ECOLOGICAL ECONOMICS 67 (2008) 574–588

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ANALYSIS

Designing, testing and implementing a trial dryland salinity credit trade scheme

Jeffery D. Connor[a,c,*], *John Ward*[a,c,1], *Craig Clifton*[b], *Wendy Proctor*[a,d,2], *Darla Hatton MacDonald*[a,c,1]

[a]*CSIRO Land and Water, Adelaide and Canberra, Australia*
[b]*Sinclair, Knight, Merz, Bendigo, Australia*
[c]*CSIRO Land and Water, PMB 2, Glen Osmond, South Australia 5064 Australia*
[d]*CSIRO Land and Water, Black Mountain Laboratory, GPO Box 1666 Canberra, ACT 2601 Australia*

ARTICLE INFO

Article history:
Received 20 July 2006
Received in revised form
2 January 2008
Accepted 15 January 2008
Available online 7 March 2008

Keywords:
Tradeable credits
Diffuse source pollution
Environmental economics
Salinity
Market based instruments
Experimental economics

ABSTRACT

This article describes implementation and outcomes of a credit trading trial focussed on dryland salinity in Victoria, Australia. In lieu of extant specified property rights, participants were invited to agree to obligations to provide groundwater recharge credits in exchange for pecuniary compensation. Participants were able to meet their obligations to supply groundwater recharge credits through land management actions resulting in monitored outcomes consistent with contractual obligations to reduce recharge. Alternatively, those in deficit were provided the option to obtain sufficient credits through market exchange. Surplus transferable recharge credits were produced by those participants who exceeded their own contractual obligations through improved land management. The paper describes the process of contract design and implementation. The trial involved a design and testing phase and an on-ground implementation phase. We describe composite methodologies deployed in the design and testing of alternative policy instruments and institutional arrangements, conducted prior to implementation. These involved community consultation, an attitudinal and behavioural survey, experimental economics and the development of a transparent and credible monitoring protocol. The conclusions drawn as a result of this analysis provided an empirical basis to implement the on-ground trial phase. Results of on-ground implementation are described. Finally, the methods and results of a Benefit Cost Analysis (BCA) of the on-ground trial implementation are outlined. The BCA accounted for salinity damage reduction, forgone river flow, carbon sequestration, production benefits and costs. The result of BCA was an estimated net benefit.

* *Corresponding author*. CSIRO Land and Water, PMB 2, Glen Osmond, South Australia 5064 Australia. Tel.: +61 8 8303 8784; fax: +61 8 8303 8582.
E-mail addresses: Jeff.Connor@csiro.au (J.D. Connor), John.Ward@csiro.au (J. Ward), Wendy.Proctor@csiro.au (W. Proctor), Darla.HattonMacDonald@csiro.au (D. Hatton MacDonald).
[1] Tel.: +61 8 8303 8685; fax: +61 8 8303 8582.
[2] Tel.: +61 2 6246 5955; fax: +61 2 6246 5560.

doi:10.1016/j.ecolecon.2008.01.020

Market Based Instruments (MBIs) involve regulations or laws that encourage behavioural change through the price signals of markets, as opposed to the explicit directives for environmental management associated with regulatory and centralized planning measures (Stavins, 2003). The primary motivation for MBI approaches is that if environmentally appropriate behavior can be made more rewarding to land managers, then private choice will better correspond to the desired social, economic and environmental outcomes. To encourage development of market based approaches to water quality and salinity from diffuse sources, the Australian Commonwealth Government allocated funds to eleven pilot projects in 2003 (Grafton, 2005).

This paper describes one of the pilot projects involving the market exchange of transferable groundwater recharge credits. Detail is provided of biophysical research to develop groundwater salinity impact assessment, and recharge accounting protocols and economics research to inform the design and testing of credit trade policy instruments and implementation arrangements. The primary objective was to provide incentives to motivate cost effective revegetation efforts with the attendant public benefits of reduced groundwater recharge, subsequent reductions of mobilized salt loads and, as a corollary, reduced levels of river salinity.

The trial was implemented in the Bet Bet catchment of North Central Victoria, Australia, a relatively small catchment of approximately 9600 ha in the Murray Darling Basin. The area was chosen for the trial because it has been identified as the major source of more than 40,000 tonnes of salt annually entering the Boort irrigation area from the Loddon dryland catchment areas (Connor et al., 2004a). The Bet Bet catchment area contributes more salt per volume of drainage to local rivers than any other sub-catchment in the region (Clifton, 2004).

The trial established an aggregate threshold of 2588 recharge units (ML) for groundwater recharge volumes for the Bet Bet catchment. An individual quantum for each trial participant was determined according to individual offers in a competitive tender, ratified as individual contractual obligations. Participants were able to meet their management obligations either through credits resulting from land management outcomes resulting in recharge reduction or through recharge credit trade amongst participants. The trial allowed for individual under-performance contingent on compensating over-performance by other participants in the catchment.

In addition to describing the trial design process, this paper describes the outcomes of implementation to date including: a summary of the level of on-ground works undertaken; outcomes of participant performance audits; and participant debit and credit positions as of early 2006. An assessment is also presented of the benefits and costs expected to result from trial implementation. Finally, the paper summarizes key outcomes and broadly applicable policy insights from the MBI trial.

1. The dryland salinity problem

Fig. 1 is a schematic representation of rising groundwater recharge levels resulting from land management effects in catchments similar to the Bet Bet. Groundwater recharge increases as an inverse function of the level of deep rooted perennial vegetation (illustrated in panel B). Groundwater drainage causes an elevated water table “mound”, increasing hydraulic pressure which in turn increases the level of mobilized salt intrusion in the river system. In the Bet Bet region, the majority of salinity impacts are exported to downstream river districts, where the costs of salinization are incurred primarily by downstream irrigators.

Increased volumes of recharge resulting from native vegetation clearance lead to episodes of increasingly mobilized salt loads in the landscape. The additional salt is exported into connected river systems, presenting a risk for the long-term viability of downstream irrigated horticultural and agricultural crops through soil salinization that leads to yield loss. In addition, increased river water salinity levels lead to accelerated infrastructure degradation and threaten the functional organization of downstream riparian ecosystems (Overton and Jolly, 2005).

Recharge rates and associated rates of salt mobilization in the area depend on the regional geomorphology, with localized fractured rock being conducive to high groundwater recharge rates (Clifton, 2004). In addition, the rate of recharge and thus external salinity impacts depend on the type of vegetation ground cover and how it is managed. Tree species endemic to the Bet Bet catchment are adapted to highly intermittent rainfall events, evidenced by highly efficient water use. Extensive replacement of deep rooted woody perennials and perennial pasture with shallow rooted annual pastures has been identified as a key factor in increased rainwater soil percolation and subsequent groundwater recharge. Thus, revegetation of sites now in annual pasture with perennial vegetation and endemic tree species is identified as a primary remedial action to reduce groundwater recharge and consequent salinity impacts.

1.1. *Trial design phase outcomes*

Tradeable permit schemes for managing environmental problems are becoming more widely accepted by policy makers in Australia, North America and elsewhere (Randall, 2003; Sterner, 2003; Harrington et al., 2004). Subject to controversy and debate ten years ago (Keohane et al., 1998), MBIs have evolved to the point of becoming received wisdom in many environmental policy circles (Stavins, 2003). Despite this increasing acceptance, Tietenberg (1998, 1999) concludes that many tradeable permit schemes have failed because of deficient attention to *ex ante* instrument and institutional design.

