Using contracts to mitigate salinity: an analysis of voluntary cost-sharing agreements

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Abstract

This paper looks at the incentives of voluntary cost-sharing agreements being used by the Department of Conservation and Land Management (CALM) in three natural diversity recovery catchments in the South West of Western Australia. These agreements represent an understanding between CALM and the farmer to undertake salinity mitigating works according to guidelines. CALM's objectives are to preserve and enhance target natural diversity assets through conservation and sustainable land use systems. These agreements are tailored to farmers according to the private and public benefits expected as a result of the works. Catchment management officers can respond to farmers needs and account for the importance of the works to the conservation of the natural diversity asset but are constrained by equity and efficiency considerations. Cost-sharing agreements can be analysed using a principal-agent framework and the theory of contracts. A theoretical model is used to determine the optimal amount of abatement undertaken by farmers in the recovery catchments, where abatement is measured as the area revegetated as a proxy for recharge reduction. This model is used to evaluate current approaches to contracting in the light of CALM's objectives. Results show that an equity constraint which pays the same transfer payment for the same area of land revegetated will result in lower total of abatement, higher total transfer payments, and lower social welfare in the form of value of abatement to the environmental regulator. These results support the approach taken by CALM to negotiate VCSA on a basis of private and public benefits rather than a standard VCSA for area abated.

Keywords: dryland salinity, contracts, cost-sharing agreements, incentives, equity

1. Introduction

Loss of biodiversity due to the spread of dryland salinity in the Western Australian Wheatbelt is a problem of national and international significance. Although not the only threat to biodiversity (i.e. other threats include weeds, pests, fire, disease), salinity deserves particular attention because of its irreversibility. The Western Australian Wheatbelt, recognised as one of the world's 25 biodiversity hotspots (Myers et al., 2000; Keighery, 2000), has the highest occurrence of secondary salinity in the country. It has been estimated that 450 flora species endemic to the lowlands of the Wheatbelt region are at risk of extinction due to the increasing salinisation of the landscape (Keighery, 2000). Given that up to 80 per cent of vegetation remnants on farms and up to 50 per cent of public lands could be lost in the Wheatbelt as a consequence of dryland salinity

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(Agriculture Western Australia et al., 1996), policy makers must persuade landholders to adopt salinity abatement measures into their farming systems. These measures may have some private benefits, but in most cases reduce farm profit (Kingwell et al., 2003). Recruiting landholders to abatement schemes is of particular importance in areas where key natural diversity assets of significant public value have been identified, such as in the natural diversity recovery catchments in Western Australia managed by the Department of Conservation and Land Management (CALM).

2. Natural Diversity Recovery Catchments

Recovery catchment's are catchments which are identified as a major high priority public asset at risk from salinity and consequently receive a high level of investment from the State government relative to other catchments. This concept, has recently been formalised in the development of the Salinity Investment Framework (SIF). The objective of the SIF is to 'guide investment to those projects with the best chance of protecting assets of high public value.'(DOE, 2004: 7).

Natural diversity recovery catchments work in partnership with CALM for biodiversity conservation and were identified as a key measure for biodiversity conservation under both the 1996 Salinity Action Plan and the current State Salinity Strategy.[3] To date there are six natural diversity recovery catchments in the Wheatbelt region: Buntine-Marchagee, Drummond Nature Reserve, Lake Bryde Complex, Lake Muir-Unicup, Lake Warden, and Toolibin Lake.

Voluntary cost sharing agreements

One of the major financial incentives available to landholders in the natural diversity recovery catchments is access to voluntary cost sharing agreements (VCSA) for on-ground works to mitigate dryland salinity and protect biodiversity. On-ground works covered by the VCSA offered by CALM include revegetation, fencing of remnant vegetation and in some catchments surface water management.

VCSA have been used in natural resource management (NRM) policy in Australia to effectively influence landholders to implement works to address land degradation issues. Essentially a subsidy, landholders are paid a proportion of the cost of the works by a government authority (Federal, State or local) or a non-government organisation in some cases, where a public benefit is derived from the works being undertaken. When landholders cleared their properties of deep rooted native vegetation and replaced it with shallow rooted annual crops they did not take into account the costs these actions would have on the biodiversity that was left standing. These costs are borne by the wider community who value biodiversity. Therefore the persistence of traditional farming systems, which induce the negative externality of biodiversity loss from rising water tables in some circumstances, justifies the intervention of government in the form of VCSA to correct for this market failure.

Two principles can be used in the implementation of cost-sharing agreements: the polluter pays principle; or the beneficiary pays principle. Polluter pays requires polluters to pay for on-ground works in proportion to their contribution to the cost of a problem. This principle is generally only applicable when the polluter can be identified. Many land degradation issues are examples of non-point source pollution, where the polluters cannot be identified. In such cases the second principle applies. Beneficiary pays involves distributing the costs of on-ground works between the beneficiaries, private and public. The beneficiary pays principle has a user pays component, where all people who directly benefit from on-ground works should contribute to their cost and a beneficiary compensates component, where people who benefit from the public goods generated

[3] Water Resource Recovery Catchments are managed by the Department of Environment.

by the on-ground works such as the preservation of biodiversity in this instance, contribute in the form of funding from government (MDBC, 1996).

The design and implementation of the VCSA is critical to achieving the objectives of a recovery catchment. CALM's implementation of VCSA in natural diversity recovery catchments involves the catchment management officer (CMO) negotiating the terms of the VCSA individually with each landholder participating in the scheme on their behalf. So although some things are the same across recovery catchments such as CALM paying in full for the cost of biodiversity seedlings, the administration of VCSA will differ between natural diversity recovery catchments according to the approach adopted by the CMO in negotiation and the characteristics and social norms of landholders in a particular catchment.[4] The differences in the implementation of VCSA can be illustrated by looking at three natural diversity recovery catchments: Lake Toolibin, Lake Warden and Drummond Nature Reserve.

