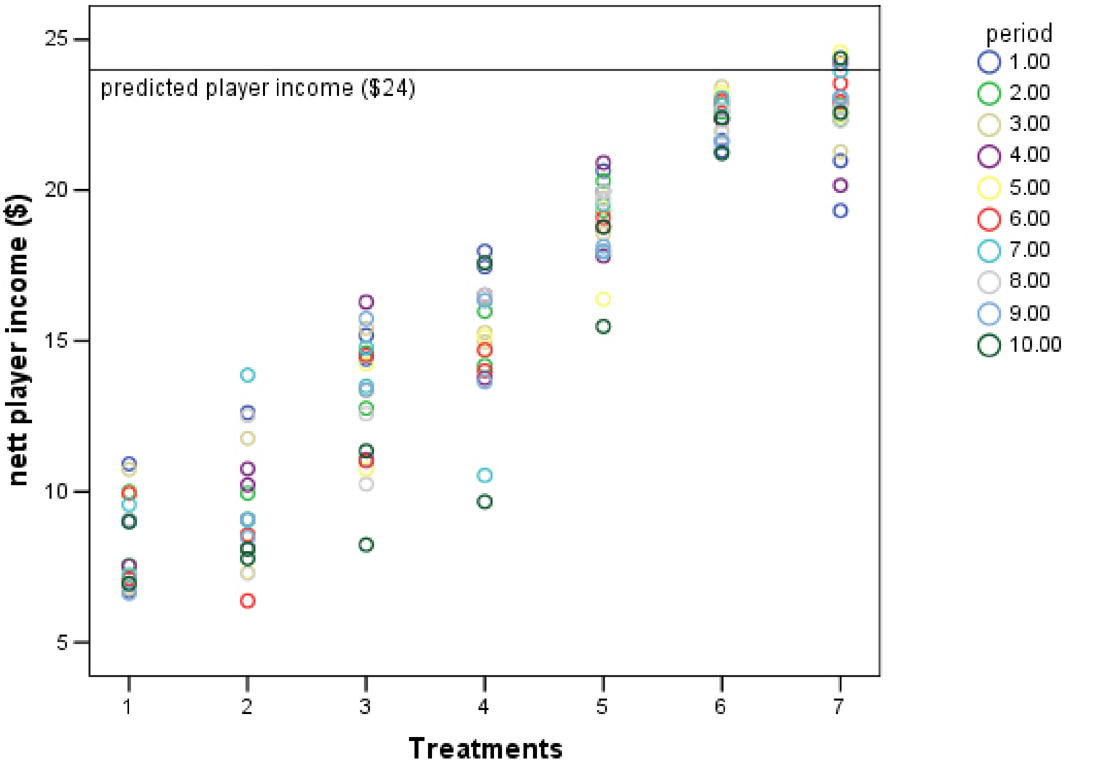
Total recharge



Aggregate crop loss



Net player income



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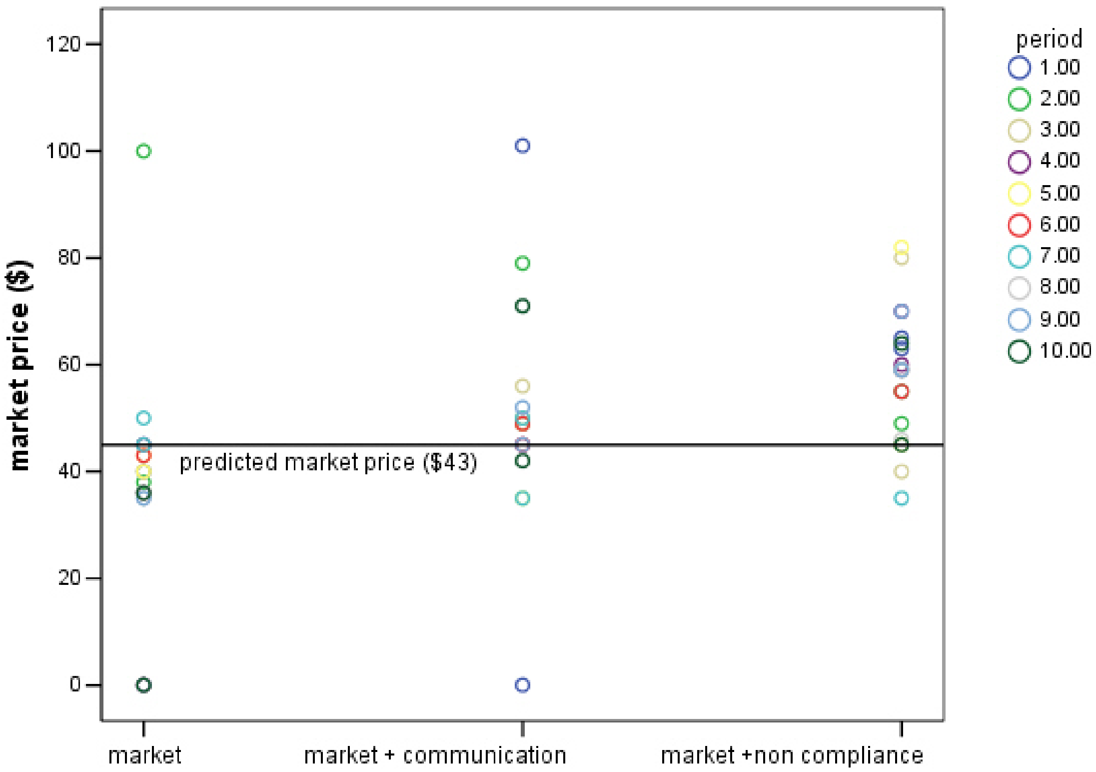
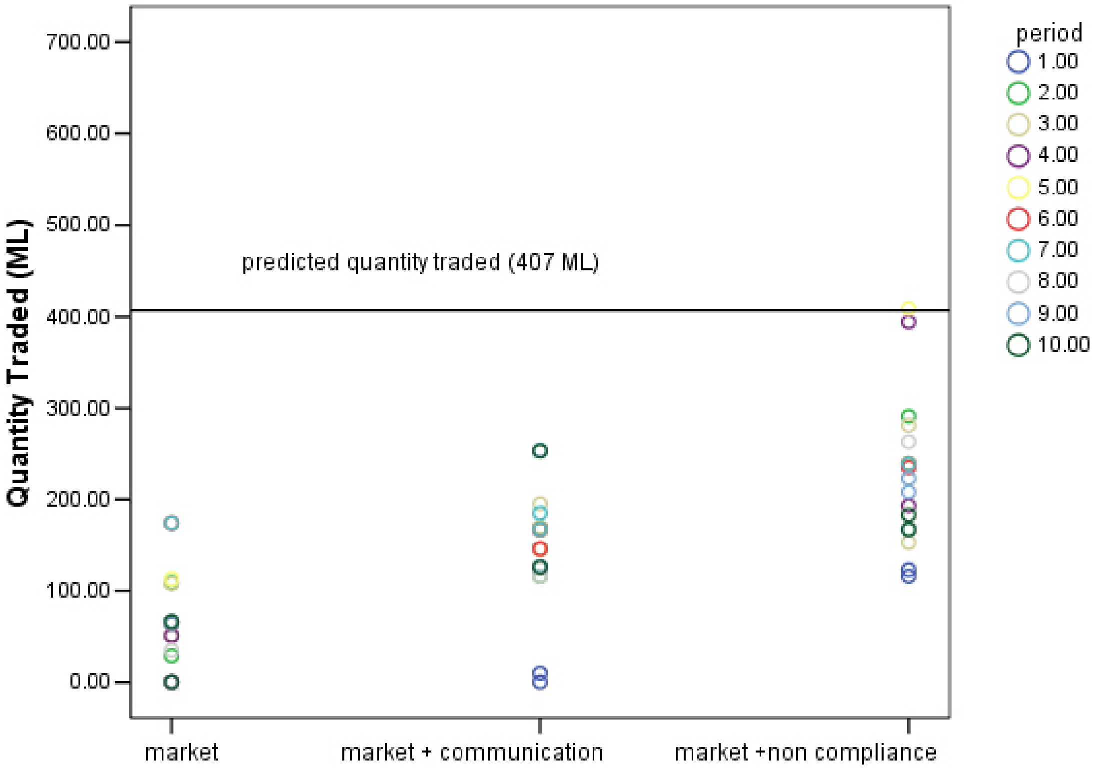
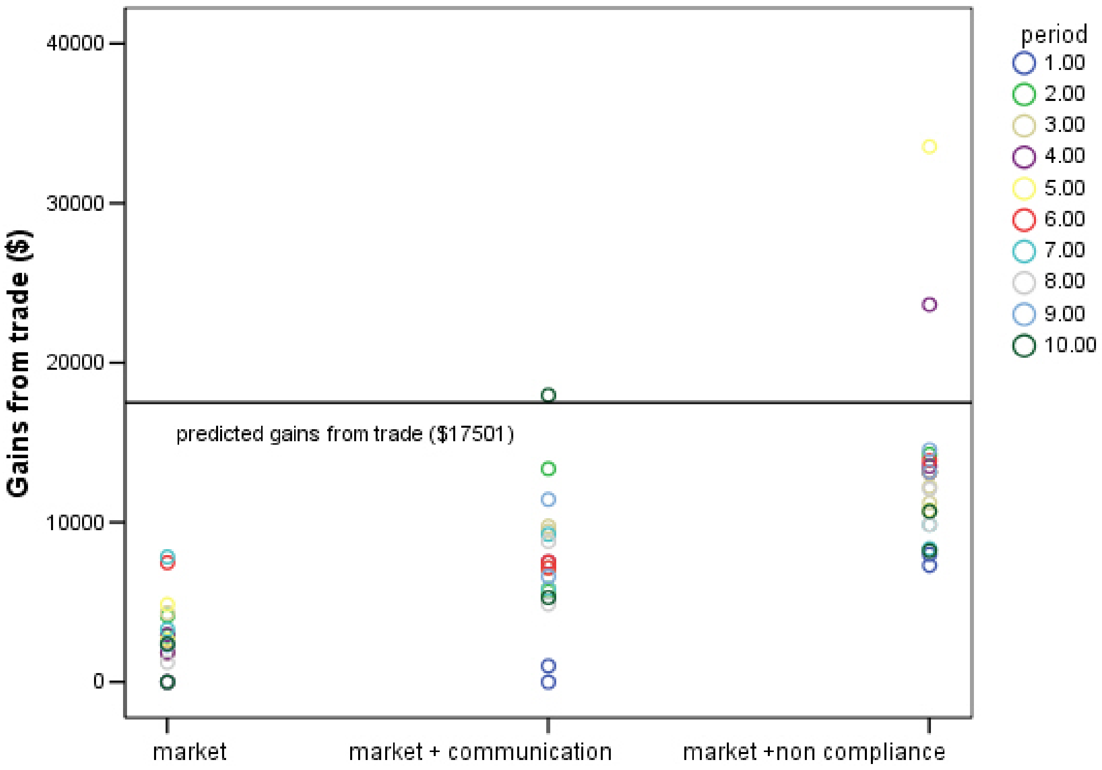
Market price



Quantity traded



Gains from trade



DESCRIPTIVES Gains from trade								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
market	20	2748.10	2202.75	492.55	1717.18	3779.02	0.00	7830.00
market+communication	20	7582.80	3925.55	877.78	5745.59	9420.01	0.00	17963.00
Market+non-compliance	20	13072.45	5966.25	1334.09	10280.16	15864.74	7308.00	33538.00
model	10	17501.00	0.00	0.00	17501.00	17501.00	17501.00	17501.00
Total	70	9186.81	6522.12	779.54	7631.67	10741.96	0.00	33538.00

	Treatment			**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 $\alpha=0.05$.)