Thus, the first step in this trial involved identifying potential impediments to cost effective, environmentally reliable and politically feasible implementation options to overcome impediments. The process (described in more detail in Connor et al., 2004a) involved: local background research and stakeholder input; integrated biophysical/economics modelling; social surveying and the application of auction theory through the methods of experimental economics.

A social survey was conducted to gain an understanding of what might motivate local landholders to participate in a recharge credit trade trial and what kinds of implementation design might be most effective given community social character (Thomson, 2004). *K*-means cluster analysis of responses ($N=58$, $n=31$) to 31 attitudinal scale items identified six farming style clusters (100% of cases were correctly classified

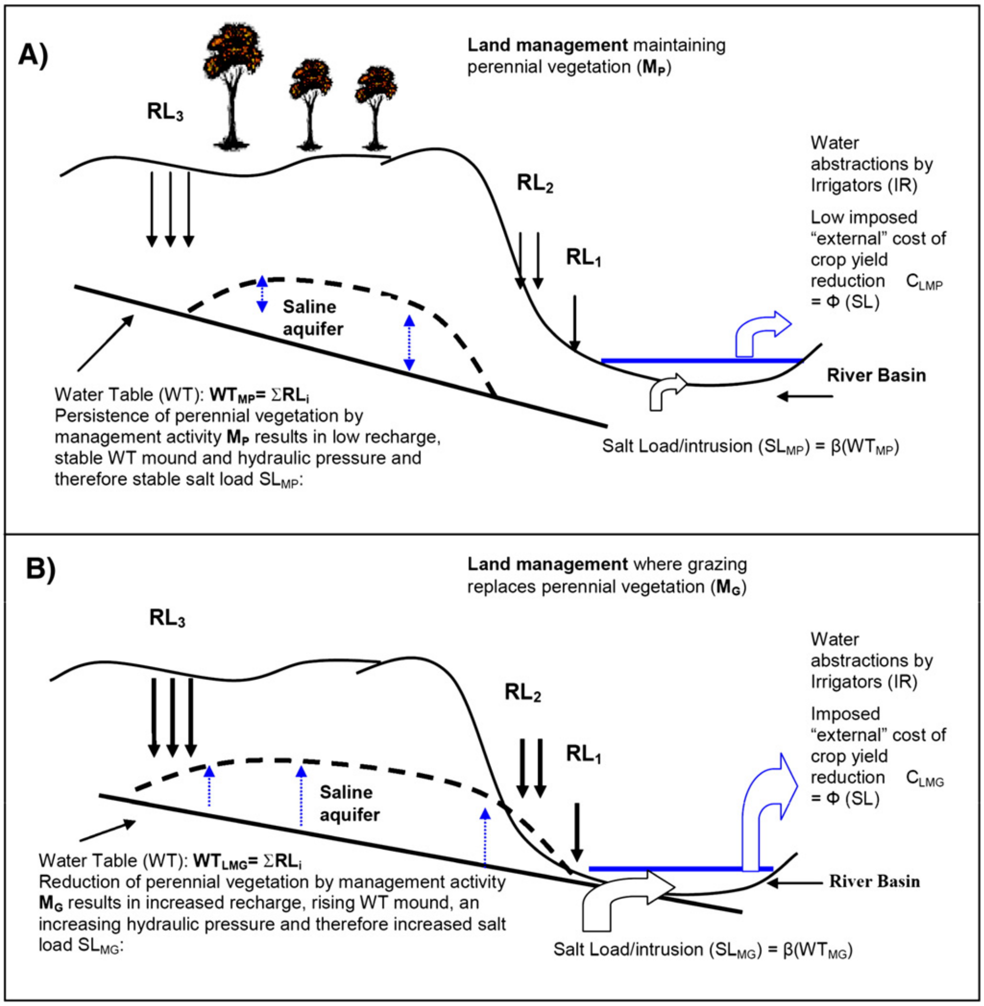

Fig. 1.

using discriminant analysis when jack-knifed). The three most common styles revealed the following characteristics:

1) Style 4 (22% of respondents). Farmers who are business-oriented, risk neutral and believe they are quite innovative, but they are also motivated to keep farming because the 'tradition' is important. These farmers are environmentally aware and are likely to agree that 'we should all share in the costs of fixing environmental problems'.
2) Style 5 (52% of respondents). Business-oriented farmers, more expansionist and focussed on profit than Style 4, but also farm because of the 'tradition'. These farmers are quite reliant on their own knowledge, and are probably quite independent in their decision-making. Style 5 farmers are moderately concerned about the environment and salinity problems but are less likely than Style 4 to believe farmers should contribute to the cost of fixing the environment.
3) Style 6 (13% of respondents). Traditionally oriented farmers in terms of their farming systems and values. They do not agree they should share the costs of fixing the environment, nor that something needs to be done about environmental issues. This style does not believe they need a high degree of education and training to farm effectively.

A key finding was that landholders in the region are classed as traditional in that they employ similar sheep grazing based farming systems. There was little use of computer record-keeping and decision-tools, little adoption of non-traditional selling methods, and little use of formal farm business planning in the survey sample. This may mean that the majority of landholders lack the skills, inclination and familiarity with markets and trading to participate effectively in a novel individualistic trading scheme.

Analysis of the survey data indicated a vector of attitudes that motivate land holder participation in a salinity recharge-credit trading scheme in the Bet Bet region. These attitudes were the strong community spirit, acceptance of conservation farming (referred to in Australia as the Landcare ethic), and the high degree of acceptance that while salinity is a problem in the district, it can be managed on-farm (Connor et al., 2004a; Ward and Connor, 2004).

Experimental economic methods were used to formally test the significance of several potential impediments to effective on-ground trial implementation and policy designs to overcome impediments. Farmer consultation and their participation in experimental economic field trials assisted in the development of a controlled experimental setting calibrated to represent the biophysical and economic decision-making and trading environment landholders in the upper Bet Bet would face under a range of recharge credit trade policy instruments (Ward et al., 2007). Formal experiments with student participants, measuring behavioural responses to variable market architectures, information provision and institutional arrangements took place in the experimental economics laboratory at Griffith University. Observed behavioural responses were enumerated as recharge levels, levels of market participation, price and quantity outcomes and participant payments (a surrogate for farm income). These primary experimental metrics provided an empirical basis for the calculation of cost effectiveness, participation rates and achieved recharge reduction attributable to experimental treatments.

Based on feedback from landholders and sociological survey results experimental treatments were selected to:

- Test the potential of a cap and trade system to reduce cost of managing groundwater recharge;
- Compare the cost effectiveness of alternative market architectures of cap and trade;
- Test the cost and recharge reduction reliability of alternative tendering system designs to induce landholders to enter into contracts to accept a cap on recharge reduction; and
- Test the potential of equally shared collective "social payments" as an additional incentive to increase scheme participation and willingness to provide recharge reduction.
- Experimental testing of instruments and institutions.

Social survey work from this research (Thomson, 2004) as well as experience with market based policy (King, 2005; Randall, 2003) suggests that the problem of low participation rates and unreliable recharge reduction could be particularly acute with novel market designs that require complex information processing. Agencies implementing novel natural resource policies involving transitions to new institutional arrangements such as recharge credit trade may need to account for the behavioral and cognitive limitations of informational processing to understand how to successfully adapt and introduce market based approaches (Simon, 1972; Sterman, 1987, p.190, Smith, 2002).