Lake Toolibin

Toolibin Lake, with a surface area of approximately 300 hectares, is the icon asset in the 49 000 hectare recovery catchment. The last remaining seasonal freshwater lake in the Wheatbelt, it was listed as a wetland of international importance under the RAMSAR Convention in 1990, a Recovery Catchment in 1996 under the Salinity Action Plan and is listed on the Register of the National Estate (Smith and Wallace, 1998). At the time the first recovery plan was written for Toolibin Lake, it was the only lake in the region that had comparatively good water quality and extensive living stands of sheoaks and melaleucas (Wallace, 2001).

Lake Toolibin catchment has a long history of Landcare activities and a strong community involvement in catchment group activities. The major review conducted by CALM of the Lake Toolibin Recovery project in 1998 noted that the Lake Toolibin Catchment Group had been crucial to its success. However, fencing of remnant vegetation and revegetation work under the recovery catchment program hasn't been extensive, with an increase in perennial vegetation in the catchment from 9 to 14 per cent (6800ha) since the implementation of the recovery plan started in 1993. These adoption rates have not been adequate to halt salinity development with recent estimates of over 20 per cent of the catchment at risk of developing salinity (at least 9 800 hectares) (Wyland et al., 2004).

The methodology for implementing VCSA in Lake Toolibin catchment was developed by CALM for use in the Dongolocking Project, Toolibin Lake and Wallatin Creek catchments where the payment by CALM for on-ground works is apportioned according to the ratio of private to public benefits resulting from the works being undertaken (Mullan and Wallace, 2001). For 50:50 example, if a landholder agreed to revegetate using biodiversity seedlings in an area on their property which would influence hydrological flows negatively impacting upon a natural diversity recovery catchment as well as derive private benefits of stock shelter and erosion control, CALM will pay for the seedlings but the landholder would have to pay for site preparation and planting as they will eventually receive private benefits. An example where CALM might pay 100% of costs might be for works for surface water management in an area which would influence hydrological flows negatively impacting upon a natural diversity recovery catchment but provide no private benefit to the landholder.

In the Lake Toolibin recovery catchment, landholders undertake works and then invoice CALM for their contribution to the VCSA. Invoices are approved once the CMO is satisfied that the works have been undertaken in accordance the VCSA. Conditions of VCSA in the Lake Toolibin recovery catchment include planting only species native to the region and undertaking appropriate weed control. Planting species native to the region extends to the VCSA that are applied to the

[4] Lake Toolibin and Lake Warden have one full time CMO and Drummond Nature Reserve has two half time CMO's.

planting of Oil Mallees, one of the few potentially commercially viable perennial crops in the region. Other species of Oil Mallee, which may be higher yielding, are not included in CALM's VCSA because they are not local to the region. Unlike the southern coastal regions, rainfall limits the use of agroforestry as an option to mitigate dryland salinity around Lake Toolibin, and the development of an Oil Mallee industry around Narrogin, where a processing plant is in the late stages of completion, has been the focus of developing a commercially viable salinity solution.

Lake Warden

Recognised as a wetland of national and international importance, the Lake Warden Wetland System is listed on the National Estate Register and under the Ramsar Convention respectively. The Lake Warden Wetland system is comprised of Lake Warden, Woody Lake and some of Mullet Lake Nature Reserves. The Lake Warden Natural Diversity Recovery Catchment is made up of the Coramup Creek Catchment (31 000 ha), the Bandy Creek Catchment (50 500 ha), the Neridup Creek Catchment (62 600 ha) and the Esperance Western Lakes Catchment (13 500 ha), a total area of 171 000 hectares.

The primary land use in the catchment is farming with 83 per cent of land (142 500 hectares) being used for agricultural purposes (Massenbauer, 2000). Despite not having a community catchment group or the same access to funding as recovery catchments, the 120 or so landholders in the Lake Warden catchment had fenced 40 per cent of original native vegetation that remained on farms, revegetated 1900 hectares with native species and 2400 hectares with commercial trees at the time it was declared a recovery catchment (Massenbauer, 2000).

When approved as a natural diversity recovery catchment in 1999, the CMO for Lake Warden undertook an extensive survey of landholders in the recovery catchment to obtain information about the land use systems, land degradation works undertaken and attitudes towards undertaking future works to address land degradation issues. The information obtained from the survey was then used to inform the design and implementation of VCSA in this recovery catchment.[5] survey. Consequently the VCSA in Lake Warden differ to those in Lake Toolibin, an example of this includes the types of species which are eligible for VCSA. Because of its location, rainfall levels allow agroforestry to be a commercially viable option for landholders combating dryland salinity. Profitable agroforestry species are available for inclusion in VCSA in this region, including those from other regions such as the Tasmanian Bluegum.

No money is exchanged in the Lake Warden recovery catchment between CALM and landholders. All materials for VCSA are paid for at the place of supply by CALM and the landholder picks up their order and supplies their labour as their share of the costs. The payment of materials by CALM upfront eliminates any rent the landholder may extract from CALM.

Drummond Nature Reserve

The Drummond nature reserve was announced as a natural diversity recovery catchment in late November, 2001 after approval by the State Salinity Council and Conservation Commission of Western Australia due to its extremely high conservation values being threatened by salinity (rising groundwater tables) and other forms of land degradation. Situated on the boundaries of the Toodyay and Victoria Plains shires, the DRNDRC is comprised of the Solomon-Yulgan and Anvil Gully catchments, covering 39 500 ha and containing 58 properties. It has several nature reserves within it, the icon being the Drummond nature reserve at 439 ha.

Drummond Nature Reserve natural diversity recovery catchment is the most recent of the three recovery catchments I will be looking at, approved in 2001, VCSA commencing in 2002. No initial survey of landholders was undertaken at its commencement, however it does follow Lake

[5] Another extensive landholder survey was undertaken in 2003 as a follow up to the 1999 survey.

Warden's approach of paying for materials for VCSA at the place of supply and have the landholder pick up their order and supply their labour as their share of the costs.

Unlike Lake Warden or Lake Toolibin, the key natural diversity asset Drummond Nature Reserve, is in the upper reaches of the recovery catchment. This has implications for which landholders should be targeted to influence hydrological flows to the reserve. In Lake Toolibin and Lake Warden recovery catchments, because the key assets are in the lower catchment, almost all landholders land use decisions have an impact.

Equity and efficiency

In deciding whether a policy mechanism should be adopted it should be assessed on its: effectiveness, efficiency, equity and information requirements. For the purposes of this paper, only efficiency and equity will be discussed.

Efficiency

The definition of efficiency that is most often applied for policy purposes, that of Pareto efficiency where an allocation is optimal and efficient if it is impossible to make an individual better off without making another worse off.

If a policy mechanism has not been designed to account for information asymmetries, such as hidden knowledge of efficiency levels of landholders determined by factors such as technology and soils, there is then scope for landholders to extract rent from the environmental regulator and reduce the efficiency of the policy. This behaviour is known as rent seeking. In particular, in offering incentives for change in land use, adverse selection is likely where landholders will select incentives that are most profitable rather than those which represent their true compliance costs. This behaviour must be considered in the design of the mechanism for the incentive, in this case the VCSA, if it is to effectively meet an efficiency objective.

Despite incorporating a 'concept' of equity within it in that an individual cannot be made better off at the expense of another (Le Grand, 1990a), the Pareto criterion for efficiency does not consider distributive equity (Bullock and Salhofer, 2003).

Equity

Equity is most often used synonymously with the terms fairness and justice (LeGrand, 1990a). The *MIT Dictionary of Modern Economics* defines equity as just that, 'Fairness or justice.'(Pearce, 1992: 130).

The role of equity in agricultural policy has a long history. Traditionally, policies have been used with the intention of raising the welfare of farm households through transferring income from other sectors under the belief that rural regional households are relatively disadvantaged compared with city residents. This perceived disadvantage is not supported by evidence (Freebairn, 2003; OECD, 2003). More recently, agricultural policy is turning to address issues such as biodiversity conservation, decline of rural and regional areas, natural resource management and food security as these areas become of concern to the general public (Bullock and Salhofer, 2003; OECD, 2003).

In the application being considered in this paper, the policy objective of the environmental regulator is to preserve and enhance specific natural diversity assets through conservation and sustainable land use. Within its objective 'to preserve and enhance' natural diversity are sub-objectives to do so efficiently, effectively and equitably.

One of the underlying principles of the VCSA scheme implemented by CALM is (Wallace, 2004):

> cost sharing arrangements are equitable between prospective partners and proponent;
>
> All prospective partners should acknowledge that the procedures, execution and implementation of cost-sharing arrangements are fair and equitable.

Again, where cost-sharing arrangements differ from place to place, then it is vital that they are all seen as meeting the equity principle as defined by CALM, and that no party (including the State) is disadvantaged, or treated inequitably.

It is often considered that the instrument chosen to implement the given policy will involve a trade-off between efficiency and equity (see Varian, 1973; Baumol, 1986; Browning and Johnson, 1984; Le Grand, 1990b). Whether there is a trade-off will depend on many factors such as the definition of equity and efficiency being applied and the priority that they have as a social objective over each other (Le Grand, 1990a).

3. Contracts as a policy instrument for dryland salinity

There are many difficulties in using contracts as a policy instrument, particularly with natural resource management issues, and probably why they are not often considered a viable option. Dryland salinity is an environmental problem that has inter-temporal considerations that in some cases may span several decades. Contracts by nature have a defined duration, over which the agent undertakes some specified actions for some desired outcome at a specified price. A contract of sufficient length to address dryland salinity would face numerous problems, including no opportunity to adjust the price to reflect the cost of mitigation activities as technology develops. Shorter contracts face the problem of renegotiation, where after the first contract is undertaken the regulator will often have more information about the landholder's costs and will try and exploit this knowledge and reduce the contract price (see Laffont and Tirole, 1993). As such, farmers are likely not to renew their contract, which for an environmental problem requiring a long term approach has potential devastating implications as well as reducing the value of the initial contract.

Also, the contribution any individual is making to total salinity in a given time period in a given landscape, is prohibitively expensive to measure, making any contract to undertake action unverifiable. The difficulties in contracting individual actions to address a collective non-point source pollution problem have been analysed in Pushkarskya (2003) and Bystrom and Bromley (1998). Both suggest non-individual contracts between farmers and a regulating authority using either a subsidy or a penalty in conjunction with a standard.

There are also problems in getting landholders to participate in schemes which involve formal contracts. Landholders are generally risk averse and suspicious of government policy in relation to the attenuation of their property rights. Evidence of this can be seen in the opposition to the extension of land clearing legislation in Queensland and Western Australia by farming lobby groups in recent times and the establishment of organisations such as the lobby group Property Rights Australia which represent landholders in matters of infringement of property rights. As such, it is not surprising that the neither the Federal or State governments have implemented the recommendation of a statutory duty of care for the environment from the *Inquiry into Ecologically Sustainable Land Management* (Industry Commission, 1998).

Research such as by Moxey et al. (1999) and White (2003) describing how contracts can be used to give incentives to landholders to produce environmental public goods, are often normative analyses which rarely have been applied in practice. Examples of applications of contracts in natural resource management tend to take the form of fixed price contracts where landholders are not distinguished by their levels of efficiency in production. Such examples include programs such as Environmental Stewardship, Conservation Reserve and Land Set-aside programs undertaken in the United States and the European Union respectively (Smith, 1995; Wu and Babcock, 1996; Bourgeon et al, 1995).