Plott (1996) and Binmore (1999) propose an iterative process of the rational expression of preferences, called the "discovered preference hypothesis", as a theoretical explanation of cognitive limits and individual processing of complex information. The hypothesis states that agents progress from an initial state of untutored and limited cognitive capacity, expressed as seemingly random impulsive responses, through a more systematic selection of choices that reflect the decision environment. Finally agents arrive at a stage where expressed choices reflect the choices of others, converging to something akin to optimal responses predicted with expected utility theory (Braga and Starmer, 2005). Given the opportunity for repeated market participation and with feedback signals of sufficient clarity and strength, the expression of increasingly rational behavior can be expected to evolve.

However, there is currently a paucity of empirical evidence or theoretical insights to help anticipate the time steps and explanatory variables of emergent learning in specific market contexts (Braga and Starmer, 2005). The recharge trial is time constrained to two iterations of the clearance market (*viz.* annual markets for two years). Time constraints preclude extensive farmer participation in the market decision environment.

Experiments were designed to provide empirical evidence comparing the recharge market outcomes of a closed call clearance market with a more informationally rich open call market. A closed call market is characterized by limited disclosure of bidding information, restricted to market prices and individual volumes traded, excluding public disclosure of individual bidding behavior. In contrast, an open call publicly declares (whilst maintaining anonymity) all individual bidding and volume offers.

All experimental sessions were held at the Griffith University experimental economics laboratory using the MWATER experimental software platform. Participants were selected from an existing subject pool of approximately 200 undergraduate students, familiar with experimental protocols and procedures.

The simulated catchment is comprised of 12 heterogeneous farms located in the three landscape positions ($RL_{1,2,3}$ Fig. 1) with four farms located in each landscape position. Farm size was set at 65 ha (the median of participant farms). The farms represent a synthesis of existing farm management styles, characterised by specific levels of farm income, groundwater recharge rates and the marginal value of a recharge unit (ML).

Throughout the experimental sessions, each participant was randomly assigned to a single farm, and could select from five possible farm management and revegetation options associated with specified recharge and income levels (Ward et al., 2007 or available upon request). These were 1) Annual pasture, 2) Phalaris set stocking 3) Phalaris rotational grazing 4) Native vegetation 5) Farm forestry.

Options characterized by higher income levels were associated with higher recharge levels for all farms. After entering the chosen management option, participant terminal screens were updated with the option specific income, the marginal value of recharge units and the required recharge balance for the selected option. Each experimental session involved 10 independent, replicate periods of annual management decisions, market trading and where the treatment dictated, a forum for group discussion.

Instruction sets explaining the farm characteristics, decision sets, rules, protocols, payments and non-compliance penalties specific to each experimental treatment were provided via individual internet access to a power-point display. Supervising staff did not verbally present the instructions to avoid personality or behavioral biases and correct for possible delivery nuances. Talking, unless formalized in the treatment, was forbidden except to clarify questions from individuals regarding the experimental setting or instructions. To control for variable learning and to ensure consistent understanding, participants were required to accurately answer a quiz comprising of 10–12 questions specific to the treatment as a condition of access to the experimental game.

Player payments were calculated as a farm specific function of aggregate farm management and trading outcomes, reflecting player capacity to comply with recharge targets, adherence to farm management agreements and trading skill. Optimal incomes were calculated assuming players act as profit maximizers, acting optimally to available information.

Table 1 – ANOVA of closed and open call market treatments

Periods 1–10	Statistics[1]	Control[2]	Open[2]	Closed[2]
Aggregate recharge (MLs)	$F_{(2,47)}=1.257$	367[a]	385 (65.40)[a][3]	355 (68.88)[a]
Qty traded (MLs)	$F_{(2,47)}=27.054$*	144[a]	83 (20.31)[b]	93 (28.18)[b]
Market price ($)	$F_{(2,47)}=0.284$	61[a]	60 (42.83)[a]	67 (21.60)[a]
Gains from trade ($)	$F_{(2,47)}=6.729$*	56,978[a]	56,150 (4681)[a]	61,762 (3950)[b]
Periods 1–5				
Aggregate recharge (MLs)	$F_{(2,22)}=0.175$	367[a]	353 (83.51)[a]	371 (71.05)[a]
Qty traded (MLs)	$F_{(2,22)}=27.668$*	144[a]	79 (19.54)[b]	77 (19.53)[b]
Market price ($)	$F_{(2,22)}=0.142$	61[a]	61 (38.182)[a]	68 (26.167)[a]
Gains from trade ($)	$F_{(2,22)}=6.4458$*	56,978[a,b]	53,825 (4505)[a]	59,584 (3338)[b]

1) ANOVA tests: * indicates significant difference across treatments at $\alpha=0.05$.
2) Treatment means (across rows) with the same letter were not statistically different at $\alpha=0.05$.
3) Mean (standard deviation).

To ensure salience of player behaviour and response to income variance in the simulated catchment, the player payments were therefore a scaled representation of the income decisions confronting farmers in the Bet Bet catchment. Access to instructions sets, farm decision models and experimental protocols can be found in Ward et al. (2007).

The market price observed in experiments with the open call design ($\mu=60.0$, $\sigma=42.83$) were unstable compared to the closed call ($\mu=67.0$, $\sigma=21.60$) and did not converge toward a predicted, stable equilibrium with experimental repetition (Table 1). The quantities traded displayed similar convergence rates and variance. If implemented on the ground, participants could well find the initial volatility of the open call market, expressed as diffuse price signals, difficult to interpret, potentially reducing the volume of market exchange. The gains from trade from a closed call market were significantly ($F_{(2,47)}=6.729$, $p<0.05$) higher than both the control treatment (regulated recharge levels with no trade) and the open call market treatment (Ward et al., 2007). Learning as determinant, expressed as the degree of inter period independence, was tested using a linear mixed model imputing periods (1–10) as a covariate to estimate random effects (AR-1 heterogeneous) using a restricted maximum likelihood estimator. The primary experimental metric is the level of aggregate recharge (or recharge reduced) observed for each treatment. The estimated covariance parameter for periods 1–10 is 23.25 ($\sigma_e=6.82$), the Wald Z coefficient is 0.497, $p=0.620$, indicating there is no significant unobserved random effects between periods. In a general linear model, interaction effects (period*treatment) for periods 1–10, periods to 1–5 and 6–10 did not significantly effect recharge ($p=0.05$) for all experimental sessions. We interpret the finding of non-significance of the repetition effect fails to provide evidence supporting the Binmore and Plott discovered preference hypothesis and we reject learning as a significant determinant of bidding behavior.

Consistent with previous experimental findings by Smith (1982) and guided by the likely cognitive limitations of early entry agents proposed by Binmore (1999), it was concluded that the simpler information requirements associated with a closed call market structure for trading recharge credits had more reliable and predictable outcomes. In contrast to the open call, experimental outcomes converged toward theoretical "frictionless market" predictions in the closed call treatment (Fig. 2). The results suggest that there is a reasonable chance of reliable, cost saving trade occurring if a closed call trading format is used in the on-ground trial implementation.

Under current property rights arrangements in Victoria, land holders are not required to manage recharge to prescribed limits nor are affected downstream water users protected by a set of water quality standards. A set of fully specified, transferable and enforceable recharge rights, vested in the individual are antecedent to an eventual cap and trade scheme. Legislative changes to extant property rights, establishing legally enforceable obligations to provide water quality across the region was not politically feasible for the trial. The solution to this property rights impediment was to establish contractual obligations for willing landholders to provide recharge reduction in exchange for monetary compensation.