Voluntary cost sharing agreements as contracts

Contracts, as described above, imply a legal document describing various actions to which the parties that are signatories to it are legally bound and is enforceable through a court of law. However, Brousseau and Glachant (2002: i) define a contract as 'an agreement under which two parties make reciprocal commitments in terms of their behaviour to coordinate'. Under this definition VCSA can be interpreted as a contract despite the fact they are not legally binding, except in cases where there is a high proportion of government input (Mullan and Wallace, 2001). As such, VCSA are a flexible alternative to formal contracts that have been used in NRM policy in Australia to effectively get landholders, especially risk averse landholders, to implement works to address land degradation issues.

It is necessary to have VCSA as legally non-binding, despite the high risk to the government, to get participation of landholders as they have no incentive to undertake more abatement than what they derive a private benefit from. This often results in landholders not meeting their obligations of the VCSA if no monitoring and enforcement mechanism is in place or the incentives aren't great enough (see Marshall, 2004). Even though VCSA ease some of the financial constraints, they do not include opportunity costs or address labour constraints faced by many landholders (Marshall, 2004, Lockwood et al, 2002,, Wallace, 1998). Financial constraints are evident when an increase in a subsidy result in greater participation such as when a 50 per cent increase in the oil mallee subsidy in Lake Toolibin resulted in a 300 per cent increase in oil mallee orders (Wyland et al, 2004).

The model in the following section will first look at design of VCSA when there is only one type of landholder, that is all landholders are equal in terms of production efficiency. Two types of production efficiency will then be introduced and the implications of an equity constraint explored.

4. Model

An environmental regulator is trying to influence the level of abatement (revegetation to lower water tables) undertaken in a catchment through the use of voluntary cost-sharing agreements. In doing so, the regulator aims to maximise social welfare as a result of protecting and enhancing the natural diversity asset of the catchment.

Consider a two producer catchment (one high efficiency and one low efficiency) where the following objective function is applied:

$$z_i = \left[\sum \left[V(a_i) + g^i(a_i) - C^i(a_i, \theta_i) - \eta b_i\right]\right]$$

The environmental regulator's aim is to:

$$\max_{a_i, b_i} \left[\sum \left[V(a_i) + g^i(a_i) - C^i(a_i, \theta_i) - \eta b_i\right]\right] \tag{1}$$

Subject to: $b_i - C^i(a_i, \theta_i) + g^i(a_i) \geq 0 \qquad i = 1,2$ (2)

The variables in the objective function (1) are, a_i is the individual level of abatement undertaken in terms of area revegetated in hectares. The relationship between deep rooted vegetation and the draw down of the watertable is used to justify the use of revegetation as a proxy for abatement in this paper. Fencing of remnant vegetation and surface water management are also cost sharing activities undertaken by CALM which could be added as an extension of this model.

The environmental regulator's value function, $V(a_i)$, is a measure of the public benefit of the natural diversity asset. It is assumed for simplicity that this function is separable and location non-specific, that is, the abatement undertaken by any landholder is not impacted upon by abatement undertaken by other landholders in the catchment and all abatement undertaken in the catchment provides equal benefit to the natural diversity asset regardless of location. Again, this is a simplification undertaken for the purposes of the model as the nature of ecosystems and natural landscapes are defined by complex interdependent relationships (see Daily, 1997). Also in some catchments, watertable levels are more responsive to revegetation in particular areas than others, for example those with local groundwater systems compared to regional groundwater systems (reference). If the value function was location specific it could be written as $V^i(a_i)$. Also if the value function was non-separable, that is, the value of a unit of abatement was determined not only by its size and location in the catchment, but also by how much abatement had been undertaken by other landholders in the catchment and where $V^i(a_i, A)$, where $A = \sum a_i$. This approach is used by Krawczyk *et al*. (2003) and Parkhurst *et al*.(2002) in designing incentives schemes for biodiversity conservation, where an agglomeration bonus is used to encourage landholders to retire land adjacent to their neighbours retired land.

The private benefit function to the landholder of undertaking abatement is given by the term $g^i(a_i)$ and represents private benefit obtained from productivity gains obtained from undertaking abatement. This function is independent of the landholders efficiency type, as a low efficiency type landholder may get substantial increases in productivity by participating in an abatement scheme relative to a high efficiency type farmer who is already at a higher productivity level.

The model assumes that there are two types of efficiency levels, θ_i, where i=1 is a high efficiency landholder with a relatively high opportunity cost for undertaking abatement and i=2 is a low efficiency landholder with a relatively low opportunity cost for undertaking abatement. It is difficult to observe a landholders efficiency type, so often a proxy is used to estimate efficiency form observed variables such as soil type, yields and production methods.

The private compliance cost, $C^i(a_i, \theta_i)$, is a function of the abatement level undertaken and the type of efficiency of the landholder.

And finally, b_i, is the transfer payment made for abatement and η is the shadow price of public funds used for the transfer payment and measures the deadweight loss of levying taxes.

The individual rationality constraint (2) states that the transfer payment to each landholder, b_i, must be greater than the private compliance cost $C^i(a_i, \theta_i)$, less the private benefits of undertaking abatement, $g^i(a_i)$. If landholders have a negative value for private benefits, they will need a transfer payment in excess of private compliance cost to compensate for the disutility (negative private benefit) they incur by participating in abatement. If landholders have a positive private value for abatement they should be compensated for abatement by *at least* the private cost of compliance minus the private benefit they obtain from abatement.

Model 1: one type of landholder efficiency

Given this model we can work through the first best solution where we assume that there is only one type of farmer, θ_1, and therefore there is no hidden information problem for the regulator in designing its incentive mechanism for voluntary participation in its revegetation scheme. Using a Lagrangian composite function, where λ is a Lagrangian multiplier:

$$\underset{\max a_i, b_i}{\phi =} V(a_1) + g(a_1) - C(a_1, \theta_1) - \eta b + \lambda\left(b - C(a_i, \theta_1) + g(a_1)\right) \tag{3}$$

First order conditions under perfect information:

$$\frac{\partial \phi}{\partial a_1} = V_{a_1} + g_{a_1} - C_{a_1} - \lambda C_{a_1} + \lambda g_{a_1} = 0 \tag{4}$$

$$\frac{\partial \phi}{\partial b} = -\eta + \lambda = 0$$

$$\lambda = \eta \tag{5}$$

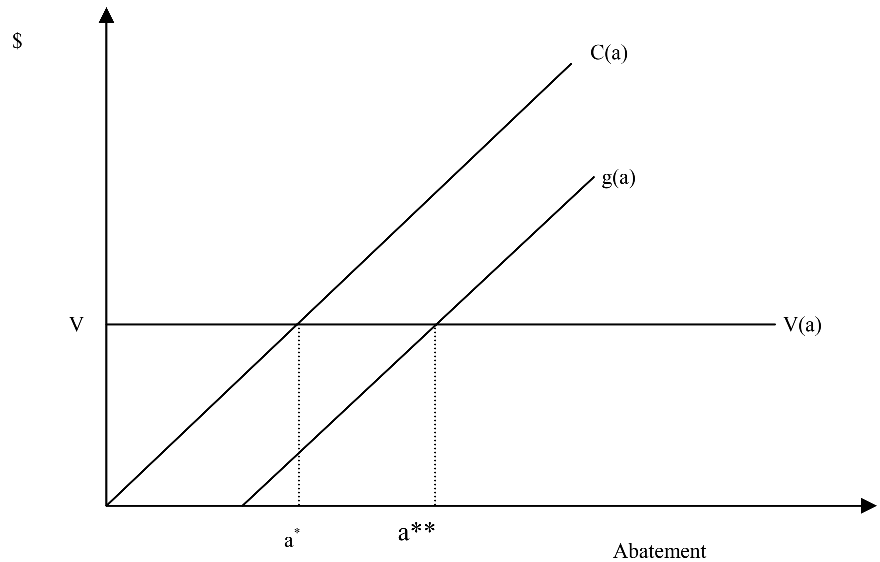
Substituting (5) into (4) and rearranging to get the first best solution:

$$V_{a_1} = \left(C_{a_1} - g_{a_1}\right)\left(1 + \eta\right) \tag{6}$$

The first best solution has the marginal public value of abatement, V_{a_1}, equal to the marginal net private cost of abatement, that is $\left(C_{a_1} g_{a_1}\right)\left(1 + \eta\right)$.

Therefore in the above scenario where there is only one type of farmer, there is no hidden information and marginal public benefits of undertaking abatement are equal to marginal private costs of abatement. The environmental regulator will offer a transfer payment which is equal to the marginal cost of abatement for the one type of landholder minus any private benefit they derive from the abatement inflated by the shadow price of public funds.

Figure 1 Impact of private benefits of abatement



When present, the private benefits of abatement give three sources of benefit: (1) they generate private benefits for landholders; (2) they save on transfer payments for the environmental regulator and (3) because transfer payments are less, the shadow price of the public funds used to finance the transfer payment is also less. The first two benefits can be seen in figure 1 where there is a positive private benefit, g(a), a constant marginal public benefit, V, means that a higher level of abatement will occur at a^{**} than if $g^i(a) = 0$, where a* abatment occurs.

Model 2: two types of landholder efficiency

In reality, landholders have different soil types and use different methods in their farming practices, resulting in many different levels of technical efficiency. By looking at two types of efficiency in landholders, θ_1 high efficiency and θ_2 low efficiency, the implications of this for cost sharing agreement incentives under full information can be analysed. Of course in reality the environmental regulator will not know which landholders belong to what efficiency groups, or even have much information of the opportunity costs faced by different efficiency groups. For simplicity, the model assumes full information just to demonstrate the implications of different levels of efficiency on levels of abatement undertaken in a catchment with a revegetation scheme.

To simplify notation, private benefits and costs of abatement are represented by:

$$B(a_i, \theta_i) = C^i(a_i, \theta_i) - g^i(a_i) > 0 \qquad (7)$$

Where $B(a_i, \theta_i)$ is the net cost of compliance of voluntary abatement. Given this simplification, the objective Lagrangian function for two types of efficiency landholders can be written as:

$$\phi = V(a_1) + V(a_2) - B(a_1, \theta_1) - B(a_2, \theta_2) - \eta b_i + \sum_i \lambda_i (b_i - B(a_i, \theta_i)) \qquad (8)$$

The above function assumes that the net cost of compliance will always be positive, i.e. that the private benefits received from the abatement are less than the public. This makes intuitive sense since if the private benefits were larger than the private costs, then landholders would undertake the abatement without the need for incentives from the environmental regulator. First order conditions of the Lagrangian:

$$\frac{\partial \phi}{\partial a_i} = V_{a_i} - B_{a_i} - \lambda_i B_{a_i} = 0 \quad (9)$$

$$\frac{\partial \phi}{\partial b_i} = \lambda_i - \eta = 0$$

$$\lambda_i = \eta$$

Equation (9) can be rewritten as:

$$V_{a_i} = B_{a_i}(1+\eta) \quad (10)$$

where this result is the same as equation (6). In the two type efficiency model, the marginal public value of abatement is equal to the marginal net private cost of abatement for each type inflated by the shadow price of public funds.

Therefore this result is also first best in that the marginal public benefits of undertaking abatement are equal to marginal net private costs of abatement for each efficiency type.