Previous Australian experience (Stoneham et al., 2003; Bryan et al., 2004) and theoretical insights (Kagel, 1995; Latacz-Lohmann and Van der Hamsvoort, 1997; Milgrom, 2004) suggests that a competitive tender should reveal the true costs of recharge abatement and act as a cost effective way to assign recharge obligations. An important objective of experiments prior to implementation was to test the capacity of alternative auction formats to induce truthful revelation of individual marginal costs of recharge reduction. Current Australian applications of tenders for conservation provision have generally relied on a sealed bid discriminant price tender format (Stoneham et al., 2003; Bryan et al., 2004). In contrast, Milgrom (2004) argues a uniform price is more incentive compatible with the revelation of true costs.

In a uniform price auction, the purchaser offers a single uniform purchase price which is paid to all successful sellers, regardless of their initial offer. That is, all sellers receive a market clearing price that exceeds their original offer, and the market price is determined exogenously of individual offers and is inclusive of a trading surplus. As a consequence sellers have a greater incentive to reveal their true costs of recharge reduction, as increasing their offer reduces the probability of bid acceptance.

Alternatively, in a discriminant price auction the purchaser pays a range of prices that match the offers of successful sellers. Sellers therefore face uncertain ranking and acceptance of offers although price is assured. Trading surplus is not determined exogenously and must be included in the sell offer. The incentive for sellers is to increase the value of their offer to include a component of surplus. A seller therefore faces a tension and costly learning effort in determining the balance between a higher probability of offer acceptance versus a higher trading surplus. Traders strategically seeking an optimal and maximum price may tend to explore the price opportunities in the market for a longer period compared with strategies in a uniform price auction. When payment is determined by an own offer, the discriminant tender format is not compatible with true cost revelation (Milgrom, 2004) but may be more cost effective for the purchasing agency when budget constrained (Cason and Gangadharan, 2005).

Cason and Gangadharan (2005) note that violations of the assumptions of the revenue equivalence theorem (Vickrey, 1961; Myerson, 1981), common to many environmental applications, precludes coherent theoretical analysis of the relative merits of the two tender formats based on theory alone. As an alternative to theoretical analysis, experimental analysis provided a formal comparison of the bidding behavior and the magnitude and reliability of recharge reduction with discriminant versus uniform tender formats.

In the simulated upper Bet Bet experimental setting, the behavior of players in the uniform tender resulted in significantly increased recharge reduction ($F_{(2,47)}=4.402$, $p<0.05$), less volatile market bidding and recharge reduced at a lower unit cost (mean of \$52.37 ML recharge^{-1} and \$86.57 ML recharge^{-1} respectively).

Results of experiments shown in Fig. 3 suggest that with a discriminant price tendering format, subjects characterized by low marginal recharge abatement costs had difficulty recognizing their optimal strategy. Sub-optimal decisions enabled other high marginal cost players to recognize and exploit an opportunity to gain large profits through strategic, successful bidding behavior. The uniform price tender was therefore selected as the appropriate tender mechanism to establish payments for farmers to enter into recharge management obligations (Ward et al., 2007).

According to Vatn and Bromley (1995) and Lowenstein (1999) the expression of individual preferences in market settings 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. Ostrom (1998) argues that individual decisions made within the rubric of common pool resources may represent a non-systematic, variable sequence filtered through the focal length of collective choice. Prestige, public recognition, group belonging, avoidance of group sanction, and desire to contribute to the public good can all represent powerful motivators in some contexts. Failure to account for such motivations in policy design can result in reductions in the willingness to supply environmental quality compared to policy designed to harness such motivations. Survey results from this research (Thomson, 2004) indicate high levels of social cohesion, reciprocal behavior and concerns about community reputation. In another Australian catchment, Marshall (2004) found the level of preparedness to cooperate and adhere to group compacts for salinity control was more sensitive to perceptions of community benefits and a belief that others will reciprocate compared to private considerations like business security.

The final set of experiments conducted tested the potential of a form of collective performance based payment to harness individual contributions to group determined collective outcomes. In one experimental treatment, part of the payment received by participants was contingent on the group as a whole achieving a defined level of aggregate recharge reduction. The results of these experiments support the conclusion that using such a collective performance incentive payment to establish initial recharge reduction obligations in the on-ground trial may increase participation and reliability of recharge reduction (Ward et al., 2007).

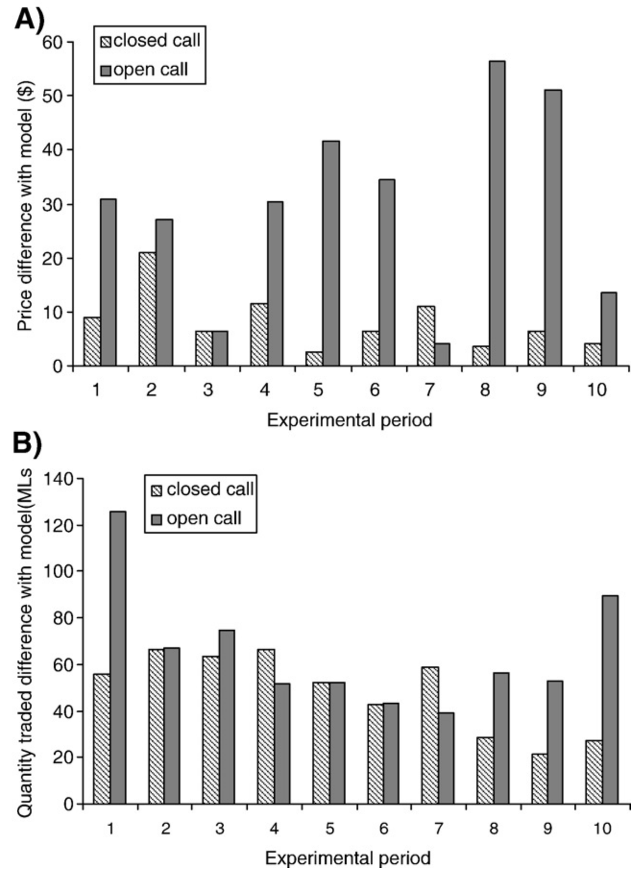

Fig. 2.

2. Implementation

Based on the survey and experimental results, key features selected for inclusion in the on-ground trial phase to address identified impediments to effective Market Based Instrument implementation are detailed in Table 2.

Two additional design steps were necessary prior to implementation. The first was the development of recharge outcome monitoring and credit accounting protocols. The second was the establishment of a legal agreement as the basis for the on-ground pilot trial implementation.