To further clarify these results, it is assumed that $V_a = V$, that is the marginal value of abatement to the environmental regulator is constant across landholders then the result (10) can be written:

$$V = B_{a_1}(1+\eta)$$

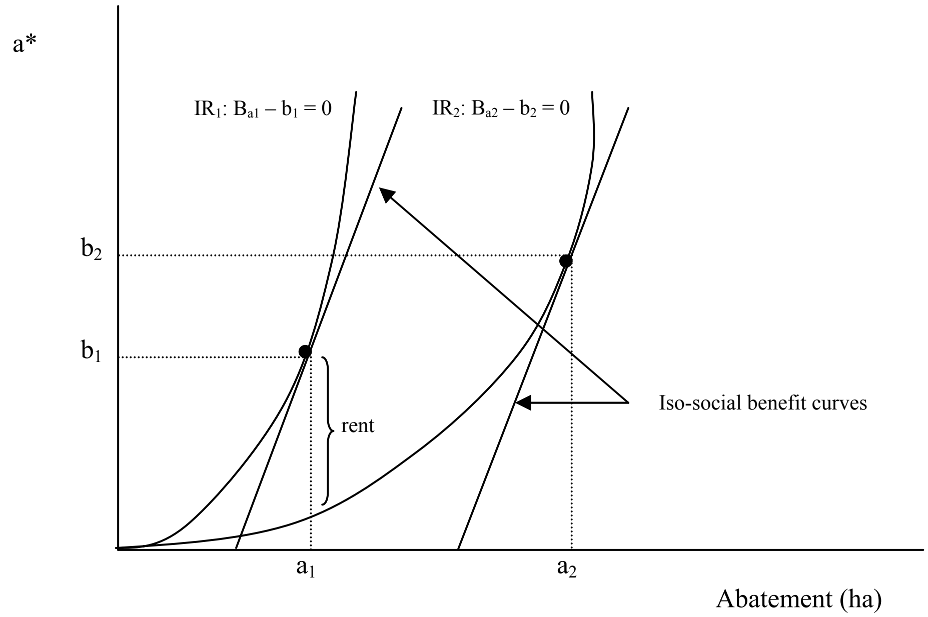
$$V = B_{a_2}(1+\eta)$$

Where marginal net compliance costs are equal across producers which is equivalent to:

$$2V = B_{a_1}(1+\eta) + B_{a_2}(1+\eta) \quad (11)$$

We can assume that because there are two efficiency types of landholders, that if they are receiving the same payment, they will adjust the level of abatement they undertake according to their total private costs of undertaking abatement. This works the other way as well, where if the same abatement levels were required by both efficiency types of landholders, the transfer payment would have to differ accordingly to cover the different private costs each type of landholder incurred from undertaking a given level of abatement.

Figure 2 Optimal abatement under perfect information



This can be seen in figure 2, where the optimal transfer payment and level of abatement for each efficiency type occurs at the point of tangency between the iso-social benefit lines and the IR constraint (2) when it is equal to zero. Iso-benefit lines represent the environmental regulators objective function (Moxey *et al*. 1999).

The IR constraint equals zero when the transfer payment is equal to the marginal net private cost. Because efficiency type 1 has a higher compliance cost, this IR=0 curve also lies higher. As such the optimal transfer payment for efficiency type 1 is b_1, which is lower than the optimal transfer payment for efficiency type 2, b_2. Consequently type 1 efficiency undertakes a lower level of abatement than type 2 efficiency.

Equity considerations

What happens when an equity constraint is introduced will depend on how an objective of equity is defined.

Given that in this model it has been assumed for simplicity that each hectare of abatement has equal benefit regardless of where it is in the catchment (location non-specific), and efficiency type is hidden information known only to the landholder, an objective of equality[6] may be perceived as 'fair' by the farming community where equal abatement receives equal payment regardless of efficiency type:

$a_1 = a_2 = a \qquad b_1 = b_2 = b$

By setting the above as a constraint to the model already defined for the two types of efficiency in the catchment, the implications of the same transfer payment for the same area of abatement for

6 It must be noted that equality and equity are not the same thing. A relevant example of equality is where landholders are paid the same subsidy for the same amount of abatement undertaken, whereas an example of equity may be where landholders are subsidised according to the cost of undertaking a given level of abatement. Under equality, landholders may be receiving the same payment for the same level of abatement but it is not necessarily equitable as it has not taken into account all of the information relevant to the situation (such as individual abatement costs).

efficiency of the revegetation scheme the environmental regulator is implementing can be analysed.

Given the same area of abatement will receive the same transfer payment regardless of efficiency type, the objective function (8) can be rewritten as:

$$\max_{a,b} = 2V(a) - B(a_1, \theta_1) - B(a_2, \theta_2) - \eta 2b$$

subject to: $b - B(a_1, \theta_1) \geq 0$

The model assumes that the individual rationality constraint is only binding on the high efficiency type landholder (IR_2). This makes intuitive sense in that by setting the transfer payment and abatement to a level that captures the high efficiency type landholder, that some low efficiency type landholders will also participate in the scheme and by doing so capture some rent. If the individual rationality constraint targeted the low efficiency type, the high efficiency type landholder would capture no rent by participating in the revegetation scheme and their costs of participating would not be compensated appropriately enough to warrant their participation on any level. This is illustrated in figure 2, where if the transfer payment was b_1 for both types, they would both revegetate a_1 hectares and the low efficiency type would capture rent to the amount r.

Therefore the equity constrained objective function is:

$$\phi = 2V(a) - B(a, \theta_1) - B(a, \theta_2) - 2\eta b + \lambda_1 (b - B(a, \theta_1)) \tag{12}$$

First order conditions:

$$\frac{\partial \phi}{\partial a} = 2V_a - B_a - B_a - \lambda_1 B_a = 0 \tag{13}$$

$$\frac{\partial \phi}{\partial b} = -2\eta + \lambda_1 = 0$$

$$2\eta = \lambda_1 \tag{14}$$

Substituting (15) into (14):

$$2V_a - B_a(1 + 2\eta) - B_a = 0$$

$$2V_a = B_a(1 + 2\eta) + B_a$$

This result has twice marginal public value equal to the marginal net private cost of type 1 efficiency influated by twice the shadow price of public funds plus the marginal net private cost of type 2 efficiency. If it is assumed that $V_a = V$, that is the marginal value of abatement to the environmental regulator is constant, as was done in the full information two efficiency type model:

$$2V = B_a (1 + 2\eta) + B_a \tag{15}$$

This result differs from the first best two type efficiency model with full information in which the marginal public benefits of undertaking abatement are equal to marginal net private costs of abatement for each efficiency type inflated by the shadow price of public funds (11):

$$2V = B_{a_1}(1 + \eta) + B_{a_2}(1 + \eta)$$

Assuming that although the total costs of the two efficiency types are different, their marginal net private costs are from the same family, we can set (11) equal to (15) to see under what conditions less abatement will occur when an equity constraint is applied:

$$2B_{a_1}(1+\eta) = B_{a_1}(1+2\eta) + B_{a_2} \tag{16}$$

Given $\theta_1 > \theta_2$, we can write $B_{a_2} = \theta B_{a_1}$ where θ is measure of efficiency such that $\theta < 1$ for type 2 and $\theta = 1$ for type 1 efficiency.

$$2B_{a_1}(1+\eta) = B_{a_1}(1+2\eta) + \theta B_{a_1}$$

$$B_{a_1} = \frac{B_{a_1}(\theta+1)}{2} \qquad \theta < 1 \tag{17}$$

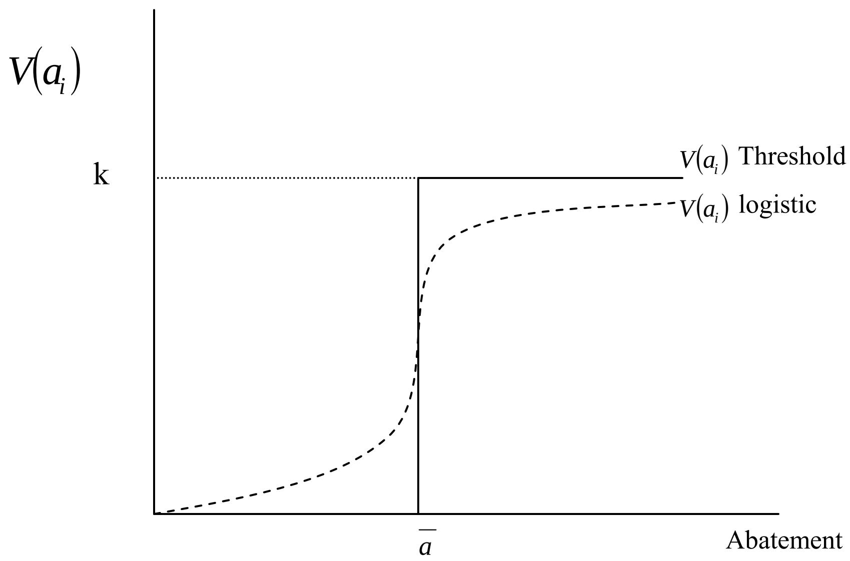
Because $\theta < 1$, then the amount of revegetation undertaken in the model with an equity constraint as defined will be less than the amount of revegetation undertaken without one.

5. Numerical example

A simulation is run to illustrate numerically the results derived from the model for one type of efficiency landholder in the catchment, a high and a low efficiency type landholder with perfect information and a high and a low efficiency type with perfect information and an equity constraint. A description and specification of each of the functional forms given in the original Lagrangian (3) is given below and summarised in Table 1.

$V(a_i)$ will be defined by the value of abatement to CALM, where there are two components that can be considered, the value of meeting the hydrological threshold component for the key natural diversity asset and the value of achieving biodiversity conservation.on private property. Figure 3 compares two possible functions, one which is just representative of a hydrological threshold value and the other combining the threshold value and the value of biodiversity conservation on private property from the implementation of a voluntary cost-sharing scheme.

Figure 3 Value of abatement to the environmental regulator



In this numerical example a logistic functional form will be used to represent the value of abatement undertaken to CALM, V(a$_i$) = $\frac{k}{\left(1+e^{-\alpha a_i}\right)}$, where k is the threshold value.

The landholders cost of undertaking abatement $C(a_i, \theta_i)$ may be specified as $\theta_i a_i^{\beta}$, where $\beta > 1, \theta_i \leq 1$. This non-linear convex cost function can be used as the opportunity costs involved in abatement mean that costs of participating in revegetation schemes increase per unit of abatement undertaken. Because the more efficient farmer in production, θ_1, can make more revenue per hectare than the inefficient farmer, θ_2, their opportunity costs will be higher such that $\theta_1 > \theta_2$ (see Figure 4).

The private benefit of undertaking abatement $g(a_i)$ has a linear functional form, γa_i, where $\gamma < \alpha$ as the marginal benefits of undertaking abatement have diminishing returns to the landholder and a significant natural diversity asset will have greater public value than private value of abatement.

Finally, η, the shadow price of public funds used for the transfer payment also has a linear functional form, $-\eta b_i$.

Figure 4 Compliance costs of abatement by efficiency type

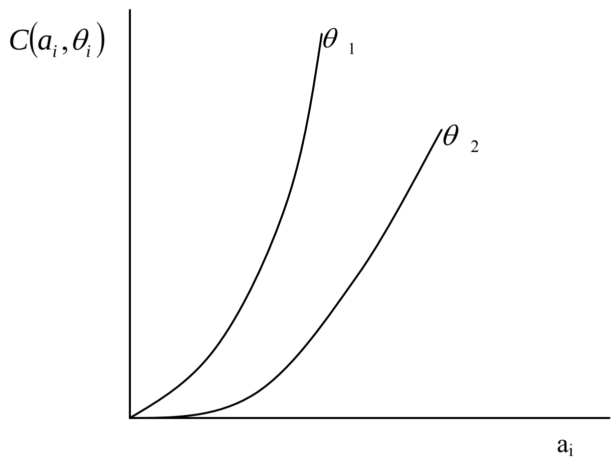


Table 1 **Numerical example parameters**

Parameter	*Symbol*	*Value*
Slope in logistic function	α	0.5
Private compliance cost slope	β	1.7
Private benefit	γ	0.01
High efficiency type	θ_1	1
Low efficiency type	θ_2	0.8
Shadow price of public funds	η	0.2
Threshold value	k	15 000