2.1. *Monitoring and credit accounting*

Shortle and Horan (2001) and Schary (2003) argue that developing policy capable of realizing savings by focussing on

Table 2 – Impediments addressed by recommended design features

Impediments/design features	Property rights	Lack of performance incentive	Capital/time preference/risk constraints	Thin market/rent seeking	Costly information	Non-market motivations
Payments to establish obligations	X					
Performance based payment		X				
Multiple year agreement with establishment and annual performance payments		X	X			
Higher payment for more permanent change		X				
Uniform price auction				X	X	
Group performance component of payment to establish initial obligations				X		X
Group incentive payment for reconciliation of credit/debits positions					X	X

performance coupled with compliance flexibility is challenging for diffuse source pollution because monitoring actual outcomes is often technically infeasible or costs are prohibitive. This represents a substantial challenge to effective cap and trade schemes to address diffuse source environmental issues such as surface water salinity affected by rates of groundwater recharge. To effectively participate in the exchange of tradeable recharge credits, land managers need recharge accounting and auditing that allows evaluation of their management decisions prior to implementation and the monitoring of progress against their targets or commitments. Similarly, administrators of the scheme must also have the capacity to monitor and audit the outcomes of changes in land use or management practice and to attribute change in recharge to either landholder action or exogenous factors such as climate. Since groundwater recharge and salinity are not readily measured directly, a prerequisite to implementing a cap and trade is the development of a reliable and transparent indicator to assist all participants in evaluating recharge and salinity impacts of land management actions.

Thus a first step in this project was development of bio-physical and hydrological modelling to relate groundwater recharge rates, observable vegetation cover type, condition and landscape position (Clifton, 2004; Connor et al., 2004a,b).

The results are shown in Tables 3 and 4 and quantify the relationship of credits to:

1. differences in rates of annual and perennial crop and native tree evapo-transpiration,
2. temporal differences between tree and crop types for maximum transpiration rates to be realized; and
3. differences in recharge reduction resulting from landscape position (differential recharge reduction is a function of rainfall, slope, soil permeability, levels of fractured granite and soil transmissivity).

Table 3 – Credits for revegetation as function of landscape position and audited plant density

		1. Granite country		2. Non-granite >650 mm rainfall		3. Non-granite <650 mm rainfall	
		Number of recharge credits					
Class boundary	Established stems (ha^{-1})	Farm forestry	Native vegetation	Farm forestry	Native vegetation	Farm forestry	Native vegetation
40–89	50	3.5	9.0	2.8	7.3	2.1	5.5
90–139	100	4.6	12.0	3.7	9.6	2.8	7.2
140–189	150	5.5	14.1	4.3	11.3	3.2	8.5
190–239	200	6.1	15.8	4.9	12.8	3.6	9.6
240–289	250	6.7	17.3	5.3	14.0	4.0	10.5
290–339	300	7.2	18.7	5.7	15.0	4.3	11.3
340–389	350	7.7	19.9	6.1	16.0	4.6	12.0
390–439	400	8.1	21.0	6.4	16.9	4.8	12.7
440–489	450	8.5	22.0	6.8	17.7	5.1	13.3
490–539	500	8.9	23.0	7.1	18.5	5.3	13.9
540–589	550	9.3	23.9	7.3	19.2	5.5	14.5
590–639	600	9.6	24.8	7.6	19.9	5.7	15.0
640–689	650	9.9	25.6	7.9	20.6	5.9	15.5
690–739	700	10.2	26.4	8.1	21.2	6.1	15.9
740–789	750	10.5	27.1	8.3	21.8	6.2	16.4
790–839	800	10.8	27.8	8.5	22.4	6.4	16.8
>=840	>800	10.8	27.8	8.5	22.4	6.4	16.8

Table 4 – Credits for perennial pasture projects as a function of landscape position and audited plant density

Established plants (m^{-2}) Class (range)	1. Granite country		2. Non-granite >650 mm rainfall		3. Non-granite <650 mm rainfall	
	Number of recharge credits					
	Lucerne	Phalaris	Lucerne	Phalaris	Lucerne	Phalaris
5 (<9)	Not applicable	0.9	2.2	0.9	1.8	0.9
10 (9.1–14)		1.2	2.9	1.2	2.4	1.2
15 (14.1–19)		1.4	3.4	1.4	2.8	1.4
20 (19.1–24)		1.6	3.8	1.6	3.2	1.6
25 (24.1–29)		1.7	4.2	1.7	3.5	1.7
30 (29.1–34)		1.9	4.5	1.9	3.8	1.9
35 (34.1–39)		2.0	4.8	2.0	4.0	2.0
40 (39.1–44)		2.1	5.1	2.1	4.2	2.1
45 (44.1–49)		2.2	5.3	2.2	4.4	2.2
50 (49.1–54)		2.3	5.6	2.3	4.6	2.3
55 (54.1–59)		2.4	5.6	2.4	4.6	2.4
60 (59.1–64)		2.5	5.6	2.5	4.6	2.5
65 (64.1–69)		2.6	5.6	2.6	4.6	2.6
≥70 (>69.1)		2.7	5.6	2.7	4.6	2.7

The basis for Tables 3 and 4 is the model illustrated in Fig. 1 where R_i represents the recharge rate for farm *i*, managing crop *j*. In the model:

$R_i = (C_{ij}, A_{ij}, R_{Ai}, G_i, L_k)$, and:
- C_{ij} is crop type and management
- A_{ij} is area of crop type
- R_{Ai} is annual rainfall
- G_i is soil type and geomorphology
- L_k is landscape position, $k=1$, 2 or 3 where:
  - $k=1$ represents lower slope;
  - $k=2$ represents break of slope;
  - $k=3$ represents ridge and upper slope.
- $j=1$–5, where:
  - $j=1$ represents annual grazing;
  - $j=2$ represents perennial pasture (phalaris set grazing);
  - $j=3$ represents perennial pasture (phalaris rotational grazing);
  - $j=4$ represents native tree vegetation;
  - $j=5$ represents farm forestry (less than 10 years old).

C_{ij}, A_{ij} represent endogenous variables in a farm decision set; and

R_{Ai}, G_i, L_k represent exogenous variables in a farm decision set.

The model developed accounts for three key biophysical determinants of recharge differences across locations and actions shown in Fig. 1:

1. *Ceteris paribus*, for crop *j*, recharge from lower slope (L_1) is less than the recharge from break of slope (L_2) which is less than recharge from upper slopes (L_3). *Viz.* $RL_1 < RL_2 < RL_3$.
2. Increased deep rooted perennial vegetation reduces groundwater recharge: *viz.* for landscape position L_k, subject to land management regime M_P (Panel A) or M_G (Panel B), recharge R_i is such that $Ri\,L_k\,M_P < Ri\,L_k\,M_G$.
3. The estimated costs of groundwater recharge for land management activity at farm *i*, at landscape position L_k is such that:

$R_{MG} > R_{MP}$; recharge from annual grazing is greater than recharge from perennial grazing or forestry;
$WT_{MG} > WT_{MP}$; the water table level is higher for annual grazing compared to perennials;
$SL_{MG} > SL_{MP}$; exported salt load is greater for annual grazing than perennials;
$C_{MG} > C_{MP}$: external costs of recharge imposed on downstream irrigation are greater for upstream annual grazing compared to perennials.

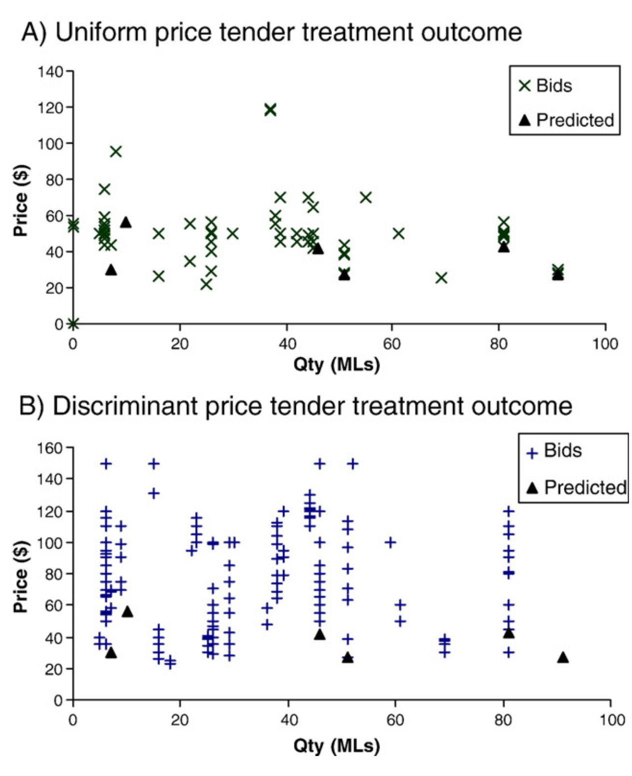

Fig. 3 – A) Uniform price tender treatment outcome. B) Discriminant price tender treatment outcome.

2.2. The contractual obligation to reduce recharge

The contract between the administrators and individual land holders represents a commitment by individuals to meet a salinity recharge obligation either through compliant land management action or offset deficits in on-site reduction through the purchase of additional salinity recharge credits. Those who exceed recharge reduction obligations are issued surplus salinity recharge credits tradeable with those who prefer to meet their obligations through market exchange. If land management change and trading occurs to the extent necessary to meet a defined collective aggregated recharge reduction target, all participants receive a bonus payment. The trial implementation involves the five stages shown in Fig. 4.

The main features of the land holder agreement are:

1. Voluntary multiple year agreements with landholders for management changes that reduce recharge to agreed levels in exchange for payment. Three types of land management change are possible under the agreement:
   a. new pasture establishment and management;
   b. a farm forestry establishment, management; and
   c. native vegetation establishment and management.
2. An establishment payment based on the vector of estimated level of annual recharge reduction, estimated permanence of the management change undertaken and the catchment location, disbursed at a payment rate of $ per ML of recharge reduction (see Tables 2 and 3).
3. Annual "performance payments" based on monitored ground cover and the look-up tables relating observed ground cover to modelled recharge reduction based on crop type and landscape position.
4. Estimated recharge achieved will be compared with the level of recharge obligation participants contract to provide. To qualify for annual performance payments available at the end of project years 2 and 3 (trial commencement), participants will require credits obtained from either farm management or trade equal to or exceeding their recharge obligation level.
5. To ensure that seasonal conditions do not result in an infeasible outcome, banking and borrowing of credits is allowed so that a deficit in one year can be made up if the deficit is redressed through increased on-ground work or credit trade before the end of the trial.
6. A collective agreement provision to achieve recharge reduction targets will require that funds be withheld unless all landholders can reach consensus to meet a minimum aggregate level of reduction. (Scheme participation increased from 11 to 34 sites after announcement of the collective payment).

3. Implementation results to date

Scheme implementation commenced in early 2005, resulted in establishment of native vegetation on 103.4 ha at 22 sites and new perennial pasture establishment on 12 sites totalling 257 ha. Audits of the vegetation ground cover achieved by scheme participants were undertaken in late 2005 and early 2006. The results for native vegetation sites are shown in Table 5. They lead to the prediction that credit deficits are likely on 5 of 22 native vegetation sites, surpluses are likely on 15 sites, and 2 sites are predicted to equal contract obligations. The aggregate net surplus of credits on all revegetation sites is estimated to be 78.4

Table 5 – Recharge credit accounts for native vegetation projects

Revegetation project	Land unit [a]	Area (ha)	Final count (Stems/ha)	Assigned credits	Total credits	Credit surplus or deficit	Credit deficit
1	2.0	1.5	3150.0	25.4	33.6	8.3	
2	2.0	1.5	2850.0	25.4	33.6	8.3	
3	2.0	9.0	5256.0	152.1	201.6	49.5	
4	2.0	2.0	3737.0	33.8	44.8	11.0	
5	2.0	2.0	396.0	33.8	33.8	0.0	
6	2.0	2.5	690.0	42.3	53.0	10.8	
7	3.0	1.5	1252.0	19.1	25.2	6.2	
8	3.0	1.1	2741.0	14.0	18.5	4.5	
9	3.0	0.9	2111.0	11.4	15.1	3.7	
10	3.0	0.9	1500.0	11.4	15.1	3.7	
11	2.0	4.0	150.0	45.2	51.2	22.4	
12	1.0	12.0	238.0	252.0	189.6		−82.8
13	1.0	15.5	1038.0	325.5	430.9	105.4	
14	3.0	18.0	2139.0	228.6	302.4	73.8	
15	1.0	4.5	267.0	94.5	77.9		−16.7
16	1.0	4.5	300.0	94.5	84.2		−10.4
17	1.0	4.0	240.0	84.0	69.2		−14.8
18	1.0	18.0	120.0	378.0	216.0		−162.0
19	1.0	4.0	2248.0	84.0	111.2	27.2	
20	2.0	5.0	943.0	84.5	112.0	27.5	
21	2.0	2.0	643.0	33.8	33.8	0.0	
22	1.0	1.0	874.0	16.9	23.9	2.9	
Total		115.4		2090.0	2176.5	365.0	−286.6

[a] 1: Granite country; 2: Non-granite >650 mm rainfall; 3: Non-granite <650 mm rainfall.

Table 6 – Recharge credit accounts for perennial pasture projects

Perennial pasture project	Land unit [a]	Area (ha)	Plant density (#/m^2)	Assigned credits	Total credits	Credit surplus	Credit deficit
1	2	27	–	54	–	–	
2	2	10	39.6	20	21	1	
3	3	11	–	22	–	–	
4	2	9	85.6	18	24.3	6.3	
5	2	10	34.6	20	20	0	
6	3	16	57.9	56	73.6	17.6	
7	2	47	28.2	54	79.9		−14.1
8	2	20	–	40	–	–	
9	2	50	31.2	100	95		−5
10	3	16	34.2	32	32	0	
11	3	12	44.8	24	26.4	2.4	
12	3	29	37.9	58	58	0	
Total		257		498	430.2	27.3	−19.1

[a] 1: Granite country; 2: Non-granite >650 mm rainfall; 3: Non-granite <650 mm rainfall.

credits. The results for pasture sites are shown in Table 6. The prediction based on these results is that deficits are likely on 2 of 10 sites audited, surpluses are likely on 6 sites and two sites are predicted to break-even with an overall net surplus of credits on all pasture sites of 8.2 credits.

Under the terms of the contract, participants are able to trade credits at any time during the three year on-ground implementation phase. No trading has taken place to date. However, given that some sites are in surplus and some in deficit, and given that there are incentive payments at the end of years two and three for any participant who meets their obligation through outcomes of land management on their property and credit trade, trades are likely over the next two years.

4. Benefit cost analysis

A Benefit Cost Analysis (BCA) was undertaken to assess the benefits of the outcomes of the MBI trial in comparison to outcomes that would have resulted had the trial not been implemented. The benefits and costs of the trial are assessed as the difference in outcomes expected between a baseline scenario with no change in vegetation cover and the MBI trial scenario. The objective was to estimate the net present benefit of changes in perennial vegetation in the Bet Bet sub-catchment expected to ultimately result from MBI trial implementation, in addition to resulting farm profit and downstream river salinity levels.

The time frame of analysis is 50 years, determined to account for the period of tree establishment and maturation and the public good nature of salinity reduction and carbon sequestration benefits and the cost of return flow reduction.