The numerical simulation is run using excel solver and the results for two type efficiency model with full information and two type efficiency with full information and an equity constraint are presented in table 2. The objective functions for the two type efficiency model with full information is:

$$z = \left(\frac{k}{\left(1+e^{-\alpha a_1}\right)} + \alpha a_1 - \theta_1 a_1{}^{\beta} - \eta b_1 \right) + \left(\frac{k}{\left(1+e^{-\alpha a_2}\right)} + \alpha a_2 - \theta_2 a_2{}^{\beta} - \eta b_2 \right)$$

IR_1: $b_1 - \theta_1 a_1^{\beta} + \gamma a_1 \geq 0$

IR_2: $b_2 - \theta_2 a_2^{\beta} + \gamma a_2 \geq 0$

And for with an equity constraint as defined:

$$z = \left(\frac{k}{\left(1+e^{-\alpha a_1}\right)} + \alpha a_1 - \theta_1 a_1{}^{\beta} - \eta b_1 \right) + \left(\frac{k}{\left(1+e^{-\alpha a_1}\right)} + \alpha a_1 - \theta_2 a_1{}^{\beta} - \eta b_1 \right)$$

IR_1: $b_1 - \theta_1 a_1^{\beta} + \gamma a_1 \geq 0$

Table 2 Simulation results

	Abatement area (ha)			*Transfer payment ($)*			*Rent ($)*		*Objective function*
Scenarios	a_1	a_2	*total*	b_1	b_2	*total*	r_1	r_2	*z*
Two types of landholder	12.84	13.25	26.09	76.54	64.53	141.07	0	0	29786
Two types of landholder with equity constraint	13.00	13.00	26	78.14	78.14	156.28	0	15.66	29783

From the above results it can be seen that when an equity constraint is introduced as defined, the high efficient type landholder will increase their level of abatement from 12.84 hectares to 13.00 hectares and the low efficient type landholder will reduce their level of abatement from 13.25 hectares to 13.00 hectares. Consequently, overall abatement is reduced by 0.09 hectares by introducing an equity constraint under perfect information.

The results also show that the high efficient type landholder's payment will increase with an equity constraint by $1.60. However, the low type efficiency landholder's payment will increase significantly more by $13.61 to undertake less abatement than they were before the equity constraint was introduced. Overall transfer payments increase by $15.21 to undertake 0.09 hectares less of abatement under an equity constrained revegetation scheme. The objective function, which is the measure of welfare obtained from the abatement to the environmental regulator decreases by three units under an equity constrained scheme.

Although these results do not seem significant, they are consistent with the model and its diagrammatical representation in Figure 2, and this simulation has been run for that purpose at this stage in the research.

6. Discussion

Results from the numerical example and equation 17, show that as long as there are high and low efficiency types in a catchment, not taking into account these differences when designing a VCSA scheme will result in lower social welfare from the value of abatement to the environmental regulator, higher transfer payments and lower levels of abatement.

Equality was used as the equity constraint in this paper to represent a conservative view of equal payment for equal abatement. However, equality and equity are not the same thing, as an equitable scheme may be defined as one that takes into account more information than area abated, such as the private costs incurred for that particular landholder for the level of abatement they undertook, to determine what the payment should be. CALM has adopted a policy of equity rather than equality, where in Lake Toolibin recovery catchment for example, VCSA are based on the ratio of private and public benefits of a project not on the going rate for an area of land revegetated, kilometres fenced or square metres of surface water management.

Also, the models used assumed perfect information to enable an environmental regulator to distinguish between efficiency types. This information is often hidden from the environmental regulator, making it difficult to design policy mechanisms in which landholder's can choose an option that is most suited to their efficiency type. This problem of asymmetric information means that environmental regulators end up paying rent to lower efficiency landholders. CALM's use of extensive survey's in the Lake Warden recovery catchment is an example of an environmental regulator investing in information on landholders in their catchment to help overcome asymmetric information problems and design VCSA that incorporate projects that have private benefits to landholders wherever possible.

Further research

The models presented in this paper relied heavily on some assumptions that don't hold in real life. The development of a model which includes location specific abatement, where some abatement is worth more in terms of hydrological and biodiversity conservation than others would better reflect what is actually happening in recovery catchments. Also, that abatement that is undertaken in a coordinated effort may have more value than the same level abatement uncoordinated.

Perfect information does not exist. So an area of further research that will continue be explored is including asymmetric information into mechanism design of VCSA. The relationship between CALM's effort in acquiring information on landholders and incorporating it into VCSA and participation in VCSA schemes will also be explored.

7. Conclusions

VCSA are an integral part of the mix of instruments available to CALM in achieving their objective of 'preserving and enhancing target natural diversity assets'. VCSA's offer incentives for landholders to change their traditional landuse systems to more salinity mitigating and biodiversity conserving systems. Factors such as private benefits derived from abatement, attitudes to CALM, effort made by CALM to increase awareness of the scheme and educate landholders on its benefits all influence the success of a VCSA and need to be investigated further. How VCSA are designed and implemented will influence their effectiveness in terms of the area of land abated and the social welfare derived from CALM's value of abatement undertaken. However, there are sub-objectives underlying the 'preserve and enhance' of achieving this goal equitably and efficiently, which depending on how they are defined may be competing. CALM's current VCSA scheme shares costs according to the private to public benefit ratio, which is consistent with the findings in this paper where equal payment for equal area abated is inefficient. If information can be obtained about landholders opportunity costs and attitudes to abatement activities, through surveys such as those conducted in Lake Warden, that will help feed into the design of VCSA to more accurately account for the differences in landholders in each particular recovery catchment and the information asymmetries faced.

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