Five categories of public and private benefits and costs expected from implementation of the recharge trading scheme are estimated in monetary terms. Table 7 shows the categories of benefits and costs that are estimated quantitatively and the assumed timing of costs and benefits and sources of data used in deriving quantitative estimates.

Participant farm incomes detailed in Table 7 were estimated based on economic modelling of Bet Bet grazing conducted for the project (Connor et al., 2004b). The opportunity cost of forgone grazing when trees are established is assumed to be $40/ha/year (a maximum grazing capacity of two dry sheep equivalent forgone) in the first three years when grazing would harm tree establishment. Opportunity cost is assumed to be $20/ha/year in years four through ten (50% grazing capacity) and $40/ha/year thereafter, as tree shading precludes grazing.

Establishing and maintaining perennial pasture, on the other hand, has a production benefit of increased grazing productivity. An average yield increase on pasture worth $60/ha/year is assumed. This represents an average productivity gain of 3 dry sheep equivalent units (DSE) at a conservative value of $20/DSE, commencing in the second year after establishment and maintained for five years.

The estimated public expenditure to fund the trial is based on assumed outcomes of land management and credit trade given the contracts that are in place now. There is currently a

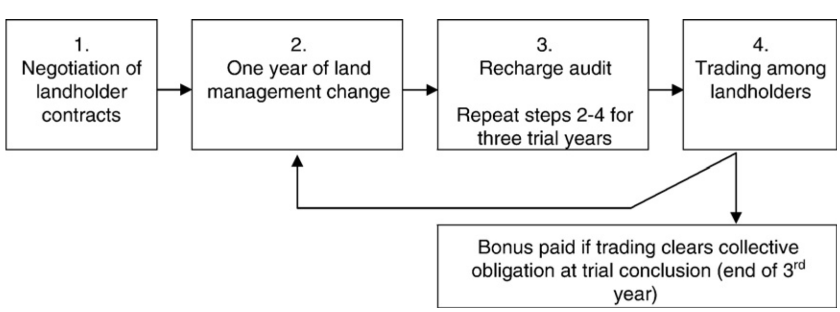

Fig. 4.

Table 7 – Economic benefits and costs quantified in benefit cost analysis

Benefit/cost category	Impact quantified	Assumed timing	Source data
Participant farm production		Years 1–3 and 11–50	Connor et al. (2004a)
a. Opportunity cost of grazing in tree establishment	−$40/ha (two dry sheep equivalent, dse yield loss); −$20/ha (−1 dse)	Years 4–10	
b. Improved yields of new pasture; opportunity cost of grazing during pasture establishment	+$60/ha (+3 dse) −$40 (−2 dse)	Years 2–5 Year 1	
Public cost of MBI trial payments to participants	2728 credits at $38.40/credit = 19,775	Year 1–3	Connor et al. (2006)
Downstream benefits of salinity damage reduction	Reduced salinity damage to downstream irrigators and rural towns as summarized in Table 6	Years 11–50	See Table 7
Opportunity cost of flow reduction	Opportunity cost of estimated 361 ML/year flow reduction	Years 11–50	Flow reduction–Clifton (2004) Water value–Brennan (2005)
Benefit of increased carbon sequestration	Benefit of native vegetation establishment of two tonnes/year/ha carbon sequestration	Years 6–35	Carbon sequestration—SKM (2002) Carbon value, Carbon point, 2006

net surplus of credits, estimated to continue until the final trial reconciliation. It is thus assumed that participants will receive maximum individual performance payments and the additional community payment. Total estimated payments of $119,775 are imputed in the analysis, comprised of $104,755 ($38.40/credit × 2728 estimated credits) plus a $15,000 community performance bonus.

There was an additional project cost of $210,000 for the trial design and development of a recharge monitoring metric, plus additional overhead costs associated with administering the MBI trial program more generally. As the intent of the MBI trials is to develop reproducible models and transferable findings, these costs are treated as a general public good research investment and not included in the BCA.

Connor et al. (2006) estimate the salinity impact of implementation at a 0.8 EC reduction in Loddon River salinity, and a 0.0045 EC reduction in the River Murray salinity at Morgan. The estimates were combined with estimates of salinity damage per EC from relevant published studies to estimate a dollar value of salinity damage avoidance benefits of trial implementation as shown in Table 8.

Based on a 2002 analysis of the capacity of native vegetation to sequester carbon in the area (Sinclair Knight Merz, 2002), it is assumed that an average of 2 tonnes of carbon (7.32 tonnes CO_{2e}) per year are sequestered in each of the first thirty years after initial establishment. The economic benefit of sequestration is estimated as the European Union carbon exchange market value of €8/tonne CO_{2e} (Au $12.60 per tonne at the exchange rate on that day). Sensitivity to carbon prices was analysed by imputing carbon at 40% of the current exchange rate.

Vertessy et al. (2003) contend that that while revegetation can reduce salt loads and consequent salinity damages, it can also reduce flows. The flow reductions will in some cases result in reductions in dam storages in follow-on years. This in turn can result in reductions in levels of water allocations to irrigators or the environment and thus represent a substantial opportunity cost (Young and McColl, 2003). The estimated value of flow loss opportunity cost used in BCA is based on a plant water transpiration/hydrology estimate that trial revegetation will ultimately reduce flow to the Bet Bet creek by 361 ML/year. The opportunity cost of water used in estimation is an average market price for water on the temporary market of $50/ML (in the high range of reported values, Brennan, 2005; Appels et al., 2004). A lower bound estimate of 40% of this value represents a reduced opportunity cost to account for modelling errors.

The overall net benefits estimated for the trial are summarized in Table 9. The table includes results of sensitivity analyses

Table 8 – Economic impacts of changes in vegetation cover in the Upper Bet Bet Creek sub-catchment

Attribute	Cost function[1,4]	Change due to MBI project ($/y)
Boort district irrigators[2]	$7600 per 10 EC	596
Kerang district irrigators[2]	00,000 per 17 EC	2,352
Boort and district households	00/EC	$210
Kerang township	$350/EC	$665
Loddon dryland towns	700/EC	$35,704
Murray River water users	51,700/EC at Morgan	$706
Total		8,423

1. Cost function from Loddon CWG (1992).
2. Land use in the irrigation districts, particularly Boort, has changed since the work in the *Loddon dryland salinity management plan*. This may have changed the sensitivity of agricultural production to salt and the cost calculations given above.
3. This assumes that all of the impact is due to change in Bet Bet Creek. This will not be the case.
4. Cost from *The Salinity Audit of the Murray Darling Basin* (MDBMC, 2000).
5. All values expressed in 2005 prices using Austat Consumer Price Index to updated older estimates.

Table 9 – Estimated net benefits of the dryland salinity credit trade trial

	Net present value low water opportunity cost, no carbon value	Net present value low water opportunity cost, low carbon value	Net present value low water opportunity cost, low carbon value, participant opportunity cost of forgone grazing offset by non-monetized non-market benefits of revegetation	Net present value high water opportunity cost, high carbon value	Net present value — high water opportunity cost, low carbon value
Opportunity cost of forgone grazing	−$72,077	−$72,077		−$72,077	−$72,077
Benefit of improve pasture	$70,643	$70,643	$70,643	$70,643	$70,643
MBI payments	−119,775	−119,775	−119,775	−119,775	−119,775
Salinity benefit	$246,334	$246,334	$246,334	$246,334	$246,334
Water opportunity of 40% flow at $50/ml or 100% at $20/ml	−$96,273	−$96,273	−$96,273		
Water opportunity of all flow loss at $50/ml				−$240,683	−$240,683
Carbon at A$ 5.4/tonne $C0_{2e}$ (40% of European price € 8/tonne $C0_{2e}$)		$58,784	$58,784		$58,784
Carbon at A2.6/tonne $C0_{2e}$ (European price € 8/tonne $C0_{2e}$)				46,960	
Total net present value	$28,852	$87,636	59,713	$31,402	−$56,774

One € = 1.62A$, http://www.pointcarbon.com/Home/Market%20prices/Historic%20prices/category390.html.

to illustrate the relationship between the results and data uncertainty. The sensitivity is estimated for alternative assumptions about flow reduction, opportunity cost, carbon benefits, and participant valuation of opportunity costs of forgone grazing.

The results of the BCA suggest that the recharge trading scheme is likely to create a net present benefit. However, the substantial estimated net present value of benefits of reduced salinity damage, the main focus of the trial, is offset by the opportunity cost of flow reduction under the conservative flow reduction assumption (an opportunity cost of $50/ML). The estimated benefits of high value carbon sequestration (equal to the current European carbon market price) are sufficient to offset the high opportunity cost of flow reduction. Under these model assumptions, scheme implementation is estimated to have a positive net present value. With an assumption of a high opportunity cost of water and a low value of carbon, however, the scheme implementation is estimated to have a negative net present value.

It is standard procedure in BCA to discuss important unquantified categories of benefits or costs of implementation which are excluded from the final evaluation and conclusions drawn. Four important categories of cost and benefit could not be quantified in this BCA:

1. Public costs of the MBI trial other than payments to land holders and longer term public benefits of the trial;
2. The public benefit of improved water quality where revegetation is along eroded gullies;
3. The benefits to participants and other local landholder of any reductions in manifestation of dryland salinity that may result;
4. Other non-market use or non-use values that participants and the wider public may place on changes resulting from project implementation.

With the exception of the first category which could conceptually have either a positive or a negative net benefit, all of the omitted effects would be expected to have positive net benefits. Thus inclusion of monetary estimates of excluded benefits and costs would lead to greater estimates of the net benefits of trial implementation.

4.1. *Higher level learnings*

The Bet Bet recharge salinity trial is not yet completed and the corollary final result is not yet available. However several lessons emerge from this trial that have implications beyond the trial case study. One widely applicable lesson from this pilot is that individual legal agreements of the type discussed here may provide advantages similar to those that can be attained with tradeable credit policy. Tradeable credit or cap and trade policies require individual limits on allowable emissions. Often, in diffuse source emissions settings no limits exist. Defining individual emission limits for all in such settings would involve fundamental changes to legal definitions of environmental property rights. Given the potential costs to landholders to comply with limits and the transactions and administrative cost involved it is typically politically infeasible to set individual emission limits for all. Using a legal agreement, as opposed to a legislated basis for environmental limits, represents a way to partially overcome more fundamental political economy and transactions cost challenges to defining individual emissions limits more generally.

In Victoria as elsewhere in Australia the only property right with respect to recharge emissions is an implicit right to emit recharge. In the trial individual legal agreements provide obligations to meet environmental limits. The limits are defined as an obligation to provide an agreed level of credits through results of own land management and credit trade. This allows realisation of some of the benefits of an emission trade policy where there are no overarching legal limits on emission.

A second lesson is that dynamic incentive can be built into both credit and auction policies with contractual arrangements. Dynamic incentive is achieved when the policy creates motivation to continuously seek out lower cost innovative ways to meet environmental goals (Young et al., 1996; Tietenberg and Johnstone, 2004).

Recent evaluations of experience with incentive based environmental policies in the United States and Europe confirm that tradable credit and charge approaches have significant capacity to produce dynamic incentive and lead to lower than anticipated policy compliance cost (Harrington et al., 2004). A prerequisite for the creation of a dynamic incentive is a feedback mechanism whereby parties subject to policy make repeated production decisions and the resultant production and policy compliance costs are revealed.

The approach trialled creates dynamic incentive contractually in a way that can be applied in other settings. The dynamic incentive is created by specifying: monitoring protocols, a basis for relating monitoring outcome to performance, repeated performance monitored at regular intervals and a payment schedule relating the level of repeated payments to monitored outcomes.

The trial approach relates groundcover monitoring outcomes to recharge credits based on plant soil water balance models. Incentive for dynamic efficiency and trade is created through second and third year payments in the three year trial, contingent on achieving agreed credit levels through monitored outcome and credit trade.

This contrasts with practice in most auctions and other payment policy to date as payment relies on input or practice implementation rather than monitored outcome. The monitored outcome basis for this trial is replicable in other dryland farming settings in Australia and provides a basis for tradeable credit and other performance based policy.

A collective performance incentive feature is included in the trial. The notion is that an equally shared group payment, in addition to individual payments, is only dispersed to participants if the sum of individual outcomes reaches an aggregate pre-specified level. The collective performance outcome based payment appeared to increase uptake of incentive payments in the Bet Bet. A third key lesson from this trial is that collective performance payments hold promise as a way to increase uptake of incentive payments for on-ground works in similar settings where environmental action is a high priority but voluntary participation in input payment programs is low.

Revegetation in the Upper Bet Bet sub-catchment of the Loddon has been a high policy priority for several years prior to this trial. This is because salt loads from drainage in the area are the highest per ML of drainage of all Loddon Sub-catchments. A result of continuing focus on the area was that most ready adopters appeared to have already undertaken substantial revegetation at the trial outset. Only 5 ha of revegetation in exchange for payments was undertaken in 2004, the year prior to the trial. In contrast, there has been a high level of enrolment in the trial with 103 ha of revegetation and 257 ha of perennial pasture establishment.

The trial outcome suggests that the group performance incentive payment feature and local Landcare administration of the trial increased voluntary enrolment. The significance is that the approach could effectively increase program uptake in other targeted environmental priority areas where enrolment rates in on-grounds programs are insufficient to satisfy natural resource management targets.

There is a considerable body of economic research supporting the notion that incentives for collective performance hold promise as an approach to reducing diffuse source emissions. Ostrom (1998), Gintis (2000) and Tisdell et al. (2004) report a willingness to diverge from individualistic profit maximizing behaviour for the public good in small, cohesive communities although other research suggests that a free riding problem can arise with collective incentive policy where there is too little individual incentive and individual behaviour is not easily observed (Poe et al., 2004).

This trial is one of the first demonstrations of the potential of policy with a collective outcome basis implemented in an on-ground setting that we are aware of. How successful a collective performance incentive approach is likely to be in other settings remains unresolved. Results of the social survey carried out in the trial region indicate a high level of social cohesion, a high level of membership in Landcare, the pilot administrators and a strong belief that on-farm action can improve salinity outcomes. We suspect that these community characteristics are at least a partial explanation for the success of the collective performance incentive in the trial. The results may not be replicable in settings where there is less social cohesion.

Acknowledgements

This research was funded by 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. The authors would like to thank Leah Thompson, Jarred Coote, and Neil Smith from Victorian Department of Primary Industries, Shawn Butters and David Clark from the project working group for their help in developing the ideas expressed in this report. The working group has provided a valuable input in developing the project plan and enthusiastically participated in a constructive review process. We would also like to acknowledge assistance in developing the economics experiments from Dr. John Tisdell of Griffith University.

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